COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

SAVANNA AGRICULTURAL RESEARCH INSTITUTE

ANNUAL REPORT 2012

Effective farming systems research approach for accessing and developing technologies for farmers

A Profile of CSIR-Savanna Agricultural Research Institute

The Savanna Agricultural Research Institute (SARI) is one of the 13 research institutes that make up the Council for Scientific and Industrial Research (CSIR) – a quasi-government organization that operates under the ambit of the Ministry of Environment, Science, Technology and Innovation. The Institute was originally known as the Nyankpala Agricultural Experiment Station (NAES). In June 1994, it was upgraded to a full-fledged Institute and re-named Savanna Agricultural Research Institute.

The Mandate of the institute is to **"provide farmers in the Northern, Upper East and Upper West Regions with appropriate technologies to increase their food and fiber crop production based on a sustainable production system which maintains and/or increases soil fertility"**. The crops covered in its research mandate include sorghum, millet, rice, maize, fonio, cowpea, groundnuts, soybean, bambara groundnuts, pigeon pea, yam, cassava, sweet and frafra potatoes, cotton and vegetables.

The Vision is to **"become a lead research and development (R&D) Institution by making agricultural research responsive to farmer needs and national development"**.

The Mission is to **"conduct agricultural research in Northern Ghana with the aim of developing and introducing improved technologies that will enhance overall farm level productivity for improved livelihoods"**.

The Savanna Agricultural Research Institute is located 16 km West of Tamale in the Northern Guinea Savanna Zone of Ghana. With one rainy season from April to October, it receives over 1000 mm of rainfall annually. The altitude is 200 m above sea level.

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Core Values – What keeps us strong!
The Institute strives to uphold nine enduring core values: Discipline, Dedication, Reliability, Transparency, Teamwork, Hard work, Mutual respect, Professionalism and Selflessness. These values guide the decisions, actions and relationships as SARI works towards fulfilling its mission.

Our Strategy
The Institute's niche is an innovative response to the challenges presented by low productivity in the agriculture sector in Northern Ghana. Three strategic goals below guide the institute. These are:

- **Access to appropriate technologies**
- **Develop and adapt technologies and**
- **Deploy and commercialize technologies for impact**

These goals are anchored on a strong and effective institutional programming and a conducive environment.

SAVANNA AGRICULTURAL RESEARCH INSTITUTE

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Savanna Agricultural Research Institute

(SARI)

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The CSIR-Savanna Agricultural Research Institute continued to live up to its mandate of providing farmers in Northern Ghana with appropriate technologies to increase their food and fiber crop production based on a sustainable production system which maintains and/or increases soil fertility.

The year 2012 was very productive with the release of five improved drought tolerant maize varieties. With climate change that we are currently experiencing, the quantity and distribution of rainfall which cannot be determined based on the long term weather data available. Plant Breeders are now braced for it, and are gearing towards developing crop varieties from early or extra-early to drought tolerant to enable our numerous farmers get something to feed their households in very bad years. Moreover, as a result of continuous farming, pests and diseases have built up and are becoming resistant to pesticide. Hence efforts are being made to get crop varieties that are tolerant to stresses like pests and diseases, low soil nitrogen and more importantly the parasitic weed – *striga*. The new drought tolerant maize varieties have been deployed into the farming systems of Northern Ghana to give meaning to "Better tools, better harvests and better lives". Efforts have been intensified towards enhancing production and access to *striga* control in maize to sustainably produce the crop in *striga* endemic farming communities.

The Institute also released three soybean varieties into the farming systems during the year under review. The improved varieties combine earliness with high yielding and good shattering ability as well as good trap trait for *striga* control.

The crop improvement programme is generally making strides in developing crop varieties that fits into the agroecologies of the mandate zone. Pearl millet improvement has had no improved pearl millet varieties beside Manga nara which was released in the colonial era. Research is far advanced for five improved pearl millet varieties to be proposed for consideration for release in 2014.

The soil improvement programme continues to develop innovative strategies to boost maize-based cropping system productivity in northern savannah zones through widespread adoption of integrated soil fertility management. Adoption of best practices by farmers resulted in maize yield of as much as 3-4 t/ha. Further studies on inoculation of soybean with rhizobium also resulted in 30-40% yield increase at farmer level.

With the completion of work on the installation of the facility for confined field trial on developing a *Maruca*-resistant cowpea, the National Biosafety Committee has permitted SARI to conduct the first trial in 2013.

Our scientists continued to mobilize resources through attraction of funding from research proposals/contract research to ensure that the Institute is prepared to take on challenges and build capacities of partners/students in the geographical mandate. All these have resulted in a stronger organization with a more relevant and focused science platform, responsive staff and more effective institutional mechanisms to ensure effectiveness and efficiency in operations, proactive and more strategic partnerships and networks, and an increase in resources that would facilitate the success of its farming systems research programmes.

I would like to thank the staff for their hard work and commitment. I encourage all to work even harder to make sure that SARI succeeds in its vision of making agricultural research responsive to farmer needs and national development. My thanks go to all donors, especially AGRA, DANIDA, USAID, EMBRAPA and others that have supported us during the course of the year. Our appreciation also goes to the Ministry of Food and Agriculture and numerous press houses that helped us disseminate our technologies. We hope that you will enjoy reading this report with much pleasure. Never hesitate to consult us for any of the technologies we have developed.

Dr. Stephen K. Nutsugah
Director

ADMINISTRATION

Management

The Institute is managed by a 7-member Management Board, chaired by Mr. Alhassan Andani, MD of Stanbic Bank, and a 16-member Internal Management Committee (IMC), chaired by the Director. Membership of the Management Board and IMC are presented below:

Membership of CSIR-SARI Management Board

No.	Name	Designation
1	Mr. Alhassan Andani	MD, Stanbic Bank, Chairman
2	Dr. (Mrs.) RoseEmma Mamaa Entsua-Mensah	Deputy Director-General, R&D
3	Dr. N. Karbo	Cognate Director, CSIR-ARI
4	Dr. S. K. Nutsugah	Director, CSIR-SARI
5	Mr. Mumuni Alhassan (deceased)	Private Sector
6	Mr. Roy Ayariga	MoFA
7	Alhaji Nashiru Kadri	Private Farmer

Staff Strength

Staff strength as at the beginning of April 2012 stood at 448. However, by the end of the year the number had decreased to 406 comprising of 49 Senior members, 104 senior staff and 295 junior staff members. Staff distribution and the list of senior members and staff are presented below. Staff strength was affected in the course of the year by promotions, appointments, retirements, resignations and deaths. See Table 1 for full details.

The out stations located in Manga and Wa also have staff total of 47 and 44, respectively. Manga has 6 Senior members, 7 senior staff and 34 junior staff while Wa has 4 senior members, 13 senior staff and 27 junior staff.

Table 1. Promotions, appointments and deaths

	Principal Research	Senior Research	Senior Members	Senior Staff	Junior Staff	Total
Promotion	3	2	-	19	2	25
Appointment		-	4	16	14	34
Consideration		-	-	-	-	-
Retirement	-	-	-	8	16	24
Death		-	-	-	3	3

Human Resource Development

The Human Resource Development Committee has received approval for 13 staff on local and foreign training for 2011/12 academic year.

No	Name	Course	Finish	*Place
1	Salifu Abdul-Wahab	PhD	2012	Univ of Florida, USA
2	Abubakari Mumuni	BSc	2012	IPS, Accra
3	Abihiba Zulai	BSc	2012	IPS, Accra
4	Francisca Abaah	BSc	2012	UEW, Kumasi
5	Yahaya Inusah	MSc	2012	KNUST, Kumasi
6	Kambe John Baptist	HND	2013	Tamale Poly
7	Thomas Coker-Awortwi	EMBA	2011	KNUST, Kumasi
8	Joseph Adjabeng-Dankwa	PhD	2014	Univ of Ghana, Legon
9	Mahama George Yakubu	MSc	2011	Kansas State Univ, USA
10	Tahiru Fulera	MSc	2012	Univ of Bonn, Germany
12	Alidu Issah Abukari	MSc	2010	Tuskegee Univ, USA

Table 3. Staff back from training

Name	Grade	Programme
Williams K. Atakora	Asst. Res. Scientist	MSc
Ibrahim Hashim	”	BSc

Membership of Committees

Staff continued to serve on various committees listed below:

- Publication/Editorial
- Human Resource Development
- Expenditure Control
- Guest House
- Housing Allocation
- Land use & Water Conservation
- Internal Management

- Ground & Compound
- Promotion Screening
- Commercialization Oversight
- Welfare
- Health Fund
- Club House
- Seminar/Field Visit
- SARI Estate Management

National Service

Ten graduates from tertiary institutions in the country undertook their national service at the Institute. The details are presented in the Table below.

Institution	**No.**
Kwame Nkrumah University of Science and Technology	2
University of Ghana, Legon	2
Domongo Agric. College	4
University of Cape Coast	1
University for Development Studies	15
Tamale PolyTechnique	8
Bolga PolyTechnique	1
Total	**33**

Membership of CSIR-SARI Internal Management Committee

No.	**Name**	**Designation**
1	Dr. Stephen K. Nutsugah	Director (Chairman)
2	Dr. Stephen K. Asante	Deputy Director
3	Dr. James M. Kombiok	Head, NR Farming Systems Research Group
4	Dr. Roger A. L. Kanton	Head, UER Farming Systems Research Group
5	Dr. Jesse B. Naab	Head, UWR Farming Systems Research Group
6	Dr. M.S. Abdulai	Head, Scientific Support Group
7	Dr. Benjamin D. K. Ahiabor	Representative, Research Staff Association
8	Mr. Mohammed Dawuni	Representative, Senior Staff Association
9	Mr. Mahama Tibow	Representative, Local Union
10	Mr. Thomas K. Coker-Awortwi	Head, Accounts
11	Mr. J. K. Bidzakin	Ag Head, CID
12	Mr. Robert K. Owusu	Scientific Secretary, Recorder
13	Mr. Robert C. A. Adongo	Workshop Manager
14	Mr. Richard Y. Alhassan	Farm Manager
15	Rev. G.Y. Nachim	Head, Administrative Division

Staff Distribution among Divisions

Division	Senior Members	Senior Staff	Junior Staff	Total
Northern Region Farming Systems Research Group	10	17	50	77
Upper East Region Farming Systems Research Group	6	7	34	47
Upper West Region Farming Systems Research Group	4	13	27	44
Scientific Support Group	24	36	57	117
Commercialization and Information Division • Documentation • Library	2	4	4	10
Accounts	1	12	6	19
Administration Division • Personnel • Transport/Workshop • Farm Management • Estate • Security	2	15	117	134
Total	**49**	**104**	**295**	**448**

List of enior Members and Senior Staff

Administration, Accounts, Farm Management and Workshop

Name	Qualification	Area of Specialisation	Designation
Administration			
S. K. Nutsugah	BSc MSc PhD	Agriculture Plant Pathology Plant Pathology	Director
G.Y. Nachim	BA MPhil Post-Graduate Dipl	Sociology & Study of Religions Sociology PGDTLHE	Administrative Officer
Bawa M. Saffiatu	BA	IDS	Principal Administrative Asst
F. Amea	DBS	Secretariat Option	Sen. Clerk
O.A. Beatrice	BA	IDS, Planning	Principal Estate Asst

I. K. Osman	HND	Sec. & Mgt	Administrative Asst
Alidu Feruza	HND	Sec. & Mgt	Administrative Asst
*Francisca Abaah	DBS	Secretariat Option	Administrative Asst
N. Taiba	DBS	Secretariat Option	Sen. Clerk
Musah Iddi	Full Techn Certificate	Radio, Television & Electronics Radio, Television & Electronics	Chief Works Superintendant
Accounts			
T. K. Coker-Awortwi	BEd (Accounts Option)	Accounting	Assistant Accountant
*Paul Berko	ICA (Inter), BEd	Accounting	Chief Accounting Assistant
Mohammed Alima	HND BA, IDS	Accounting	Principal Acc Assistant
Wumbei Mohammed	HND	Accounting	Accounting Assistant
Abdulai Baba Alhassan	IDS		Principal Accounting Assistant
R. S. A. Adongo	RSA III Lcc III	Accounting	Principal Accounting Assistant
N. K. Abass	HND	Accounting	Chief Accounting Assistant
A. K. Alhassan	BSc Accounting & Finance	Accounting	Chief Accounting Assistant
Bawa Ford	HND	Accounting	Chief Accounting Assistant
S. F. Farouk	HND	Accounting	Principal Accounting Assistant
Issah Issifu	Dpl Com	Accounting	Principal Accounting Assistant
Sebastian Tigbee	RSA III Dip. in Com	Accounting	Principal Accounting Assistant
Mahama A. Rufai	HND	Accounting	Principal Accounting Assistant
Zulai Abihiba	DBS	Accounting	Senior Storekeeper
Kofi Konadu Asare	HND	Accounting	Senior Accounting Assistant
Alhassan Abukari	HND	Accounting	Senior Stores Superintendent
Farm Management			
R.Y. Alhassan	Dpl	Horticulture	Chief Technical Officer
Moses Jabituk	Farm Inst. Cert.	Farm Mgt	Asst Farm Mgr

Workshop			
R. C. A. Adongo	MVT	Part I & II	Chief Works Superintendent
I. K. Acquah	Certificate	NVTI	Chief Works Superintendent
A.Y. Ndinyah			Chief Works Superintendent
Patrick Apullah	City and Guilds	Carpentry& Joinery Art	Principal Works Superintendent
A. Owusu	MVT	Part I & II	Senior Works Superintendent
B.D. Boamah	Basic Refrigeration and Air Conditioning	NVTI Grade 1	Senior Works Superintendent
J.Y. Wasaal	Jnr Techni Supervisory Mgr	Workshop	Works Superintendent
J.Y. Xerxers	Snr Techni Supervisory Mgr	Workshop	Prin Works Superintendent
G. Akotia	TradeTestGrade 1	Workshop	Works Superintendent
Emmanuel Tetteh	N.V.T.I Grade 1	Workshop	Works Superintendent
P. A. Anaaba	N.V.T.I. National Craftman	Workshop	Works Superintendent
M. Jabiru	HND	Workshop	Works Superintendent
Z. S. Seini	HND	Workshop	Principal Techn Officer

Upper East Farming Systems Research Group

Name	**Qualification**	**Area of Specialisation**	**Rank**
R. A. L. Kanton	MSc PhD	Agronomy	Principal Research Scientist
E. Y. Ansoba	BSc	Agriculture	PTO
*F. Kusi	MSc	Entomology	Research Scientist
Julius Yirzagla	MSc	Agronomy	Research Scientist
Issah Sugri	MPhil	Post Harvest	Research Scientist
*Abdul-Wahab Salifu	BSc	Agric Economics	Assistant Research Scientist
Peter A. Asungre	BSc	Agric Engineering	PTO
Zakaria Mukhtaru	BSc Agric	Agriculture	PTO
Abdulai Abubakari	HND	Sec & Mgt	Prin Admin Asst
Musah Zakari	Agric College Cert	Farm Mgt	Assistant Farm Mgr
Salim Lamini	BSc Tech	Agric	PTO
Albert Alem	Dipl	Agric	Technical Officer

Northern Region Farming Systems Research Group

Name	Qualifications	Area of Specialisation	Designation
Wilson Dogbe	MSc PhD	Agronomy Soil Microbiology	Senior Research Scientist
J. M. Kombiok	BSc MSc PhD	Agriculture Agronomy Agronomy	Principal Research Scientist
Mumuni Abudulai	BSc MSc PhD	Agriculture Agricultural Entomology Agricultural Entomology	Principal Research Scientist
Baba Inusah	MSc	Irrigation Agronomy	Research Scientist
A. N. Wiredu	BSc MSc	Agriculture Agricultural Economics	Research Scientist
Afia S. Karikari	MSc	Entomology	Research Scientist
M. Mawunya	BSc	Agriculture	Assist Research Scientist
D. Y. Opare-Atakora	BSc MSc	Agriculture Crop Science	Assist Research Scientist
Aliyu Siise	BSc MSc	Agric Biotechnology	Principal Technical Officer
Jerry Ansalma Nboyine	MSc	Entomology	Research Scientist
B.A. Alhassan	Dipl	Agriculture	Chief Techn Officer
Samuel Oppong-Abebrese	MSc	Crop Breeding	Research Scientist
Sulemana Daana Alhassan	BSc Tech	Agriculture	Chief Technical Officer
Rakiatu M. Abdulai	HND	Statistics	Principal Technical Officer
Haruna Abdulai	BSc	Agric	PTO
I. Misbow	Dipl	Agric	Technical Officer
E. O. Krofa	BSc Tech	Agriculture	Chief Technical Officer
Mahama Alidu	Dipl	Horticulture	Chief Technical Officer
Iddrisu Sumani	Dipl	General Agriculture	Chief Technical Officer
Sayibu Zaanyeya	Cert in Agric	General Agric	Asst Farm Mgr
Haruna Bashiru	BSc	Agric	PTO
K. Foster Y.	BSc Tech	Agric	Principal Techn Officer
Prince M. Etwire	BSc Tech	Agric	Principal Techn Officer
Elsie Sarkodee-	BSc	Agric	Principal Techn Officer

Addo			
Alhassan Sayibu	BSc Tech	Agric	Principal Techn Officer
Jalilatu Ayuba	BSc Tech	Agric	Principal Techn Officer
Abdul-Rahaman A. B. Iddrisu	BSc Tech	Agric	Principal Techn Officer
Abdul Salam B. Alhassan	BSc Tech	Agric	Principal Techn Officer
Freda Ansah Agyapong	BSc Tech	Agric	Principal Techn Officer
Daniel E. Halolo	BSc Tech	Agric	Principal Techn Officer
Douglas B. Alhassan	Dipl	General Agric	Chief Techn Officer
Desmond A. Sunday	BSc	Mathematics	Principal Technical Officer

Upper West Farming Systems Research Group

Name	Qualification	Area of Specialisation	Rank
J. B. Naab	BSc PhD	Soil Science Soil Physics	Senior Research Scientist
S. Saaka J. Buah	BSc MSc PhD	Agriculture Agronomy Soil Fertility & Plant Nutrition	Senior Research Scientist
S. S. Seini	BSc MPhil	Agriculture Agricultural Entomology	Research Scientist
*George Mahama Yakubu	BSc MS	Agriculture Agronomy	PTO Ass Res Scientist
Asieku Yahaya	BEd	Agricultural Science	PTO
Yahaya Iddrisu	MPhil	Agric Economics	Research Scientist
Nyour Anslem Bawayede-Azee	BSc	Agriculture Economics	Principal Technical Officer
Alhassan Nuhu Jimbaani	BSc	Agriculture Economics	Principal Technical Officer
Bavid B. Barton	BA	IDS	Principal Technical Officer
A. Ali Asiata	Dipl		Senior Admin. Asst
Haruna K. Ali	Dipl	General Agric	Senior Technical Officer
Gordon Opoku	BSc	Laboratory Technician	Chief Technical Officer
Ibrahim Hashim	HND BSc	Statistics Statistics	Principal Technical Officer
A. Ibrahim Ali	HND	General Agric	STO

Vincent K. Dordah	HND	Agric Engineering	TO
Francis Alemawor	HND	General Agric	TO

Scientific Support Group

Name	Qualifications	Area of Specialisation	Designation
S. K. Asante	BSc MSc PhD	Agriculture Plant Protection Agricultural Entomology	Principal Research Scientist
I. D. K. Atokple	BSc Dip Ed MSc PhD	Agriculture Education Plant Breeding Plant Breeding	Senior Research Scientist
M. S. Abdulai	BSc MSc PhD	Agriculture Plant Breeding Plant Breeding	Senior Research Scientist
M. Fosu	BSc Dip Ed MSc PhD	Agriculture Education Soil Chemistry Soil Chemistry	Principal Research Scientist
N. N. Denwar	BSc MPhil	Agriculture Plant Breeding	Research Scientist
B. D. K. Ahiabor	BSc MSc PhD	Agriculture Plant Physiologist Mycorrhizology	Research Scientist
N. Tabi Amponsah	BSc MSc PhD	Agriculture Nematology Plant Pathology	Research Scientist
Joseph Adjebeng-Danquah	BSc MSc	Agriculture Plant Breeding	Research Scientist
Fulera Tahiru	BSc	Agriculture	Asst Research Scientist
George Oduro	Certificate	General Agriculture	Chief Tech Officer
N. A. Issahaku	HND	Agriculture Engineering	Principal Tech. Officer
H. Mohammed	HND BSc	General Agriculture	Principal Tech. Officer
A. L. Abdulai	BSc MSc	Agriculture Agrometeorology	Research Scientist
Esther Wahaga	BA	Sociology	Asst. Research Scientist
A. S. Alhassan	Diploma	General Agriculture	Principal Tech. Officer
A. Mohammed	Certificate	General Agriculture	Senior Tech. Officer
M. M. Askia	BSc	Chemistry	Asst. Research

	MPhil		Scientist
K. Acheremu	BSc MSc	Agriculture Crop Breeding	Research Scientist
Richard Oteng-Frimpong	MPhil	Crop Science	Research Scientist
A. A. Issah	BSc	Agriculture	Asst. Research Scientist
Abukari Saibu	BSc Tech	Agriculture	Principal Tech. Officer
Abubakari Mutari	BSc	Agriculture	Asst Research Scientist
Williams K. Atakora	BSc	Agriculture	Technologist
Issah A. Rashid	BSc Tech	Agric	PTO
Haruna Alidu	MSc	Plant Breeding	Research Scientist
Emmanuel Vorleto	HND	Laboratory Technology	Principal Techn. Officer
Edwin K. Akley	BSc Tech	Agric	PTO
Prosper Amenuvor	HND	Lab Technology	Technical Officer
Michael Asante	BSc Tech	Agric	Principal Techn Officer
Ibrahim Sumaila	Agric College	Agric	Technical Officer
Fuseini S. Issifu	Agric College	Agric	Asst Farm Mgr
Gloria Boakyewaa Adu	BSc	Agric	PTO
Richard Agyare	BSc	Agric	PTO
Emmanuel Y. Owusu	BSc	Agriculture	Principal Tech. Officer
Godfred D. F. Atawura	BSc Tech	Agriculture	Principal Tech. Officer
Wohor Osman Zakaria	BSc Tech	Agriculture	Principal Tech. Officer
Kangben Foster Yambout	BSc Tech	Agriculture	Principal Tech. Officer
B. D. Alhassan	BSc Tech	Agriculture	Principal Tech. Officer
Emmanuel Ayipio	BSc Tech	Horticulture	PTO
Alhassan Ibrahim Zakaria	BSc Tech	Agric	PTO
Abdul-Aziz Abdul-Latif	BSc Tech	Agric	PTO
Alhassan Sayibu	BSc	Agric	PTO
Issah Issifu Ramat	HND	General Agric	PTO
Abukari Saibu	HND	General Agric	PTO
Isaac K. Nantari	GCE O L	Agric Sci	PTO

Business Development and Information Unit

Name	Qualification	Area of Specialisation	Rank
J. K. Bidzakin	BSc MSc	Agric Technology Agric Economics	Ag Marketing Officer
R. K. Owusu	BSc MSc	Agricultural Postharvest & Food Preservation Engineering	Senior Scientific Secretary
Mumuni Abukari	HND	Marketing	Marketing Asst
Ms. Warihanatu Baako	HND	Marketing	Principal Marketing Asst
Wilhelm Kutah	BSc Tech	Agric	Principal Techn Officer
Yamyolya Alhassan	HND	Marketing	Marketing Asst
Issah Issifu	Dipl	Library	Library Asst
Musah Iddi	Tech III Cert	Radio, TV & Electronics	Prin Superintendent

List of Research Scientists and Conferences/Workshops attended in 2012

Name	Period	Country/Town	Conference/Training/Workshop
Afia Serwaa Karikari	24-28 Sept	Accra	IFS-EU-ACP Value Chain Research Training on Neglected and Underutilized Species of Plants
	18-22 June	Accra	EU-ACP Research Design and Data Analysis with focus on Neglected and Underutilized crops
	30 Apr - 30 May	Tel Aviv, Israel	MASHAV-CINADCO-ARO International R&D Course on IPM
	15-17 May	Israel	The International CIPA Conference 2012: Plasticulture for a Green Planet
Alidu Haruna	18-22 Apr	Kumasi	DTMA Regional Planning Workshop
	1-5 Oct	Nairobi, Kenya	Maize Breeders Refresher Course
Abubakari Mutari	29th June	Accra, Ghana	Ghana Climate Change Adaptation Network Meeting.
Mohammed Haruna	14-15 May	Accra	AGRA M&E training for grantees in Ghana
	28-29 Mar	Tamale	Sustainable Intensification of cereal-based farming systems in the Sudano-Sahelian zone in Ghana
	15-16 Mar	Niamey, Niger	GCP Training workshop on introduction to molecular breeding and the use of Galaxy-table to generate electronic data-base
	12-14 Mar	Niamey, Niger	Inaugural workshop of TL II Phase 2
	13-15 Mar	Accra	Regional consultation on increasing farmer access to conserved diversity for cowpea, Pearl millet, sorghum and Yam in West Africa
Alhassan Lansah Abdulai	9-13 Apr	Dakar, Senegal	Regional Training workshop on using climate scenarios and analogues for designing adaptation strategies in agriculture. Organized by AGRHYMET and CCAFS
	6-17 Aug	Niamey, Niger	Training on GIS and Remote Sensing. Organized by International Crops Research Institute for the Semi-Arid Tropics
	17-20 Sept	Niamey, Niger	CRP1.1 protocols development workshop organized by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
M. Fosu	14-16 Mar	Tamale	Gender Training workshop
	1-3 May	Nairobi, Kenya	Scoping workshop on best management practices and decision support systems for cropping systems of sub-Saharan Africa

	13-19 May 20 May 24 May 10-13 July 24-27 July 24-29 Sep 1-3 Oct 5-9 Nov	Brazil Accra Accra Kumasi Adis Ababa, Ethiopia Arusha, Tanzania Accra Cote d'Ivoire	Cowpea inoculant production Ghana-Norway collaboration on Climate Smart Agriculture Workshop Africa's Agriculture Green Revolution Forum - Is Ghana ready? Improving Fertilizer Development workshop International START/UNEP workshop on Climate Change Effect Assessment on Urban and Peri-Urban Agriculture Africa's Agriculture Green Revolution Forum AGRA Grantees workshop CORAF Steering Committee meeting. 5[e] Session ordinaire du Comité Régional de Pilotage
Dr. S. K. Asante	7-9 Aug 22-25 Nov	Kumasi Kumasi	RTIMP Farmer Field Fora (FFF) Implementation Review and Team Meeting RTIMP Annual Review and Planning Workshop
Dr. Nicholas N. Denwar	23-25 July 1-3 Oct 28-29 Mar 13-14 June 15 Nov 18 Dec	Nairobi, Kenya Dar es Salaam, Tanzania Tamale Kumasi Kumasi Kumasi	The Modern and Visionary Plant Breeders' Conference Annual Policy Action Nodes General Meeting IITA/Africa Rising Review/Planning Workshop FABS Awardees Workshop Needs assessment of AGRA-supported private seed companies Workshop National Variety Release and Registration Committee Meeting
Mutari Abubakari	1-15 Feb 14-26 May 30 Sept to 3 Oct	India Burkina Faso Las Vagas, USA	Upgradation of food testing skills for food processing professionals. Organized by Shrriram Institute of Industrial Research under the aegis of India-Africa Forum Summit Impacts of climate change and desertification on agriculture and food security. Organized by the AU/ SAFGRAD in conjunction with the Arab Fund for Technical Assistance to African Countries Annual General Meeting of the Association of Analytical Chemists
Francis Kusi	13-16 October	Niamey, Niger	West Africa Cowpea Consortium Meeting and training

Dr. S. S. J. Buah	16-27 July 18-22 Apr	Tamale Kumasi	Training workshop on experimental data and analysis organized by IITA/Africa RISING Regional planning meeting of the DTMA Project (DTMA Project)
Robert K. Owusu	13-17 Feb	Benin (Cotonou)	Diagnostic Survey, Rice Processing and Value Addition Task Force Workshop
Dr. Wilson Dogbe	25th – 28th July 26th – 28th Sept. 29th Oct. – 1st Nov.	Ouagadougou, Burkina-Faso Arush and Niono, Tanzania Punta del Este, Uruguay	Regional Workshop on system of Rice Intensification Research. Africa Green Revolution Forum (AGRF) Second Global Forum for Agricultural Research (GFAR)
Inusah I. Y. Baba	3rd July – 4th August	Japan	"Fiscal Year 2011-2012 Development of Core Agricultural Researchers for Rice Promotion in Sub-Saharan Africa.
Dr. E. B. Chamba	18th – 22nd Aug. 27th – 28th Aug.	Ouagadougou, Burkina-Faso Accra, Ghana	Exchange of experience with cotton seed supply in West Africa. 1st Stakeholders workshop on private sector led strategy for the Yam industry in Ghana
R.K. Owusu	26th – 31st July	Teri Gram, India	India-Africa Training Program on Innovation and Technology Management.
A. N. Wiredu	23rd July-3rd Aug. 6th - 10th Aug	Johannesburg, South Africa Niger, Niamey	Conference on How to manage, Design and Conduct Impact Evaluations. Planning Meeting on Socioeconomic Activities.
Dr. J. M. Kombiok	10th – 12th Sept.	Ouagadougou, Burkina-Faso	Exchange travel and Steering Committee JEF Project.
G. Y. Nachim	10th – 12th Sept. 2012	Ouagadougou, Burkina-Faso	Exchange travel and Steering Committee JEF Project.
Dr. J. B. Naab	9th – 12th Oct. 18th - 24th Oct. 28th Oct. – 1st Nov.	Rome, Italy Cincinnati, Ohio Punta del Este, Uruguay	Millet and Sorghum Models Improvement Aspects. Sustainable Agriculture And Natural Resource Management Collaborative Research Support Project. Second Global Forum for Agricultural Research (GFAR)
Dr. R. A. L. Kanton	15th -20th Jan. 18th-24th October	Mali-Bamako Cincinnati, Ohio	Data Analysis to enhance Scientists data analysis skills. Sustainable Agriculture And Natural Resource Management Collaborative Research Support Project.
Joseph Adjebeng-	23rd April-4th May	Nijmegen, The Netherlands	Training Workshop under integrated breeding platform of the generation

Danquah			challenge programme.
Alexander N. Wiredu	28th May – 2nd June	St. Louis, Senegal	Annual Rice Policy and Training Workshop
Richard Oteng-Frimpong	12th -16th March 23rd April-4th May	Niamey, Niger Nijmegen, The Netherlands	Tropical Legume II (TL II) Lunching and Planning Workshop and GCP Training Workshop. Training Workshop under integrated breeding platform of the generation challenge programme.
Kwabena Acheremu	23rd April-4th May	Nijmegen, The Netherlands	Training Workshop under integrated breeding platform of the generation challenge programme.
Abubakari Mutari	1st Sept. – 31st Dec	USA	Norman E. Borlaug International Agricultural Science and Technology Fellowship Program.

COMMERCIALIZATION

Introduction – With the CSIR Act (CSIR Act 521, 1996) serving as the basis of its activities, Commercialisation and Information Division (CID) of the Institute is the Division which spearheaded and coordinated commercialization efforts of the Institute during the year 2012. Research efforts by the Institute over the year have yielded significant results culminating in outputs such as drought-tolerant and disease-resistant crop varieties of various maturity periods, namely short, medium and long term. The CID has the responsibility to market the Institute and its products. In doing this, the CID among others;

- Indentified technologies and services that can be commercialized
- Determined the cost of the technologies and services
- Promoted available technologies and services
- Sensitized the institute on technologies and services that can be commercialized
- Negotiated for sale of technologies and services on behalf of the Institute

Staff Strength

The Division was staffed during the year under review by;

- Mr. Eric Appiah – Head and Marketing Officer
- Mr. Robert Owusu – Senior Scientific Secretary
- Mr. Abukari Mumin – Senior Marketing Assistant
- Miss Baako Warihana – Senior Marketing Assistant
- Mr. Alhassan B. Yamyolya – Marketing Assistant

Identified Technologies for Commercialization

The CID, with the support of the Commercialization Oversight Committee, identified the following technologies for commercialization;

- Improved Crop Varietites
- Crop and Soil Management Practices
- Soil Fertility Management
- Insect Pest and Diseases Control Methods

Beside the above-mentioned technologies, other sources of revenue to the Institute during the year under review were:

- Guest House – CSIR-SARI has an eight room Guest house and 4 chalets. However, they all need total refurbishment as they have run down.
- Soil and Plant Analytical laboratory – the Institute is well known for undertaking analysis of soil and plant materials.
- Provision of Mechanization Services – the Institute has 10 tractors out of which 6 were in good condition and two of the tractors are multi-purpose. In addition, the Institute has 3 combine harvesters out of which 2 are pneumatic and cannot work on soggy fields. Only 1 crawler combine harvester is versatile and can work on all types soil conditions.
- Documentation – Photocopying, binding and laminating services offered to clients.
- Conference Hall – the Conference hall has 12 offices with internet facility.
- Rice Processing Centre – the Institute has 2 rice mills, each with an installed capacity of 1.5 MT per hour but the current operating capacity is about 1.2 Mt per hour
- Farm Produce – these are mostly research by-products which were sold to the public after research work.

The Tables below shows the monthly performance of the various sources of revenue to the Institute during the period under review.

Table 1. Monthly income for the Institute, 2012

	Guest House	Soil Analy-sis	Tractor Services	Docum-entation	Confe-rence Hall	Rice Processing Centre	Combine Harvester	Seed/ Farm Produce	**Total**
Jan	0	14,470	500	957	32,401	10,770	-358	0	**58,741**
Feb	-164.5	-271	0	-1,992	25.5	-1,430	-815	0	**-4,647**
Mar	-400	1,633	0	-422	0	-11,691	-450	**0**	**-11,330**
Apr	440	-2134	0	-47.2	-384	575.7	-30	30	**-1,550**
May	538	-3,001	-3,499	257	0	4,477	0	0	**-1,228**
Jun	441	-10,197	-11,642	-228	7,200	2,100	-288	0	**-12,614**
Jul	0	-625	-5,578	72	300	2,838	0	0	**-2,993**
Aug	724	7,929	-1,405	774	0	-5951	0	0	**2,072**
Sept	-570	431	5,045	127	930	-4,214	0	0	**1,751**

Oct	-587	1,480	3,205	1,052	7,600	6,989	0	904	**20,644**
Nov	664	-8,435	930	-158	200	4,523	0	0	**-2,277**
Dec	142	-489	-70	100	150	577	-570	0	**-158**

Table 3: Making Meaning of Commercialization Report -2012

Product/Service	**Classification**	**What needs to be done**
Combine harvester	Cash cow	Invest to maintain
Tractor Services	Cash cow	Invest to maintain
Soil/Plant Analysis	Cash cow	Invest to maintain
Documentation	Dog (customers are moving to other service providers)	Draw customers back
Rice Processing Centre	Not sure about success	Invest to grow & cut cost of production
Gbewaa Rice	Dog (lacks innovation & customers are moving to other products)	Innovate & draw back customers

Contribution to Corporate IGF

The Institute contributed 15% of its Internally Generated Fund (IGF) to the Head Office on quarterly basis. Table 4 shows these contributions over the year under review.

Table 4: Contribution to Corporate IGF

Quarter	**Amount GH₵**
1st Quarter	6,414.49
2nd Quarter	0 (Net Income Negative)
3rd Quarter	124.42
4th Quarter	2,731.26
Total	**GH₵ 9,270.00**

Conclusion

A cursory look at the various quarterly Income and Expenditure reports for the year 2012 reveals a commonness of high expenditure of the various cost centers. Efforts should therefore be put in place to reduce the incidence high expenditure.

DOCUMENTATION AND LIBRARY

Robert Kwasi Owusu, Wilhelm Kutah Nonu, Issah Issifu and Ibrahim Sumaya

DOCUMENTATION

Introduction

The function of the Documentation Centre is to collate and edit all reports prior to submission to Head Office, deal with correspondences in relation to research reports, coordinate exhibitions, seminars, and field visits within and outside the institute.

Preparation and submission of Reports

The 2011 fourth quarterly report was submitted to Head office in early 2012 whilst the first, second and third quarterly reports were submitted within the year under review when due. Editing of 2010 Annual Report was completed and submitted for printproduction whilst editing of the 2011 one commenced.

The Documentation Centre also coordinated the following exhibitions:

- The Third West and Central Africa Agricultural Science Week and CORAF/WECARD 10th General Assembly at Ndjamena, Chad, 10 -19 May, 2012.
- The commemoration of the Day of Scientific Renaissance of Africa held on 29th June 2012, which was held at SARI Conference Centre.
- National Farmers Day celebration at Abokobi (near Accra) on the 1st and 2nd November 2012
- WAAPP Regional Workshop on Root and Tuber Crops. November 19 – 23, 2012 at CSIR-Crops Research Institute

Experimental Field Visit

The weekly field visit started on late August and ended in October, 2012. Attendance was generally good except the last field visited, which was the Cassava Improvement. For the first time participants were supplied with soft drinks after each field visit. Dr. Wilson Dogbe supplied two kilograms of red rice (NERICA 14) to each participants after the visit to the Rice Improvement Programme.

Seminar

One external seminar was organized within the year. Dr. Claude Piquet, Cassava Biotechnologist delivered a seminar on Biotechnology on 17th September, after which the Cassava Improvement field was visited

LIBRARY AND INFORMATION

The institute’s library was established in 1980. Its main objective is to develop a strong information service to support the institute's research programmes and to meet the needs of the scientific community. The Library's collections are mainly on Agriculture with special collections on Farming Systems Research. The book collections currently exceed 5900 volumes. The Library get donations from over 40 journals and subscribe to two daily newspaper and one weekly newspaper. The library also stocks theses, seminar and conference papers, as well as journals of Scientists, which are stocked in their various box files (except the theses, which are shelved)

Electronic Resources
The library currently offer literature search from the following sources:

- AGORA (Access to **Online** Research in Agriculture): username and password are available at the library
- OARE (Online Access to Research in Environment)
- HINARI (Health InterNetwork Access to Research Initiative): username and password available
- ScienceDirect. Username and password available
- CD-ROMS (FAO, INASP, AGROMISA & CTA, CAB Int. Compedium, etc.)
- TEEAL

So far 755 books were catalogued, classified and shelved according to the class number. These materials have been entered into a database. Within the year the Library recorded 185 clients, who were mostly students from UDS, KNUST, Tamale Polytechnic and other institutions.

Book Donation
Within the year the Library receive over 87 volumes of book and journals, 59 magazines and Newsletters and 13 Reports all through donations.

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MAJOR ACHIEVEMENTS AND PROGRESS MADE IN RESEARCH PROGRAMMES

SCIENTIFIC SUPPORT GROUP

The Scientific Support Group (SSG) is made up of Agronomists, Soil Scientists, Agrometeorologist, Entomologists, Plant Breeders and Plant Pathologist whose objectives include conducting on-station investigations to find solutions to problems encountered on farmers' fields. Such problems, under normal circumstances, do not lend themselves easily amenable at the farmers' level. Members of the group when necessary work in collaboration with the Farming Systems Research Groups on-farm to monitor and evaluate new technologies being assessed on the farmers' fields. Presented below are reports on activities carried out in 2012.

AGRO-METEOROLOGY

A. L. Abdulai

Introduction

Weather is a key factor of agricultural production because it affects all crops at all stages of their growth and development cycles. The economies of the interior Savannah of Ghana depend mainly on rain-fed agriculture which is highly sensitive to climate variability and/or extremes. CSIR-SARI has responsibility for churning out agricultural technologies (crop varieties and appropriate agronomic practices) for optimizing agricultural production in these areas. The Agro-meteorology unit of the Scientific Support Group (SSG) is responsible for monitoring weather elements within the mandate area of CSIR-SARI and maintaining a data base for the weather elements, producing quarterly reports and outlooks on weather elements, as well as communicating the implications of observed patterns in weather elements for agricultural production.

Proper information on key weather elements is crucial for delivering on the duty of the Agro-meteorology unit as well as for effective delivery on the mandate of CSIR-SARI. A number of manual and automated weather stations are being managed by the unit at different locations within the catchment/mandate area of CSIR-SARI. This report seeks to highlight the patterns observed for the key weather elements during the year 2012.

Table 1: Coordinates of Stations used by CSIR-SARI in 2012

Station	Latitude	Longitude	Altitude (msl)
Nyankpala	09°25'N	00°58'W	183
Damongo	09°01'N	01°36'W	260
Salaga	08°33'N	00°31'W	168
Yendi	09°27'N	00°01'W	195
Wa	10°04'N	02°30'W	323
Manga (Bawku)	11°01'N	00°16'W	246

The stations used by researchers of CSIR-SARI in 2012 were located between latitude 09°01'N and 11°01'N and between longitude 00°01'W and 02°30'W, with elevations ranging from 168 m to 323 m above mid sea level (msl) (

Table 1). Data on weather elements were collected across the sites using manual and/or automated devices.

General Climate at Nyankpala

For Nyankpala, the lowest rainfall was recorded in March, the humid portion started in April, while the highest monthly rainfall was recorded in September during 2012. No rainfall events were observed January and November. The respective months with the highest and lowest monthly figures for pan evaporation were February and September respectively (Table 2).

Table 2: Monthly patterns for various weather elements monitored at Nyankpala in 2012

Month	Rainfall (mm)	Evaporation (mm)	Temperature (°C)			Wind (m/s)	RHm (%)	RH max (%)	Sunshine (hrs)
			min	max	mean				
Jan	0.0	195.9	14.0	38.0	26.6	3.8	31.4	44.4	9.3
Feb	41.7	209.4	20.0	39.5	30.2	3.7	34.8	59.7	8.1
Mar	1.7	245.0	24.5	41.0	32.7	3.0	41.0	66.8	6.4
Apr	108.9	163.6	20.5	39.0	30.6	3.5	56.7	83.5	7.4
May	88.1	147.1	21.2	37.0	29.0	3.2	62.6	86.7	7.2
Jun	148.9	114.9	21.0	36.5	27.6	2.9	69.0	91.2	5.9
Jul	198.8	92.3	20.5	32.0	26.1	2.0	77.7	92.7	4.5
Aug	77.0	80.1	21.0	34.0	25.6	2.3	76.3	93.0	3.8
Sep	209.1	74.4	21.0	34.0	26.5	1.2	74.8	92.7	4.8
Oct	151.3	98.9	21.0	34.0	27.6	1.1	69.3	91.0	8.3
Nov	0.0	138.7	22.0	36.5	29.1	1.1	59.4	86.4	9.5
Dec	4.8	118.3	16.0	38.0	27.6	0.9	51.7	88.7	2.2

The coldest month was January (with the highest range in mean temperature) in 2012; March was observed as the hottest month; July had the lowest range in mean monthly temperature. Average wind speed was at least 3.0 m/s for the first five months (Jan-May), greater than 2.0 m/s but less than 3.0 m/s from June to August, and less than 2.0 m/s from September to December. Means of both maximum and minimum relative humidity were lowest in January; highest means for minimum and maximum relative humidity were recorded in July and August respectively; highest range for relative humidity occurred in December. Monthly means of daily sunshine hours ranged from 3.8 hrs in August to 9.5 hrs in December (Table 2).

Rainfall for research sites used CSIR-SARI

Monthly rainfall amounts for each of the locations where research scientists of CSIR-SARI conducted experiments are presented in Table 3. The humid portion of 2012 started in April for all the sites except Manga where it started in May. For all the locations, September received at least 200 mm of rain. Intra-annual distribution of rainfall was better in 2012 compared with 2011 when there was more but poorly distributed rainfall at most of the sites.

Table 3: Monthly rainfall totals for the locations used for research work in 2012

Month	Damongo	Bole	Salaga	Yendi	Wa	Manga
Jan	0.2	0.0	0.2	0.3	0.0	0.0

Feb	22.5	7.1	24.4	18.5	5.3	2.2
Mar	21.7	39.1	17.3	13.6	5.2	2.2
Apr	83.1	97.0	100.2	100.9	81.6	58.2
May	85.7	122.9	140.1	103.2	134.1	91.0
June	147.4	141.5	179.2	139.0	145.1	121.4
July	141.2	174.6	88.9	154.1	218.7	192.9
Aug	80.4	120.5	88.6	101.2	225.9	248.1
Sept	201.4	215.3	232.8	202.7	211.5	224.3
Oct	81.3	104.2	199.9	145.9	82.1	62.5
Nov	3.4	66.5	49.3	20.5	24.3	5.9
Dec	2.7	13.4	0.9	6.7	6.9	0.0
Total	870.7	1101.9	1121.9	1006.6	1140.8	1008.7

The rainfall events that occurred in October made significant contributions to crop production, while those in November created some post harvest challenges for farmers and researchers.

Rainfall Anomalies for Nyankpala

Monthly rainfall anomalies for Nyankpala were positive for 7 months (February, April, June, July, September, October, and December) with the highest (> 50 mm) being in October. Of the 5 months with negative anomalies at Nyankpala (January, March, May, August, and November), August was the most aberrant with a shortfall of more than 100 mm (Figure 1a). Considering decadal rainfall anomalies, 14 decads were positive, 17 decads were negative, while 5 were normal. Nine of the decads with positive anomalies occurred between June and October. The first and third decads of August were the two most negatively aberrant (Figure 1b). The rainfall distribution was such that no critical dry spell was observed despite the negative anomalies observed. 2012 could therefore be classified as a year with very high potential for crop productivity due to the near perfect rainfall distribution.

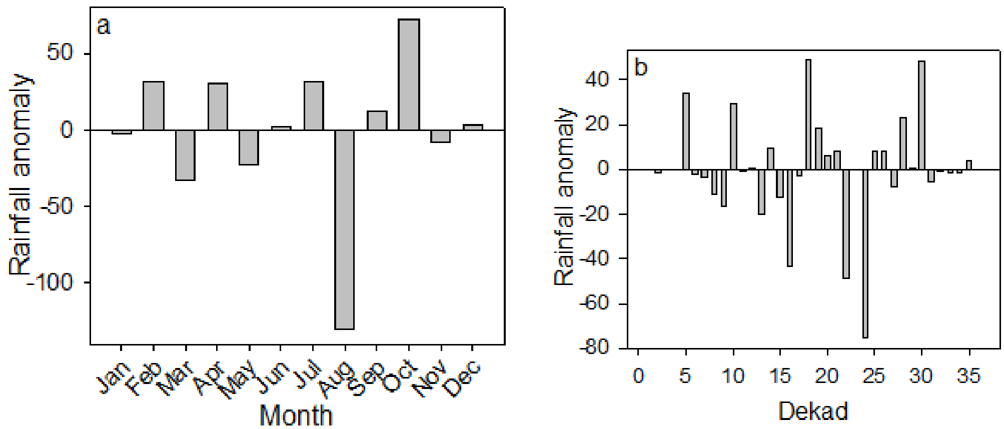

Figure 1: Monthly (a) and Decadal (b) patterns of rainfall anomaly for Nyankpala in 2012

Temperature Anomalies for Nyankpala

Minimum Temperature Anomalies

Generally, average minimum temperatures (Tmin) were higher than normal in 2012 for Nyankpala. This was evidenced by the observation of positive monthly Tmin anomalies for all months except January and April. Tmin for February, March, November and December were more than 1°C higher than normal (Figure 2a). This means that crops grew under higher than normal minimum temperatures in 2012 and would have shorter development cycles unless the average maximum temperatures were lower than normal such as to normalize the ranges. The decadal means of Tmin showed positive anomalies for 23 decads, negative anomalies for 12 decads, and 1 decad with no anomaly. This confirms what was observed for the monthly anomalies of Tmin (Figure 2b).

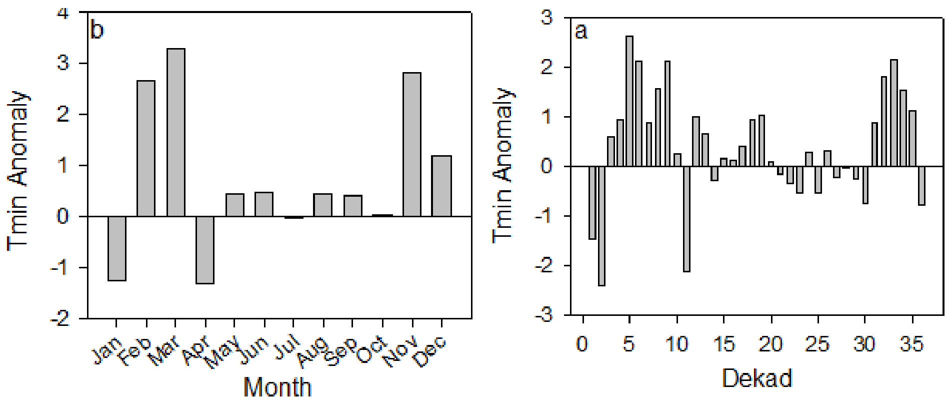

Figure 2: Monthly (a) and Decadal (b) patterns of Tmin anomaly for Nyankpala in 2012

Maximum Temperature Anomalies

Figures 3a and 3b show the respective means for monthly and decadal anomalies of maximum temperature (Tmax) Average maximum temperatures for Nyankpala were generally lower than normal 2012. Evidence for this resides in the negative monthly Tmax anomalies observed for all months except August and December.

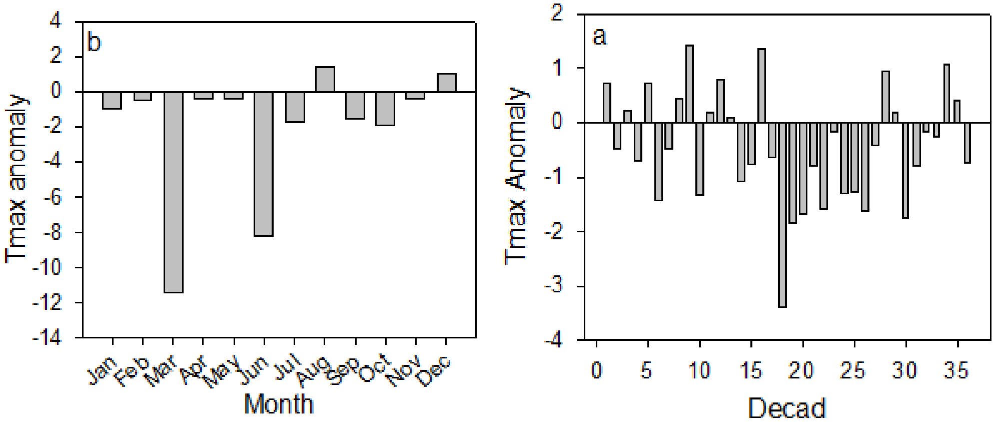

Figure 3: Monthly (a) and Decadal (b) patterns of Tmax anomaly for Nyankpala in 2012

Anomalies for the 2 months with positive values were both less than 2°C. Two of the ten months with negative anomalies had values lower than -8°C. Negative Tmax anomalies were experienced in 23 decads whiles positive Tmax anomalies were experienced in 23 decads. From the second decad in June to the last decad in September (the major period for crop growth) positive Tmax anomalies were experienced. This might offset the effects of higher than normal Tmin through reduced diurnal temperature ranges.

The year 2012 could be classified as a good year in terms of weather because:

- Rainfall distribution was quite favorable for crop growth.
- Higher minimum temperatures reduced the risk of stunted growth normally associated with low soil temperatures
- The lower maximum temperatures also reduced the risk of lethal temperatures and loss of soil moisture through excessive evaporation.
- There was little or no effect of intermittent and terminal drought on crops.

MAIZE IMPROVEMENT PROGRAMME

Multi-Location Testing of Drought Tolerant Varieties and Hybrids in Regional Trial

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Executive Summary

Four main activities were carried out in the 2012 farming season. They included:

- On-station evaluation of genotypes for tolerance to *Striga hermonthica* to identify superior stable yielding varieties.
- Evaluation of extra-early, early and late/intermediate maturity groups of hybrids and OPV's tolerant to drought to identify superior stable yielding varieties.
- Production of breeder seeds of some released varieties.
- Release of five new maize varieties.

To achieve the objectives set for these activities several trials were designed and planted in Nyankpala, Yendi and Damongo in the Guinea savanna zone and Wa and Manga in the Sudan savanna zone, of Ghana. Germplasm used was obtained from the International Institute of Tropical Agriculture (IITA), Ibadan and local sources. The experimental design used was the randomized complete block design and lattice design with four replications per location. Multiple trait selection method was used based on all important traits conferring superiority in a line. Combined analyses of the data across locations were done to increase the efficiency of selection. At the end of the cropping season, five new maize varieties (CSIR-Sanzal-sima, CSIR-Ewulboyu, CSIR-Wang-data, CSIR-Bihilifa, and CSIR-Tigli) which combine tolerance to drought/Striga with high grain yields and qualities and farmer/consumer acceptability were released.

Introduction

In Ghana, maize is the most important cereal grain in terms of total production and utilization. It is the largest staple crop and the most widely cultivated due to its high potential grain yield. The crop is the largest commodity crop in the country second only to cocoa (MiDA, 2010). It is a major source of food, feed and cash for many households in Ghana. Over 85% of the rural population grows maize because it fits well into the different farming systems and has great potential for increasing yield under improved management practices compared with other cereal crops. The crop has the greatest potential of combating food security challenges posed by population increase in the country due to its high yield potential, wide adaptability and relative ease of cultivation.

The Guinea and Sudan savannas of Ghana have the highest potential for increased maize production and productivity due to high solar radiation, low night temperatures and low incidence of diseases. Regrettably production is seriously constrained by natural low soil fertility (low levels of Nitrogen), low investment in nitrogenous fertilizers, recurrent drought and *Striga hermonthica* parasitism. These stresses have an overwhelming importance to maize production in this region, affecting the livelihood of millions of people, food security and economic development. Yield losses in maize from *Striga* infestation in the area are often significant with estimates ranging from 16% to 100%.

Drought is a potential major constraint to maize production in all areas where it is grown, but it is a greater problem for the rural poor of developing countries including the Guinea and Sudan savannas of Ghana. It is second only to poor soil fertility in reducing yield especially in the developing world, leading to about 15% overall reduction in grain yield in these countries. Grain yield losses can even be greater if the drought stress occurs at the most drought-sensitive stages of the crop growth, such as the flowering and grain filling stages. Global warming, deforestation, and urbanization all stand to increase the severity and frequency of drought in the future, leading to a possible decrease in global food production at the same time that increasing human population demands an increase in the same food supplies.

Maize varieties targeted to the Guinea and Sudan savannas of Ghana must be tolerant to drought and Striga. The development of such maize varieties will constitute an important, practical and reliable approach to increasing maize yield and productivity thereby enhancing people's livelihoods, food security and economic development in the region. The Multi-location testing of drought tolerant and Striga resistant/tolerant varieties and hybrids in regional trials through the Drought Tolerant Maize for Africa (DTMA) Project seeks to identify such elite germplasm with high yield potential and tolerance to these stresses. Evaluating varieties across several locations for a few years makes it possible to identify and release such tolerant genotypes to farmers within a short period of time.

Objectives:

- To provide the National Maize Programme a wide range of germplasm from which to identify and select superior stable yielding drought and Striga tolerant maize genotypes:
- For developing experimental varieties, hybrids and synthetics.
- For population Improvement by introgressing drought and or Striga tolerance into locally adapted germplasm.
- Release superior drought tolerant and Striga tolerant/resistant varieties to farmers within a very short time for cultivation in the guinea and the Sudan savanna zones of Ghana
- To produce breeder seed of drought tolerant commercial maize varieties and new varieties.

Materials and Methods

The genetic materials used in this project were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan and local sources. The materials comprised of hybrids (single crosses, three-way crosses and top crosses) and Open Pollinated Varieties (OPV's) of maize, developed for grain yield and adaptation to abiotic (drought) and biotic (Striga) stress factors. They can be classified into three main maturity groups: extra-early, early and intermediate/late maturing. For this reason, they were planted at different geographical locations in Ghana (Lat.4^{o} 44′- 11^{o} 11′ N, Long. 1^{o} 11′ E – 3^{o} 11′ W).

The experimental design was Randomized Complete Block Design and lattice design with three replications across locations. The materials were arranged in both variety and hybrid trials and planted in Nyankpala, Yendi and Damongo in the Guinea savanna zone and Wa and Manga in the Sudan savanna zone, of Ghana. Trials were established in the main cropping seasons of these zones. The experimental fields were ploughed, harrowed and ridged before planting. Each plot consisted of two rows of each entry. The rows were 5.0 m long and were spaced 0.75 m apart. Three seeds were sown per hill at an intra-row spacing of 50 cm or 40 cm and the seedlings thinned to two plants per hill at 3 weeks after planting (WAP) to obtain the target population of 53,333 plants per hectare.

Weeds were controlled both chemically (by the use of Pre- and post-emergence herbicides) and manually by the use of the hoe. NPK 20-20-5 fertilizer was applied at the rate of 60 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} as basal fertilizer at two weeks after planting and top-dressed with additional N at 30 kg N ha^{-1} at four weeks after planting.

Data was collected from the two rows of each plot on plant stand (PLST), plant height (PHT), days to 50% pollen shed (DTA) and silking (DTA), grain yield (GYLD), root lodging (RL) , stalk lodging (SL), husk cover (HUSK), plants harvested (PHARV), ears harvested (EHARV) and moisture (Moist) at the time of harvesting. The data were analyzed using statistical system analyses (SAS, 1996) after conversions of grain yield in kilograms per plot to grain yield in tonnes per hectare (GYLD) at 15% grain moisture. The data were analyzed by location and were combined across locations, assuming the random effects model. Genotypes and locations were all considered as random factors in the analysis. The generalized linear model (GLM) procedure (SAS, 1996) was used to test heterogeneity of variances among the genotypes and locations.

Highlights of Results and Discussions

Extra-early DT hybrid trial

Two types of Regional extra-early maturing DT hybrid trials were planted. These included: regional extra-early white DT hybrids and regional extra-early yellow DT hybrids.

Extra-early White DT hybrids:

Thirty genotypes with a standard check variety (2008 Syn EE-W DT STR) were evaluated in Babile, Manga, Nyankpala and Yendi in this trial. There were significant differences ($p<0.01$) among locations for all the parameters measured. Among the 29 DT varieties included in this trial, six (EEWH-34, EEWH-30, EEWH-31, EEWH-2, EEWH-19 and EEWH-13) produced significantly higher grain yield across locations compared to 2008 Syn EE-W DT STR. Yield averages of these varieties over 2008 Syn EE-W DT STR ranged from 21% to 31%. Genotype by location interaction effects was not significant for grain yield and anthesis- silking interval. The mean grain yields for Babile, Manga, Nyankpala and Yendi were 2999.0, 3424.0, 4798.2 and 2696.1 kg/ha respectively. The mean grain yield at Nyankpala (4798.2 kg/ha) was significantly higher than those at Babile, Manga and Yendi. Yendi had the least mean grain yield of 2696.1 kg/ha.

The grain yields of genotypes EEWH-2, EEWH-18, EEWH-30 and EEWH-34 were stable across locations whilst the grain yields of genotypes EEWH-10, EEWH-13, EEWH-19 and EEWH-21 were location specific. The highest grain yielding genotype across locations in the trial was EEWH-34 (4080.1 kg/ha) and the lowest EEWH-24 (2920.8 kg/ha). Base on the mean grain yields across locations, genotypes EEWH-2, EEWH-13, EEWH-19, EEWH-31, EEWH-30 and EEWH-34 have been identified as promising genotypes and selected for further testing.

Extra-early yellow DT hybrid trial

Thirty genotypes including a standard check (2008 Syn EE-Y DT STR) were evaluated in Babile, Manga, Nyankpala and Yendi in this trial. Among locations genotypes were significantly different ($p<0.01$) for grain yield and all other agronomic traits measured. Among the 29 DT hybrids included in this trial, only one (EEYH-28) produced significantly higher grain yield compared to 2008 Syn EE-Y DT STR. Yield average of this variety over 2008 Syn EE-Y DT STR was 29%. There was no significant genotype by location interaction effects for grain yield. Differences in grain yield of genotypes within locations were significant for all the locations. Mean grain yield in Nyankpala was significantly higher than the mean grain yields in Babile, Manga and Yendi. Hybrid EEYH-28 was selected from this trial as the most promising.

Regional early maturing DT trials

Four types of Regional early maturing DT trials were planted. These included: regional early white DT hybrids, regional early yellow DT hybrids, regional early white DT QPM hybrids and regional early yellow DT QPM hybrids trials.

Regional early white DT hybrid trial

Forty genotypes including a standard check (TZE COMP3 DT C1 F2 (RE)) were evaluated in the early white DT hybrid trial at Damongo, Manga, Nyankpala and Yendi. There were significant differences ($p<0.01$) among locations for all the parameters measured. Genotype by location interaction effects was not significant for grain yield and anthesis- silking interval. Out of 36 DT hybrids in the trial, 18 hybrids produced significantly higher grain yield (23% to 68% more grain yields) compared to TZE COMP3 DT C1 F2 (RE). The six highest yielding genotypes across locations were EWH-28, EWH-8, EWH-24, EWH-26, EWH-27 and EWH-6. They produced grain yields of between 4,422.5 kg/ha and 3,667.1 kg/ha. They were stable across locations being among the best ten genotypes at each location. Genotype EWH-28 which produced the highest grain yield across locations was also either the highest yielding genotype or among the first five at each location. Genotypes EWH-5, EWH-16, EWH-21, EWH-22, EWH-31, EWH-32, SC533 and SC529 were location specific with SC533 being the highest yielding genotype at Nyankpala. Genotypes EWH-28, EWH-8, EWH-24, EWH-26, EWH-27 and EWH-6 were selected as promising hybrids for further test.

Regional Early Yellow DT Hybrid Trial

Thirty-six genotypes including a standard check (EV DT-Y 2000 STR (RE)) were evaluated in the early yellow DT hybrid trial at Damongo, Manga, Nyankpala and Yendi. There were significant differences ($p < 0.01$) among locations for all the parameters measured and among genotypes for all the parameters measured except for anthesis-silking interval and husk cover across locations. Genotype by location interaction effects was significant for all the parameters measured except for anthesis- silking interval and husk cover. The mean grain yield across locations was 3,300.1 kg/ha. Mean grain yields for all the locations were significantly different with Nyankpala producing significantly the highest mean grain yield of 4,294.4 kg/ha.

Out of 35 DT hybrids in the trial, only 3 hybrids produced significantly higher grain yield than the standard check across locations. Genotype EYH29 was the best across locations producing grain yield of 5,026.6 kg/ha. It was also the highest grain yielding in three locations out of the four. Three other genotypes (EYH-10, EYH-16 and EYH-19) were found to be stable across three locations. Since there was significant genotype by location effects, both the location specific genotypes and those that were stable across the locations were selected for further test. They are EYH29, EYH-10, EYH-16, EYH-19, EYH-6, EYH-7, EYH-13, EYH-26, EYH-27 and EYH-30.

Regional early White DT QPM Hybrid Trial

In this trial, 19 DT QPM hybrids and one non-QPM DT hybrid (check) were evaluated at Babile, Damongo and Nyankpala. There were significant differences ($p < 0.01$) among the locations for all the traits measured. Grain yield, flowering and plant and ear heights were also significant ($p < 0.01$) among genotypes. Genotype by location interaction effect was significant (0.01) for grain yield, flowering and plant and ear heights. Among the 19 DT QPM hybrids included in the trial, three hybrids (EWQH-5, EWQH-2 and EWQH-9) produced significantly higher grain yields than the check (EWH-27) across locations. Mean grain yields of these hybrids over EWH-27 ranged from 22% to 31%. Hybrid EWQH-5 produced the highest grain yield of 3,643.3 kg/ha across locations. It was the most stable genotypes across the three locations producing grain yields of 5,444.4 kg/ha at Nyankpala, 3,537.9 kg/ha at Damongo and 1,947.6 at Babile (where grain yields for all trials were generally low). Mean grain yields for locations were significantly different with Nyankpala producing significantly the highest mean grain yield of 4,827.5 kg/ha. The following hybrids were found promising and were selected for further observation, EWQH-1, EWQH-2, EWQH-5, EWQH-6, EWQH-9, EWQH-10, EWQH-12 and EWQH-16.

Regional Early Yellow DT QPM Hybrid Trial

Twenty (20) genotypes – 19 DT QPM hybrids and one non-QPM DT hybrid (EYH-8) as a check – were evaluated in this trial at Babile, Damongo and Nyankpala. There were significant differences ($p<0.01$) among the locations for all the traits measured and among genotypes for grain yield, flowering and plant and ear heights. Genotype by location interaction effect was significant (0.01) for grain yield. Only one QPM hybrid (EYQH-8) significantly out yielded the check (by 20%) among the 19 QPM hybrids. At the Nyankpala location the check produced the highest grain yield (5,168.8 kg/ha), significantly out yielding 11 of the main entries. Genotypes EYQH-6, EYQH-8 and EYQH-11 were stable in grain yield across the three locations while EYQH-2, EYQH-5 and EYQH-7 were stable across two locations. Genotypes EYQH-1, EYQH-10 and EYQH-17 were location specific. Based on their performance across locations and individual locations, the following genotypes have been selected for further observation – EYQH-6, EYQH-8, EYQH-11, EYQH-2, EYQH-5, EYQH-7, EYQH-1, EYQH-10 and EYQH-17.

Intermediate/Late maturing DT Variety Trial

Thirty (36) varieties including a local check (Okomasa) were evaluated at two locations (Damongo and Nyankpala) in this trial. There were significant differences ($p<0.01$) among the locations for all the traits measured except for root lodging, husk cover and ear aspect. Grain yields were also significantly different ($p<0.01$) among genotypes. Genotype by location interaction effect was significant (0.01) for grain yield. Among the 35 DT entries included in this trial, seven produced significantly higher grain yields compared to the local check (Okomasa) across locations. Yield averages of these varieties over Okomasa varied from 23% to 34%. Two varieties (IWD C3 SYN F2 and DT-SR-W C2) were stable in grain yield across the two locations producing mean grain yields of 5,748.0 kg/ha and 5,190.1 kg/ha and 3,285.4 kg/ha and 3,081.7 kg/ha at Nyankpala and Damongo respectively. Except for these varieties (IWD C3 Syn F2 and DT-SR-W C2), the best 10 varieties in each location were all location specific.

Top-cross DT and DTSTR Hybrids Trial

Thirty (30) entries including a local check (Mamaba) were evaluated in this trial at Damongo, Nyankpala and Yendi. Results of the combined analysis of this trial across the three locations indicated significant differences (0.01) among locations for all the traits measured except for root lodging and husk cover. There were also significant differences (0.01) among entries for grain yield. 17 hybrids out-yielded the local hybrid check (Mamaba) by 18% to 45% across locations. Hybrid M1126-2 produced the highest mean grain yield (4,458.0 kg/ha) across locations.

Mean grain yield at Nyankpala was significantly higher than mean grain yields at Damongo and Yendi. Hybrid M0926-7 produced the highest grain yield (6,232.5 kg/ha) at Nyankpala whilst hybrid M1126-2 produced the highest grain yield (3,892.3 kg/ha) at Damongo and hybrid M1026-1 the highest grain yield (4,590.0 kg/ha) at Yendi. Hybrids M0926-12, M1126-2, M1026-11, and M1026-3 were stable in yield across two locations whilst hybrids M0926-6, M0926-8, M0926-7, M0926-9, M1026-1 and M1226-3 were location specific. These ten hybrids have been selected for further study.

Three-way cross DT and DTSTR Hybrids Trial

Forty (40) hybrids with a local check (Mamaba) were evaluated at Damongo and Nyankpala in this trial. There were significant differences ($p<0.01$) among the locations for all the traits measured except for husk cover and plant and ear aspects. There were also significantly differences ($p < 0.01$) among genotypes and for genotype by location interaction effect for grain yield, flowering and plant and ear heights. 72% of the 40 hybrids included in this trial significantly out yielded the local check, Mamaba, by between 21% and 61% across locations. Hybrid M1124-6 produced the highest mean grain yield (5637.2 kg/ha) across locations and was very stable across the locations.

At Nyankpala 50% of the entries significantly out yielded the local check by between 35% and 67% whilst 67% of the entries at Damongo significantly out yielded the local check by between 14% and 77%. Hybrids M1227-2, M1227-3, M1227-5, M1227-12, M1227-13, M1227-17, M1227-18 and Oba Super 7 were among the best five yielding hybrids at each location producing grain yields of between 4,781.6 kg/ha (Oba Super 7) and 6570.7 kg/ha (M1227-12). They were location specific. They have been selected for further observation.

Striga Resistant/Tolerant Varieties and Hybrids Trials

Three types of *Striga* Trials involving RSVT-Early Striga Resistant OPV, Single-cross and three-way cross STR hybrids and Striga Resistant Early Inbred Lines were evaluated in

Nyankpala in 2011. The RSVT-Early Striga Resistant OPV's trial was composed of 21 STRs, 3 non-STRs (TZE Comp 5-W C7F2, DMR-ESR-W QPM (RE), 2008 TZE Comp-Y (set A)) and a local check (Dorke SR). The single-cross and three-way cross STR hybrid Trial on the other hand, consisted of 16 *Striga* resistant cultivars a local check (Mamaba) and a susceptible hybrid (8338-1). The regional *Striga* resistant early inbred lines trial consisted of 25 *Striga* resistant early inbred lines. All these trials were conducted under two contrasting environments – infested and noninfested environments. For the artificial infestation, the *Striga* infestation method developed by IITA maize program that ensures uniform *Striga* infestation with no escapes (Kim 1991; Kim and Winslow 1991) was used. The infested plots were artificially infested with *Striga hermonthica* seeds collected from maize and sorghum fields at the end of the previous cropping season. Infestation was carried out by digging small holes at 40-cm intervals along a ridge and infesting with a sand-*Striga* seed mixture containing about 5000 germinable *Striga* seeds.

RSVT-Early Striga Resistant OPV Trial

The analysis of variance indicated significant differences between the infested and non-infested environments for grain yield, flowering and plant height. Genotype differences were also significant for grain yield, flowering and plant height both under *Striga* infested and non-infested environments . Grain yield of the varieties ranged from 447.5 kg/ha for Syn DTE STR-W to 2,472.8 kg/ha for 2008 TZE Comp-Y (set A) under *Striga* infestation and 2,447.2 kg/ha for TZE Comp 5-W C7F2 to 4377.4 kg/ha for 2011 DTMA-W STR under non-infested conditions. Under *Striga* infestation, 2008 TZE Comp-Y (set A), TZE-Y DT C4 STR C4, TZE-W DT C4 STR C4, 2011 DTMA-W STR and 2010 TZE-W DT STR were the top five yielding genotypes in terms of grain yield. Except for TZE-Y DT C4 STR C4, they all supported relatively low numbers of *Striga* plants, suggesting that they were resistant to *Striga*. Varieties 2011 DTMA-W STR, TZE-W DT C4 STR C4 and TZE-Y DT C4 STR C4 were also the best three genotypes in terms of grain yield under non-infested conditions. The local check (Dorke SR) recorded the highest number of *Striga* plants and produced grain yield of less than 1 t/ha, suggesting that it is susceptible to *Striga hermonthica*. The top five yielding varieties under *Striga* infestation have been selected for further testing.

Single-cross and Three-way Cross STR Hybrid Trial

The analysis of variance indicated significant differences (0.01) between the infested and non-infested environments for grain yield, flowering and plant height. Genotype differences were significant for grain yield under both *Striga* infested and non-infested environments. Out of the 18 hybrids included in this trial, no hybrid produced significantly higher grain yield compared to the susceptible hybrid, 8338-1 while only one hybrid produced significantly higher grain yield compared to the local check, Mamaba, under *Striga* infestation. Under the non-infested condition two and seven hybrids significantly out yielded the local check (Mamaba) and the susceptible hybrid (8338-1) respectively. The most promising hybrids under *Striga* infested conditions were 1001-9 STR, 1113-3 STR, 0804-7 STR, 0601-6 STR and 1113-13 STR. Yield averages of these hybrids ranged from 1575.2 k/ha for 1113-13 STR to 2,126.1 kg/ha for 1001-9 STR. Differences in grain yield among these hybrids were not significant. They all produced over 3.5 t/ha of grain under the non-infested condition. Hybrid 1113-3 STR supported high emerged *Striga* plants and yet was the second highest grain yielding hybrid under the infested condition, suggesting that this hybrid is *Striga* tolerant. These hybrids have been selected for further testing.

Striga Resistant Early Inbred Lines

There were significant differences (0.01) between the infested and non-infested environments for grain yield, flowering and plant height. Genotype differences were significant for grain yield, flowering, *Striga* damage rating and *Striga* emergence count under *Striga* infestation. Under *Striga* infestation, inbred line TZEI 25 produced the highest mean grain yield of 1137.2 kg/ha while inbred line TZEI 135 produced the highest mean grain yield of 1123.6 kg/ha under non-infested condition. The five best grain yielding inbred lines under *Striga* infestation (TZEI 25, TZEI 161, TZEI 106, TZEI 157 and TZEI 23) and the four best grain yielding inbred lines under non-infested condition (TZEI 135, TZEI 178, TZEI 136 and TZEI 129) have been selected for further observation.

Release of Five new Drought/Striga Tolerant Maize varieties

Five improved drought/Striga tolerant maize varieties were released by CSIR – Savanna Agricultural Research Institute in collaboration with CSIR-Crops Research Institute and the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, under the DTMA Project, for the Guinea and Sudan savannas of Ghana on December 20th, 2012. These new maize varieties have higher acceptability ratings among farmers in terms of grain yield, tolerance to drought and Striga and good grain qualities and will assist in reducing vulnerability and food insecurity posed by drought and Striga infestation in the Northern savannas of Ghana.

The varieties are:

CSIR-Sanzal-sima (Drought's friend in Dagbanli language)
CSIR-Ewulboyu (Tolerates drought conditions Gonja language)
CSIR-Wang-data (Kusal language meaning Striga's enemy)
CSIR-Bihilifa (Sisali language meaning withstands drought condition)
CSIR-Tigli (Dagbani language meaning roll back hunger)

These maize varieties are more adapted to the Guinea and Sudan savannas of Ghana which are most challenged with such constraints as drought and Striga infestation. The varieties which combine tolerance to drought/Striga with high grain yields and qualities and farmer/consumer acceptability would contribute to increased productivity, food security and incomes of all stakeholders in the maize industry.

The Way Forward

Multi-location trails:

Multi-location testing of drought tolerant and Striga resistant/tolerant varieties and hybrids will be conducted across selected locations in the Guinea and Sudan savanna zones in regional trials to evaluate the performance of genotypes of the different maturity groups for tolerance to abiotic (drought) and biotic (Striga) stresses. Germplasm will be obtained from IITA, CIMMYT and local sources. The materials will comprise of Hybrids and OPV's developed for grain yield and adaptation to drought or Striga. The *Striga* trials would be conducted only in Nyankpala under infested and non-infested plots. Infested plots will be artificially inoculated with *Striga hermonthica* seeds collected from maize and sorghum fields and stored for 7 or more months. Apart from Striga seed infestation, all other management practices for both Striga infested and non- infested plots will be the same. The trials would be conducted according to the protocols in the IITA field books that would be attached to the trials. Estimates of genetic effects and variance components will be made utilizing expected means squares from analyses of variance. Data will be analyzed by location and combined across locations.

Hybrid maize development:

Fifty inbred lines of extra-early, early and intermediate/late maturing groups which were received from IITA late last cropping season and could not be planted would be planted at Nyankpala during the 2013 cropping season. About ten promising lines from each maturity group would be selected from the 50 lines. Single-cross hybrids will be generated from these lines. Crosses from each of the 3 maturity groups plus 2 checks would be evaluated separately during the off season under irrigation. About 8-10 promising lines with good general combining ability from the evaluation will be selected and used to form a synthetic variety. Superior single cross hybrids would be crossed to superior drought tolerant inbred lines to form three-way cross hybrids. In addition, top-cross hybrids would be developed by crossing drought tolerant lines to superior IITA and Ghana drought tolerant populations.

Breeder seed production and maintenance of parental lines:

During the cropping season of 2013, breeder seed fields would be established at Nyankpala and/or Damongo for the production and maintenance of the newly released drought tolerant maize varieties in support of on-farm trials and community-based seed production schemes.

Methodology

The isolated half-sib ear-to-row crossing block procedure for maintaining and producing breeder's seed of an open-pollinated variety will be used. Plant spacing will be 0.75m between rows and 0.45m within rows in a 20m x 20m crossing blocks. An isolation distance of 400 metres will be ensured to maintain genetic purity since the breeder’s seed provides the source of the first and subsequent increase of foundation seeds. The breeder’s seed production of the open-pollinated varieties will be initiated with the seed of individually shelled 100-200 F_2 ears, saved as progenitors of the breeder's seed. Seed from these ears will be planted as individual female rows (ear-rows) in a half-sib crossing block. The male rows will be planted with a bulk made up by compositing equal quantities of seed from all ears. A planting system of 1 male row alternating with 3 female rows will be used. Off-types, variant and diseased plants will be removed from the field before tasseling under the supervision of the Breeder. All plants in the female rows will be detasseled before they shed pollen. Detasseling will be done carefully so that the female rows will produce more seed of better quality. The male rows provide a good indication of environmental variation in the field and this will facilitate selection among and within the female rows for those plants which conform to the varietal description. Prior to harvest, 4-8 plants in approximately 50% of the ear-rows that meet the varietal description for plant traits will be selected and tagged. Two-to-four ears that best fit the ear and grain characteristics of the OPV will be selected from the tagged plants in each family, to provide a total of 100-200 ears. Seed from these ears and other true-to-type ears can be used for breeder's seed, progenitors of breeder's seed, and for varietal evaluation.

NB: In the event that isolated fields cannot be secured, the half-sib ear-to-row hand pollination block procedure for maintaining and producing breeder's seed of an open-pollinated variety will be used. In this method controlled hand-pollinations will be made by bulking pollen from plants of the male rows and applying it to the female flowers of selected typical plants of the female rows. At least 600 plants will be pollinated and the seed from at least 400 purposefully selected typical, disease-free plants with desirable cobs bulked as breeder seed. Expected quantities and hectarage to be planted are presented in Table 4.

Table 4: Expected Breeder seed production for 2013

Variety	Quantity (kg)
Sanzal-sima	300
Ewul-boyu	300
Wang Dataa	300
Bihilifa	300
Tigli	300
Omankwa	100
Aburohemaa	100
Abontem	100
Total	1800

Challenges and Recommendations

The Maize Program of CSIR-SARI is poised to shift from the current technology adapting status to generation of crosses, improvement of existing populations and development of hybrids for increased maize productivity so as to reduce vulnerability, food insecurity and the damage to local markets accompanying food aid in Ghana. However, the biggest challenge here is inadequate funds. Breeding activities are expensive. Unfortunately funds allocated to the DTMA Project are always too meagre to support any meaningful breeding work. There is therefore the need for financial support outside the DTMA Project for the Maize Program to successfully carry out its planned breeding activities.

LEGUMES IMPROVEMENT PROGRAMME

Executive Summary

The cowpea improvement programme aims to identify or develop improved high yielding genotypes of cowpea with stable resistance to the major biotic and abiotic stress factors and to conduct research to establish partnership to upscale the promotion, dissemination and diffusion of already developed technologies in northern Ghana. In 2012, three major projects were implemented. These included 1. *"Breeding for high yielding improved cowpea varieties with resistance to thrips, pod sucking bugs and Striga gesnerioides in Northern Ghana, 2.* "*Improving the livelihood of smallholder farmers in drought-prone areas of Sub-Saharan Africa and Asia through enhanced grain legume production and productivity* and 3. "*Cowpea breeders' seed production for enhanced production and productivity and improve farmers' accessibility to improved seed".* Insect pests and inadequate supply of improved seed limits cowpea production in Ghana. Research was therefore conducted to develop and disseminate improved high yielding cowpea varieties with stable resistance to thrips, pod-sucking bugs and to *Striga gesnerioides* with high Nitrogen fixing capacity and to promote, disseminate and improve on farmers' accessibility to newly released cowpea varieties through demonstrations and on-farm participatory community seed production schemes. Generally, yields were low because the season extended beyond the normal, resulting to increase insect pests' pressure especially, pod sucking bugs (PSBs), however, it provided ideal conditions for effective screening of most germplasm for their reaction to these pests. Fifty-two (52) cowpea germplasm with various characteristics including earliness, dual purpose, drought tolerance and resistance to *Striga* and *thrips* were added to existing stock to enrich the programme with genetically diverse materials. F_1 generations of crosses to improve resistance/tolerance of existing improved varieties to flower *thrips*, drought and heat were planted under drip irrigation in the "technology park". Findings from the research are discussed below.

Breeding for high yielding Improved Cowpea Varieties with Resistance to thrips, pod sucking bugs and Striga gesnerioides in Northern Ghana

M. Haruna, I.D.K. Atokple, Mumuni Abudulai, James Kombiok, Benjamin Ahiabor, Alexander N Wiredu, Yaw Owusu and Issaha Memunatu

Introduction

Project rational/Background:

Cowpea (Vigna unguiculata (L) Walp) is the second most important legume crop in northern Ghana after groundnut and serve as a cheap source of protein and income but yields are low, averaging 0.8MT/ha on farmers fields. Biotic and abiotic stresses (low soil fertility, drought, insect pests and disease infestations and post-harvest losses etc.) account for low yields in farmers' fields in Ghana. The root parasitic weed, Striga gesnerioides (Willd) Vatke causes extensive grain yield reduction in legume crops especially cowpea in northern Ghana. Grain yield losses of up to 80% are estimated on susceptible cultivars (Singh and Emechebe, 1990). There is a positive correlation between the menace of Striga infestation and low soil fertility (Muleba et al, 1997). Host plant resistance is the most practical and economic strategy to control this weed. One of the objectives of the project is to incorporate Striga resistant genes into the genetic background of recommended cowpea cultivars.

Flower thrips caused by Megalurothrips sjostedti is perhaps the most important insect pest on cowpea in Ghana and is found in almost everywhere that cowpea is cultivated. They cause considerable damage in areas where there has not been any chemical intervention though losses are yet to be quantified. Studies elsewhere indicate that total crop loss could result from severe infestation from this insect. The adult thrips which are minute insects feed in the flower buds and flowers. Severely infested plants do not produce any flowers and when populations are very high, open flowers are distorted and discolored. The flowers then fall early with the result that pods are not formed leading to reduction in the number of pods per plant and subsequently seed yield. It has been estimated that 50-100% yield loss can occur during severe infestation (Adidgbo et al, 2007).

Soil infertility remains the major constraint to sustainable agricultural production in northern Ghana. Farmers in this region apply mostly chemical fertilizers to improve the soils which are costly and often unavailable. The Ghana government in 2008 spent about GH¢20m on subsidizing fertilizer under the fertilizer subsidy program (FSP) but farmers still apply less than the rate required per hectare due to their low income status. Policy makers and farmers would therefore welcome any strategy that seeks to turn around the general soil fertility constraint in the north into a resource for sustainable agriculture. The major objective of the project was therefore to develop through genetic enhancement, improved early cowpea varieties with resistance to thrips, Striga gesnerioides and high nitrogen fixing ability to improve on the fertility status of northern soils for sustainable crop production.

Materials and Methods

Research activities were concentrated on collection and evaluation of germplasm with relevant traits that will assist accelerate the attainment of the project's set objectives and production of breeder seed of existing varieties. In general, steps followed in the improvement work were as follows.

Germplasm collection and introduction:

Cowpea lines with traits relevant to the attainment of project objectives were collected locally across the country and in international research institutes such as IITA. Fifty-six (56) cowpea lines consisting of both local and exotic materials were assembled. Collection was focused on cowpea lines with the following characteristics:

Resistance to Thrips, pod-sucking bugs and S. gesnerioides

Drought tolerance

High nitrogen fixing ability

Hybridization and evaluation of progenies:

Crosses, reciprocal crosses and backcrosses were done in plastic pots on lines with the above traits to produce first filial generations (F_1) in the screen house at CSIR-SARI. The pedigree method of selection was used to develop the desired homogeneous lines. Crosses were done to integrate Striga and aphids resistance into existing improved varieties. $F_{5:6}$ generation of these crosses was evaluated on-farm under natural Striga and aphid infestation ("hot spot") with farmer participation.

Breeder seed production and variety maintenance:
Breeder seed production is the starting point of any seed industry. Hence breeder seed of released varieties were produced to maintain genetic purity, viability and increase cowpea production.

Results and Discussion
Development of cowpea varieties with multiple resistances to major pests: Germplasm collection
Fifty-two (52) cowpea lines with various characteristics including earliness, dual purpose, drought tolerance and resistance to Striga and thrips were introduced to enrich the programme with genetically diverse materials. They included local collections from northern Ghana (Upper West, Upper East and northern regions) and 16 drought tolerant lines, 12 dual purpose, 12 extra early lines and 15 medium maturing lines from IITA.

Preliminary Evaluation
The above collections were evaluated on-station at Nyankpala, Yendi and on-farm with farmers' participation in "Bugbomo" Binaaba and "Bihinaayili", which are cowpea farming communities in the Tolon/Kumbugu, Bawku west and Savelugu districts of the northern region respectively. The necessary field and agronomic data collection was done for analysis. Results indicated that, there were genotypic differences for grain yield with IT07K-299-6 and IT07K-273-2-1 obtaining yields above one ton per hectare and out yielding songotra, the local check variety (Fig. 4). Efforts were also made to develop dual-purpose cowpea varieties for the crop-livestock integration farming systems. There were significant differences ($p \leq 0.05$) among the twelve lines for both grain and fodder yields. Lines that combine higher yields in both grain and fodder will constitute treatments for the cowpea advanced yield trial (CAYT) in the 2013 cropping season.

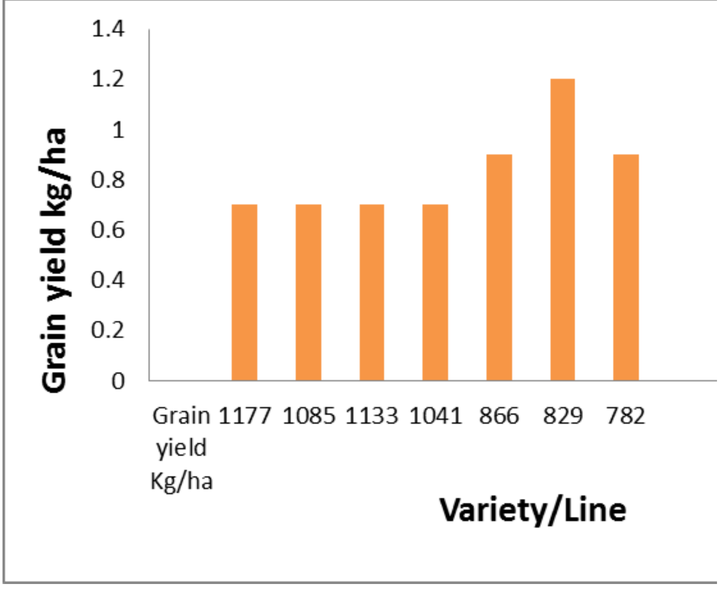

Figure 4. *Yield performance of 15 early cowpea lines evaluated at Nyankpala, 2012.*

Genetic improvement (Hybridization)

$F_{6:7}$ generations of crosses to combine S*triga* and *aphids* resistance to improve the genetic makeup of existing lines were evaluated on-farm under natural S*triga* and *aphid* infestation ("hot spot") with farmer participation. The trial was conducted last year (2011) and was repeated in 2012 to collect adequate on-farm data for the release protocol. We propose releasing them by the end of 2012 (Dec. 2012). It was conducted in three locations. Two of the trials were on naturally infested *Striga gesnerioides* plots with full protection from insects so that any significant reduction in the performance of the lines could be due mainly to the effect of Striga and the third trial was on *Striga-free* plot with no insect pests protection at the vegetative stage to assess the effect of *aphids* on the performance of the lines. About 20% yield reduction was attributed to the combine effect of *Striga* and *aphids* (Fig. 5). Among the crosses SARVx-09-003 gave the highest grain yield of 444 kg/ha under zero insect protection (Fig. 6). The trial will be repeated on-farm to generate adequate data for the release protocol.

Forty (40) F_1 generations of crosses between existing improved varieties and varieties/lines with resistance/tolerance to flower *thrips*, drought and heat were planted under drip irrigation in the "technology park" of CSIR-SARI (Table 5.). This was to facilitate the introgression of drought tolerance and *thrips* resistant genes into existing improved adapted varieties. Good performing progenies with respect to these traits will be selected from the F_2 segregation population. Selected lines will be planted in progeny rows for further evaluation.

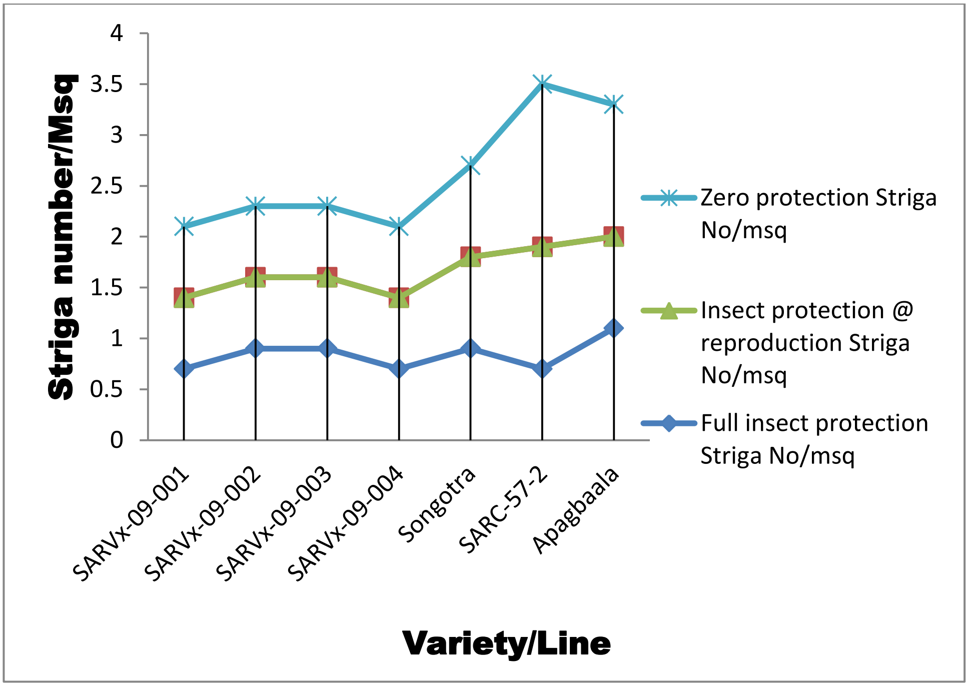

Figure 5. *Performance of Aphids/Striga varieties under different pest control*

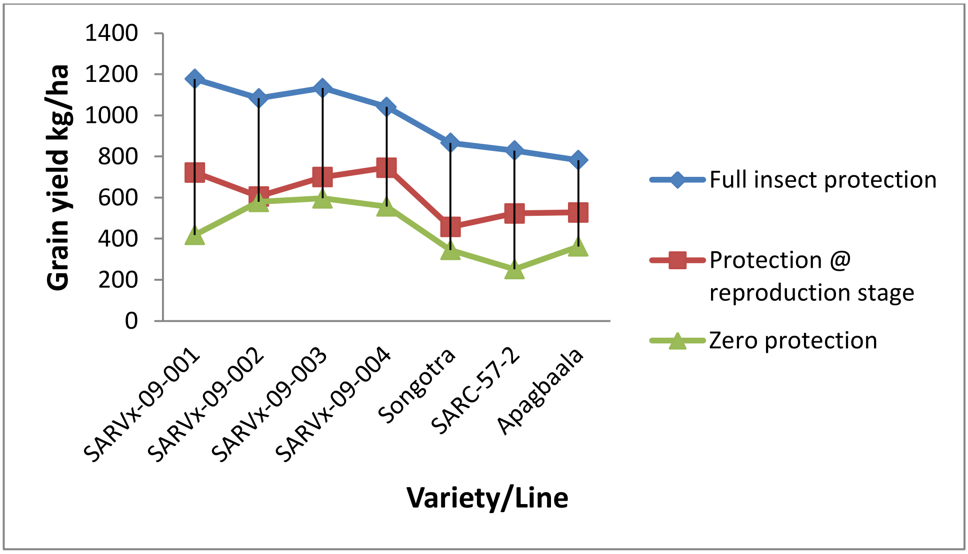

Figure 6. *Yield performance of aphids/Striga resistant lines under different insect control.*

Screen adapted varieties for high nitrogen fixation to enhance soil fertility and crop productivity. Seventeen (17) cowpea lines with drought tolerance and high nitrogen fixation received from IITA were screened to select best performing lines to be used as parents for crossing. The agronomic data used in assessing the lines include; the number of active nodules per plant and dry nodule weight (Table 6). Data was transformed using the square root transformation. Lines identified to have higher nitrogen fixing ability will be crossed with the above F_1 crosses to pyramid genes for drought, Striga and *thrips* resistance into a single variety.

Breeder and foundation seed production

Breeder seed production is a vital component of the seed industry because it is the basic seed that is obtained from the originating plant breeder/institute for the production of foundation and certified seed. In Ghana, research institutes are mandated to produce breeder seed of released varieties to supply foundation seed growers. The production and maintenance of breeder seeds of release varieties is necessary to ensure genetic purity of these varieties over time. Four hectares breeders' seed of released varieties was produced. To increase the breeder seed stock in order to meet the overwhelming demand of foundation seed growers, we embarked on dry-season seed production under irrigation.

Table 5. *F1 generation of crosses between improved adapted high yielding cowpea varieties and lines with thrips, drought and heat resistance developed at SARI in 2013*

Line	Cross/Pedigree	Female parent characteristics	Male parent characteristics
SARVx-12-001	29IT99K-529-2 x Apagbaala	Drought tolerance	Aphids/Striga resistance
SARVx-12-002	IT06K-281-1 x Baawutawuta	Higher grain yield	Highly resistant to Striga
SARVx-12-003	IT07K-243-1-5 x Apagbaala	Extra-early maturing	Aphids/Striga resistance
SARVx-12-004	Baawutawuta x IT07K-299-6	Highly resistant to Striga	Early maturing, high grain yield
SARVx-12-005	Padi-tuya x IT07K-298-15	Moderately resistant to Striga	Early maturing, high grain yield
SARVx-12-006	Apagbaala x IT07K-249-1-11	Aphids/Striga resistance	Dual purpose (Grain/fodder)
SARVx-12-007	IT00K-834-45 x Apagbaala	Dual purpose (Grain/fodder)	Aphids/Striga resistance
SARVx-12-008	Songotra x IT00K-1263	Striga resistance, higher yield	Drought tolerance
SARVx-12-009	IT04K-333-2 x Baawutawuta	Dual purpose (Grain/fodder)	Highly resistant to Striga
SARVx-12-010	IT98K-628 x Baawutawuta	Dual purpose (Grain/fodder)	Highly resistant to Striga
SARVx-12-011	IT07K-249-1-11 x Padi-tuya	Dual purpose (Grain/fodder)	Moderately resistant to Striga
SARVx-12-012	IT07K-206-1-3 x Songotra	Medium maturing/High yield	High Striga resistance, high yield
SARVx-12-013	Baawutawuta x IT98K-628	Highly resistant to Striga	Drought tolerance
SARVx-12-014	Sanzei x Padi-tuya	Highly resistant to *thrips*	Moderately resistant to Striga
SARVx-12-015	IT07K-249-1-11 x Sanzei	Dual purpose (Grain/fodder)	Highly resistant to *thrips*
SARVx-12-016	Baawutawuta x IT06K-134	Highly resistant to Striga	Early maturing, higher yields
SARVx-12-017	IT07K-273-2-1 x Songotra	Early maturing, higher yields	Striga resistance, high yield
SARVx-12-018	Apagbaala x IT07K-304-9	Aphids/Striga resistance	Dual purpose (Grain/fodder)
SARVx-12-019	IT07K-292-10 x Apagbaala	Medium maturing/High yield	Aphids/Striga resistance
SARVx-12-020	IT07K-291-92 x Songotra	Medium maturing/High yield	Striga resistance, high yield

Table 6. *Characteristics of cowpea varieties and quantity of breeder seed produced, 2012*

Variety Name	Yield potential (kg/ha)		Maturity (days)	Qty of seed produced (kg)	Special Attribute
	Grain yield	Fodder yield			
Songotra	2,000	3,600	60-65	250	High yielding, *Striga* resistance
Padi-tuya	2,400	5,400	65-70	600	Higher grain and fodder yields, moderately resistant to aphids and *Striga*
Bawutawuta	2,200	4,200	75-80	50	Highly resistant to *Striga gesnerioides*

Improving the livelihood of smallholder farmers in drought-prone areas of Sub-Saharan Africa and Asia through enhanced grain legume production and productivity.

M. Haruna, I.D.K. Atokple, Mumuni Abudulai, Alexander N Wiredu, Yaw Owusu and Issaha Memunatu

Introduction

Project rational/Background:

Over the past decades farm level yields of cowpea on area basis has remained low (600-800kg/ha) compared to research fields (1600-2500 kg/ha). Among the several factors that account for the low productivity include lack of farmer access to high yielding varieties, biotic and abiotic stresses and improper cultural practices in its cultivation. Despite the fact that CSIR-SARI has developed and released for cultivation improved cowpea varieties suitable for the interior savanna, diagnostic surveys have shown that rural farmers invariably do not have access to these improved varieties. This is due to the fact that the seed industry in Ghana has been privatized and dealers find it unattractive to open sale outlets in these hinterlands. Hence, the project’s activities were initially tailored on promotion, dissemination and diffusion of technologies developed in Phase 1. Introducing to farmers new drought tolerant varieties of cowpea and train selected farming communities on improved techniques in the cultivation of cowpea through on-farm participatory research and demonstrations. However, since this was the first year of project implementation, it was necessary to undertake adaptation studies on these materials before embarking on promotion and dissemination. Therefore, 16 drought tolerant elite cowpea lines received from IITA were evaluated both on-station and on-farm using the participatory approach. The major objective of the project was to enhance the competitiveness of grain legumes (cowpea) for enhancing income and nutrition security of smallholder farmers in the dry lands of sub-Saharan Africa.

Specifically to:

Develop sustainable seed production and delivery system for reaching smallholder farmers in drought prone areas.

Establish partnerships to upscale the promotion, dissemination and diffusion of resources (varieties developed) from phase 1.

Materials and Methods

Ghana was not included in Phase 1 which was on varietal development therefore, efforts was concentrated on (objective 3), *establishing partnerships to upscale the promotion, dissemination and diffusion of resources from Phase 1, identification of gaps, and applying lessons of the first phase from other countries in the region.* Sixteen drought tolerant cowpea lines developed by IITA during phase 1 of the project were used to establish Participatory Varietal Selection (PVS) trials in three sites of the northern region of Ghana to create farmers awareness of the varieties, introduce farmers to these varieties and identify farmers' preferred traits. Breeder's seed of four existing improved varieties was produce to supply foundation seed growers.

The elite cowpea lines were screened at three locations in northern Ghana. The "mother and baby trial" concept was used to evaluate the genotypes. Entries for the "mother trial" were all 16 lines and were conducted on-station whilst the "baby trials" consisted of four (4) elite drought tolerant lines plus farmer's cultivar and was conducted on-farm under the farmer's environment and management. Selection of promising lines in both mother and baby trials was done using the participatory approach. The "mother trial" was planted such that the critical developmental stages (pod formation stages) coincided with the terminal drought to provide an opportunity for an effective selection for drought tolerance. Two" baby trials" were conducted in two different cowpea farming communities (Bugbomo and Bihinaayilli) in the Tolon/Kumbugu and Savelugu districts of the northern region respectively. Generally, no grain yield was recorded in the baby trials due to late planting of the materials. However, farmers participated in selecting good performing lines during the plants' vegetative stages. The qualities farmers considered before making their choice were; growth habit (erect and determinate without vines were preferred) and higher biomass yield. Some lines were selected both in the mother and baby trials indicating that these lines were good performers across the locations.

About fifty (50) farmers from two communities were brought to the "mother trial" to make their observations on the performance of the varieties and to select their preferred lines as part of a learning and technology dissemination process. Participatory farmers were organized into four groups.

Experimental design for both on-station and on-farm trials was randomize complete block with three replications. Planting was done at spacing of 60 cm x 20cm and fertilizer was applied at rate of 25-60-30 of urea, triple single supper phosphate (P_2O_5) and muriate of potash (K_2O). *Lambda cyhalothrin* (Karate 2.5 E.C) at rate of 60mls per 15litres knapsack sprayer was applied to effectively control insect pests at the vegetative, pre-flowering, flowering and pod development stages. The treatments were assigned to four row plots in a block. Plots were 4 meters long by 1.8 meters wide. Plants were spaced 0.60 meters between rows and 0.20 meters within rows. Data was collected in the two inner rows for analysis.

Results and Discussion

Generally, yields from the mother trial were low because the season extended beyond the normal, resulting to increase insect pests' pressure especially, pod sucking bugs (PSBs). As a result, there was no significant difference (p≥0.05) between the lines for pod and grain yield. However, there was genotypic difference for days to flowering, maturity, height and biomass yield (Table 7). The following lines were preferred and selected by all four farmer groups; IT98K-412-13, IT98K-491-4, IT89KD-288, IT98K-628, IT86D-610 and Baawutawuta (SARI's variety) indicating that farmers will readily adopt these varieties. Among the criterion used by farmers in selecting good performing lines were yield, quantity of biomass produced, colour of the seed coat and size of the seed. Varieties with bold or large grain size and white seed coat were preferred (Table 7).

Table 7. Preferred cowpea lines selected during FPVS (mother trial). 2012. Nyankpala

Variety/line	Seed color	Grain size	Maturity	Biomass (kg/ha)
IT98K-412-13	White	Large	70	5220
IT98K-491-4	Pure White	Large	75	1555
IT98K-628	White/black eye	Medium	60	900
Baawutawuta	White	Small	75	440
IT89KD-288	White	Large	85	3790
IT86D-610	Cream white	Medium	60	1000
IT98K-128-3	White	Large	60	5560
IT99K-529-2	White	Large	85	2335
IT99K-1122	Cream	Large	60	2000
IT97K-390-2	White	Medium	85	4220
IT99K-216-24-2	White	Medium	85	1670
IT98K-311-8-2	White	Medium	75	1000
Mean	-	-	73	2474

Cowpea breeder seed production for enhanced production and productivity

M. Haruna, I.D.K. Atokple, Mumuni Abudulai, Yaw Owusu and Issaha Memunatu

Introduction

Project rational/Background:

Cowpea (*Vigna unquiculata* (L) Walp) is the second most important legume crop in northern Ghana after groundnut. An average of 143,000 MT is produced annually on about 156,000 ha. Ghana is the fifth producer of cowpea in Africa. Cowpea yields (1.0 kg/ha) in this country are the 4th highest in the world, after Peru, Cameroon and Uganda. Ghana also has the fastest growing production of the crop in Africa. Annual rates of growth for cowpea for area, yield and production for the period from 1985-7 to 2005-7 were -0.1%, 39.6%, and 39.8, respectively. It has been projected that the rate of growth for the period between 2010 and 2020 would be 11.1% for cowpea. Unavailability of improve seed is a major constraint to cowpea production in northern Ghana. Despite the development of improved cowpea varieties by the

Savanna Agricultural Research Institute (SARI), many farmers do not have access to these varieties partly due to inadequate seed as a result of inability of research institutes to produce adequate quantities due to logistical and financial constraints. Breeder seed is a vital component of the seed industry because it is the basic seed that is obtained from the originating plant breeder/institute for the production of foundation and certified seed. The production and maintenance of breeder seeds of release varieties is necessary to ensure genetic purity of these varieties over time. In Ghana, research institutes are mandated to produce breeder seed of released varieties to supply foundation seed growers leading to certified seed production to supply farmers for increase production and productivity. The purpose of the project was to produce adequate quantities of improve cowpea varieties with dual purpose properties (high grain and fodder yields) to effectively integrate into livestock production systems for increase crop and livestock production. It also seek to organize and train selected cowpea farming communities on improved production techniques and link cowpea farmers and farmer groups to private seed companies and SeedPAG.

Specific objective(s)

Enhance the availability of adequate improved cowpea seed to private seed companies and farmers. Increase the accessibility of farmers to improved varieties for increased production and productivity, Enhance and accelerate crop and livestock integration systems through increase production of dual purpose cowpea.

Materials and Methods

Breeder seed production of two improved cowpea varieties (Songotra and Padi-tuya) were produced during the 2012 cropping season. These varieties have higher grain and fodder yields, preferred seed coat color and resistant to *Striga gesnerioides.* Two districts in the northern region (Tolon/Kumbungu and Yendi districts) were selected for project implementation. Two acres of Padi-tuya and one acre Songotra was put under cultivation at Nyankpala (Tolon/Kumbungu district) whilst at Malizeri (Yendi district), two acres seed of Padi-tuya was cultivated. At both locations the land was ploughed, harrowed and ridged. Planting was done at spacing of 60 cm between rows and 20 cm between plants in a row. Fertilizer was applied at rate of 25-60-30 of urea, triple super phosphate (P_2O_5) and muriate of potash (K_2O). *lambda cyhalothrin* (Karate 2.5 EC). at rate of 60 mls per 15 litres knapsack sprayer was applied at vegetative, pre-flowering and pod formation stages to effectively control insect pests. Weeds were controlled at four and six weeks after planting using a hand hoe. Plants were harvested when pods were 95% dry. Threshing was done manually by beating harvested pods with a stick.

Results and Discussion

Three hundred kilograms (300 kg) of S*ongotra and Padi-tuya* varieties was produced. These varieties gave higher grain and fodder yields with resistance to aphids and Striga gesnerioides which are major constraints to cowpea production in northern Ghana and are therefore appropriate varieties that can fit into crop and livestock integration systems. This quantity was enough to cultivate twelve (12) hectares foundation seed and fifteen (15) hectares certified seed and over 30,000 smallholder farmers will have access to these improve seed to increase production and productivity in the next cropping season. The produce was stored in thematic triple bags and will be distributed to foundation seed growers for cultivation. This will help promote and disseminate these improved seed and enhance farmers' accessibility of these varieties for increase cowpea production.

Conclusion

Resources (human and material) and the necessary logistics exist for the attainment of projects objections. Genetic makeup of selected genotypes will be enhanced through hybridization to incorporate traits relevant to the attainment of set objectives. The only threat to the project is environmental conditions. High night temperatures and erratic rainfall, major products of climate change in our part of the world may affect the performance of high performing genotypes.

Way forward

The AGRA-Cowpea project will continue with screening more genotypes for resistance to *Striga, thrips,* pod sucking bugs and high nitrogen fixing ability. Five set of trials consisting 82 cowpea genotypes with various characteristics have been received from IITA to enrich the programme with more diverse materials for local selection and adaptation. They will be screened and promising genotypes will be identified and selected. Genetic makeup of selected genotypes will be enhanced through hybridization to incorporate traits relevant to the attainment of project objectives.

Genetic analysis (mode of inheritance) will be performed on crosses to ascertain the possibility of developing a single variety that will combine all four attributes (high yielding and resistance to Striga, pod sucking bugs and thrips). Scale up the acreages under breeder seed production of all recommended cowpea varieties to meet seed requirements of foundation seed growers.

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Development of improved soybean varieties adapted to the agro-ecologies and farming systems of the Savanna zones of northern Ghana.

Nicholas N. Denwar and Zackariah Wohor

Executive Summary

The importance of soybean in the farming systems of northern Ghana cannot be downplayed. Soybean has high levels of protein, oil and some essential amino acids needed for growth and development. As a legume it fixes nitrogen which complements the low level of chemical fertilizer application. Again, the haulm is used to feed small ruminants during the dry season when natural pastures are burnt by the annual bushfires. Northern Ghana is also plagued with the menace of *Striga hermonthica*, a parasitic weed that is endemic in many areas, with the potential to cause complete yield loss in cereal crops under severe infestation. The Soybean Improvement Programme of SARI has, over the years, made efforts to minimize the effects of

this parasitic weed by developing and testing improved lines that are efficacious as trap-crop and also have comparable yield potentials as the existing cultivars with the aim to increasing maize productivity through the use of soybean as a trap-crop in complementation with Striga and drought tolerant maize lines. Efforts were also directed towards reduction of the maturity period of commercial varieties available to farmers in order to fit the crop into the dwindling rainfall regime, particularly in the Sudan Savanna ago-ecological zone. Following results of on-farm tests with selected promising lines conducted throughout northern Ghana to determine their performance and acceptability to farmers, two medium (110-120 days) maturing lines bred with enhanced abilities to control Striga and two early (85-90 days) maturing lines were proposed to the National Variety Release and Technical Committee for consideration for release to farmers in 2012. After careful consideration, three of them were accepted and released in December, 2012. These were Afayak (TGX 1834-5E) and Songda (TGX 1445-3E), both excellent trap-crop for Striga, and Suong-Pungun (TGX 1799-8F), an early maturing variety (90 days). Plans were made to produce breeder seed of these new materials under irrigation to ensure availability of breeder seed for foundation seed production by private seed companies during the 2013 main cropping season. Part of the seed will also be used for demonstrations across northern Ghana. Factsheets and production guides would also be produced to facilitate the production process by farmers, extension agents and seed companies.

Introduction

The three regions of northern Ghana constitute about 40% of the total land mass of the country with a population close to 4 million people, 70% of whom live below the poverty line. Agriculture is the dominant economic activity in the area, employing about 80% of the population. However, agricultural productivity in the area is low, attribu Table to the over-dependency on rain-fed subsistence agriculture and low external inputs application to the largely degraded and infertile soils. As a result, widespread hunger, malnutrition and food insecurity are prevalent, leading to high rates of infant mortality and economic decline.

Soybean is an important source of high quality and relatively inexpensive protein and oil, containing about 40% protein and 20% oil. Soybean has superior amino acid profile in that it contains such essential amino acids as lysine and tryptophan. The crop, being a legume, has considerable capacity to fix nitrogen and that put it in good stead as an integral part of subsistence agriculture. The menace of the parasitic weed *Striga hermonthica* further reduces maize yields as resistant maize varieties are non-existent. However, the yields of current soybean varieties are just above break-even levels while the capacity to stimulate suicidal germination in *S. hermonthica* seeds is low. The importance of soybean as a food and cash crop in rural communities is growing, occupying the third place after groundnut and cowpea. With the proliferation of soybean processing plants in Ghana of late its potential as a poverty alleviation and wealth creation crop cannot be over-emphasized.

The main goals of the Soybean Improvement Programme are to develop varieties that are suited to the agro-ecological conditions as well as the major farming systems in the interior Savanna zone of Ghana, transfer appropriate technologies to farmers for the realization of food security of farm-families and thereby create wealth in the country.

Materials and Methodology
The trials comprised of 12 early and 15 medium/late maturing lines tested across 3 locations.
Design: RCBD with 4 replications
Plot size: 4 rows, 5 m long
Spacing: 75 cm x 5 cm (medium/late); 60 cm x 5 cm for early lines.
Planting Method: seeds drilled by hand and seedlings thinned to 20 per metre length
Fertilizer application: 25-60-30 kg N, P_2O_5 and K_2O per hectare
Average Population: 266,000 plants/ha
Locations: Nyankpala, Yendi and Damongo.
Planting time: Mid-June to mid-July depending on rainfall

Results and Discussion
Scientific findings
1. Germplasm introduction and preliminary evaluation: Two sets of trials, comprising 18 early and 17 medium maturing lines were introduced from IITA and evaluated in preliminary trials. Four lines were selected based on yield, earliness and seed quality.

2. Advanced yield trials of medium/late soybean lines were composed and planted at test sites in Nyankpala, Damongo, Yendi and Manga for 2012. These included F_4 segregating generations of crosses made between pod-shattering resistant varieties Jenguma and Quarshie and high stability, longer maturing, shattering susceptible cultivar Salintuya-II. Individual plants were selected and bulked to form a population.

3. Response of Soybean to fertilizer and Rhizobium inoculum in Northern Ghana -2012

Objectives: To assess the agronomic and economic benefits of using fertilizer and rhizobium inoculum on soybean production. Preliminary results indicate that grain yield advantage of inoculation was not clearly differentiated from chemical fertilizers, but both had significant advantage over no fertilizer application.

Technology Developed: Two early maturing lines, TGX 1799-8F and TGX 1805-8F, and two medium maturing lines, TGX 1834-5E and TGX 1445-3E, which are efficacious for causing suicidal germination of Striga seed, were proposed to the National Varietal Release and Registration Committee for consideration for release in 2012. Except TGX 1805-8F, the others were accepted and released. Their descriptors are given below.

Scientific Name: TGX 1799-8F
Given Name: Suong-Pungun
Maturity Period: 85-92 days
Yield Potential: 1.5-1.8 t/ha
Pod Shattering Score: less than 10%
Special Attribute: Earliness over previous varieties (90 compared to 115days)
Consumer Preference: Very Acceptable
Benefit/Cost Ratio: 1.63
Preferred Ecology: Broadly Adapted

Scientific Name: TGX 1445-3E
Given Name: Songda
Maturity Period: 110- 115 Days
Yield Potential : 1.8 – 2.2 t/ha
Pod Shattering Score: Up 20%
Special Attribute: Excellent for Striga Control (as a trap-crop)
Consumer Preference: Very Acceptable
Benefit/Cost Ratio: 1.12
Preferred Ecology: Broadly Adapted

Scientific Name: TGX 1834-5E
Given Name: Afayak
Maturity Period: 110-115 Days
Yield Potential: 2.0-2.2 t/ha
Pod Shattering Score: Less than 8%
Special Attribute: Excellent for Striga control (as a trap-crop)
Consumer Preference: Very Acceptable
Benefit/Cost Ratio: 2.04
Preferred Ecology: Broadly Adapted

Technology transferred: Breeder seed of released and promising lines was produced for distribution to private seed companies and individual farmers and seed growers for the production of foundation and certified seed for cultivation by farmers. Table 8 shows the breakdown of the quantities of the various varieties and lines produced.

Table 8: Breeder seed production of released varieties and promising lines of soybean by the Legumes Improvement Program of SARI for 2012.

Location	Variety	Maturity	Status	Yield (kg)
Nyankpala	Jenguma	Medium	Existing cultivar	1200
	Quarshie	Medium	Existing cultivar	200
	Afayak (TGX 1834-5E)	Medium	Released, 2012	150
	Suong-Pungun (TGX 1799-8F)	Early	Released, 2012	100
	TGX 1805-8F	Early	Release deferred	80
	Salintuya-I	Medium	Existing cultivar	300
	Salintuya-II	Late	Existing cultivar	400
	Songda (TGX 1445-3E)	Medium	Released, 2012	200
Total yield (mt)				2.63

Conclusions/Recommendations:
The release of the three varieties concluded a cycle of breeding activities. Farmers now have the needed technology to manage Striga on cereal fields by a two-year rotation of efficacious trap-crop soybean varieties with Striga-tolerant maize varieties developed under the Drought Tolerant Maize for Africa (DTMA) project, of which SARI is a major player. Breeder and foundation seed of these lines would be produced during the dry season of 2013 for seed companies interested in producing certified seed. Part of the seed will also be used for demonstrations across northern Ghana for wider dissemination by inviting farmers to observe these technologies during farmers' field days. Factsheets and production guides would also be produced to facilitate the production process by farmers, extension agents and seed companies.

Future activities/The way forward:
The Soybean Improvement Programme would continue varietal development using parental lines selected in a crossing programme in the coming years. With the screen house due for rehabilitation soon, a comprehensive crossing work would be started by June, 2013 to incorporate desirable traits into commercial and breeding lines. Traits of concern include earliness, high yield, resistance to pod-shattering, biological nitrogen fixation, disease and pest resistance/tolerance, drought resistance/tolerance, etc.

Efforts would be made to widen the current gene pool by germplasm introduction from sources other than the International Institute for Tropical Agriculture (IITA). Requests have been made to AGRA for assistance to acquire germplasm from other institutions affiliated to it throughout Africa, particularly from East and Southern Africa. Additional sets of early and medium/late maturity lines will nonetheless continue to be introduced from IITA.

Response of soybean to fertilizer and Rhizobium inoculation in the NR and UWR

(N. N. Denwar and S. S. Buah)

Executive summary
Soybean is becoming important cash and oil seed crop which is relatively drought tolerant and requires lower production inputs, yet grain yields are generally low on farmers' fields. The low yields are due partly to low soil nutrient levels and low management levels. In order to increase soybean yields on savanna soils that are inherently low in plant available nutrients, field trials were conducted to assess the agronomic and economic benefits of using fertilizer N, P and K as well as rhizobium inoculants for soybean production in the Guinea savanna of Ghana. The five soybean varieties tested responded similarly to the fertilizer treatments at all locations but soybean response to fertilizer and Rhizobium inoculation was inconsistent. Application of P and K fertilizers with or without inoculants tended to increase grain yield relative to the no fertilizer treatment or the treatment with only Rhizobium inoculants. Grain weight was highest for the treatment with Rhizobium inoculants only in Yendi. The synergy between Rhizobium inoculation and PK fertilization was evident at Bamahu and Yendi. However, Rhizobium inoculation did not increase soybean yields at Nyankpala and Wa. Fertilizer application as well as Rhizobium inoculation affected both growth and development of soybean plants and no

fertilizer treatment reduced crop growth and grain yield significantly. Most of the locations had been planted to soybean in past years, and indigenous Rhizobium bacteria populations were probably adequate for soybean nodulation. More data is required to confirm soybean response to Rhizobium inoculation in the Guinea savanna zone. These results are preliminary and it would therefore be imperative that the experiments are repeated so as to confirm or reject these current results.

Introduction

Soybean is becoming important cash and oil seed crop which is relatively drought tolerant and require lower production inputs. Soybean may serve the dual purpose for cash and food in many households. However, yields on farmers' fields in the Guinea savanna zone are relatively low due to erratic rainfall, low soil nutrient levels (particularly nitrogen and phosphorus), use of unimproved varieties and poor management practices. Nitrogen is the most important nutrient element which limits yield in crop production.

Trials were set up to study the effect of fertilizers and Rhizobium inoculation on soybean yield in the Guinea Savanna zone at SARI Experimental fields at Wa, Nyankpala and Yendi. Both locations are in the Guinea Savanna zone of Ghana which is a semiarid zone, characterized by low, erratic, and poorly distributed monomodal rainfall, averaging about 1100 mm per annum. Most of the rain in the area comes as short duration high intensity storms between May and October. Mean monthly temperatures during the growing season ranged between 26 ^{O}C and 30^{O}C. The soils are typical upland soils used for soybean production in the Guinea Savanna zone of West Africa.

Materials and Methods

The experiments involving two maturity groups of soybean were conducted in a split-plot design in a randomized complete block with four replications. The experimental area was ploughed and harrowed before the treatments were imposed. For the trial involving medium maturing soybean, the main plot treatments were five soybean varieties (TGX 1834-5E, TGX 1445-3E, TGX 1448-2E, TGX 1904-6F and Jenguma). Five fertilizer treatments (no fertilizer, PK only, Rhizobium + PK fertilizer, Rhizobium only, NPK fertilizer) were applied to the subplots. Each 6-row subplot measured 5.0 x 4.5 m. The N, P and K rates were 25, 60 and 30 kg/ha as N, P_2O_5 and K_2O, respectively. Nitrogen was applied as urea (46% N). Phosphorus was applied as triple superphosphate (46% P_2O_5) and K as muriate of potash (60% K_2O). All fertilizers were applied in a subsurface band about 0.05 m to the side of the soybean row. Farmers do not commonly use fertilizer for soybean production in the area; hence the no fertilizer treatment was the control representing the farmers' practice. Sowing date of all experiments was between 6 and 19th July, 2012. The medium maturing varieties (100-115 days) were sown in six rows of 5 m in length and 0.75 m apart. In the early maturity (90-100 days) group, plots were sown in six rows of 5 m in length and 0.60 m apart. Distance between plants was 5 cm in all experiments with one seedling per stand. The soybean varieties were chosen on the basis of their superior performance in on-station and on-farm trials. Weeds were controlled manually using a hand hoe. Soybean grain was harvested at physiological maturity. Data taken included days to 50% flowering (days), plant height (m) and grain yield (kg/ha). Grain and above-ground dry matter yields were determined by harvesting the central two rows of each subplot. Biomass yield was based on samples dried to constant weight at 60^{o}C. Data collected were subjected to analysis of variance (ANOVA) to establish treatment and the interactions effect on grain yield and yield components. Statistical analyses were performed with the Statistical Program SAS for Windows 9.1® (SAS Institute Inc., Cary, NC, USA). Variety and fertilizer treatments were considered as fixed effects and replication were treated as random effects. Main effects and all interactions were considered significant when $P \leq 0.05$. Simple correlations were used to test association among traits.

Results and Discussion

At all locations where this study was conducted, the interaction of variety x fertilizer treatments interactions were not statistically significant for grain yield and yield components, therefore the main effects of variety and fertilizer effects are reported and discussed in this report.

Nyankpala location

At the Nyankpala site, differences among the medium maturing varieties were significant for pod number, pod weight per plant as well as grain yield. Jenguma, TGX 1448-2E and TGX 1904-6F had numerically more pods per plant than TGX 1834-5E and TGX 1445-3E. It should be noted that Jenguma and TGX 1448-2E are the same varieties except that they are from different sources. Although TGX 1834-5E recorded numerically fewer pods per plant, its pods were quite heavy and were comparable to those of Jenguma, TGX 1448-2E and TGX 1904-6F. Three varieties (Jenguma, TGX 1448-2E and TGX 1904-6F) had higher but similar grain yields. Their yields on one hand, however, were greater than those of TGX 1834-5E (released as Afayak) and TGX 1445-3E (released as Songda). Fertilizer treatment only had a significant effect on nodule dry weight per plant. Although the use of mineral fertilizer tended to have higher grain production, the yields were not significantly different from those obtained from no fertilizer and only Rhizobium inoculants treatments. The application of Rhizobium inoculants only tended to increased grain yield when compared with the no fertilizer treatment but the difference was not statistically significant. Soybean did not respond to inoculation at this site even with N, P and K fertilizer addition.

Yendi location

At the Yendi site, differences among the medium maturing varieties were significant for pod and grain weight per plant only. The varieties differed very little with respect to time required to obtain specific growth stages. The varieties produced similar yields. TGX 1904-6F recorded the highest pod weight per plant (16.2 g/plant) while TGX 1448-2E had the least (9.5 g/plant). Grain weight per plant was highest for TGX 1834-5E and least for TGX 1448-2E. Fertilizer treatment had a significant effect on grain weight per plant and final grain yield at maturity only. Grain weight was highest for the treatment with Rhizobium inoculants only although this was not statistically significantly different from those obtained from the mineral fertilizer treatments. The no fertilizer treatment had the least grain weight per plant. Grain yield and grain weight per plant followed a similar trend. Rhizobium inoculation significantly increased grain yield at Yendi and this yield was comparable to those obtained from the treatments with PK only or PK with Rhizobium inoculants. The synergy between Rhizobium inoculation and PK fertilization was evident at Yendi. The recommended fertilizer rate for soybean (25-60-30 kg/ha as N, P_2O_5 and K_2O, respectively) and the no fertilizer treatments had similar yields at Yendi. The reason for these inconsistencies in grain yield response to NPK fertilization at this site is unclear.

Evaluation of Yellow-Root Cassava Genotypes for High Yields and Earliness in the Guinea Savanna Ecology of Ghana

Kwabena Acheremu, J. Adjebeng-Danquah, E. B. Chamba

Executive Summary:
Cassava plays an important and major role in food security and reduces rural poverty. There is a growing need to select cassava varieties that are early bulking, as well as contributing significantly to resolving the problem of vitamin-A deficiency and also suit the system of keeping animals in the northern communities and Ghana as a whole. Seven (7) β-carotene cassava genotypes (01/1181, 01/1206, 01/1404, 01/1412, 01/1417, 01/1635 and 01/1662) received from IITA together with a check (Biabasse) were evaluated for the best early bulking (harvested at 6 and 9 MAP) genotypes among the β-carotene cassava and to select for high yield and dry matter content, at the Savanna Agricultural Research Institute (SARI) experimental fields at Nyankpala in the Tolon Kumbugu District of Northern Region during the June 2012 to February 2013 season. Genotype 01/1417 recorded the highest (386) number of leaves at 6 MAP, while genotype 01/1635 recorded the highest (154) number of leaves at 9 MAP and emerged the highest recorded overall (262) number of leaves. Genotype 01/1404 recorded the highest number of tubers at 6 MAP and among the highest at 9 MAP, and emerged the overall highest (37) in number of root tubers recorded. Genotype 01/1206 recorded the highest (9.38 kg) root tuber yield at 6 MAP, and the overall best (8.81 kg) in tuber yield at the end of the season. The results of the research showed that genotype 01/1206, 01/1404 and 01/1412 were respectively high yielding among the 7 tested genotypes as they showed early high yielding potential than the check (Biabasse).

Introduction

Project rationale/Background

Cassava (*Manihot esculenta Crantz)* is one of the most important food staples in the tropics and the third most important food, after rice and maize (CIAT, 2011). More than 250 million Africans rely on the starchy root crop for their source of calories. A typical cassava-based diet, however, provides less than 30% of the minimum daily requirement for protein and only 10%-20% of that for iron, zinc, and vitamin A. The pro-vitamin-A carotenoid is cheaper sources of vitamin A since they are found abundantly in plants and yellow cassava roots have considerable amount of carotene. Although cassava is a perennial crop, the storage root can be harvested 6 to 24 months after planting depending on cultivar and growing conditions (E1-Sharkawy, 1993). It is one of the most drought-tolerant crops, and capable of growing on marginal soils.

The problem of late bulking and low nutritional value of cassava in Ghana and Northern Region in particular – which has a unimodal rainfall pattern and also where the system of keeping animals is mainly extensive – could be reduced by selecting cassava varieties with early bulking potential and high β-carotene content, respectively. The high β-carotene content could also contribute to resolving the problem of vitamin A deficiency, while the early bulking could suit the system of keeping animals in the northern Ghana communities since they could be harvested at the onset of the dry season.

Objectives:

The main objective of the study was to select high yielding β-carotene cassava for the major rainy season in Northern Ghana. Specifically, the study seeks to screen for the best early bulking variety of cassava among the β-carotene cassava varieties, and select for high yield and dry matter content.

Materials and Methodology,

Cuttings of seven (7) yellow rooted cassava lines (01/1412, 01/1206, 01/1635, 01/1417, 01/1404, 01/1662, 01/ 01/1181) together with a local check (Biabasse) were planted at 1m apart on 4 ridged plot made at a distance of 1m apart and 7m long. A split plot design in a randomized complete block was used with four replicates, where genotypes served as the main plots and the time of harvest as subplot. The experimental units composed of 4m x 7m plot within which the subplots were laid were four rows of cassava planted obtaining seven strands in each row. There were two harvest times (i.e. harvest at 6 months and 9 months after planting, respectively). Net plots of 4 plants were used for each harvest for the yield data. GenStat Statistical software Discovery Edition 4, was used for the data analysis. The study was carried out at the CSIR-SARI experimental fields.

Results and Discussions

Scientific findings

Genotype 01/1417 recorded the highest (386) number of leaves at 6 months after planting (MAP), while genotype 01/1635 recorded the highest (154) number of leaves at 9 MAP and emerged the highest recorded overall (262) number of leaves. Genotype 01/1404 recorded the highest number of tubers at 6 MAP and among the highest at 9 MAP, and emerged the overall highest (37) in number of root tubers recorded. Genotype 01/1206 recorded the highest (9.38 kg) root tuber yield at 6 MAP, and the overall best (8.81 kg) in tuber yield at the end of the season (Table 9). The results of the research showed that genotype 01/1206, 01/1404 and 01/1412 were respectively high yielding among the 7 tested genotypes as they showed early high yielding potential than the check (Biabasse).

Table 9: Root Tuber yield (kg) of cassava genotypes harvested at 6 and 9 months after planting

Genotypes	Harvest 1	Harvest 2	Mean
01/1181	5.43	8.61	7.02
01/1206	9.38	8.25	8.81
01/1404	8.38	7.11	7.74
01/1412	8.03	7.62	7.83
01/1417	5.39	8.50	6.94
01/1635	4.96	5.46	5.21
01/1662	7.59	7.78	7.68
Biabasse	5.30	8.20	6.75
LSD	2.225	2.225	
CV (%)	30.5	30.5	

Technology Developed

Three (3) beta carotene rich cassava lines were identified during the study with respect to earliness as well as root dry matter yield. The genotype 01/1206, 01/1404 and 01/1412 were selected.

Technology transferred

These genotypes identified during the study were selected based on their performance on on-station trials at Nyankpala. Recommendation to farmers outside this environment will be based on a validated evaluation at the various cassava growing areas.

Conclusions/Recommendations

The results of the research showed that genotype 01/1206, 01/1404 and 01/1412 were respectively high yielding among the 7 tested genotypes as they showed early high yielding potential than the check (Biabasse). However, this result needs to be validated for another year.

Future activities/The way forward

This study will be repeated on-station and carried-out at the on-farm level for on-farm validation.

Effect of Tunnel Screen on Rate of Sweet Potato Vine Multiplication for Increased Food Production and Income

Kwabena Acheremu, Edward Carey, E. B. Chamba, John K. Bidzakin

Executive Summary:

Sweet potato produces more food energy per unit area and unit time than any other major food crop and has higher protein, vitamin and mineral contents compared to cassava. It is harvested after a period of about 4-5 months and planting materials must be available for the next growing season, which can be 5-7 months later, especially those in sub-Saharan African regions with extended dry season. Most farmers are losing 4-6 weeks of the growing period at the beginning of the rainy season while they re-establish sufficient vine production for planting, obtaining initial limited planting material from residual plants, re-sprouting roots, or secondary growth of harvested fields, limiting sweet potato production areas. Low tunnel screen cover was used to assess vine production rate in three (3) harvests of "Apomuden" and "Ogyefo", compared with opened raised beds, as control, in a randomised complete block design experiment with 3 replications at the experimental fields of CSIR-SARI. "Apomuden" recorded the highest average vine lengths of 81.6 cm and 59.6cm, respectively, under tunnel cover and on opened beds, at 6 WAP; 65.2 and 64.6 cm at 11WAP; and 81.3 and 65.7 cm long at 16 WAP. On the contrary, the opened bed or "control" bed produced higher vine cuttings than the tunnel covered beds, with "Ogyefo" recording the highest average cuttings of 421 plan Table vines and "Apomuden" recording an average of 408 plan Table vines per $2m^2$ area. However, the difference in number of plan Table vine cutting was not statistically significant. Plan Table cuttings on opened beds for "Apomuden" and "Ogyefo" were higher compared to tunnel cover at 6, 11 and 16 WAP, respectively, irrespective of the highest vine lengths recorded under tunnel cover.

Introduction

Background:

Sweet potato is among the root and tuber crops in which more than two billion people in Asia, Africa, and Latin America will depend on for food, feed, and income by 2020 (Scott *et al*, 2000). It is the third highest production after cassava and yam and amongst the most widely grown root crops in Sub-Sahara Africa. However, sweet potato produces more food energy per unit area and unit time than any other major food crop and has higher protein, vitamin and mineral contents than cassava. It serves as human food, animal feed and industrial raw material in the production of sugar syrups, ethanol and flour for confectionaries.

It covers an estimated 2.1 million hectares with an annual estimated production of 9.9 million tonnes of root (Stathers *et al,* 2005). The yield of sweet potato is potentially high and has aggressive growth pattern which smolder weeds soon after establishment. The needs of farmers and breeding objectives are generally classified into yield and yield stability, quality and resistance to biotic and abiotic stress. However, sweet potato has an additional need of survivability and availability of planting materials. The crop is harvested after a period of about 4-5 months and planting materials must be available for the next growing season, which can be 5-7 months later, especially in those sub-Saharan African regions with extended dry season.

A typical grower in the United States retains 8% of the previous-year's root yields to generate adequate supply of vines for planting. This is done a month earlier in the growing period to initiate sweet potato propagation on beds with cover mulch to raise soil temperature and promote early sprouting and transplant emergence. The mulch is removed when the sprouts reach the soil surface (Wilson and Averre, 1989). In Ghana, most farmers are losing 4-6 weeks of the growing period at the beginning of the rainy season while they re-establish sufficient vine production for planting, obtaining initial limited planting material from residual plants, re-sprouting roots, or secondary growth of harvested fields. This limits sweet potato production areas. Timely supply and availability of planting material during the beginning of the planting season is necessary to increase food production and income of farmers. This work therefore, is aimed at assessing the effect of tunnel screen on vine multiplication rate of Apomuden and Ogyefo varieties.

Objectives:

The objective of this study was to assess the effect of tunnel screen on vine multiplication rate of "Apomuden" and "Ogyefo" varieties

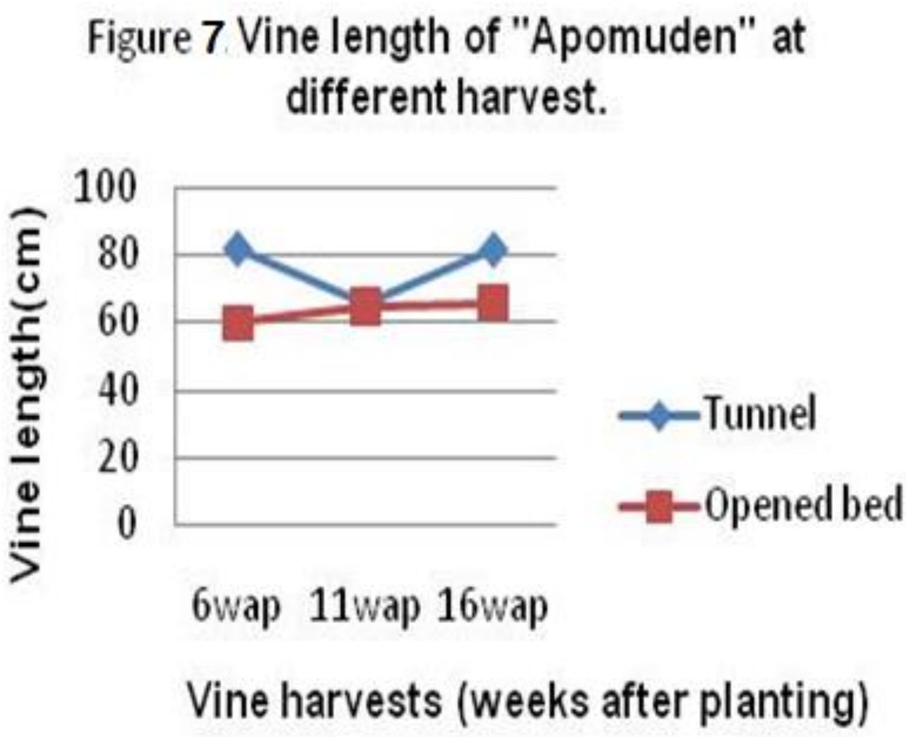
Materials and Methodology:

Vine cuttings of "Apomuden", (orange flesh) and "Ogyefo", (white flesh) sweet potato varieties were nursed on a raised bed plots of 2m² during 2012 raining season. Initial basal compost fertilizer comprising 1:3:1 in volume of rice husk, false yam (*Icacina senegalese*) leaves and cow dung was applied at 20t/ha before planting. Four (4) node vine cuttings of each variety were planted at 0.10 x 0.20m distance, at a population of 50,000 plants/ha, in a split plot arranged in a randomised complete block design and 3 replications at SARI's experimental fields. The beds were covered with 0.5m high tunnel screen, with opened beds as the control plots. Vines were harvested at 6, 11 and 16 WAP. Data was collected at each harvest on plant establishment, vine length, leaf area, number of shoots, and the number of cuttings produced. Ammonium sulphate was applied at 2t/ha (400g/2m^2) after each vine harvest. Data was analyzed using GenStat discovery Edition 4.

Results and Discussions

Scientific findings:

The results of the study showed significant differences (p≤0.05) in the 2 varieties with respect to vine length, average number of cuttings/plant and the total number of vine cuttings recorded under the tunnel screen cover compared to the opened bed plots. “Apomuden” recorded the highest average vine length of 81.6 and 59.6cm under tunnel cover and opened beds at 6 WAP; 65.2 and 64.6 cm at 11WAP, and 81.3 and 65.7 cm at 16 WAP, respectively. (**Fig 7**).



On the contrary “Apomuden” produced higher vine cuttings on the opened beds than the tunnel covered beds (**Fig. 9**), with “Ogyefo” recording the highest overall average cuttings of 421 plantable vines and “Apomuden” recording an average of 408 plantable vines per 2m^2 area. However, the difference in number of transplantable vine cutting yield was not statistically significant.

Figure 8 Vine length of "Ogyefo" at different harvest

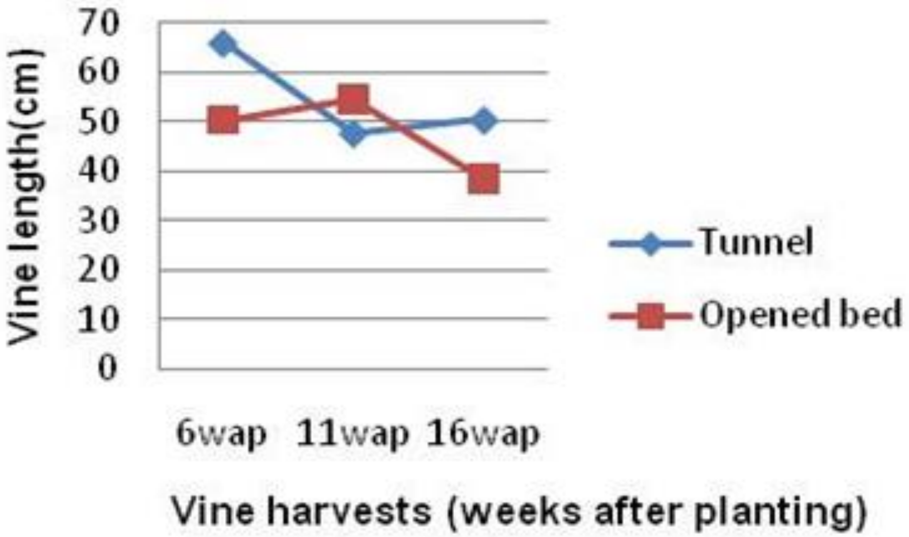
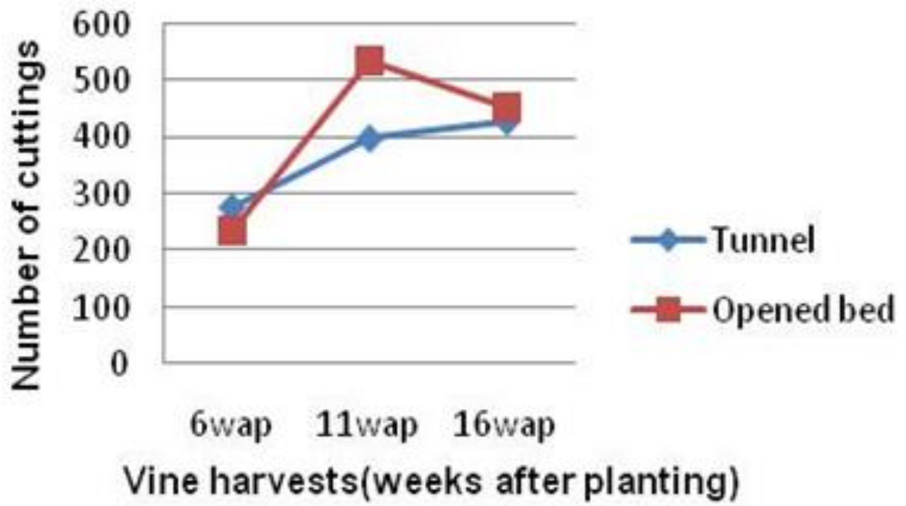
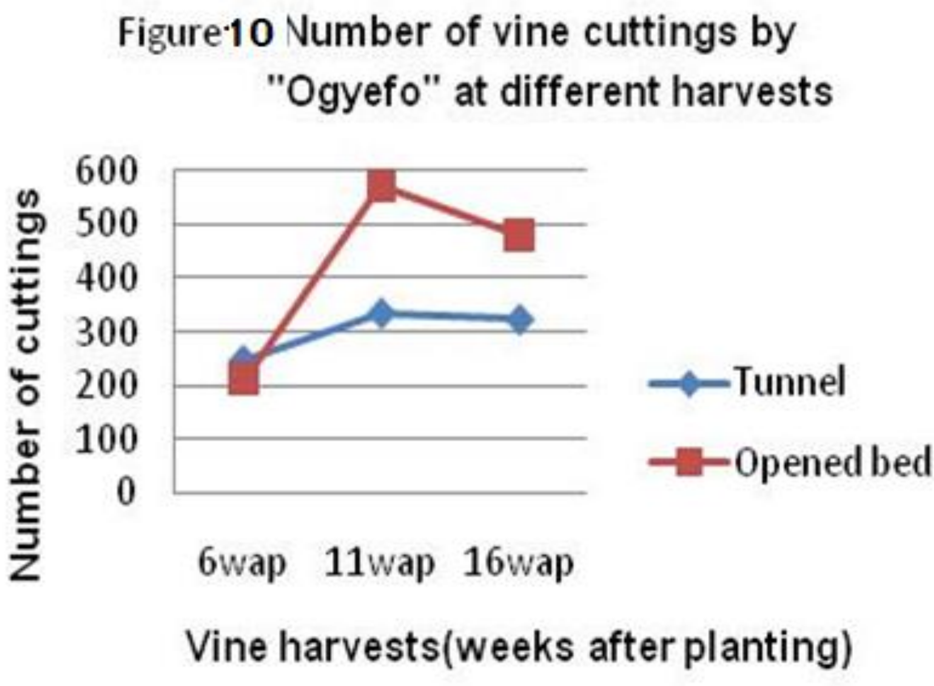


Figure 9 Number of vine cuttings by "Apomuden" at different harvests





Technology Developed
The study has shown that the open bed method of Vine propagation for seed supply is the most economic method of sweet potato vine multiplication to increase availability of planting material for increased production.

Technology transferred
The open bed method of vine multiplication is the simplest method and has been adopted by small scale planting material producers at the farmer's level. Small to medium scale sweet potato vine producers will be trained to supply planting materials for increased production and productivity.

Conclusions/Recommendations
The results showed the effect of the tunnel cover as mulch for Apomuden and Ogyefo in the production of seed transplant for the sweet potato varieties. Planting at a population of 33,333 plant stands per hectare for sweet potato roots tuber production, the result of vine cuttings obtained by Apomuden from tunnel cover and opened beds in the first harvest at 6 WAP is enough to supply 42 and 35.3 hectares of land area for cultivation, respectively. At 11 WAP the number recorded is enough to supply 60 and 80.5 hectares more of land, and at 16 WAP, up to 64.2 and 68 hectares seed cuttings can be obtained from tunnel cover and opened beds, respectively. The higher vine lengths recorded under tunnel covered bed for sweet potato varieties produced longer internodes and less number of four (4) node plantable cuttings.

Future activities/The way forward:
This study will be repeated on-station and to study the effect of vine cuttings on the yield at different vine cuttings stages.

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Determination of appropriate input requirements for cowpea, groundnut and soybean in northern Ghana

Benjamin D. K. Ahiabor, Yahaya Asieku, Peter Asungre

Executive Summary

Twenty-four (24) input trials involving soybean variety (Jenguma), cowpea variety (Songotura) and groundnut variety (Chinese) were established between June 14, 2012 and August 20, 2012 in various communities in the Chereponi, Karaga, Savelugu-Nantom Municipal and Tolon Districts in Northern Region. The communities in the Upper East Region were located in the Kasena-Nankana East Municipal, Bawku West District whereas in the Upper West Region they were in Daffiama-Fiam-Issa, Nadowli-Kaleo and Wa East Districts.

For each legume, seven treatments were imposed, namely (i) Triple superphosphate (TSP), (ii) Single superphosphate (SSP), (iii) TSP + Fertisoil (iv) TSP + Fertisoil + BoostXtra, (v) Yaralegume, (vi) None (no input) and (vii) Weedy fallow. The weedy fallow was to provide weeds as reference plants in the determination of nitrogen fixed from the atmosphere by the respective legumes. Soybean was additionally inoculated with rhizobium inoculants *Legumefix*) and also an additional treatment, TSP+Urea-Inoculation was included for assessment of the need for inoculation for soybean.

In all the regions, wherever increases in biomass, pod and grain yields were observed in the legumes, the significant ones were due to either TSP+Fertisoil treatment or TSP+Fertisoil+BoostXtra treatments. For example, the tripartite combination of TSP, fertisoil and BoostXtra significantly favoured biomass, pod and grain yields of Chinese at Nyankpala resulting in increases of 63%, 78% and 78%, respectively over the non-fertilized (None) treatment. However, application of fertisoil alone resulted in the highest nodulation, biomass, pod and grain yields of Songotura in the Upper East Region and all these responses were greater in Bawku West District than Kassena-Nankana District with even a grain yield difference of was about 176% between the two districts.

Introduction

Legume grain yields and contributions to the nitrogen (N) economy of farming systems are commonly limited by nutrient deficiencies particularly phosphorus (P), but also other nutrients. Large increases in legume grain yield due to addition of P fertilizer are common but this effect may be insignificant when the initial soil fertility is very low. In degraded soils, other nutrient deficiencies often need correction in addition to P, such as deficiencies of calcium (Ca) and magnesium (Mg), or micronutrients, stressing the need for balanced fertilization (Zingore *et al.*, 2008a,b). Phosphorus is often available in short supply – either due to the inherent small stocks of P in light-textured soils (sandy) found across drier regions, or due to the fixation of P into unavailable forms which is a major problem in heavy-textured soils (clay) which are predominant in the humid tropics. Animal manures can supply P, but only if applied in large quantities, and plant residues contain too little P to be of use.

Nutrient constraints need to be overcome by use of manure and/or mineral fertilizers. Phosphorus deficiency can also be overcome by using germplasm that is efficient at mobilizing and using P from low-P soils. Plant genetic variation in P uptake and use efficiency is manifested through a variety of physiological adaptations including mycorrhizal dependency, root exudation and functional root architecture. Attention to nutrient management for crop sequences and intercrops using the principles of Integrated Soil Fertility Management (ISFM) would ensure most efficient use of nutrient resources and the contributions from Biological Nitrogen Fixation (BNF). Development of effective agronomic management practices is, therefore, essential.

The objectives of this study were a) To determine the response of cowpea, groundnut and soybean to P and K fertilizers, organic manure and micronutrients and b) To determine the response of soybean to *Rhizobium* inoculation with and without P application.

Materials and methods

A total of 24 input trials were established between June 14, 2012 and August 20, 2012 in Northern Ghana. The location of the trials in the Northern Region were Komba, Jakpa and Achuma, (Chereponi District), Nangunnayili, Komoayili (Karaga District), Yong and Duko (Savelugu-Nantom Municipal) and Nyankpala (Tolon District). The locations in the Upper East Region were Nayagnia (Kasena-Nankana), Kubore and Yarigu (Bawku West District) whereas in the Upper West Region they were Daffiama-Dachie (Daffiama-Fiam-Issa District), Kaleo-Buodori, Ombo (Nadowli-Kaleo District) and Loggu-Kparisaga (Wa East District).

All soybean trials were planted on 4.5 m x 3.0 m plots whereas those of cowpea and groundnut were installed on 4.2 m x 3.0 m plots. Soybean was sown at three seeds per hill at 50 cm (inter-row) x10 cm (intra-row) whereas cowpea and groundnut were each sown at three seeds per hill and thinned to two stands per hill two weeks after planting at an inter-row and intra-row distance of 60 cm and 20 cm, respectively. The varieties used for soybean, cowpea and groundnut were Jenguma, Songotura and Chinese, respectively. For each legume, seven treatments were imposed, namely (i) Triple superphosphate (TSP), (ii) Single superphosphate (SSP), (iii) TSP + Fertisoil (iv) TSP + Fertisoil + BoostXtra, (v) Yaralegume, (vi) None (no input) and (vii) Weedy fallow. The weedy fallow was to provide weeds as reference plants in the determination of nitrogen fixed from the atmosphere by the respective legumes. In the case of soybean, each of the above-stated treatments was either inoculated with or without rhizobium inoculants (*Legumefix*). An additional treatment, TSP+Urea (N)-Inoculation was included for soybean for assessment of the need for inoculation. Apart from the on-station trial at the SARI research farm and the Upper East trials which were planted on ridges, the other trials were established on the flat.

The fertisoil was broadcast (at 4 t/ha) and incorporated in the soil by shallow tillage two weeks before sowing whereas the TSP and the Munate of Potash (MoP) were applied (at 30 kg P/ha and 30 kg K/ha, respectively) in bands in a trench made 5 cm away from the plant stands at two weeks after sowing and covered after application. BoostXtra (a foliar fertilizer complex) was also applied to the plants through foliar spraying at 4L/ha at two weeks intervals starting at 50% flowering until full pod stage.

Results and discussion

Scientific findings

Integration of TSP, fertisoil and Legumefix inoculants remarkably enhanced grain yield in Jenguma on-station at Nyankpala in the Northern Region but this may not be attributed to inoculation but rather to the effect of the combination of TSP and fertisoil. In the Upper West Region, however, the highest soybean dry biomass yield, highest nodule score, nodule weight and grain yield were recorded from the TSP + Fertisoil + BoostXtra treatment.

In the NR, integrated application of TSP, Fertisoil and BoostXtra remarkably enhanced above-ground biomass production of Songotura at Nyankpala. However, application of TSP alone and combination of TSP and fertisoil with or without BoostXtra significantly increased both grain and biomass yields at Nangunnayili. In the Upper West Region, application of fertisoil alone resulted in the highest nodulation and biomass, pod and grain yields of Songotura and all these responses were greater in Bawku West district than Kassena-Nankana district with a grain yield difference of was about 176%.

Of all the fertilizers applied to Chinese at locations, only the combination of TSP, fertisoil and BoostXtra significantly favoured biomass, pod and grain yields of Chinese at Nyankpala resulting in increases of 63%, 78% and 78%, respectively over the non-fertilized treatment. Though the fertilizer integration enhanced biomass production at Yong, even the unfertilized plants tended to produce more pod and grain than plants treated with the combination of TSP, fertisoil and BoostXtra at Yong and Achuma. In the Upper East Region Chinese produced more biomass and grain in Kassena-Nankana East Municipal than in Bawku West District across the various treatments. In the Upper West, the TSP+Fertisoil treatment tended to give the highest grain yield and larger seed size but only the latter was significant compared to the other treatments.

Technology Developed

During the implementation of the N_2 Africa project in northern Ghana in both the 2011 and 2012 and cropping season the following integrated fertilizer management technologies were observed to have enhanced the above-ground biomass and grain yields of cowpea (Songotura), groundnut (Chinese) and soybean (Jenguma) in many of the locations covered:

- Integration of TSP+Fertisoil
- Integration of TSP+Fertisoil+BoostXtra

In some places grain yield increases of up to between 91-108% were obtained with the above combinations. In the case of soybean, Rhizobium inoculants may or may not be included in (1) or (2).

Technology transferred - indicate scope (districts/regions covered and number of clients/beneficiaries)

The technology mentioned above has been disseminated throughout northern Ghana and some parts of the Brong Ahafo Region through on-farm demonstrations. More than 25,600 soybean farmers (both nucleus farmers and out-growers) have been covered in addition to agro-input dealers, students and research scientists. Leaflets and manuals have been produced and are being distributed to these stakeholders as some of the dissemination tools. This technology is being scaled out to some of these farmers through the Africa RISING and ADRA-AGRA projects

Conclusions

Irrespective of the type of legume, the integration of either TSP and fertisoil or TSP, fertisoil and BoostXtra should be encouraged to increase grain yields of soybean, cowpea and groundnut and these two fertility management options should be scaled out across northern Ghana

Future activities/The way forward

The N_2Africa project under which this work was done ended at the end of April, 2013 but has been given a no cost extension up to 31st October, 2013. During this extension period, only some few training activities will be carried out.

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Farmer Field Fora (FFF) Implementation under the Root and Tuber Improvement and Marketing Programme (RTIMP)

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Executive summary
The Farmer Field Fora (FFF) implementation which began in 2007 (CSIR-SARI Annual Report 2007) is still on-going. So far 78 FFFs have been conducted on cassava, yam, sweet potato and frafra potato between 2008 and 2012. The target for the year under review (i.e. 2012) was to conduct 12 FFFs for yam, cassava and frafra potato in seven (7) districts (viz. East Gonja, Yendi, Nanumba north, Nanumba south, Kpandai, Kassena-Nankana East

The objective of the FFF implementation is to bring researchers, extension agents and farmers together to identify constraints to root and tuber crop production, conduct experiments to develop technologies to address the constraints and implement or disseminate these technologies together. Before the programme started, Participatory Rural Appraisal (PRA) was conducted to (i) interact with the farmers; (ii) know their farming practices; (iii) challenges; (iv) select the thematic area for the training, Fora participants, site or land for the Fora and develop learning guide. Based on the constraints or challenges identified with the farmers, the twelve (12) Farmer Field Fora (FFFs) were established.

A total of 1,040 farmers/traders/processors were involved in the training. After the land preparation for the yam cultivation, the farmers realized that their practice results in considerably low plant population. Whereas three hundred (300) mounds were obtained in the integrated crop management (ICM) plot, the farmers practice plot gave a range of 144 – 225 mounds from the same land area. Also, percentage sprouting was higher on the ICM plot than the farmer practice (FP) plot. Moreover, pest infestation was higher on FP than ICM. At harvest, the farmers observed that the number of tubers obtained from the ICM plot was more and also weighed higher than that of the FP due to closer mounding, application of fertilizer and insecticide. Therefore, the farmers concluded that the yield from ICM plot would give them more money than their normal practice. Hence, they pledged to adopt ICM practices such as closer mounding, seed treatment, application of fertilizer and farm sanitation in their farms during the next cropping season.

Methodology
The twelve (12) FFFs were established in twelve communities in 7 districts/municipalities with four hundred and eighty (480) participants (comprising of 315 men and 165 women). The establishment of the FFFs (learning plots) was preceded by participatory rural appraisal (PRA) which was conducted between 26th April and 11th May, 2012. A total of six hundred and forty-five (645) farmers comprising 470 men and 175 women participated in the PRA (Table 10). The thematic areas selected by the farmers for the training include: (i) improved crop varieties (ii) integrated pests and diseases management (iii) Improved cultivation practices and (iv) integrated soil fertility management. All the learning plots were established between 20th June and 5th July 2012. The three different learning plots established in each community were (i)

Farmer practice (FP) plot (ii) Integrated crop management (ICM) plot and (iii) Participatory Action Research (PAR) plot. Six training sections were conducted in all the 12 communities between July and November. The two frafra potato FFFs were harvested in November 2012, the six yam FFFs were harvested in January 2013 whereas the cassava will be harvested between July-September 2013.

Results

Details of the Participatory Rural Appraisal (PRA) and thematic areas selected by farmers are presented in Tables 10 and 11. Results from the yam FFFs indicated that tuber yield was significantly higher on the integrated crop management (ICM) plot than the farmer practice plot in all the six communities. The ICM plots recorded yield ranging from 13 to 18 t/ha whereas the farmer practice plots yields ranged from 3.8 to 8.8 t/ha (Table 12). Yam cultivars (Laribako, Olodo, Kprinjo) were found to respond positively to NPK fertilizer (Table 13). Also, application of insecticide to mounds to control pests increased yam yield.

Moreover, all the Frafra potato accessions yielded significantly higher than the local variety being cultivated at Babile and Tekuru in Kassena-Nankana West and East Districts, respectively (Tables 14 to 16). At Babile, the mean number of roots per stand for the local variety was 70.2 whereas that of the accessions ranged from 57.0 – 180.5 (mean: 129.2). Also, weight of roots per stand was 0.25 kg for the local variety whilst the accessions yields ranged from 0.25 – 0.86 (mean: 0.49) (Table 14). The yield at Tekuru was considerably low mainly due to drought and poor field management (Table 15). Moreover, results from the spacing experiment indicated that optimum yield could be obtained from planting at 15 cm x 15 cm or 20 cm x 20 cm spacing (Table 16).

Table 10: Districts, communities, crop and dates on which PRA was conducted

S/No	District	Location	Crop	Date	Beneficiaries		Total
					M	F	
1	East Gonja	Kpolo	Yam	26/04/12	24	26	50
2	Kpandai	Nanjuro	Yam	6/5/2012	105	26	131
3		Nyimbordo	Yam	7/5/2012	46	23	69
4	Nanumba S	Kukuo	Yam	3/5/2012	40	14	54
5		Kpayensi	Yam	4/5/2012	48	12	60
6	Yendi	Gbunbgaliga	Yam	30/04/12	24	8	32
7	East Gonja	Kpanshegu Yepala	Cassava	25/04/12	36	5	41
8	Nanumba S.	Lungni	Cassava	5/5/2012	39	12	51
9	Nanumba N.	Makayili	Cassava	2/5/2012	33	14	47
10	Yendi	Sunsong -Gbung	Cassava	1/5/2012	26	15	41
11	Kassena N. W	Babile	F. potato	11/5/2012	22	13	35
12	Kassena N. E	Tekuru	F potato	10/5/2012	27	7	34
					470	175	645

Table 11: Thematic areas selected by participants after the interaction

S/No	District	Location	Crop	Thematic Area
1	East Gonja	Kpolo	Yam	Integrated Pests and disease management
		Yepala	Cassava	Planting Material and Crop varieties
2	Kpandai	Nanjuro	Yam	Integrated Pests and disease management
		Nyimbordow	Yam	Soil fertility Management
3	Nanumba South	Kukuo	Yam	Improved cultivation practices of yam
		Kpayensi	Yam	Soil fertility management
		Lungni	Cassava	Soil fertility management
4	Yendi	Gbunbgaliga	Yam	Integrated Pests and disease management
		Sunsong-Gbung	Cassava	Planting Material and Crop varieties
5	Nanumba North	Makayili	Cassava	Integrated Pests and disease management
6	Kassena-Nankana West	Babile	Frafra potato	Improved crop varieties and cultivation practices
7	Kassena-Nankana East	Tekuru	Frafra potato	Improved crop varieties and cultivation practices

Table 12. Tuber yield (t/ha) of 2012 yam FFFs in 6 communities in Zone 1

Mgt practice	Yield (t/ha)					
	Nanjuro (Kpandai)	Nyimbordow (Kpandai)	Kpolo (East Gonja)	Gbungbaliga (Yendi)	Kukuo (Nanumba South)	Kpayensi (Nanumba south)
ICM	13.69	18.17	15.63	13.02	14.88	13.23
FP	8.51	6.79	3.76	8.84	8.17	6.81
P-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Yam Variety	Kprinjo/ Dente	Kprinjo/ Dente	Kprinjo/ Dente	Kprinjo/ Dente	Laribako	Laribako

Table 13a. Response of yam cultivars to fertilizer and different insecticide application methods:Response of yam cultivars to NPK fertilizer

District	Community	Cultivar	Yield (/ha)	
			NPK fertilizer	No fertilizer
Kpandai	Nyimbordor	Olodo	16.4	13.2
		Kprinjo	12.6	12.3
Nanumba South	Kpayensi	Laribako	13.0	9.8

Table 13b. Response of yam cultivars to fertilizer and different insecticide application methods: Effect of different insecticide application methods on yield of yam

District	Community	Variety	Yield (t/ha)		
			No spray	Spray	Drench
	Nanjuro	Olodo	14.0	17.3	17.1
Kpandai		Kprinjo	10.5	14.2	13.5
East	Kpolo	Kprinjo	9.6	10.9	12.6
Gonja		Laribako	9.2	11.8	12.3

Table 14. Yield of Frafra potato FFF at Babile, Kassena-Nankana West District. 2012

ICM		Yield	
	Accessions	Mean number of roots/stand	Mean weight of roots/stand (
1	QA99/056	142.5	0.597
2	ACC01/017	172.5	0.862
3	QA99/030	173.9	0.588
4	NO3	110.8	0.362
5	QA99/067	149.9	0.489
6	QA99/044	96.6	0.371
7	QA99/059	57.0	0.254
8	QA99/003	180.5	0.564
9	QA99/016	117.6	0.490
10	QA99/058	89.7	0.295
Farmer Practice			
1	Local Black	70.2	0.247

Table 15. Yield of Frafra potato FFF at Tekuru, Kassena-Nankana East District. 2012

ICM		Yield	
	Accessions	Mean number of roots/stand	Mean weight of roots/stand (
1	QA99/030	94.8	0.248
2	QA99/056	58.6	0.201
3	QA99/059	92.3	0.298
4	QA99/003	70.4	0.155
5	NO. 3	79.8	0.262
6	QA99/057	40.5	0.108
Farmer Practice			
1	Local Black	36.3	0.125

Table 16. Yield of Frafra potato at different planting distance

No.	Planting distance	Yield (t/ha)
1	30cm x 30cm	13.95
2	25cm x 25cm	15.80
3	20cm x 20cm	18.60
4	15cm x 15cm	19.77
5	Farmer Practice (10-15cm)	16.74

Biological control of the larger grain borer, Prostephanus truncatus (Horn) in northern Ghana

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Executive summary

Work on the biological control of the larger grain borer (LGB), *Prostephanus truncatus* Horn which was started at CSIR-SARI in 2001 is still in progress. *Prostephanus truncates*, which is the most damaging pest of stored dried cassava chips and maize in storage, is being controlled by an exotic predatory beetle, *Teretrus nigrescens* Lewis, an environmentally friendly antagonist. The main objective is to reduce post harvest losses in dried cassava chips to economically acceptable level by managing the LGB populations using this predatory beetle. So far (i.e., from 2001 to 2012), 734,878 predators have been produced in the laboratory and released in 296 locations in 16 districts in Northern, Volta and Brong-Ahafo Regions of Ghana. During the year under review, 161,344 predators were reared and released in 64 locations in 5 districts of Northern Region.

Background

The larger grain borer (LGB), *Prostephanus truncatus* (Horn.) (Coleoptera: Bostricidae), is the most damaging pest of dried cassava chips and maize in storage in northern Ghana. A native of the Americas, it was accidentally introduced into Africa in the early 1980s. In Ghana, its infestation was observed in 1984 but currently it has spread to all maize and cassava growing districts in Ghana particularly northern Ghana where large proportions of the cassava produced is processed into dried chips for storage. Currently, this appears to be the only method that our resource poor farmers can store their produce after harvest for extended period (3-9 months). LGB activities in stored dried cassava and maize cause various types of losses such as weight loss (30-70%), loss in quantity or market value, promotion of mould development, reduced nutritional value and reduced germination in maize seed. At these levels of damage, the produce is generally regarded as unfit for human consumption, leaving subsistence farmers in a potentially desperate situation. As part of an effort to improve cassava production and storage under the Root and Tuber Improvement Programme (RTIP), work on the biological control of this economically important pest which was started at CSIR-SARI in 2001 is still in progress (CSIR-SARI Annual Reports 2007, 2008, 2009, 2010, 2011).

Methodology

Work on the biological control of the larger grain borer (LGB) started in 2001 in the Northern Region when samples of the predator (100 individuals) were obtained from the Plant Protection and Regulatory Services Division (PPRSD) of the Ministry of Food and Agriculture (MoFA) at Pokuase. The main activities involved in the study include; (i) laboratory mass production of the predator (the steps for mass rearing of the predator are described in CSIR-SARI Annual Report 2009) (ii) baseline survey (iii) releases into areas of high pest incidence (iv) monitoring of establishment and spread and (v) impact assessment.

Results

From August 2001 to December 2012, 734,878 predators have been produced in the laboratory and released in 296 locations in 16 districts in Northern, Volta and Brong-Ahafo Regions (

Table 17). These include: West Gonja, East Gonja, Yendi, Saboba, Bole, Nanumba North, Nanumba South, Zabzugu-Tatale, Tolon-Kumbungu, Tamale, Central Gonja, Nkwanta North, Nkwanta South, Kpandai, Gushegu and Kintampo North. Baseline survey of 145 farmers and traders was conducted in these locations before the predators were released. From January and December 2012 (i.e. the year under review), 161,344 predators were reared in the laboratory and released in 64 locations in 5 districts (viz. West Gonja, East Gonja, Central Gonja, Yendi, Gushegu) (Table 18). Survey conducted in the released areas in 2012 indicated that LGB damage to dried cassava chips has gone down considerably. However, impact assessment will be conducted in 2013 to substantiate it.

Table 17. Larger Grain Borer predators reared and released in northern Ghana between 2001 and 2012

Month/Year	Locations	Number of predators released
August – December 2001	6	1,135
January – December 2002	18	5,664
January – December 2003	20	8,850
January – December 2004	31	42,885
January – December 2005	12	41,000
January – December 2006	9	13,000
January – December 2007	37	82,000
January – December 2008	37	102,000
January – December 2009	23	72,000
January – December 2010	33	90,000
January – December 2011	39	115,000
January – November 2012	64	161,344
Total	296	734,878

Table 18. Larger grain borer predator reared and released by CSIR – SARI in 2012

Date	District	Community	Number
15/02/2012	West Gonja	Zanzugu Yipala	2000
		Kuswagu Junction	4000
		Alipe	4000
		Ntereso	4000
		Nyangurupe	4000
		Kankponyili	2000
Sub total			20,000
27/03/2012	East Gonja	Kura	2000
		Kpalayili	2000
		Masaka	4000
		Gidanture	2000
Sub total		10	

27/06/2012	West Gonja	Sori No 1	2000
		Sori No 2	2000
		Sori No 3	2000
Sub total			6000
27/06/2012	Central Gonja	Nwampe	2000
		Old Buipe	2000
Sub total			4,000
14/07/2012	East Gonja	Kpolo	2000
		Okpando	2000
		Garinshaani	2000
		Kinkilin	2000
Sub total		9	18,000
28/08/2012	Yendi	Malizeri	4000
		Tuusaani	4000
		Sungsongbun	4000
		Sakpegu	4000
		Sang	4000
		Kpligini	2000
Sub total		6	22,000
03/10/2012	Yendi	Sakpegu	2000
		Sunsonggbung	2000
		Malzeri	2000
		Tuusaani	2000
		Korachiyili	2000
		Pion	2000
	Gushegu	Chririfoyili	2000
		Puanjuyili	2000
		Bumbongnaayili	2000
		Tuwuo	2000
Subtotal		10	20,000
05 – 10 - 2012	Central Gonja	Janipe	2000
	West Gonja	Sumpini	2000
		Busunu I	2000
		Busunu II	2000
		Tailorpe	2000
		Kunkunde	2000
		Mempeasem	2000
		Jonokponto	2000
		Achubunyo I	2000
		Achubunyo II	2000
		Bonyanto	2000

Subtotal		11	**22,000**
15 – 11 - 12	East Gonja	Nakpayi	4000
		Kunkowo	4000
		Matilapo	4000
		Sissipe	4000
		Kayereso	4000
		Kimobur	4000
		Nyikata	2000
		Nbowupe I	2000
		Nbowupe II	2000
		Katanga I	2000
		Katanga II	2000
		Kpolo	2000
Subtotal		12	**36,000**
16 – 11 - 12	East Gonja	Tungu	2000
		Bunjai	2000
		Gida Turu	2000
		Kpallbisi	2000
		Kpalbe	3344
		Gbung	2000
Subtotal		6	**13,344**
Grand Total	5	64	161,344

On-farm evaluation of improved yam (Dioscorea rotundata) genotypes from the International Institute of Tropical Agriculture (IITA) breeding programme

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Executive Summary

Trials were conducted at Lantinkpa, (East Gonga district); Akukayili, Tolon district and Gbungbaliga, (Yendi district) all in northern region of Ghana during 2012 cropping season to evaluate 10 yam genotypes obtained from the International Institute of Tropical Agriculture (IITA) breeding program for high yield, consumer acceptance, pests and diseases resistance/tolerant. The ten yam genotypes include; 95/019156; 95/18949;95/18922; 95/01942; 96/02025; 96/02610; 95/19158; 95/18544; 96/00594; 95/19177. Experimental design used for the trials was Random Complete Block design (RCBD) with 3 replicates per genotype. Mounding and planting of the trials were carried out in May and June. Each plot consisted of 10 mounds planted at 1.2m x 1.2m. Four local checks (Puna, Laribako, Asana and Dente) were used. Data collected include; percentage germination/establishment, pests and diseases attack/damage, tuber yield and food quality assessment. Germination and plant establishment were higher for the improved genotypes than the local checks.

The common diseases found attacking the yam leaves and tubers are Anthracnose, virus and tuber rot. Virus infection was comparatively higher on the local checks than the improved genotypes. Pests found attacking the yam at these locations include; millipedes, mealybugs, scale insect, nematodes, yam leaf beetle. Yield assessment at the three locations where the evaluation was conducted indicated that the improved genotypes yield significantly (P>0.05) higher than the local checks. All the genotypes have been found to store longer than Puna and Laribako. The most promising genotypes in terms of yield are; 96/00594, 95/19158, 96/02610, 95/19177 and 96/02025. When the food quality of the different genotypes was assessed based on: colour of peeled slices, appearance of cooked slices, texture, flavour, taste, Farmers' and consumers selected the following genotypes as the most preferred; 95/18949, 95/01942, 96/00594, 95/19158 and 95/18544. Poundability test indicated that genotypes 96/00594 and 95/01942 are the most suitable for fufu.

Methodology

Trials were conducted in three districts during the 2012 cropping season to evaluate 10 yam genotypes obtained from the IITA breeding program for high yield, consumer acceptance, pests and diseases resistance/tolerant. The ten yam genotypes include; 95/019156; 95/18949;95/18922; 95/01942; 96/02025; 96/02610; 95/19158; 95/18544; 96/00594; 95/19177. The districts are (i) East Gonja (location of trial: Lantinkpa) (ii) Yendi (location of trial: Gbungbaliga) and (iii) Tolon (location of trial: Nyankpala). Four local checks (viz. Puna, Laribako, Asana and Dente) were used as checks. Random Complete Block Design (RCBD) was used at all locations with 3 replicates per genotype. Each plot consisted of 10 mounds planted at 1.2 m x 1.2 m spacing. Therefore, there are 30 mounds per each genotype at each location. Mounding and planting of trials were carried out between May and June. Lantinkpa, 15 May; Gbungbaliga, 01 June; Nyankpala, 05 June. Forty farmers (both men and women) participated in the evaluation at each location. Data taken include: percentage sprouting/establishment, pests and diseases, yield and food quality analysis.

Results

Plant establishment was high for both improved genotypes and local checks at all locations. It ranged from 80 – 99% with some of the improved genotypes having the highest establishment (Table 19). The common diseases found attacking the yam leaves and tubers are Anthracnose, virus and tuber rot. With the exception of genotype 95/19177, virus infection was higher on the local check (Laribako). Also, the incidence of anthracnose disease was very high (43.3 – 86.7%) at Gbungbaliga (Yendi district) than Lantinkpa (East Gonja district) and Nyankpala (Tolon district) (Table 20). Pests found attacking the yam (leafs and tubers) at all locations include; millipede, mealybug, nematode, yam leaf beetle, scale insect and yam tuber beetle. Yield assessment at the three locations indicated that the improved genotypes yielded significantly (P>0.01) higher than the local checks (Table 21). Tuber yield was comparatively low at Yendi mainly due to high incidence of diseases (Table 20). When harvesting was done at 6 and 8 months after planting at Lantinkpa, the genotypes were found to be either late, medium or early maturing. The percentage dry matter of the improved genotypes was found to be lower than that of the local cultivars. The most promising genotypes in terms of yield across the three locations were; 95/19158, 96/00594, 95/19177, 96/02610, 96/02025. However, when the food quality of the different genotypes was assessed based on the following characteristics; boiling, pounding (elasticity, expansion, lumps), taste, texture, flavor, the most preferred genotypes by farmers and consumers were; 95/18949, 5/01942, 96/00594 and 95/19158. Poundability test also indicated that the following genotypes could be used for fufu; 95/00594, 95/01942, 95/19156, 95/18949, 96/02025 and 95/18544.

Table 19. Percentage germination/establishment of yam genotypes

No.	Genotypes	% Establishment Lantinkpa (East Gonja)	Nyankpala	Gbungbaliga (Yendi)	Mean
1	95/19156	96.6	90.0	96.7	94.4
2	95/18949	100.0	70.0	100.0	90.0
3	95/18922	90.0	66.7	96.7	84.5
4	95/01942	96.6	96.7	100.0	97.8
5	96/02025	93.3	96.7	100.0	96.7
6	96/02610	100	100.0	96.7	98.9
7	95/19158	100	90.0	96.7	95.6
8	95/18544	100	91.7	96.7	96.1
9	96/00594	96.6	96.7	93.3	95.5
10	95/19177	100	93.3	96.7	96.7
11	Laribako	100	93.3	90.0	94.4
12	Puna	80.0	-	-	80.0
13	Kprinjo/Dente	90.0	-	100	95.0
14	Asana	93.3	-	96.7	95.0

Table 20. Incidence of diseases on yam genotypes

Genotypes	Anthracnose Gbungbali ga	Lantinkpa	Nyan-kpala	Virus Gbung-baliga	Lantin-kpa	Nyank-pala
95/19156	58.7	32.4	43.3	13.3	7.4	6.7
95/18949	70.0	35.0	10.0	6.7	3.3	0
95/18922	79.0	12.5	3.3	3.7	0	6.7
95/01942	66.7	17.5	3.3	6.7	0	0
96/02025	53.3	25.5	3.3	3.3	0	0
96/02610	61.3	21.6	23.3	0	0	3.3
95/19158	76.3	36.6	0	21.0	0	0
95/18544	63.5	60.0	26.6	7.3	0	0
96/00594	61.7	37.7	23.3	10.0	3.3	16.7
95/1917	86.7	41.6	23.3	43.3	0	6.7
Laribako	77.7	25.0	30.0	28.3	63.3	10
Puna	-	9.8	3.3	-	12.5	3.3
Kprinjo/ Dente	43.3	37.6	0	20.0	0	26.7
Asana	53.3	48.5	6.7	0	3.3	0

Table 21. Tuber yield (t/ha) of improved yam genotypes planted in three locations during the 2012 cropping season

No.	Genotypes	Nyankpala (Tolon)	Gbungbaliga (Yendi)	Lantinkpa (East Gonja)	Mean
1	95/01942	10.07	9.33	12.68	10.69
2	95/18544	8.59	5.60	12.13	8.77
3	95/18922	10.32	4.31	9.98	8.20
4	95/18949	9.79	10.65	14.45	11.63
5	95/19156	8.49	7.36	14.72	10.19
6	95/19158	19.79	12.68	15.92	16.73
7	95/19177	16.69	11.16	13.33	13.73
8	96/00594	15.60	11.32	16.53	14.48
9	96/02025	11.50	11.55	13.19	12.08
10	96/02610	13.63	10.00	15.23	12.95
12	Laribako	10.91	9.49	9.81	10.07
	Mean	12.31	9.83	12.8	11.72
	Lsd (0.05)	4.998	3.558	3.764	2.291

POSTHARVEST

Determination of pesticide (Chlorpyrifos) residues and degradation in Kale and Collard greens

Abubakari Mutari, George Antonius (Kentucky State University, USA – (Leader), Regina Hill (Kentucky State University), John Snyder (University of Kentucky)

Executive Summary
Residue from chlorpyrifos application to kale and collard greens was determined using Gas Chromatograph Mass Spectrometry (GC-MS) at the Environmental Science laboratory of the Kentucky State University in Frankfort, USA. The crops were harvest at different intervals from I hour, I day, 5days, 7 days, 12 days, 14 days and 23 days after spraying. The collected samples were then analyzed to assess the degradation of the residue over the period.

Introduction
Chlorpyrifos is a broad-spectrum insecticide which kills insects upon contact by affecting the normal function of the nervous system. Data from two human studies indicate that humans may be more sensitive to chlorpyrifos compared to rats or dogs, following acute oral and dermal exposure, based on plasma ChE inhibition and blurred vision (Christensen et al., 2009). Pesticide application is intended to control pest that destroy crops both on and off the field. However, these chemicals leave residues in harvested produce which when consumed in appreciable quantities, cause harm to non-target organisms such humans and animals. Against this backdrop, pesticide residue analysis is a sure way in determining the presence and quantities of these residues in comparison to tolerable levels.

The objectives of the experiment were therefore:
To assess common pesticide residue (chlorpyrifos) in kale and collard greens.
To assess the decay of the pesticide residue over time.
To determine safe period of commodity consumption after spray of pesticides.

Materials and Methodology
Kale and collard were grown at the Kentucky State University in Franklin County. The two crops were sprayed with chlorpyrifos and cyfluthrin at recommended rates of application. After the application, leaf samples were taken at 1 hour after spraying (AS), 1 day AS, 5 days AS, 7 days AS, 12 days AS, 14 days AS and 23 days AS. The samples were kept frozen in environmental science laboratory of the Kentucky State University at -18 ^{o}C until extraction

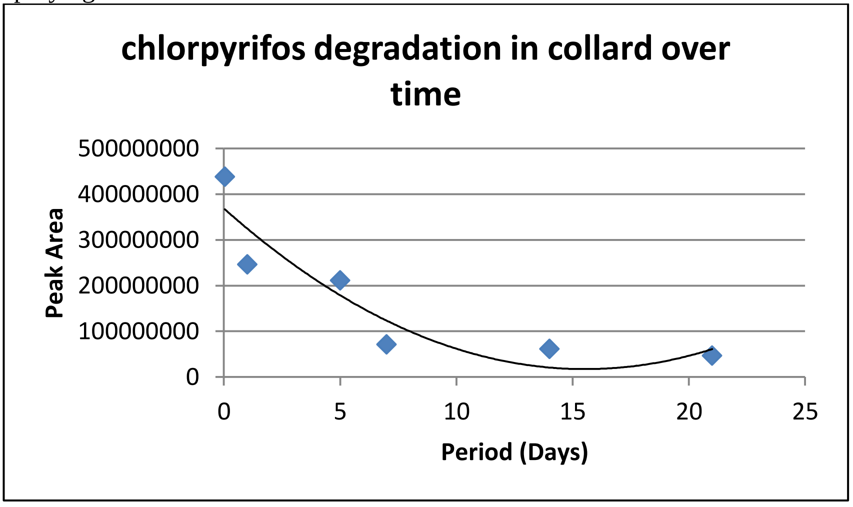
Sample preparation and clean – up
The samples were thawed at room temperature after which 50g was weighed from each sample into a three – pronged horizontal blade blender. 100ml of ethyl acetate was added to each weighed sample, covered with aluminium foil and blended for 1minute. The homogenates were vacuum-filtered through a Buchner funnel containing 934-AH glass fibre filter into flat bottom flasks. Each flask was then covered with aluminium foil and properly secured with elastic rubber band.

All the samples were concentrated to near dryness using a rotary evaporator. After the concentration, the volumes of the nearly dried samples were brought to 10ml by rinsing the flasks with ethyl acetate. The contents were then transferred into a 20ml vials, capped and properly secured with parafilm. The samples were refrigerated for subsequent clean – up.

Clean – up columns were prepared by filling up to a third of a 250ml chromatographic column with florisil, anhydrous sodium sulphate, and then florisil in a ratio of 4:1:6 (v/v) respectively. The contents were eluted with 30ml of a mixture of petroleum ether and ethyl acetate in a ratio of 7:3 (v/v). During the elution, the column was not allowed to dry and the eluent was discarded. 3ml of the aliquot was injected into the column using a 1ml pipette. This was then eluted with 100ml of the petroleum ether – ethyl acetate mixture. The eluent was collected and concentrated to near dryness. it was then brought up to 10ml by the mixture of ethyl acetate and petroleum ether. About 0.3g of activated charcoal was added to sample, swirled for a minute and allowed to settle. This aided in removing remnant chlorophyll observed in the samples. The samples were then filtered through Whatman filter paper No. 1 This was then concentrated to 1ml by nitrogen stream blowing over the sample on warm water bath. The concentrated sample was then filtered into 1.5ml GC vials for determination of pesticide residue.

Results and Discussions

As shown in the graph below, the amount of pesticide residue degraded over the three week period fell progressively to safer levels at 23 days compared to that of 1 hour and day after spraying.



Conclusions/Recommendations

It could be concluded from the experiment that pesticide application not only control the target organisms but leave residues in the produce which at levels of or beyond the maximum residue limits can cause harm to the consumer. It is therefore recommended to allow a waiting period of at least three weeks after application before consumption.

Future activities/ The way forward

A continuous collaboration with the Scientists at the University of Kentucky (John Snyder) and the Kentucky State University (George Antonius) has been established for future projects.

Formation of listening clubs and radio broadcast) in Northern Region.

Mathias Fosu, Benjamin Ahiabor, Abubakari Mutari

Executive Summary

The AGRA Soil Health Programme (SHP) led by the CSIR-SARI focused on Integrated Soil Fertility Management (ISFM) to help improve the productivity of farmers in the Northern, Upper East and West Regions of Ghana. The programme adopted a systems approach to achieve this. Thus, it built the capacities of farmers from production through to marketing. To reach a larger population of beneficiaries, the programme formed listening clubs throughout the project area and held radio discussions in both English and the local languages for the benefit of the illiterate farmer. The discussions spanned from production to postharvest handling and marketing.

Introduction

The aim of this sub-component of the project was to form listening centres /groups in communities where the project is involved in disseminating the ISFM technologies. Owing to the fact that not all communities in Northern Ghana will benefit from the current technology transfer drive, the project sought to hold radio discussions to ensure that the benefits reach a larger number of farmers.

Materials and Methodology

Serious farmer groups under the project were identified. They were then sensitize on the import of the listening groups and the need for them to contribute to the radio discussion for the benefit of their colleague farmers who were not directly involved in the project. Radio discussions on Radio Savannah in Tamale were held, each time discussing a particular cultural practice spanning from land preparation to postharvest handling. Listeners phoned in and asked questions and/or make contributions to the discussion.

Results and Discussions

Six farmer groups comprising 107 individual farmers were formed in 6 six districts of the Northern Region. It could be observed from the interactions that farmers appreciated the intervention of the AGRA-SHP and are already reaping the benefits of the project. It is recommended that the project be extended to cover additional communities and the radio programme be continued for the benefit of indirect beneficiaries.

Future activities/ The way forward

The radio broadcast will continue this time including additional radio stations in the region and the formation of more listening groups.

NORTHERN REGION FARMING SYSTEMS RESEARCH GROUP

The Northern Region Farming Systems Research Group (NR-FSRG) is tasked with analyzing the farming systems of the Northern Region with the view to generating appropriate innovations that could bring about improvement in the livelihoods of the people. The group has at Damongo, Yendi and Salaga. The work focuses on characterizing and describing the farming systems of the region, identifying and prioritizing constraints to increase sustainable agricultural production and generating suitable interventions to address the prioritized problems of the farmers through adaptive on-farm as well as on-station research. Besides, the team also has oversight responsibility of coordinating Research, Extension and Farmer Linkage Committee (RELC) activities in the NR. This report highlights activities of the year under review.

RICE IMPROVEMENT

Multi-Locational Evaluation of Aromatic Rice Genotypes

Dogbe, W., Aliyu, S., Abebrese, S. O., Owusu, R.K., Inusah, B. Mahama A., Abdul-Rahman, A., Krofa, E. O., Danaa, A. and Halolo, E.

Executive Summary
Rice genotypes with aromatic traits are very much desired in Ghana. Against this backdrop, a multi-locational trial was set up in a randomised complete block design (RCBD). This is to evaluate the yield potentials and agronomic adaptability of nine rice genotypes (including one local check) with aromatic traits to the rice growing ecologies of northern Ghana. The analysis of variance (ANOVA) for all parameters measured are statistically significant ($p<0.05$) among the genotypes. Significant genotype by environment interaction was also observed for most parameters measured. Average yield for two years (2011-2012) indicate that across all locations, Jasmine 85 is the highest yielding genotype. The trial will be repeated in 2013 across all locations.

Introduction
Food security for the ever-growing population of the world has become one of the most pressing issues of humanity in this 21st century. With the world population expected to hit nine billion by 2050 (Hodges, 2005; Borlaug, 2002) ensuring a sustainable food security for humanity (both qualitative and quantitative aspect) has become an important issue for discussion among policymakers and all the stakeholders within the agricultural sector from production to postharvest and storage of agricultural produce. With many factors coming into play such as population growth, consumer habit changes, globalization and/or urbanization, rice has gradually become a major staple food in Ghana (Nyanteng, 1987). With a per capita consumption of 22kg per annum and an annual production increase of 5% (MoFA, 2009) the significance of rice with respect to food security in Ghana cannot be under estimated. Ghana has huge rice import deficit ($ 700 million) which is having a negative effect on the foreign exchange earnings of the country. Domestic production by resource poor farmers is also

affected due to trade liberalization and the issue of subsidy which farmers in the developed world receive compared to the farmers in the developing world. This has resulted in Ghana and most Sub-Saharan African countries turning into dumping grounds for all sorts of rice brands. The issue has been compounded further because Ghanaians have developed a particular likeness for rice genotypes with fragrance (perfume or aromatic rice). Against this backdrop, the availability of aromatic genotypes of rice adaptable to the northern ecological zones of Ghana could contribute to food security, enhance farmers' livelihood and lead to reduction in rice import deficit of the country.

Objective(s):
To evaluate rice genotypes with aromatic characteristics for their yield potential and general agronomic adaptability to the rice growing ecologies of northern Ghana

Materials and Methodology
Nine genotypes (Table 22) were advanced from initial yield assessment trial for two years (2009-2010) and were evaluated in advanced yield trials in 2011. The evaluation of these genotypes continued in 2012 in the same multi-locational fashion. The experimental setup consisted of Randomised Complete Block Design (RCBD) with four replications.

Table 22: Names and sources of genotypes evaluated in this study

Genotype	Source of material
Anyofula	CSIR-PGRRI, Ghana
Basmati 112	IRRI, Philippines
Basmati 113	IRRI, Philippines
Basmati 123	IRRI, Philippines
Basmati 370-1	IRRI, Philippines
Basmati 370-5	IRRI, Philippines
JASMINE 85 (Local Check)	CSIR-SARI, Ghana
Local Basmati-2	IRRI, Philippines
PERFUME(Short Type)	Thailand

Seeds were dibbled (maximum of three per hill) at planting distance of 20x20cm. The planting dates for Manga, Nyankpala and Libi were 16th June, 2012, 19th July 2012, and 25th July 2012 respectively. The recommended fertilizer application rate of 60-60-30 NPK kg/ha was adopted for the trial (applied through broadcasting) with the N component applied in split dose. All other cultural practices were carried out as and when it becomes necessary. Generalized linear model ANOVA in Genstat (9th Edition) was the model used for all data analyses.

Results and Discussions
The analysis of variance (ANOVA) for all parameters measured were statistically significant ($p<0.05$) among the genotypes (Table 23). The effect of environment (location) is also significant ($p<0.05$) for all the parameters measured except for panicle length and number of grains per panicle (Table 23). There is significant genotype by location interaction (genotype x Environment) for most parameters except for panicle length, number of grain per panicle and 1000 grain weight

Table 23: Results of the ANOVA for the parameters measured among the genotypes

Source of variance	Df (GxL)	MS (GXL)	F-pr (genotype)	F-Pr (location)	F-pr (Inter)	CV (%)	LSD (5%)
% Emergence	16	144.1	0.02	<.001	0.148	13	15.293
Days to 50% Flowering	16	118.24	<.001	<.001	<.001	3.1	4.226
Days to maturity	16	90.155	<.001	<.001	<.001	1.5	2.715
Tiller count/hill	16	14.819	<.001	<.001	<.001	15.4	2.791
Plant height (cm)	16	1944.07	<.001	<.001	<.001	6.4	13.466
Panicle count	16	16.65	<.001	0.01	0.005	17.6	1.477
Panicle length (cm)	16	2.289	<.001	0.09	0.297	5.6	2.312
No of grains/ panicle	16	470.5	<.001	0.567	0.843	21.6	37.67
Yield_14%MC (kg/ha)	16	890171	<.001	<.001	<.001	15.6	768.1
1000 grain weight(g)	16	0.5366	<.001	<.001	0.636	3.2	1.181

Table 24: Mean grain yield of the evaluated rice genotypes across the three locations for the year under review (2012 cropping season)

Genotype	Yield (kg/ha)			
	Libi	Manga	Nyankpala	Average across location
ANYOFULA	1925	3071	3333	2776[3]
BASMATI 113	1484	2624	2766	2291[5]
BASMATI 112	1438	2404	2851	2231[7]
BASMATI 123	1598	2818	2450	2289[6]
BASMATI 370-1	1466	3480	2615	2520[4]
BASMATI 370-5	1409	2399	2372	2060[8]
GBEWAA	2030	4562	4441	3678[1]
LOCAL BASMATI-2	1225	2051	2173	1816[9]
PERFUME(Short type)	2115	3345	5078	3513[2]
LSD (5%)				768.1

NB: Superscript on mean values denotes their ranking in terms of yield performance

In terms of grain yield, the four top yielding genotypes are Gbewaa, Perfume (Short type), Anyofula and Basmati-370 respectively, whilst Local basmati is the low yielding genotypes among the rice genotypes (Table 24). This pattern of grain yield performance is very much consistent with the results of 2012 evaluation where Gbewaa, Anyofula and Perfume short type are the top three yielding genotypes respectively (Refer to SARI 2011 Annual Report). Although Gbewaa is the top yielding genotype, the difference in terms of grain yield between Gbewaa and the second highest yielding genotype (Perfume short) is not statistically significant (Table 23 and 24).

For the year under review, the performance at the Libi site was not very encouraging. This was due to flooding which occurred after seeding which affected percentage seedling emergence and plant stand. This might have reduced grain yield at this location.

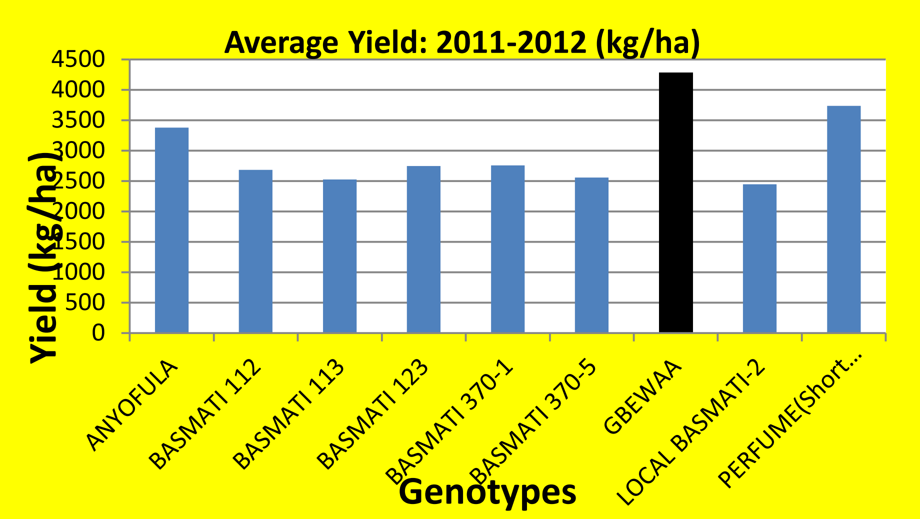


Figure 11: The average yield potential (2011-2012) of the lowland aromatic genotypes across all locations (Libi, Nyanpala and Manga).

Conclusion:

The average yield potential of the genotypes for two years of the evaluation is presented in Figure 11. In general, it can be said that Jasmine 85 still remains the highest yielding genotypes. Anyofula which ranked second across all locations is a good material. The long duration and the tall nature of this genotype however, make it more susceptible to lodging. Perfume short type and the Basmati's in general equally have good potential. The trial will be repeated in 2013 for the final round of evaluation.

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Multi-Locational Evaluation Of Red Rice Genotypes

Dogbe, W., Aliyu, S., Abebrese, S. O., Owusu, R.K., Inusah, B. Mahama A., Abdul-Rahman, A., Krofa, E. O., Danaa, A and Halolo, E.

Executive Summary

To evaluate the yield potentials and general agronomic adaptability of nine rice genotypes with red coloured caryopsis, a multi-locational experiment (Nyankpala, Libi and Manga) was set up in a RCBD with four replications. The ANOVA results for parameters measured are statistically significant ($p < 0.05$). Statistically significant differences were observed across the three locations on all parameters. Genotype by environmental interactions is also significant ($P < 0.05$) for all the parameters measured but for panicle length, number of grains/panicle and 1000 grain weight. The average yield (kg/ha) across location for years (2011-2012) indicates that Jasmine 85 (red) is the highest yielding, followed by Magitey and Gbewaa respectively. The trial will be repeated in 2013.

Introduction

Rice has become a symbol of food security worldwide. Red coloured caryopsis (the dehulled rice grain) has a particular place in the Ghanaian society. This is due to the unique role it plays in most Ghanaian culinary preparations in most cultures. More importantly, red coloured caryopsis genotypes of rice have comparative nutritional and health advantages. Some of these advantages include the good source of iron and zinc compared to other coloured caryopsis.

Anthocyanins, the colour pigments that give grains and leaves their deep rich red, blue, and purple colours (responsible for the red coloured caryopsis of red rice genotypes) have antioxidant properties. The antioxidant properties of anthocyanins lower the risk of heart problems notably atherosclerosis. Red rice contains high level of fibre compared to polished white rice. With these health and nutritional benefits of red rice as against the current increase in the level of health consciousness of an average Ghanaian with respect to his/her choice of food, there is now an unprecedented interest/demand for red rice on the market. The traditional red rice verities currently being grown by farmers are low yielding, with numerous less desirable agronomic traits (long duration and susceptible to lodging, pests and diseases).

Objective(s):

To evaluate rice genotypes with red coloured caryopsis for their yield potentials and general adaptability to the rice growing ecologies of northern Ghana.

Materials and Methodology

This is a continuation of an advance yield trial started last year (2011 cropping season). The experimental setup consisted of multi-locational trial (Nyankpala, Libi and Manga) in RCBD with four replications. A total of 9 genotypes (Two local checks) were evaluated (Table 25). Each plot measured $15m^2$ with an alley of 0.5m between two adjacent plots. Planting dates for Libi, Manga and Nyankpala respectively are 16^{th} June, 19^{th} July and 25^{th} July respectively. Seeds were dibbled (maximum of two per hill) at planting distance of 20x20cm. The recommended fertilizer application rate of 60-60-30 NPK kg/ha was adopted for the trial (applied through broadcasting) with the N component applied in split dose. All other cultural practices were carried out as and when it becomes necessary. Generalized linear model ANOVA in Genstat was the model used for all data analyses.

Table 25: Names of genotypes and their sources used in the present study

Genotype	Source
GH 1837	CSIR-PGRI, Ghana
Jasmine 85 (red)	CSIR-SARI, Ghana
Kawawa (red)	CSIR-PGRI, Ghana
Local red (check)	Farmer collection
Matigey	CSIR-PGRI, Ghana
NERICA 14 (Local checK)	AfricaRice, Cotonou
V 47	CSIR-PGRI, Ghana
Viwornor	CSIR-PGRI, Ghana
Gbewaa (Local Check)	CSIR-SARI, Ghana

Results and Discussions

The ANOVA for all parameters measured during the course of the evaluation show statistical significance (Table 26). The effect of environment (location) on the performance of the genotypes on all the parameters measured is statistically significant (Table 26). There is strong genotype by environment interaction ($p < 0.001$) for all the parameters measured except for Panicle length, number of grain per panicle and 1000 grain weight (Table 26).

Across all the three locations for the year under review (average of the three locations), the top four highest yielding genotypes are Viwornor, Gbewaa, Jasmine 85 (red) and Magitey (Table 27). However, the best yielding genotypes for last year (2011) cropping season) respectively are Jasmine 85 (red), Magitey, GH 1837 and Kawawa (red) (Refer to 2011 SARI Annual Report).

Table 26: Results of the ANOVA for the parameters measured on the rice genotypes

Source of variance	Df (GxL)	MS (GxL)	F-pr (genotype)	F-Pr (location)	F-pr (Inter)	CV (%)	LSD (5%)
% emergence	16	112.1	0.002	<.001	0.632	14.8	15.78
Days to 50% Flowering	16	162.454	<.001	<.001	<.001	2.2	3.016
Days to maturity	16	195.424	<.001	<.001	<.001	2	3.293
Tiller count/hill	16	13.988	<.001	<.001	<.001	15.6	3.127
Plant height (cm)	16	2793.48	<.001	<.001	<.001	5.9	13.121
Panicle count	16	8.427	<.001	<.001	<.001	17	2.325
Panicle length (cm)	16	1.191	<.001	<.001	0.705	5.1	1.777
Number of grains/panicle	16	968.5	<.001	0.046	0.251	19.3	40.46
Yield_14%MC (kg/ha)	16	1774135	<.001	<.001	<.001	23.2	915.7
1000 grain weight(g)	16	1.0829	<.001	0.004	0.152	3.1	1.1839

Table 27: Mean grain yield of the evaluated rice genotypes across the three locations for the year under review (2012/2013 cropping season)

Genotype	Yield (kg/ha)			Average across location
	Libi	Manga	Nyankplala	
GBEWAA (check)	1771	3259	4197	3076[2]
GH 1837	1451	2276	2436	2054[9]
JASMINE 85 (RED)	2030	3686	3217	2978[3]
KAWAWA	1705	3451	3070	2742[5]
LOCAL RED (check)	1728	1613	3365	2235[7]
MATIGEY	2083	3849	2460	2797[4]
NERICA 14	584	3836	1841	2087[8]
V47	1696	2899	2567	2387[6]
VIWORNOR	1637	4450	3672	3253[1]
LSD				915.7

NB: Superscript on mean values denotes their ranking in terms of yield performance

For the year under review, the performance at the Libi site is not very encouraging. This is due to flooding which occurred after seeding greatly affecting percentage seedling emergence. This may have affected grain yield at this location leading to the low figures reported. The average yield performance of the genotypes for the two year period (2011-2012) at the multil-location sites is presented below (Figure 12). The genotype jasmine 85 (red) is the highest yielding followed by Magitey and Gbewaa (local Check) respectively (Figure 1.0). It is worth mentioning that genotype Jasmine 85 (red) has all the good traits (short duration, perfumed, good plant height, high tillering ability etc.) of the original released 'Jasmine 85' genotype' (Gbewaa rice variety). As such it is a good inclusion to our germplasm for promotion. Nerica 14 though not among the best yielding material observed in this study will be recommended for further trials. This is because of the ecological niche (Upland ecology) it serves.

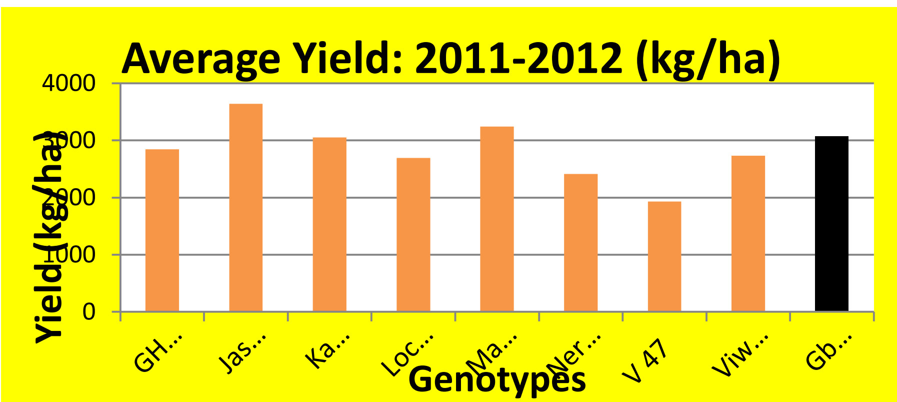

Figure 12: The average yield potential (2011-2012) of the red caryopsis genotypes across all locations (LIbi, Nyanpala and Manga).

Conclusion: The trial will be repeated in 2013 for the final round of evaluation.

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Participatory Varietal Selection (PVS) of Lowland Rice Genotypes

Dogbe, W., Dartey[1], K., Aliyu, S., Abebrese, S.O., Owusu, R.K., Inusah, B. Danaa, A. Abdul-Rahman, A., Mahama, A., Halolo, E. and Krofa, E.O.
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Executive Summary
Thirty-three new genotypes of lowland rice were evaluated with farmers using the PVS model at three locations (Nyankpala, Manguli and Libi) in the year 2011. Twenty-two of these genotypes were selected and advanced into multi-locational trials in 2012. ANOVA analysis for all parameters measured among the genotypes show statistical significant differences ($P<0.05$). In terms of average grain yield/ha across all the three locations, the top five performing genotypes are L-19, L-15, L-4, L-40 and L-50. Nabogo and Gbewaa (the local checks in the trial) placed 19th and 15th respectively in terms of average yield performance across the three locations. The trial will be repeated in 2013.

Introduction
To facilitate variety development and adoption, the PVS concept was coined out (AfricaRice, 2010) and is being championed by both the Consultative Group on International Agricultural Research (CGIAR) centres, and the National Agricultural Research Institutes (NARIs). As part of the collaboration between the Institutes within the council (CSIR) thirty new rice genotypes were received from the breeding programme of CSIR-CRI. These materials were evaluated together with three local checks with farmers at three locations (Nyankpala, Libi and Mangouli) in a PVS model.

Materials and Methodology
Some genotypes were selected (22 in total) from last year's PVS trial based on farmer selection but also yield potential and other agronomic characteristics of the genotypes. These set of genotypes including 2 local checks were advance into yield trial at multi-locational level

(Table 28). The trial was a Randomised Complete Block Design (RCBD) with four replications at three locations (Manga, Libi and Nyankpala). Planting dates for Nyankpala, Libi and Manga 16th June, 2012, 19th July 2012 and 27th July, 2012.

Table 28: The set of genotypes used for the advanced yield trial

Number	Genotype	Number	Genotype
1	L-27	12	L-21
2	L-15	13	L-24*
3	L-34	14	L-50
4	L-63	15	L-60
5	L-62	16	L-19
6	L-40	17	L-25*
7	L-4*	18	L-18*
8	L-28*	19	L-38*
9	L-33*	20	L-32*
10	L-39	21	Nabogo* (check)
11	L-41	22	Gbewa (check)

NB: Asterisk indicates famer-selected genotype during PVS

Seeds were dibbled (maximum of two per hill) at planting distance of 20x20cm. The recommended fertilizer application rate of 60-60-30 NPK kg/ha was adopted for the trial (applied through broadcasting) with the N component applied in split dose. All other cultural practices were carried out as and when it becomes necessary. Generalized linear model ANOVA in Genstat was the model used for all data analyses.

Results and Discussions

The ANOVA results indicate that the genotypes show statistical significant differences ($P<0.001$) for all parameters measured (Table 29). The effect of environment on the genotypes is also significant for all parameters except Panicle length. Genotype by environment interaction is also significant for all the parameters except panicle length.

In terms of grain yield the top five performing genotypes are L-19, L-15, L-4, L-40 and L-50 (Table 30). This represents the average of the three locations for the year under review. Nabogo and Gbewaa (the local checks in the trial) placed 19th and 15th respectively in terms of average yield performance across the three locations. This is an indication that most of the genotypes in this evaluation are good materials. It is worth noting that genotype L-27 could not be included in the analysis as data was not available for two of the locations.

Conclusion

The trial will be repeated in 2013 to further monitor the yield and agronomic performance of the genotypes at multi-locational level.

Table 29: ANOVA for the parameters measured on the 21 rice genotypes evaluated.

Source of variance	Df (GxL)	MS (GxL)	F-pr (genotype)	F-Pr (location)	F-pr (Inter)	CV (%)	LSD (5%)
% emergence	38	7.777	<.001	0.478	0.134	2.6	4.115
Days to 50% Flowering	38	108.955	<.001	<.001	<.001	2.5	4.087
Days to maturity	38	36.955	<.001	<.001	<.001	1.1	1.7744
Tiller count/hill	38	12.422	<.001	0.006	0.015	18.2	5.045
Plant height (cm)	38	99.23	<.001	0.019	<.001	5	7.006
Panicle count	38	4.404	<.001	0.01	<.001	10.5	1.471
Panicle length (cm)	38	8.39	<.001	0.93	0.964	15.9	5.185
Yield@14%MC (kg/ha)	38	1933362	<.001	0.046	<.001	30	1415.8
1000 grain weight(g)	38	7.668	<.001	<.001	<.001	7	2.592

Table 30: The yield performance of the of genotypes across location

Genotype	Location (Yield kg/ha)			Average across location
	Libi	Manga	Nyankpala	
GBEWAA	3056	1697	2546	2433[15]
L – 15	2160	3275	4912	3449[2]
L – 18	2033	1888	2832	2251[16]
L – 19	2680	3312	4968	3653[1]
L – 21	3124	1692	2537	2451[14]
L – 24	2833	1871	2807	2504[13]
L – 25	1494	3022	4534	3017[6]
L – 28	1604	1912	2868	2128[18]
L – 33	1968	2414	3621	2668[12]
L – 34	2088	114	171	791[20]
L – 38	2398	1695	2543	2212[17]
L – 4	3381	2729	4094	3401[3]
L – 40	2181	2763	4145	3030[4]
L – 41	2499	2398	3598	2832[9]
L – 50	1870	2884	4325	3026[5]
L – 60	1534	2886	4330	2917[7]
L – 62	2142	2487	3731	2787[10]
L – 63	1573	2612	3917	2701[11]
L -32	3123	2211	3317	2884[8]
NABOGU	1503	1587	2380	1823[19]
LSD (5%)				1415.8

NB: Superscript on mean values denotes their ranking in terms of yield performance

References

International Rice Research Institute (IRRI) (2002). Standard evaluation system for rice. Los Banos, Philippines.

Participatory Varietal Selection of Rice-The Technician's Manual (2010.).Africa Rice Centre (AfricaRice). Cotonou, Benin.120pp.

Multi-Locational Evaluation of Upland Rice Genotypes

Dogbe, W., Aliyu, S., Abebrese, S. O., Owusu, R.K., Inusah, B. Mahama A., Abdul-Rahman, A., Krofa, E. O., Danaa, A and Halolo, E.

Executive Summary

Ninety-six upland genotypes were evaluated in a preliminary nursery evaluation at Nyankpala in 2011 for yield performance. Thirty-two of these genotypes (including two local checks) were selected for advance un-replicated nursery trial at multi-locational level in three locations (Nyankpala, Libi and Manga) in 2012. The ANOVA results shown that differences for all parameters measured among the genotypes are not statistically significant. In terms of average grain yield (kg/ha) across all locations, the top 15 highest yielding genotypes did not include the control. The trial will be repeated in 2013.

Introduction

The upland ecologies have become an important part of rice production systems with the potential to supplement the lowland systems and increase rice production. Since the introduction of the NERICAs, the upland ecologies have received particular attention and more of such ecologies are now being put under rice cultivation.

Objective(s):

To evaluate upland rice genotypes (including two control genotypes) for initial yield performance in a nursery establishment.

Materials and Methodology

In 2011, 32 out of 96 genotypes (Table 31) including two local checks were selected for preliminary nursery evaluation at Nyankpala. These genotypes were advanced for evaluation at multi-locational level in the form of un-replicated nursery. The seeding dates for Manga, Libiand Nyankpala respectively are 13th July, 2012, 27th July 2012 and 28th June, 2012.

Seeds were dibbled (maximum of two per hill) at planting distance of 20x20cm. The recommended fertilizer application rate of 60-60-30 NPK kg/ha was adopted for the trial (applied through broadcasting) with the N component applied in split dose. All other cultural practices were carried out as and when it becomes necessary. Generalized linear model ANOVA in Genstat (9th Edition) was the model used for all data analyses.

Results and Discussions

From the analysis of variance results, only plant height and panicle count show statistical significant differences ($P<0.05$) the rest of the parameters did not (Table 32). In terms of average grain yield across all locations, the top 15 highest yielding did not include the control genotypes (Table 31). In general, it can be said that the performance of the genotypes in terms of grain yield is very low compared to the results obtained for last year at Nyankpala (during the initial nursery evaluation) (Table 31 and Table 33). This could be attributed to the late planting at some of the sites particularly Libi.

Table 31: Average yield performance of the upland rice genotypes for the year under review (2012/13 cropping season)

Code	Genotype	Yield (kg/ha)	Code	Genotype	Yield (kg/ha)
V94	ARCCU 16 bar-12-13-3-B-1	2166	-	NERICA 2	1203
V55	ARCCU 16 Bar 9-19-25-2-B-B	1933	V90	ARCCU 16 Bar-12-17-29-2-B-1	1171
V96	ARCCU 16 Bar-12-22-4-1-B-1	1635	V100	ARCCU 16 Bar-12-12-33-2-B-1s	1143
V88	ARCUU 16 Bar 5-6-14-1-5-1	1629	V86	ARCCU 16 Bar-4-2-1-4-B-1	1143
V54	ARCCU 16 Bar-9-4-16-1-B-B	1533	-	NERICA 1	1112
V18	ARCCU 16 Bar 4-14-2-4-B-B	1485	V42	ARCCU 16 Bar 9-33-2-1-B-B	1069
V99	ARCCU 16 Bar 22-1-1-2-B-1	1472	V72	ARCCU 16 Bar 13-15-25-1-B-B	1052
V63	ARCCU 16 Bar 13-11-1-2-B-B	1463	V7	ARCCU 15 Bar 7-16-38-B-B	1010
V67	ARCCU 16 Bar 12-17-27-3-B-B	1435	V66	ARCCU 16 Bar 19-3-31-1-B-B	1009
V53	ARCCU 16 Bar 9-2-10-4-B-B	1412	V59	ARCCU 16 Bar 9-9-25-3-B-B	909
V74	ARCCU 16 Bar 14-2-33-1-B-B	1352	V65	ARCCU 16 Bar 13-12-19-1-B-B	889
V77	ARCCU 16 Bar 9-9-24-4-B-1	1351	V19	ARCCU 16 Bar 12-12-16-3-B-B	880
V56	ARCCU 16 Bar 9-1-32-3-B-B	1342	V58	ARCCU 16 Bar 12-22-3-2-B-B	869
V26	ARCCU 16 Bar 5-10-2-2-B-B	1283	V97	ARCCU 16 Bar 12-12-33-3-B-2	796
V98	ARCCU 16 Bar 5-6-25-1-B-1	1281	V64	ARCCU 16 Bar 8-11-6-2-B-B	758
V85	ARCCU 16 Bar 5-10-22-2-B-1	1208	V73	ARCCU 16 Bar 19-11-23-2-B-B	724
LSD (5%)					936.1

Conclusion

The multi-locational nursery evaluation will continue this year (2013) using the same number of genotypes to further monitor their performance. Ten top yielding genotypes with good agronomic characteristic will then be selected for advanced yield trials (replicated trial) at the multi-locational level.

Table 32: ANOVA result of the evaluated upland rice genotypes

Source of variance	Df	MS	F-pr (genotype)	CV (%)	LSD (5%)
% emergence		250.3	0.717	26.1	28.43
Days to 50% Flowering	31	65.31	0.249	10.3	11.94
Days to maturity	31	38.21	28.43	4.8	7.506
Tiller count/hill	31	1.687	0.939	26.7	2.736
Plant height (cm)	31	186.2	0.031	10.3	16.86
Panicle count	31	3.8159	<.001	16.7	1.5729
Yield_14%MC (kg/ha)	31	330103	0.482	46.2	936.1

Table 33: Twenty top yielding genotypes during 2011 evaluation (Initial nursery evaluation at Nyankpala alone)

Code	Pedigree name	Yield (kg/ha)
V7	ARCCU 15 Bar 7-16-38-B-B	2407.4[12]
V18	ARCCU 16 Bar 4-14-2-4-B-B	2262.6[16]
V19	ARCCU 16 Bar 12-12-16-3-B-B	2607.8[8]
V54	ARCCU 16 Bar 9-4-16-1-B-B	2559.1[9]
V55	ARCCU 16 Bar 9-19-25-2-B-B	2257.8[17]
V56	ARCCU 16 Bar 9-1-32-3-B-B	2310.0[14]
V59	ARCCU 16 Bar 9-9-25-3-B-B	2883.0[6]
V63	ARCCU 16 Bar 13-11-1-2-B-B	2231.1[20]
V64	ARCCU 16 Bar 8-11-6-2-B-B	2939.9[5]
V65	ARCCU 16 Bar 13-12-19-1-B-B	3412.1[1]
V66	ARCCU 16 Bar 19-3-31-1-B-B	3100.0[3]
V73	ARCCU 16 Bar 19-11-23-2-B-B	2989.8[4]
V77	ARCCU 16 Bar 9-9-24-4-B-1	2248.1[18]
V85	ARCCU 16 Bar 5-10-22-2-B-1	3287.6[2]
V88	ARCUU 16 Bar 5-6-14-1-5-1	2424.8[11]
V90	ARCCU 16 Bar-12-17-29-2-B-1	2269.3[15]
V94	ARCCU 16 bar-12-13-3-B-1	2330.4[13]
V96	ARCCU 16 Bar-12-22-4-1-B-1	2481.0[10]
V97	ARCCU 16 Bar 12-12-33-3-B-2	2820.1[7]
V99	ARCCU 16 Bar 22-1-1-2-B-1	2240.8[19]

NB: Superscripts on mean yield values denotes the ranking of the 20 best yielding genotypes.

References

International Rice Research Institute (IRRI) (2002). Standard evaluation system for rice. Los Banos, Philippines.

Participatory Varietal Selection of Rice-The Technician's Manual (2010.).Africa Rice Centre (AfricaRice). Cotonou, Benin.120pp.

Evaluation of Hybrid rice genotypes (NSL-trial)

Dogbe, W., Abebrese, S. O., Aliyu, S., Owusu, R.K., Inusah, B. Mahama A., Abdul-Rahman, A., Krofa, E. O., Danaa, A and Halolo, E.

Executive Summary

We evaluated a total of ten lowland genotypes of rice (some of which are hybrid) at two locations (Nyankpala and Libi) for yield potential and general agronomic adaptability to the rice growing ecologies of northern Ghana. The analysis of variance for most of the parameters measured among the genotypes are statistically significant (P<0.05) except grain yield (kg/ha). Most of the genotypes performed better than the control treatment. The trial will be repeated in 2013.

Introduction

Hybrid rice varieties are becoming popular for cultivation particularly in the Asian continent because of their superior yield performance compared to the traditional inbreed varieties. Another reason for the success of hybrid rice in those countries is also partly due to their good irrigation facilities and a credible and functional seed industry most championed by the private sector. With the recent passage of the seed law, the anticipation is that the seed industry in Ghana will see some improvement. Against this back drop the evaluation of hybrid varieties of rice in the northern ecological zones of Ghana is a welcome ideal.

The objective(s) of the study is to evaluate a total of ten lowland genotypes of rice (including one local check) some of which are hybrid genotypes for their yield potential and general adaptability to the rice growing ecologies of the northern Ghana.

Materials and Methodology

Ten genotypes (Table 35) were planted at two locations (Libi and Nyankpala) in a Randomised Complete Block Design (RCBD) with four replications. Seeds were dibbled (maximum of two per hill) at planting distance of 20x20cm. The recommended fertilizer application rate of 60-60-30 NPK kg/ha was adopted for the trial (applied through broadcasting) with the N component applied in split dose. All other cultural practices were carried out as and when it becomes necessary. Generalized linear model ANOVA in Genstat (9^{th} Edition) was the model used for all data analyses

Results and Discussion

The data from Nyankpala site could not be included in the analysis. This is because due to late arrival of the materials, the site where the trial was established was hydromorphic (midland) instead of the typical lowland best suited for these genotypes. Hence, the trial suffered from terminal drought later in the season leading to the failure of the trial. At the Libi site also, there was flooding of the field after the trial was established leading to very poor crop establishment as indicated by seedling percentage emergence (Table 35).

The analysis of variance for all parameters measured show statistical significance ($p<0.05$) except for grain yield. Even though the yield figures recorded in this study are generally low, it worth mentioning that most the genotype performed better than the control treatment (Figure 13 and Table 34). The response of the genotype to common stress factors prevalent in the area can generally be said to be good (Table 35). However incidence of brown spot and leaf scald disease is comparatively high.

Table 34: ANOVA results of the rice genotype evaluated in this study.

Source of variance	Df	MS	F-pr	CV (%)	LSD (5%)
% emergence	9	503.3	0.066	36.3	22.46
Days to 50% Flowering	9	224.225	<.001	3.1	4.159
Days to maturity	9	238.636	<.001	1.9	2.928
Tiller count/hill	9	12.678	<.001	9.9	1.854
Plant height (cm)	9	407.01	<.001	4.8	6.155
Panicle count	9	10.389	<.001	12.1	2.012
Panicle length (cm)	9	28.351	<.001	6.6	2.145
Number of grains/panicle	9	739.1	0.001	14.7	18.96
Yield_14%MC (kg/ha)	9	257309	0.253	27	630.2
1000 grain weight(g)	9	35.5412	<.001	3.1	1.078

Conclusion:

Due to the problems enumerate above during the course of this evaluation, we are of the view that the yield figures recorded here may not be the true potentials of the genotypes. Under much favourable environment, the genotypes may yield higher. To ascertain this in the meantime, the same genotypes are been evaluated under irrigation in a screening platform. The trial will be repeated in 2013/14 cropping season.

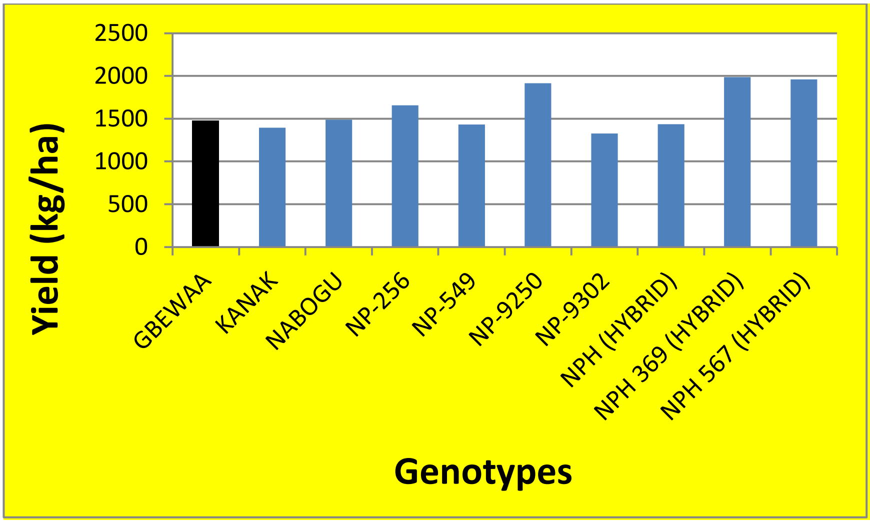

Figure 13: The average yield performance of the rice genotypes evaluated in this study

Table 35: The performance of the genotypes on some agronomic parameters measured during the course of this study at Libi

Genotype	% Emergence	50% flowering	Days to Maturity	Plant height (cm)	Tiller count/hill	Grains/panicle	Panicles count/hill	1000 grain weight (g)	Panicle length	Yield (kg/ha)
GBEWAA (check)	28	86	107	83	12	103	11	25	24	1476
KANAK	51	103	123	77	16	73	14	18	19	1393
NABOGU	28	95	113	114	15	98	14	24	26	1488
NP-256	59	96	108	94	11	93	10	29	22	1657
NP-549	55	85	100	86	13	76	11	25	22	1433
NP-9250	53	99	118	86	13	99	12	28	24	1913
NP-9302	40	81	98	81	12	63	11	23	17	1326
NPH (hybrid)	33	87	105	88	12	99	10	23	25	1435
NPH 369 (hybrid)	43	86	105	87	11	93	10	23	23	1985
NPH 567 (hybrid)	37	99	110	92	14	93	12	23	24	1960

References

International Rice Research Institute (IRRI) (2002). Standard evaluation system for rice. Los Banos, Philippines.

Achievements of the productivity component of the Agricultural Value Chain Mentorship Project (AVCMP)

Dr. Wilson Dogbe, Robert Owusu, Prince Maxwell Etwire, Abdul Basit Tampuli, Mr. Inusah Baba, Edward Martey, Mr. Siise Aliyu, Krofa E. Ofosu, Edem Halolo

Introduction

The CSIR-Savanna Agricultural Research Institute (CSIR-SARI), International Fertilizer Development Center (IFDC), and the Ghana Agricultural Associations Business Information Centre (GAABIC) are grantees implementing the Agricultural Value Chain Mentorship Project (AVCMP) funded by the Danish International Development Agency (DANIDA) through the Alliance for a Green Revolution in Africa (AGRA). The project is an integral part of DANIDA's Support to Private Sector Development (SPSD) Phase II, and falls under Component 2: Enterprise Growth and Job Creation. IFDC, CSIR-SARI and GAABIC are implementing *sub-component 2.2: Agricultural Value Chain Facility* in 16 districts in the Northern Breadbasket Region of Ghana focusing on rice, soybeans and maize value chains. By supporting the private sector to serve as a catalyst for increased agricultural production and viable livelihoods for smallholder farmers, the project will increase incomes and employment in the Northern Ghana and in turn contribute to the overall Government of Ghana's objective of food security and becoming an agro-industrial economy.

The Agricultural Value Chain Facility (Sub-Component 2.2) has 3 main intervention areas: A) Mentorship and Advisory Services B) Financial Capacity Development Facility and C) Loan/Guarantee Facility Leveraging Commercial Bank Lending to SMEs and Farmer Organizations. The main activities of IFDC, SARI and GAABIC focus on Intervention areas A and C with linkages to intervention area B.

CSIR-SARI is responsible for the implementation of the productivity component of the Project, which has the objective of improving entrepreneurial and technical skills of FBOs and their member farmers to upscale ISFM technologies for rice, soybean and maize production. This report covers the achievements of the productivity component in 2012.

Problem being addressed by Productivity component of AVCMP

The Productivity component is contributing to address the following underlying factors to low agricultural productivity, and income, food insecurity and poverty in the Northern Region of Ghana:

- Low use of improved seeds and fertilizers
- Poor soil health
- Low agricultural land use and poor crop management practices by farmers
- Inadequate extension services and weak-research extension linkages.
- Poor farmer access to cultivation equipment services

- Insufficient agricultural marketing system to spur supply response from smallholder producers due to a myriad of factors including: lack of sufficient access to market outlets and high post - harvest losses.
- High transaction costs due to inadequate road and transport infrastructure
- Limited access to credit due to high interest rates and stringent collateral requirements and low investment in agriculture

Expected outcomes of the Productivity Component

A1: Increased farmer access to farm inputs (seeds and fertilizers) from agro-dealers
A2: Improved capacity of national institutions and FBOs to upscale ISFM technologies
A3: Increased awareness on and use of ISFM technologies among smallholder farmers

Objectives of Productivity Component

The objective of the productivity component is to improve entrepreneurial and technical skills of FBOs and their member farmers to upscale the application of ISFM technologies for rice and soybean cropping systems while also strengthening their linkages with actors across the agricultural value chain specifically agro-dealers, SMEs, commercial banks, seed and fertilizer producers and suppliers and extension agents.

Implementation strategies

- Identification and Profiling of FBO's, Nucleus Farmers, and Secondary FBO's producing Rice, Soybean and Maize
- Training FBOs, in business and technical skills, business development, and to prepare them to access financial services;
- Assisting FBOs, to develop bankable business plans for production loans
- Linking FBOs to production inputs
- Awareness creation on ISFM technologies through OFDs, radios, drama and digital video, print media and farm learning centers
- Identification of institutions that can partner the Project in ISFM Scale up
- Capacity building of institutions (public & private) to support ISFM technologies scale up

Achievements in 2012

During the period under review, the following strides were made under the different project outputs and outcomes.

Outcome A1: Increased smallholder farmers' access to farm inputs (seeds and fertilizers) and ISFM technology.
Output A1-1: Number of FBO, nucleus farmers and secondary FBOs identified to participate in the project
About 342 FBOs, 2 nucleus farmers and 4 SFBO's working with over 14,000 smallholders farmers have been identified and are benefiting from the project, Ten percent (1400 farmers) of the number has participated directly in the on-farm demonstrations and farmer learning center activities. Others have benefited in the FBO trainings, radio messages, ISFM drama and feedback sessions.

Output A1-2: Number of FBOs linked to input dealers to access seed and fertilizer in bulks
Efforts to link FBO’s to credit, inputs and services did not yield much result because credit institutions were not ready to work with the FBO’s for various reasons. Moreover Input dealers were not ready to provide inputs on credit to FBO’s

Output A1-3: Number of FBOs trained in value chain approach, strategies for sustaining FBOs and monitoring and evaluation
Four hundred and eighty (480) FBO leaders from 250 FBO’s have been trained in FBO management, group dynamics and business development skills.

Left: A farmer seeking clarification. Right: Role play on how to sustain an FBO threatened by conflict

Output A1-4: Number of business plans developed for FBOs to access credit
No business plans were developed for FBO’s to access credit because the banks were not ready to engage them. A study was conducted to understand why the banks were shying away from the FBO’s. The result of this study is being collated and will be reported in the next annual report.

A2: Improved capacity of national institutions and FBOs to upscale ISFM technologies
The project in 2012 signed partnership agreement with four radio stations (Bishara, Radio Savannah, Simli Radio and Radio Kitawoln), 16 MoFA districts, Tamale Youth Home Cultural Group, Countrywise communication and Some media houses (Ghana News Agency (GNA), Daily Graphic and Times). The partnership led to:
The facilitation and the production of ISFM on-stage drama in 8 districts to create awareness by Tamale Youth Home Cultural Group. The drama has been captured on video by Countrywise Communication Ghana for wider dissemination.

Training of partners (MoFA, FBO’s leaders and the media partners) on PLAR-ISFM
Institution of quarterly review meetings with the media partners

Joint field monitoring with partners
Provision of partner radio stations with digital voice recorders and data storage drives to enhance their work.
Identification and supported of resource persons to work with radio stations
Together the 4 partner radio stations aired 96 radio programs on ISFM. Also annual zonal feedback meetings have been instituted to share results with value chain partners at the districts. Annual regional feedback and review meeting have also been instituted.

Outcome 3: Increased awareness on and use of ISFM technologies among smallholder farmers
Output A3-1 Percent farmers in target area using improved agricultural (ISFM) technologies
87 demonstrations of ISFM technologies were conducted
87 lead farmers and 32 MoFA staff trained on 10 ISFM technologies demonstrated.
1500 farmers were directly reached with demonstration
Six Farmer learning centers established in 6 districts (Tamale, Tolon, Yendi, East Gonja, Karaga and West Mamprusi)

Productivity of ISFM technologies demonstrated on farmers fields: Results from 87 ISFM demonstrations comprising 14 technologies in different combinations planted across six farmer learning centres (Libi Woribogu, Cheshei, Shelli-Lanyili, Katabanawa and Kpatia) and 57 FBO's working with the AVCMP across the 16 project districts in 2012 revealed the following.

a. Demonstration of Improved Rice and Soybean Production Practices:
Compared to 2011, rice and soybean yields wee generally low. The improved ISFM practices demonstrated were however in all cases were superior to farmer's practices. Yields from improved rice management demos ranged from 167 to 3600kg/ha with a mean of 2027 kg/ha compared to a range of 335 to 2400 kg/ha and a mean of 818kg/ha in farmers practice.
Similar result (Table 36) was recorded for the improved soybean demo across 25 FBO's

Table 36. Mean Soybean yield recorded from Improved Soybean production demonstration across 25 FBO's in AVCMP project districts

Treatment	Farmer management	Improved Practice
Max	1500	2250
Min	142	280
Mean	421	961

Demonstration of certified seed and fertilizer for rice
The use of certified rice seed and fertilizer were found to improve rice yield significantly Fig.14. Certified seed use was found to be superior at all levels of fertilization and gave a yield advantage of about 35% compared to farmer saved seed. The application of 3t/ha compost in addition to the recommended fertilizer rate for rice (60-60-30 NPK) increased yield by 35% for the farmer saved seed and 40% when certified seed was used compared to the recommended fertilizer rate.

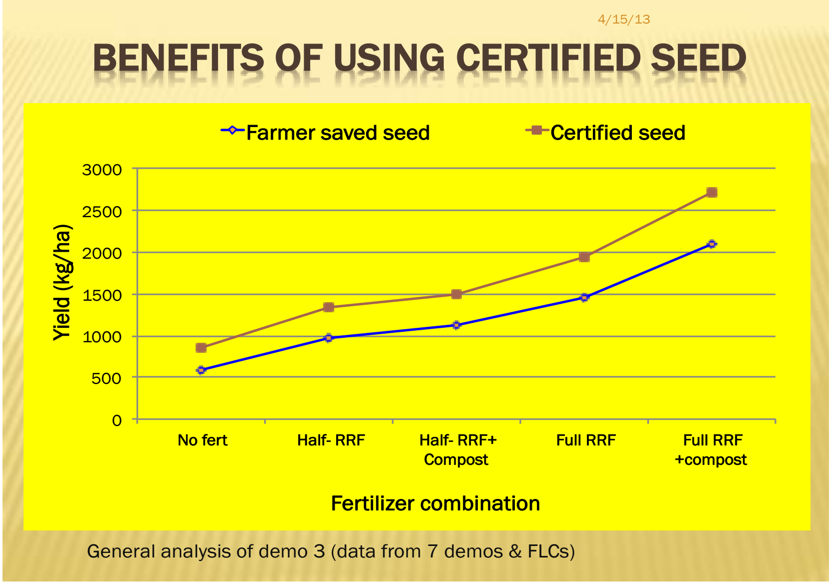

Fig 14. Effect of seed source and fertilization on rice yield

Demonstration of Nitrogen fertilizers for rice

Results from evaluation of nitrogen fertilizers from 10 communities in NR indicate the superiority of Urea Super Granule over the two commonly available nitrogen fertilizer sources (Urea and Sulphate of Ammonia) Fig 15.

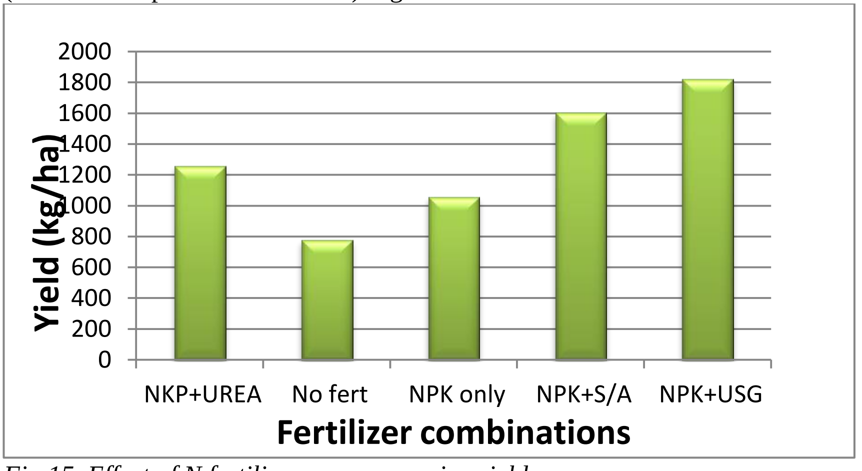

Fig 15. Effect of N fertilizer sources on rice yield

Impact of ISFM demonstrations on productivity of Rice and Soybean in AVCM Project district. To understand the contribution of demos to productivity, 244 FBO's were surveyed in 2012 to estimate total area put under cultivation for the three target crops (Rice Soybean and Maize). At maturity, yield cuts were done from 10 farmers per crop per district to estimate average yields. For the yield cuts 50% of the farmers (5 per district) were randomly selected from farmers who had participated or were participating in AVCMP ISFM demos and the remaining 50% from none demo participants.

The objectives of this survey were to assess the impact of the demonstrations on farmers yield and productivity and to estimate the production of these crops by farmers.

Five 4-metre square sample areas were demarcated randomly in each farmer's field for yield assessment. The area was then harvested and yields from the area converted to yield per ha. A total of 130 farmers from 13 districts were surveyed for the soybean yield cut assessment while 70 from seven districts were surveyed for the rice. Yield cuts were not performed for maize. As a result the data from SRID-MoFA was used to compute the total production.

For the calculation of the district production the mean of the yields from participants and non-demo participants was used. The overall average yield for rice and soybean for the sampled districts were used to compute the total district production for districts that were not sampled.

Results and discussion.
We found significant differences in yield cut data for rice and soybean received from SRID-MoFA compared to that collected by the AVCMP (Table 37). In all districts the SRID_MoFA estimate were almost double that recorded by AVCMP. Assuming that the yield cut data from AVCMP is the true reflection on the ground this means the district productions as reported by MoFA have been overestimated by 84 and 96% for rice and soybean respectively. Given that the source of most of the baseline data for the AVCMP is MoFA such a disparity as reported above makes it difficult to capture the real impact of the project relative to the baseline

Table 37. Comparison of data for yield estimates from SRID-MoFA and AVCMP sources

Source of data	Average yield (t/ha)		
	Rice	Soybean	Maize
SRID-MoFA	2.43	1.77	NA
AVCMP	1.32	0.90	1.36
Diff	1.11 (84%)	0.87 (96%)	NA

Table 38 gives the area cropped by the surveyed FBO's, the average yield and production for the different crops. A total of 7,327 hectares were cultivated by the 244 FBO's (71% of 342 project FBOs) with a breakdown of 1961 ha for rice, 1628 ha for Soybean and 3737 ha for Maize. The distribution per district is on Table 38a, b and c. Mean rice yield per district ranged from 1 to 1.98 t/ha with a mean of 1.32 across the 16 project districts. For Soybean yields range from 0.3 to 1.95 tons per hectare with a mean of 0.9 t/ha. The average Maize yield was 1.32 t/ha with a range of 0.52 to 1.65 t/ha.

Table 3a. Cropped area, average yield and total production of Rice by 244 surveyed AVCMP FBO's across the project districts in 2012

DISTRICT	No of FBO's surveyed	Total area cultivated (ha)	Av. Yield (t/ha)*	Total production (t)
Bunkpurugu-Yunyoo	8	212.8	1.3	277
Central Gonja	13	66.6	1.3	87
Chereponi	7	27.8	1.19	33
East Gonja	18	151.2	1.3	197
East Mamprusi	8	60.6	1.3	79
Nanumba North	7	22.8	1.12	25
Nanumba South	8	39.2	1.3	51
Saboba	13	28	1.3	36
Savelugu-Nanton	27	224.4	1.3	292
Tolon-Kumbungu	28	112.4	1.05	118
Yendi	8	21.6	1.3	28
West Mamprusi	25	196	1.3	255
Tamale	28	454.8	1.66	755
Gushiegu	9	43.2	1.98	86
Karaga	27	266	1.18	314
Kpandai	10	34	1.3	44
TOTAL	244	1961.4	1.32	1,891

Average yield cut by AVCMP; ** Average 2012 district yield estimate collected from SRID MoFA

Table 38b. Crop area, average yield and total production of Soybean by 244 surveyed AVCMP FBO's across the project districts in 2012

District	No of FBO's surveyed	Total area cultivated (ha)	Av Yield (t/ha)*	Total Production (t)
Bunkpurugu-Yunyoo	8	112.40	0.89	100.3
Central Gonja	13	3.20	0.75	2.4
Chereponi	7	79.60	1.53	121.5
East Gonja	18	10.80	1.08	11.6
East Mamprusi	8	23.20	0.37	8.6
Nanumba North	7	35.20	0.58	20.3
Nanumba South	8	35.20	0.89	31.4
Saboba	13	87.20	0.75	65.4
Savelugu-Nanton	27	176.00	0.73	129.2
Tolon-Kumbungu	28	21.20	0.30	6.4
Yendi	8	68.80	0.79	54.2
West Mamprusi	25	216.40	0.83	178.5
Tamale	28	31.60	1.19	37.6
Gushiegu	9	175.20	0.92	161.0
Karaga	27	518.00	1.95	1010.1
Kpandai	10	34.40	0.89	30.7
TOTAL	244	1,628.4	0.90	1969.2

Farmer's participation in ISFM demonstration had significant influence on his or her soybean and rice yields across project districts (Figs 16 & 17). Farmers who participated in demos in 2011 or 2012 had higher yields than those who had not participated in AVCMP demos. Average yield increase as a result of farmer's participation in AVCMP demonstrations was about 25%. Reasons attributed to increased yield recorded by farmers were adherence to recommended practices as taught during PLAR-ISFM trainings at the demo sites eg dibbling to ensure optimum population, and timely weed control and fertilizer management. Some farmers observed that even though they were not able to afford the recommended fertilizer rate the timely application and burying of fertilizer made the difference in yield especially for rice. For soybean farmers said the timely harvesting reduce their yield losses

Table 38c. Crop area, average yield and total production of Maize by 244 surveyed AVCMP FBO's across the project districts in 2012

District	No of FBO's surveyed	Total area cultivated (ha)	Av. Yield/Ha (t/ha)**	Total Production (t)
Bunkpurugu-Yunyoo	8	257.2	1.14	293
Central Gonja	13	133.6	1.33	178
Chereponi	7	80	0.52	42
East Gonja	18	127.6	1.65	211
East Mamprusi	8	151	1.1	166
Nanumba North	7	70.6	1.54	109
Nanumba South	8	119.2	1.54	184
Saboba	13	86.6	1.48	128
Savelugu-Nanton	27	464	1.3	603
Tolon-Kumbungu	28	202.2	1.5	303
Yendi	8	128	1.42	182
West Mamprusi	25	603	1.24	748
Tamale	28	729	1.13	824
Gushiegu	9	782	1.4	1,095
Karaga	27	137	1.46	200
Kpandai	10	692	1.32	913
TOTAL	244	3737.2	1.32	6,178

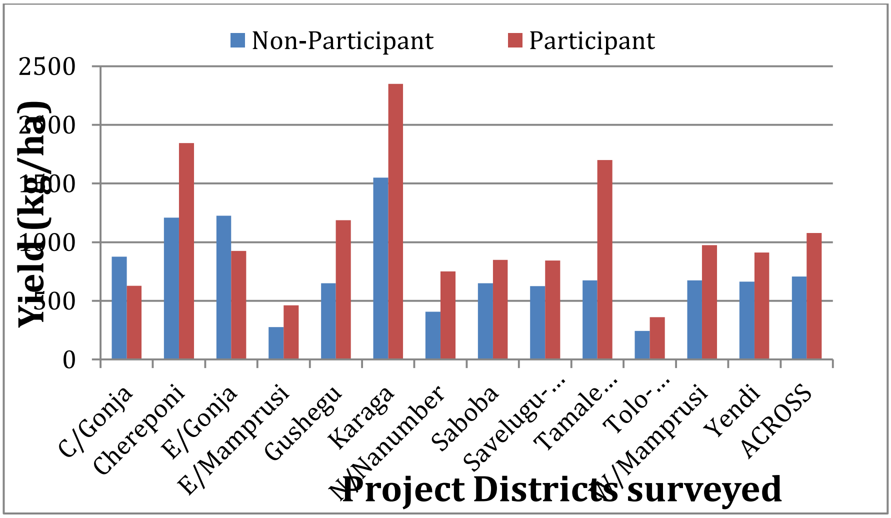

Fig. 16. Soybean Yield estimates (kg/ha) from farmers who participated and non-Participants in AVCMP Demonstration in 2012 across project districts

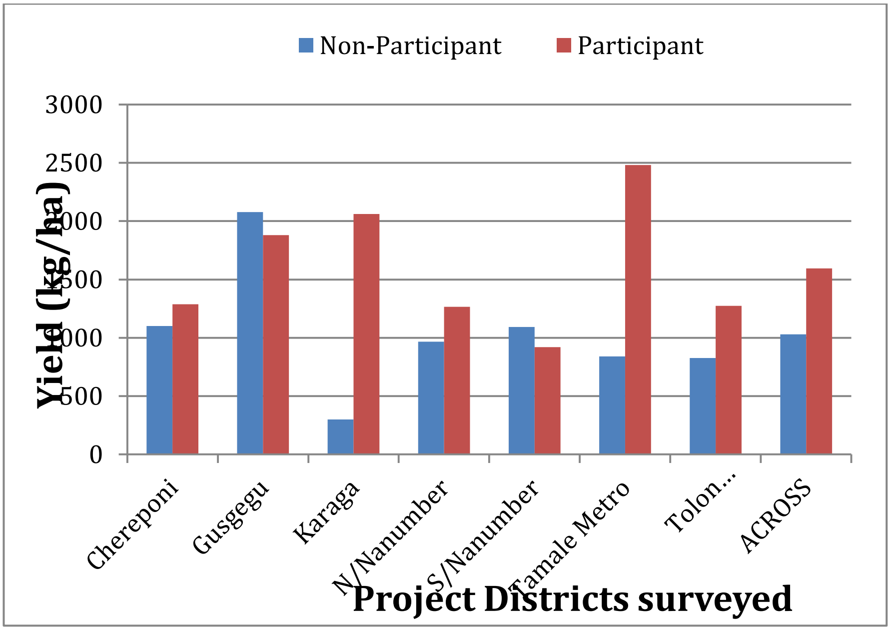

Fig. 17. Rice Yield estimates (kg/ha) from farmers who participated and non-Participants in AVCMP Demonstration in 2012 across project districts

Challenges

The rudimentary nature of FBO's and the high project target of FBO's to reach make it difficult for effective mobilization and linkage to inputs and services. High Farmer Extension ratio (1400:1) and many conflicting demands on AEA is a disincentive for effective extension delivery by AEA's. Very poor FBO access to credit and cultivation and harvesting equipment is negatively impacting on large-scale adoption of ISFM technologies. Baseline data from SRID seem to be higher than what pertains in the communities

Way Forward
All project activities will continue with the following few modifications for efficiency:
Identify and train community extension volunteers to support in project implementation.
Shift attention to nucleus farmers and aggregators with FBO's.

The Rice Sector Support Project (Rssp)

Background
The Rice Sector Support Project (RSSP) being implemented by MoFA and other partners aims at contributing to reduce poverty in the northern parts of Ghana, strengthening capacity of stakeholders along the rice value chain and contribute to national food security. The Savanna Agricultural Research Institute (SARI) of Council for Scientific and Industrial Research (CSIR), CSIR-CRI and CSIR-FRI have signed two year (2010-2012) contract with the project to provide enhanced adaptive research support to the project implementation.

For the 2012 reporting period, SARI successfully executed its planned research activities under the contract. These include : 1.Cordination of rice seed production, 2. On-farm evaluation of suitable lowland rice varieties using Participatory Varietal Selection (PVS) technique, 3. Capacity building of actors in Participatory Learning Action Research (PLAR) for integrated rice management and, 4.Development of Poly-aptitude rice and Direct seeding mulching cropping (DMC) system using cover crops.

The specific objectives of the 2012 enhanced adaptive research activities were to:
1. Coordinate the production of all categories of rice seed (breeder, foundation and certified) required by the project.
2. Provide PLAR training of trainers (TOT) to actors (MoFA, FBO's and NGO's).
3. Conduct on-farm evaluation of six improved rice varieties in eleven project districts, using the Mother and Baby PVS approach.
4. Conduct experiments on Direct-seeding in mulch cropping (DMC) systems in lowland, midland and upland ecologies
5. Produce seeds of poly aptitude rice varieties and cover crops imported for the DMC

The methodologies employed for the implementation of these activities and the results obtained are provided below.

Activity 1: Coordination of riceseed production
To fulfil this task, SARI identified the following stakeholders to be involved in the rice seed production.

Table 39 Seed distribution

Activity	Institutions/Stakeholders
Breeder seed	CSIR-SARI & CRI
Foundation seed	Ghana Grains and Legumes Development Board (GGLDB)
Certified Seed	Seed Producers Association of Ghana and Community seed growers
Seed Inspection and Certification	Ghana Seed Inspection Unit of MoFA
Training and Backstopping	CSIR-SARI and CSIR-CRI

A stakeholder meeting for rice seed production was held in April 2012 to plan for the seed production. The objectives of the meeting were to provide an update on seed production in 2011, to highlight achievements and challenges met and to work out the projection for 2012. The meeting maintained the 2011 targets for 2012 seed production: They included production of 0.5 tonne of breeder seeds, and 10 tonnes of foundation and 240 tonnes of certified seeds of the same varieties of Gbewaa, Tox3107, Katanga and Nabogo. The stakeholders agreed that SARI continued to produce breeder seed, and also support GGLDB to make foundation seeds available for the project in 2012. Besides, it was approved that certified seeds be produced by community seed growers in Upper West, Upper East and Northern regions and by Seed Producers Association of Ghana(Seed PAG) for the project.

To achieve these targets, CSIR-SARI made available to GGLDB 400kg Breeder seed and 4800kg Foundation seed to SeedPAG and community seed producers as per Table 39. A coordination meeting was conducted with SeedPAG members in northern Region on 5th June 2012 to plan distribution of Foundation seed among the seed growers and the cropping activities. During the season SARI provided backstopping and monitoring meeting with Libi community seed growers to ensure the best crop management practices were performed to produce good seeds. Table 40 presents the distribution of seed among the producers.

Table 40: Foundation seed (FS) released for certified seed production in 2012

Variety	*Qty of FS produced (Kg)	NR		UWR		UER		Total Qty released (kg)
		Qty (kg)	Targeted Area (ha)	Qty (kg)	Targeted Area (ha)	Qty (kg)	Targeted Area (ha)	
Gbewa FS	2660	900	18	500	10	660	13	2060
Nabogu FS	5580	800	16	250	5	300	6	1350
Katanga FS	1680	300	6	250	5	200	4	750
TOX 3107 FS	810	500	10	0	0	140	3	640
TOTAL FS	10730	2500	50	1000	20	1300	26	4800

*Qty: Quantity

Results & Discussion
The total production of the different categories of seed is presented in Tables 41 and 42.

Table 41 .Breeder and Foundation seed produced in 2012

Rice varieties	Breeder Seed (produced by SARI)		Foundation Seed (produced by GGLDP)	
	Area cultivated (ha)	Quantity harvested (kg)	Area cultivated (ha)	Quantity harvested (kg)
Gbewa	0.1	60.5	2.0	2700
Tox 3107	0.1	40.4	0.5	500
Katanga	0.1	41.7	0.8	2200
Nabogo	0.1	20.5	1.5	3200
Totals	0.4	163.1	4.8	8600

The quantity of certified seed produced for the project in the northern region was 75.3tonnes, table2. Although all RSSP certified seed growers were allocated foundation seeds most of them did not plant their seeds because of early flooding of their fields. It was also observed that some seed growers did not prioritize the production of certified seed for the project owing to their difficulty in selling the seed produced in 2011.

At Libi, 1.6 hectares Katanga and part of 2 hectares of Nabogo certified seed fields were severely infected with a disease .As a result, Katanga fields had no yield, whiles yields of Nabogo were poor, table3.

Table 42.Certified Seed Produced in 2012 by Northern Region

Rice Variety	Northern Region						Totals
	Nyankpala Seed growers		SeedPAG		Libi		
	Area (ha)	Quantity (kg)	Area (ha)	Quantity (kg)	Area (ha)	Quantity (kg)	Quantity of Rice (kg)
Gbewaa	18	26700	-	Nplt	1.6	4500	31200
Tox3107	-	Nplt	10	10000	2.8	10500	20500
Katanga	-	Nplt	5	17100	1.6	0*	17100
Nabogo	10	3000	5	500	2	6000*	6500
Totals	28	29700	20	27600	8	21000	75300

Nplt= not planted, *Fields were affected by diseases

As at the time of preparing this report no result on production was received from Upper West and East regions.

Activity 2: PLAR-IRM
The Participatory Learning and Action Research is an adult learning approach being used by the RSSP to educate farmers on Integrated Rice management. Under this component, MoFA is to coordinate the implementation of PLAR-IRM with technical support for training and backstopping from CSIR-SARI.

Objectives:

- To build capacity of MoFA staff in the PLAR-IRM and ensure a wide dissemination of the techniques.
- To strengthen the capability of MoFA and other extension service providers to analyse and effectively address environmental vulnerabilities in rice cropping
- To empower farmers in developing their capacities to observe, analyze and experiment the technology
- To strengthen FBO members to become more autonomous, more proactive in developing appropriate technologies, in order to improve the sustainability of the systems
- To improve rice cropping performances and farmers' decision making in terms of rice management

Target:
Partners (MoFA, FBO's and NGO's) in the RSSP project districts. Specifically they shall include the District Development Officer (DDO) or RSSP schedule officer and an AEA in charge of one operational area for RSSP and One FBO representative per district.

Under the terms of the partnership RADU who is in charge of the coordination, monitoring and evaluation of the activity is to contract SARI to conduct training of trainers in the 3 project regions in Northern Ghana (NR, UER and UWR). RADU and SARI are to monitor and backstop the implementation by providing detailed monitoring and evaluation system as well as making field visits.

The expected outputs of these supervision visits are:

- Monitor how the trainings are implemented, provide back up and corrections when necessary: this will ensure that the trainings have been well understood
- Strengthen the skills of the regional and districts units on how the trainings should really be implemented. That will enable them to carry out supervision on their own and fully grasp the trainings
- Witness the results of the methods on the farmers' groups
- Evaluate the impact of the trainings: are the trainings enough to build the capacities of the participants or there are lapses? What are the main difficulties or misunderstandings in the application of the training?

The DADUs are in charge of implementing the approach in the communities at district level after being trained by SARI during the ToT. They are to select the staff to be trained and ensure that the selected staffs participate regularly in future trainings to be offered. After the ToT, each DADU is expected to implement the approach with at least a farmers' group per district. They were to develop a budget and an action plan and submit it to RADU and PCU for district level implementation. Attendance and minutes of PLAR-IM sessions should be recorded and sent to RADU. If time and means are available DADU can implement the approach with other farmers groups. Trained district trainers were if possible to train more AEAs from the District.

Achievements:
Three training of trainer's sessions were organized in the three regions. A total of One hundred and six trainers made up of MoFA AEA's, FBO leaders and NGO field staffs drawn from the RSSP project districts were trained. SARI followed up implementation of PLAR sessions in the districts. Tables43,44 and 45 below presents the districts and the communities that implemented PLAR with the number of sessions reported in 2012.

Table 43: Districts and communities involved in PLAR in NR

District	Community	No of sessions conducted
Tamale Metro	Taha	5
Tolon	Kanfieyili	5
Savelugu-Nanton		0
Central Gonja	Nyekpegu	6
Nanumba South	Selected	0
Gusheigu	Sampibga	0
Yendi	Pion	5
West Mamprusi	Zungum	5
Karaga	Gunayili/kpakpia baa	4
Nanumba North	Jua/Salnayili	0
East Gonja	Libi	0

Table 44: Districts and communities involved in PLAR in UER

District	Community	No of sessions conducted
Bolga Municipal	Gambibigo, Yebongo	Introductory meeting + 1 sessions
Kassena Nankena	Tindago, Sapeliga	7 sessions
Builsa	Doninga, Chuchuliga	Introductory meeting + 1 and 2 sessions
Garu tempane	Azimsi-Nomboko, Yizigug	Introductory meeting + 6 sessions

Table 45: Districts and communities involved in PLAR in UWR

District	Community	No of sessions conducted
Wa Municipal		
Wa East	Yaala 1 & 2, Bulenga, Chaggu, Goripie, Dupari	1
Wa West	Polee, Chogsia, NaahaTin, doma, Eggu, Buka, Wechiau bao, Losse	1

Fig 18.Farmer reporting on a group work

Fig 19.Group photo for participants at Wa

Challenges

Communication with the districts is arduous and reports and working plan are difficult to obtain from the facilitators. Time dedication to PLAR by MoFA trainers was a challenge as a result of many conflicting roles. Because PLAR is a systemic approach, a team only devoted to the activity should be appointed to ensure an efficient implementation.

Activity 3: On- farm evaluation of suitable lowland rice varieties (using PVS)

Six improved rice varieties evaluated by SARI using the PVS approach since 2009 both on-station and at multilocation sites were evaluated in 2011 using the Mother and baby variety evaluation approach.

Objectives

- To increase the speed of adoption of new varieties by involving farmers in variety needs assessment, selection and testing of new lowland cultivars
- To sensitize farmers on the importance of quality seeds and on the performance of improved seeds compared to local seeds.
- To evaluate the adaptability of the new improved varieties to field conditions, to various ecologies and to farmers practices.

Methodology

The varieties are: Exbaika, Long grain ordinary 2, L2-4, WAS 163-B-5-3, WAS 122-13-WAS-10-WAR and perfume irrigated. The same approach is to be used in 2012. A Mother trial consists of a maximum of six most preferred varieties selected by researchers. Facilitators and/or innovative farmers manage mother trials. The trial is managed under good cropping practices management. The farmer evaluates the Mother trial. All the other farmers are invited to visit the field. Baby trials consist of any two of the 6 selected varieties in all possible combinations. All collaborating farmers within a community qualify to evaluate baby trials. Researchers or extension agents assisted farmers with the layout and sowing of PVS trials. Full responsibility for management and harvesting of baby trials is then after transferred to Farmers. Baby trials are implemented at farmers' management level and fertilizer may be applied depending on the capability of the collaborating farmer.

Agronomic and farmer preference data on varieties are collected using qualitative (Participatory) and quantitative methods. At vegetative, flowering, maturity and postharvest stages farmers ranked each trait of interest according to their preferences between each variety.

For ease of identification of varieties on farmer's field, PVS varieties within a community are colour coded. Facilitators are trained to monitor and supervise the implementation of Mother and Baby trials within a community. Joint monitoring by a combined team of Research, Extension and farmers to interact with farmers and monitor performance of varieties is performed during the season.

In 2012 Upper East, Upper West and Northern regions implemented the activity in each of the project districts. One community per district was identified. 2 Mother trials and 10 baby trials are proposed for each community. Before implementation a one-day training on the implementation was organized for the MoFA AEA's. The Table 46 presents the communities selected and where trials were evaluated.

Table 46: Communities involved in Mother and baby trials in the 3 regions

Region	District	Community	Mother Trials planted	Baby trials planted
Northern	Tamale Metro	Gbirma	1	1
	Tolon-Kumbungu	Kanfieyili	2	10
	Savelugu-Nanton	Sakpalgu	2	6
	Central Gonja	Dakoalpe	0	0
	Nanumba South	Nakpayili	0	1
	Gushegu	Sampibga	0	0
	Yendi	Pion	1	7
	West Mamprusi	Wungu and Moagtani	1	5
	Karaga	Ntanyili and Nyangbolo	2	5
	Nanumba North	Jua and Salnayili	0	0
	East Gonja	Libi	0	0
Upper East	Bolga	Gambibigo and yebongo	2	10
	Garu tempane		1	5
	Builsa	Sandema- Chuchuliga valley	2	6
	Kassena Nankena			
Upper West	Wa West	Polee	2	10

Monitoring visits were undertaken to monitor management of the trials. Data collection on farmers' preference on varieties undertaken.

Fig 20.Mother and baby trials: Field visit at vegetative stage in Karaga and dat
collection in West Mamprusi

Fig 21.Variety ranking in Mother Trials.

Results and Discussion

For the Mother trials , response by participants ranked on a scale of 1 to 7 where a score of 7 meant the best variety compared to other varieties and 1 as the worst variety, participants indicated they preferred most of the varieties for tillering abilities, days to maturity, germination, and grain yields. Exbaika and L2-4 had highest mean ranking for their tillering abilities, days to maturity , germination and grain yields, Fig 22.

Similar ranking was performed on all the varieties used in the Baby trials. A scale of 1to 3 was used, where 3 meant the most preferred variety in terms of tillering ability, days to maturity and grain yield. Fig 3 shows that all the six varieties had more than mean ranking for their tillering abilities, days to maturity and grain yield. Long grain ordinary, Exbaika and WAS122-13 WAS-10-WAR were ranked higher for tillering ability, days to maturity and grain yield compared to the other varieties, Table 47and4 8.

Table 47.Yields of Mother trials

Variety	Rice grain yield/(kg/ha)
Exbaika	2855
Long grain ordinary	2435
L2-4	2530
Perfume Irrigated	2395
WAS 122-13WAS-10 –WAS	3180
WAS 163-13-5-3	3110
CV%	13.7

Table 48 .Yield of Baby Trial

Variety	Rice Grain (Kg/ha)
Exbaika	2337
L2-4	2483
Long grain ordinary	3217
Perfume Irrigated	2837
WASS122-13WAS-10-WAS	3027
WAS163-13-5-3	3360
CV%	17.4

Challenges

The challenges with the management of the RSSP lowlands affected the implementation of Mother and Baby trials. The communities that benefited from the lowland development in 2011-2012 had difficulties to plough their fields. The plots allocated for Mother and Baby trials are within the lowlands and most of them could not be ploughed in June.

Communities within the districts that didn’t benefit from the lowland development from RSSP were those who implemented the trials because they were not waiting for any inputs from the project. In RSSP project communities were highly dependent on the project for inputs and services delivery.

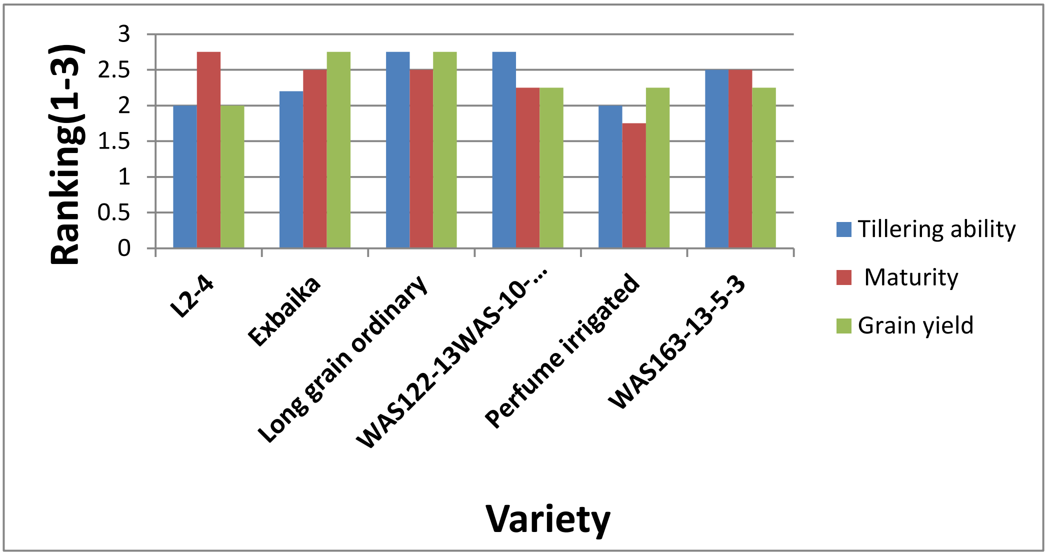

Fig 22.Variety ranking in Baby Trials.

Activity 4: Direct-seeding mulching cropping system (DMC) research program using poly aptitude rice and cover crop: A. Procurement of germplams and equipment

For the reporting period 99 rice varieties and 46 cover crops varieties were received by SARI from various location: France, Cameroun, New Zealand, Cambodia and Brazil through Lucien Seguy and Matsuda Company. The seed were received through DHL services and private messengers. Equipment's to be purchased for direct seeding and DMC implementation were described in CIRAD mission report, May 2012. Invoices on different equipment's to purchase for direct seeding and DMC implementation have been sent to AFD. AFD is asking for supplementary invoices to take action to give no objection for procurement. The challenge has been getting local companies to supply. The Directorate of Agricultural engineering services of MoFA has recommended that we apply for sole sourcing. We are yet to act on that.

Baseline survey and monitoring

Typology building of farming systems has started and indicators to assess the outputs of the new systems are being designed. The report on the baseline survey carried out in 2011 is to be disseminated.

Multiplication and conservation of seeds (polyaptitude rice and cover crop)

One hundred and fifty microplots for germplasm evaluation and purification were constructed at SARI. Two types of microplots were designed: one simulating the lowland ecology and one the upland ecology. Twenty polyaptitude rice varieties and 11 cover crops were planted under controlled conditions in the microplots. Data collection on agronomic and phenotypic characteristics (Germination, tillering, number of panicles.) and on yield and yield components was collected.

Cover crop seed production

Cover crop seeds were multiplied in the lowland, midland, and upland. In the lowland, a 4-replication trial was established to produce seeds as well as to determine the performance of 7 cover-crop based cropping systems. A number of cover crops were also established in the Midland and Upland. They comprised 10 m^2 each of *Brachiaria, Panicum, Stylosanthes, Sesbania, Crotalaria* and a number of cowpea varieties. The treatments (systems) used in the lowland are as follow:

Brachiaria mutica sown at first rain
Stylosanthes +*Sesbania* sown at first rain
Stylosanthes sown at water withdrawal
Stylosanthes+ *Brachiaria* sown at water withdrawal
Brachiaria +Centrosema+ Sesbania sown at water withdrawal
Stylosanthes +*Sesbania* sown at water withdrawal
Sorghum+Sesbania +Crotalaria juncea at water withdrawal

Results & Discussion

The cover crop multiplication experiments in the lowland failed owing to the early and prolong flooding of the seeds. Consequently, the plots were not planted in the lowland. Cover crop seeds were however multiplied in both midland and upland. These types cover crop seeds available for 2013 season include those produced in 2012 and old seeds which were not planted in 2012, Table 49. Cover crop seeds successfully produced include *Sesbania sesban* and different varieties of cowpea. Late planting of the cover crops might be the cause of poor or no harvest of most of the cover crops.

Table 49. Cover crop seeds for 2013 DMC research.

Type of crop	Number of varieties	Old stock seed (kg)	2012 harvested seed (kg)	Totals (kg)
Cowpea varieties	10	None	26.8	26.8
Stylosanthes varieties	1	12.76	0	12.8
Crotalaria varieties	2	3.99	4.93	8.92
Centrosema	1	0	0	0
Sesbania varieties	1	6.46	89.2	95.7
Brachiaria varieties	1	21.6	0	21.6
Dolicos lablab	2	8.96	0	9.0
Black beans (*Phaselus* sp)	1	0	0.48	0.48
Mixture of Cover Crop seeds	Assorted	6.1	0	6.1
Totals				181.4

Development of polyaptitude rice and cover crop based cropping system

For the development of polyaptitude rice and cover crop based cropping system a backstopping mission by CIRAD experts Mr. Lucien Seguy and Balarabe was conducted in May 2012. Based on their advice a protocol for on station trials on Direct Mulch Cropping systems and polyaptitude rice was developed. The experiments include treatments with rice intercropped with different cover crops sowed at different time of the season, sole cover crop or mixtures of cover crops and sole rice as check. Maize is the main cereal used in the upland trials.

Fig 22. .Maize intercropped with Dolichos lablab and Cover crop mixtures for soil improvement

CIRAD monitoring and backstopping

A mission of CIRAD Technical experts from Cameroun (Sodecoton), Mr Mahamt Alifa, was organized from 17th July 2012.

The consultant provided training and technical support for the implementation of the DMC trials and completed the germplasm collection of cover crops.

In coherence with the wishes of SARI about the DMC Research-Development (R-D) approach, he offered:

Appropriate monitoring techniques: monitoring data collecting sheets, especially in relation with agronomic monitoring and harvesting operations.

Support in management of different prescribed experimental design, in accordance with available vegetative material and effective climatic conditions,

Information on administrative and technical procedures to organise exchange visits for RSSP team in Cameroon

Field technical training of SARI and RSSP staff on cover crop seed production, DMC systems and their management.

Detailed Methodology of Direct-seeding mulching cropping system (DMC) experiments

Trials of Direct Mulch Cropping systems (DMC) were designed based on the recommendations made in CIRAD report (Appendix). The DMC trials were conducted in SARI rice fields along the Tamale road. Based on the topography of the rice field, three ecologies (lowland, midland and upland) along the toposequence were identified. Each of the three ecologies was planted with a DMC trial. Treatments of the DMC trials in the lowland, midland and the upland consisted of crop-based and cover crop based systems and a conventional system (check). In addition, each treatment was divided into three subplots corresponding to three levels of fertilization (i.e. no fertilization [F0] normal fertilization [F1] and high fertilization [F2]).

Details of the main treatments used in respective ecologies are as follows;
Objectives of the DMC trials;
The objectives of the DMC experiments were to:
Determine the suitability of the crop-cover crop based system and the cover crop system in 3 ecologies.
To assess the performance of the systems, using 3 levels of fertilizer applications.
Lowland Ecology-
Rice +(*Stylosanthes* sown at water withdrawal)
Rice+(*Stylosanthes* +*Brachiaria* sown at water withdrawal)
Rice+ (*Brachiaria*+ *Centrosema* sown at water withdrawal)
Rice +(cowpea +water melon sown at water withdrawl)
Check=conventional rice production system

Midland Ecology
Rice +*Stylosanthes*, simultaneous sowing
Rice +S*tylosanthes* broadcasted at rice flowering stage
Rice+*Stylosanthes* sown I holes at rice floweringstage
Rice +(mixture of *Brachiaria*, *Sesbania*, *Centrosema*, *Crotalaria juncea*) at water withdrawal
Rice +cowpea/water melon at water withdrawal
Check=conventional rice production system (Gbewaa)
Cover crop 3:*Stylosanthes guanensis* sown in rows in June
Cover crop 4:*Stylosanthes guanensis* +*Centrosema* sown in rows in June
Cover crop 5:*Stylosanthes guanesis* +*Centrosema* +*Sesbania*, sown in rows in June

Upland ecology
Maize +S*tylosanthes*, sown simultaneous
Maize + dolicos, sown 25days after sowing of maize
Maize+ cowpea, planted 25 days after sowing of maize
Check=conventional maize production system (Obantapa)
Cover crop1: 1st rows of Brachiaria, Crotalaria retusa, Centrosema, Stylosanthes hamata, Stylosanthes guainensis 2nd rows of Brachiaria r. Stylosanthes guianensis, black bean, Crotalaria retusa,Centrosema and Stylosanthes hamate :3rd :rows of Brachiria r., Crotalaria ,centrosema, Eleusine Stylosanthes hamata stylosanthes
Fertilizer levels:

F0: No fertilizer
F1: (60-60-30 kg/ha NPK).
F2: (120-120-60 kg/ha NPK)

Data collection on DMC experiments.
Data were taken on biomass using 1m^2 quadrat thrown randomly 3 times in each plot for fresh weight of biomass. Yield of rice and maize were assessed from whole plot and two rows respectively and converted to yield per hectare.

Results & Discussion

DMC experimental plots in the lowland were not intercropped with cover crops as the field was flooded very early and water remained on the field for long time. Hence, yields obtained from the lowland are for only rice with the 3-levels of fertilization, Table 50. The yields of rice in the lowland are low because of disease infection. The yield of rice showed no significance difference at the 3 levels of fertilizer application. Biomass yields however were significant at all the levels of fertilizer application. Higher level of fertilization gave the highest biomass yield of 3700kg/ha (Table 50).

Table 50. Yield of rice as affected by levels of fertilizer in the lowland.

Fertilization levels	Rice yield (kg/ha)	Biomass (kg/ha)
1.No fertilizer	129.7 NS	2433
2.60-60-30 kg/ha NPK *	136.5 NS	3633
3.120-120-60 kg/ha NPK **	137.3 NS	3700
CV%	8.9	33.1

*: Recommended rate, **: Higher rate & NS: Not significant

Midland

The yields of rice in the midland were generally low also because plots were diseased during the reproductive stage of the crop, Table 51. Yields were obtained for both rice and the cover crops in the midland. Significance differences were observed in all the crop-cover crop based systems and the cover crop only systems. High yields of biomass and rice were recorded in systems received high levels of fertilizer, Table 52. Similarly, biomass and maize yields in the upland was significant although yields were low, Table 52.Biomass ranged between 2333and 4067kg/ha (Table 52).

Table 51.Yield of DMC systems in the Midland

Cropping system	Rice yield (kg/ha)			Biomass (kg/ha)		
	*Fertilization levels			*Fertilization levels		
	F0	F1	F2	F0	F1	F2
Stylo guainensis in row sown in June	-	-	-	1467	3200.	3767
Stylo g.+Centrosema in row in June	-	-	-	2467	3567	3733
Stylo g.+centro+Sesbania in row in June	-	-	-	2633	3533	4167
Rice+ Stylo sown simultaneously	233.6	688.7	1325.6	1600	3067	3500
Rice+Stylo broad,at flow'g of rice	533.6	2091.6	2782.4	1700	2700	2233
Rice+stylo (hole plant'g) at flow' of	322.4	1800.6	1908.3	2033	2200	2600
Rice +mixture cover crops at flow'	425.0	1970.5	2700.5	1033	2567	3533
Rice +cowpea at water withdrawal	482.2	2782.4	2957.2	1000	2733	2967
Rice only(conventional system)	60.4	300.9	380.6	1000	2733	2967
CV%	23.7			16.7		

Table 52. Yields of DMC in the upland

	Maize yield (kg/ha)			Biomass (kg/ha)		
Fertilizer Level Cropping system	F0	F1	F2	F0	F1	F2
Cover crops(Brachiaria,stylo..,mixed	-	-	-	3167	3367	4067
Maize +Stylo sown simulta..,	277	1988	2158	3200	3233	3900
Maize +Dolicis sown 25 DAP maize	519	1977	1977	2667	3233	2333
Maize +cowpea psown 25DAP maize	334	1935	1977	2567	2733	3267
Maize only(Check)	385	1454	2149	2600	2567	2333
CV %	23.0			20.4		

Protection of DMC Experiment Biomass against bush fires and stray animals
To ensure that the biomass produced on the field are not destroyed, SARI embarked on a sensitization mission to educate the 11 communities around the SARI's experimental field where the DMC research was planted, in knowing the importance of the DMC and the need to protect the accumulated biomass against bushfire and livestock.

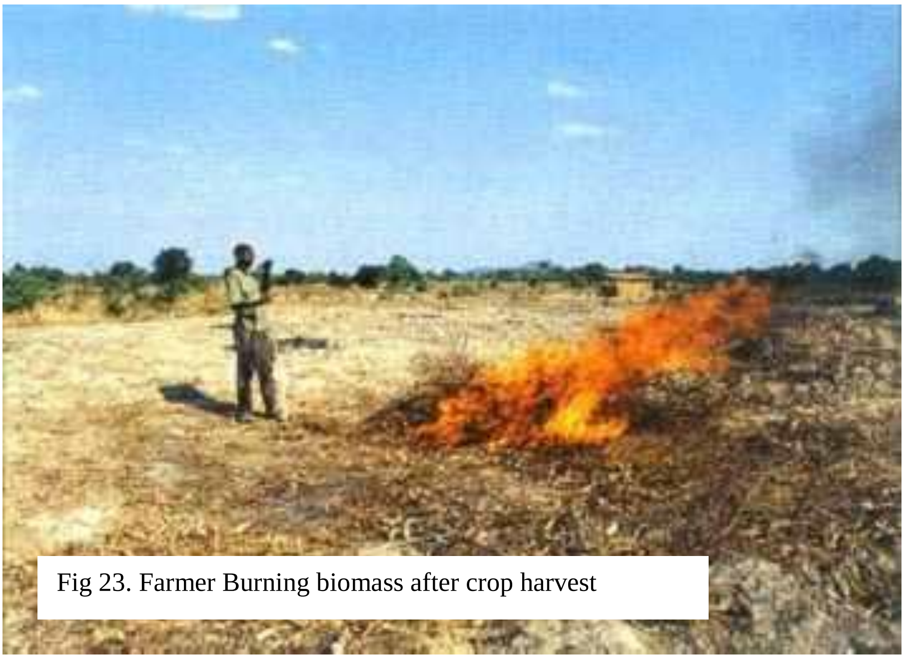

Fig 23. Farmer Burning biomass after crop harvest

The Tolon district information services department was contracted by SARI to sensitize the communities through public announcements with jingle developed to dissuade people from burning the bush. The Suhini Drama Group was also contracted by SARI to develop on-stage drama on the theme “No bush- burning”. The drama was staged in all the 11 communities around the rice fields. Between 250 and 400 people watched the drama in each of the communities. A video documentary of the drama was produced for future advocacy against bush burning. The Institute also engaged some field guards to protect the field against damage.

Conclusion

Major activities performed by CSIR-SARI under RSSP for the 2012 cropping season were successfully executed amidst some few setbacks. Plans are underway to ensure prompt execution of activities that suffered in 2012 season to avoid same challenges.

Sustainable Intensification of Key Farming Systems in the Guinea Savannah Zone of West Africa: Rice-based cropping systems component

Introduction

The northern part of Ghana accounts for about 60% of rice cultivated in the country. Rainfed and irrigated lowland rice systems in inland valleys are dominant. Due to favorable water availability, inland valleys are more suited for intensive and diversified cropping systems. Furthermore, there is a potential for expanding the rice cultivation area. However, rice productivity in inland valleys is generally low, due to various abiotic and biotic stresses as well as socio-economic factors. To raise rice productivity, there is a need to better understand which bio-physical factors limit productivity in farmers’ fields, and to what extent productivity could be increased via improved crop management. This will facilitate the identification of opportunities for yield improvement in farmers’ fields. Raising rice productivity may require the adoption of alternative crop management practices or capital investment in, for example, bunding, land leveling or irrigation. Integration of crops, animals, and natural resources is also essential for improving on-farm productivity, as farmers generally grow not only rice but also other crops and animals. In the rice-based systems in the inland valleys, some diversification exists but tremendous improvements are needed to make such efforts more sustainable and economically viable. Cropping diversity can be accomplished in time (rotation), space (intercropping), or in both space and time (relay-intercropping).

The ultimate goal of this component is to increase food and feed production in a sustainable manner in the rice-based cropping systems in northern Ghana. The overall aim is to improve livelihoods through improving on-farm productivity of rice-based systems in northern Ghana. Improving productivity can be achieved through alternative good agricultural practices, which should include integration of component technologies.

Planned outputs

Output 2.1. Integrated crop and livestock production systems developed, evaluated, and effectively delivered to end-users

Output 2.2. Nutrient cycling and use efficiency improved and the potential for inland valley development assessed

Output 2.3: Institutional capacities for the promotion of interactive learning and multi-stakeholder innovations through collective action - Multi-stakeholder Platforms (MSPs) enhanced

Partners

S/No.	Partner	Responsibility
	Africa Rice Center (AfricaRice)	Project coordination, backstopping for baseline survey, diagnostic survey, yield gap survey, multi-stakeholder platform establishment and monitoring, seed production and seed production protocol, rice sector development Hubs establishment, training of trainers, monitoring and evaluation,
	Savanna Agricultural Research Institute (CSIR-SARI):	In-country project implementation and coordination, baseline survey, diagnostic survey, yield gap survey, multi-stakeholder platform establishment and monitoring, rice sector development Hubs establishment, training of farmers and other stakeholders, organization of community-based seed production systems and linking to seed companies, monitoring and evaluation
	World Vegetable Research and Development Center (AVRDC):	Introduction, evaluation and promotion of high value fruits and vegetables to improve system productivity and farmer's incomes; Establish and operate Rice Sector Development Hubs and MSP process at key sites, including assessment and backstopping
In-country partners of CSIR-SARI		
1	University of Development Studies (UDS)	Involve in the introduction, evaluation and promotion of high value fruits and vegetables to improve system productivity and farmer's incomes; establish and operate Rice Sector Development Hubs and MSP process at key sites, including assessment and backstopping
2	Crops Research Institute	Exchange of experiences with CSIR-SARI in MSP and Hub related activities
3	Animal Research Institute (CSIR-ARI)	Integration of crop livestock activities
4	Food Research Institute (CSIR-FRI)	Promotion of healthy nutrition within the Hub
5	Catholic Relief Services (CSIR-CRS)	Facilitate community-based seed production systems and link to seed companies (Seed production protocol) for enhanced farmer access to good seed.
6	Ministry of Food and Agriculture (MoFA)	Diagnostic survey; Establish and operate Rice Sector Development Hubs and MSP process at key sites, including assessment and backstopping
7	Seed Producers Association of Ghana	Seed production

	(SeedPAG)	
8	Seed companies. (Lexbog Investments, Heritage Seeds and Savanna Seeds Services Company)	Seed production and supply to project farmers
9	ICOUR	Management of irrigation facility at Tono and provision of cultivation services and extension to irrigated farmers.
10	Single Mothers Association	Responsible for aggregating and processing of rice within the Navrongo Hub.
11	Agro-Input Dealers	Provision of inputs (seed, fertilizers, crop protection chemicals, etc.)
12	Kwame Nkrumah University of Science and Technology (KNUST)	Partner in the improved on and off-farm natural resource mgt.
13	Environmental Protection Agency (EPA)	Ensures that the intensification of the rice based system is done within acceptable EPA standards
14	Water Research Institute (CSIR-WRI)	Development of sound water mgt strategies that ensures reduced vulnerability of farmers to climate change and integration of rice fish culture.
15	(CSIR-INSTI)	
16	Farmers	Responsible for the production of rice and vegetables and their integration with animal production
17	Ministry of Health (MoH)	Responsible for health related issues associated with intensification of rice based system
18	SANREM-CRSP	Evaluate and promote good agricultural practices (GAP) for integrated soil fertility management (ISFM) options (yield gap assessment and nutrient omission validated)
19	International Soil Fertility and Agricultural Development Center (IFDC)	Evaluate and promote good agricultural practices (GAP) for integrated soil fertility management (ISFM) options (yield gap assessment and nutrient omission validated)
20	Traders	Aggregation and marketing of rice
21	Processors	Processing of rice
22	AMSIG Resources company	Agri-business services (Input support and aggregation)
23	Pioneer Foods Services	Agribusiness services (Input support and aggregation)
24	Ghana Grains and Legumes Development Board (MoFA)	Production of Foundation Seed
25	Ghana Seed Inspection Division (MoFA)	Inspection and certification of different categories of seed produced by seed producers and companies

2. Implementation strategy

In line with AfricaRice's partnership mode of operation, the implementation of the project activities was the responsibility of the National Agricultural Research and Extension System (NARES) of Ghana, coordinated by the Savannah Agricultural Research Institute (CSIR-SARI). AfricaRice provided technical backstopping by including the development of work plans, budgets, log frames, research protocols, training on research methodologies and active participation in field activities. AfricaRice and CSIR-SARI signed a formal agreement for the project in May, 2012 and funds were disbursed by AfricaRice to CSIR-SARI immediately thereafter. All the in-country partners were identified by CSIR-SARI based on the comparative advantage of each partner. The participation of these partners was confirmed at the inception meeting held at CSIR-SARI in April, 2012. Six local project implementation teams were established during the inception workshop. Local planning and review meetings were held as frequently as was necessary (initially every two weeks but later every month) to ensure effective implementation of agreed tasks

3. Implemented work program and results per output and activity

The achievements of the different activities are summarized under the different outputs below:

Output 1. Integrated crop and livestock production systems developed, evaluated, and effectively delivered to end-users

Activity 1. Baseline survey to identify bio-physical and socio-economic constraints, opportunities and entry points in rice-based cropping systems

Background and Purpose

In response to challenges in rice production systems and agriculture as a whole, governments over the years have implemented far-reaching interventions that seek to promote domestic rice production. Rice farmers of northern Ghana in particular are key beneficiaries of myriads of such interventions that also seek to enhance the food security, income and livelihoods of the resource-poor farmers. Recent among such interventions is the USAID-funded project called "Africa Research in Sustainable Intensification for the Next Generation (Africa RISING)" which is part of the overall initiative to increase farm productivity and improve natural resource management in the Guinea Zone of Ghana.

Sustainable intensification of the rice-based systems requires good knowledge of existing systems in the target domain. The baseline study aimed at contributing to the component on "Situation analysis" by providing a clear description of the farming systems, identify constraints and estimate *ex-ante* the potential impact of the project in the identified Rice Sector Development Hubs (concentration domains). The study was also to generate relevant information to describe the prevailing socio-economic conditions in the Hubs.

In the short-term, baseline study was expected to guide the implementation of the project and identify key project indicators for monitoring and evaluation purposes.

AfricaRice's new strategy of using the Rice Sector Development Hub to drive the research and development agenda in member countries to boost rice production in Africa calls for a reliable baseline information and knowledge of the targeted Hubs. The baseline study is thus to generate relevant data on the rice value chains in the selected Rice Sector Development Hubs.

Objective

The primary objective was to document current socioeconomic and biophysical structure of the project domain. The baseline study is necessary for monitoring and evaluation (M&E) and impact assessment.

The following were the expected outputs:

- Characterization of the rice value-chains in the identified hubs
- Description of the nature and access to agricultural inputs and improved technologies
- Determination of the factors that affect access to agricultural technologies
- Estimation of the rates of adoption of existing rice technologies in the hubs
- Determination of the factors affecting adoption of improved rice technologies in the hub
- Measurement of the current status of welfare indicators including income, food security, health, etc. of all actors of the rice value-chain.
- Determination of the impact of improved agricultural technologies on welfare indicators

Input for the development of a SMART M&E system

Planned Activities

Development and testing of survey tools
Community listing
Sampling
Training and pre-testing of survey tools
Sensitization of selected survey units
Implementation of field surveys
Data management and analysis
Reporting

Approach

Survey instruments

The baseline collected both qualitative and quantitative data on all stakeholders of the rice-based production system. Survey instruments were developed jointly by AfricaRice and CSIR-SARI for both communities and households. These instruments allowed us to collect socio-economics data including personal characteristics of the identified rice stakeholders, characteristics of their rice business (production, processing etc.) as well as existing constraints faced by the agents.

Sampling

The basic sample frame for the producer level survey was the list of rice producing communities in the selected rice Hubs namely, Navrongo Hub in Upper East Region and Savelugu Hub in Northern Region. Sampling of communities followed a stratified set of processes using: population, importance of rice in the farming system, accessibility and rice market potential. However, information generated during community listing revealed that the communities were largely homogenous. All the identified rice-producing communities were therefore given equal opportunity to be part of the survey. Out of the list of rice producing communities in each Hub, 20 were randomly selected. Within each of the selected communities, 10 producers were randomly selected from a list of rice producers. In all, 400 rice-producing households (200 per Hub) were to be interviewed (Table 53).

Stratified sampling procedure was also explored for the rice processors, traders and consumers. For the processors, two groups were identified - large scale and small scale. Traders were also grouped as wholesalers and retailers. Similarly, consumers were categorised into urban dwellers and peri-urban dwellers. For each Hub, 50 processors, 100 traders and 150 consumers were to be engaged.

Table 53: Proposed sample for baseline survey

Hub	Community	Producer	Processor	Trader	Consumer
Savelugu	20	200	50	100	150
Navrongo	20	200	50	100	150
Total	40	400	100	200	300

Achievements

Development and testing of survey tools

AfricaRice developed the survey tools together with its NARS partners. The tools include the modular questionnaires and software application (Mlax survey) for real time data collection with the use of hand held gadgets (smart phones and tablets). The software application is still being upgraded to ensure efficiency and the full automation of database management system.

The next stage of the process is the development of data capturing and analysis interface. When completed the automated database management system will reduce considerably the total time spend in the implementation of socioeconomic surveys.

Community listing

The process began with the listing of all communities in the designated Rice Sector Development Hubs. For the Navrongo Hub, the communities were grouped under irrigated and lowland ecologies. Each project community was further described by their GPS coordinates, role of rice (major/minor) and access to infrastructure (market). All rice-producing communities in the lists were extracted and re-grouped into two accessibility groups (accessible and limited accessibility). It was, however, revealed that almost all the communities were accessible. Very few had limited accessibility. The criteria could not be used since the number of communities with limited accessibility was very small and could not be justified statistically.

The role of rice as a criterion for stratification had a similar challenge. For the Navrongo Hub, almost all the listed communities (irrigated and lowland) were major rice producers. Again, the number of minor rice producers in the Savelugu Hub was also very small. The role of rice could therefore not be used to stratify the sampled communities. For this reason, sampling was not stratified as prescribed in the protocol produced by AfricaRice. All rice producing communities therefore had an equal chance of being selected for the project.

Sampling

The first step in sampling involved the selection of a global sample for the baseline survey. In all, 20 communities were randomly selected per Hub. Sub-samples of communities were then selected randomly for each of the major activities under the project. There were three categories of communities for each activity, including the core sample (treatment community), observer sample and control. Sub-samples for each of the activities were selected independently of the other. In effect, each activity had 4 core communities, 4 observer communities and 12 control communities. The list of selected communities for each Hub is presented in Table 55.

As at the time of community listing, the list of rice producing households was not available. The second stage of sampling was therefore not possible. The second stage of sampling is being done directly on the field during the interviews.

Training and pre-testing of survey tools

There were two days of training (15 September and 17 September, 2012) by AfricaRice, including discussions on the questionnaires and training on the use of the smartphones. Given the experience of the enumerators with the questionnaire and its structure, the discussion of the selected modules for the survey was very interactive and successful.

Training on the use of the smartphones was both in-class and on the field for mock enumeration. Enumerators were met with the challenge of maneuvering through the menus and commands of the application software. There were also differences in the appearance of modules and questions in the paper questionnaire and the smartphone. Additional tutorial provided after the field practice further enhanced the understanding of the enumerators.

A representative of AfricaRice together with the survey team members at CSIR-SARI facilitated the training of enumerators. In addition to the class lectures, the facilitators also followed up with field practice. The enumerators were allowed to fully work and familiarize themselves with the smartphones for data collection.

Sensitization of selected survey units

Given the timing for the survey, it was practically impossible to sensitize the selected communities and farmers before the interviews. Enumerators were therefore encouraged to spend some time to discuss the importance of the survey to the respondents and also seek their consent. For the remaining communities, sensitization will be done by the survey team to ensure full collaboration of the stakeholders.

Implementation of field surveys

To improve the quality of data, modules of questionnaires are divided into 5 parts or rounds (Round 0 to Round 4). Data collection for each round is done during three visits. Round 0 of the field survey has proceeded in several stages mainly due to some technical challenges. The enumerators are yet to complete the Savelugu Hubs and then proceed to the Navrongo Hub and perhaps the proposed Wa Hub.

So far, 13 community level interviews have been completed. Household interviews for 10 of the communities are complete. All the data from completed interviews have been uploaded onto the main server at AfricaRice for conversion into viewable format (Tables 54 and 55).

Data management and analysis

Although the completed household interviews have been uploaded, the program to convert it into viewable format is still being developed by AfricaRice. Presently, the interphase is ready and some data can be viewed but cannot be downloaded. Given that the analysis will be automated, the survey implementation is expected to minimize the time spent in general. A detailed technical report will then be produced.

Table 54: Status of survey in the Savelugu Hub

No	Community	Completed interviews	
		Community	Household
1	Chihi-Yepala	Completed	Planned for 2013
2	Yizegu	Completed	Planned for 2013
3	Libga	Completed	Planned for 2013
4	Duko	Completed	Few modules to be completed for some households
5	Tibali	Completed	Few modules to be completed for some households
6	Manguli	Completed	Round 0 completed
7	Jankpem	Completed	Round 0 completed
8	Jegun	Completed	Round 0 completed
9	Tunayili	Completed	Round 0 completed
10	Digu	Completed	Round 0 completed
11	Boggu	Completed	Round 0 completed
12	Nabogu	Completed	Few modules to be completed for some households
13	Tigla	Completed	Round 0 completed
14	Zoonayili	Planned for 2013	Planned for 2013
15	Nyolgu	Planned for 2013	Planned for 2013
16	Nambagla	Planned for 2013	Planned for 2013
17	Zokugu	Planned for 2013	Planned for 2013
18	Lagbani	Planned for 2013	Planned for 2013
19	Nagdigu	Planned for 2013	Planned for 2013
20	Sankpiem	Planned for 2013	Planned for 2013

Way forward
The implication of the outcome of the first round of survey is that there is the need for more time to complete the entire survey. Given the outstanding communities to be interviewed in the Savelugu Hub and the estimated time for data collection, 8 enumerators will be required for a period of 8 months to complete the data collection for the Savelugu and Navrongo hub. It is planned that 8 enumerators will require two months to finish each round (putting together round 0 and round 1). To monitor field data collection, two supervision plans will be implemented. The first plan is the field monitoring by two field supervisors. Their mission is to monitor the work of enumerators in the field and to ensure that data are regularly sent to the server. Field supervisors will help enumerators send data using the Smartphone Wi-Fi connection. The field supervisors will also be responsible for checking the quality of data collected by the investigators. For this work, field supervisors have at their disposal the two smartphones. The second plan will consist of supervision by the survey team at SARI and the AfricaRice staff. Their role is to monitor data sent to the server and to notify enumerators for possible corrections before leaving the field.

New sets of Samsung Galaxy Tabs procured to replace the smart phones are being tested by the enumerators to establish their efficiency relative to the smart phones.

Planned activities (January – December, 2013)
A detailed baseline survey of all the actors in the rice value chain as well as agronomic practices will be conducted by CSIR-SARI from January to September, 2013. The survey will include the following:
Complete Round 0 and Round 1: producer survey
Complete Round 2: producer survey
Complete Round 3: producer survey
Complete Round 4: Traders, processors and consumer survey

Table 55: List of sampled communities in the two Hubs

Hub	Ecology	Sub sample	Community selected for agronomy work	Community selected for mechanization work	Community selected for PVS work	Community selected for seed training
Navrongo	Lowland	Core	Kologo – Kulebingo/Awinyabisi	Bavugunia	Gia	Gumongo
Navrongo	Lowland	Core	Nyangua	Dambisi	Naaga-Kunjebisi	Gingabnia
Navrongo	Lowland	Observer	Naaga-Kunjebisi	Gia	Gumongo	Punyoro
Navrongo	Lowland	Observer	Gia	Punyoro	Dambisi	Naaga-Kunjebisi
Navrongo	Lowland	Control	Bavugunia	Bavugunia	Kologo – Tindawu	Dambisi

Navrongo	Lowland	Control	Kologo – Tindawu	Naaga-Kunjebisi	Kologo – Kulebingo /Awinyabisi	Nyangua
Navrongo	Lowland	Control	Gingabnia	Kologo – Tindawu	Punyoro	Bavugunia
Navrongo	Lowland	Control	Punyoro	Gingabnia	Bavugunia	Gia
Navrongo	Lowland	Control	Gumongo	Gumongo	Gingabnia	Kologo – Tindawu
Navrongo	Lowland	Control	Dambisi	Kologo – Kulebingo/ Awinyabisi	Nyangua	Kologo – Kulebingo/Awinyabisi
Navrongo	Irrigated	Core	Gonia	Jaata	Janania	Bonia
Navrongo	Irrigated	Core	Tampola	Vunania	Chuchulga Chodema	Upper Nangalikinia
Navrongo	Irrigated	Observer	Bonia	Chuchulga Chodema	Tampola	Chuchulga Chodema
Navrongo	Irrigated	Observer	Upper Nangalikinia	Janania	Bonia	ICOUR Township I Tono
Navrongo	Irrigated	Control	Jaata	Gonia	ICOUR Township I Tono	Bonia Kanjenyala
Navrongo	Irrigated	Control	Janania	ICOUR Township I Tono	Jaata	Vunania
Navrongo	Irrigated	Control	ICOUR Township I Tono	Upper Nangalikinia	Vunania	Janania
Navrongo	Irrigated	Control	Vunania	Bonia	Gonia	Gonia
Navrongo	Irrigated	Control	Bonia Kanjenyala	Bonia Kanjenyala	Bonia Kanjenyala	Jaata
Navrongo	Irrigated	Control	Chuchulga Chodema	Tampola	Upper Nangalikinia	Tampola
Savelugu	Lowland	Core	lagbani	Zokugu	Jankpem	Tunayili
Savelugu	Lowland	Core	Zoonayili	Manguli	Jegun	duko
Savelugu	Lowland	Core	Nabogu	Tigla	Nyolgu	Sankpiem
Savelugu	Lowland	Core	Boggu	Libga	Yizegu	Tibali

Savelugu	Lowland	Observer	Manguli	Jankpem	Nabogu	Chihi – Yepala
Savelugu	Lowland	Observer	Nambagla	Digu	Zokugu	Jankpem
Savelugu	Lowland	Observer	Tibali	Sankpiem	Sankpiem	Zokugu
Savelugu	Lowland	Observer	Jegun	Zoonayili	Tibali	Libga
Savelugu	Lowland	Control	Yizegu	Jegun	Tigla	Digu
Savelugu	Lowland	Control	Jankpem	Chihi – Yepala	Lagbani	Zoonayili
Savelugu	Lowland	Control	Tigla	Tunayili	Digu	Boggu
Savelugu	Lowland	Control	Tunayili	Lagbani	Boggu	Nambagla
Savelugu	Lowland	Control	Nyolgu	Nabogu	Chihi – Yepala	Tigla
Savelugu	Lowland	Control	Zokugu	Tigla	Duko	Nyolgu
Savelugu	Lowland	Control	Libga	Nagdigu	Libga	Nagdigu
Savelugu	Lowland	Control	Nagdigu	Nyolgu	Nambagla	Jegun
Savelugu	Lowland	Control	Digu	Yizegu	Zoonayili	Manguli
Savelugu	Lowland	Control	Sankpiem	Boggu	Nagdigu	Sankpiem
Savelugu	Lowland	Control	duko	Nambagla	Tunayili	Yizegu
Savelugu	Lowland	Control	Chihi – Yepala	Tibali	Manguli	Tibali

Output 1.Integrated crop and livestock production systems developed, evaluated, and effectively delivered to end-users

Activity 2. Organize community-based seed production systems and link to seed companies (Seed production protocol) to farmers

Objective
The community-based seed production component of the rice-based systems seeks to increase the availability of quality rice seed to farmers.

Implementation strategies
All seed production and training activities were implemented by CSIR-SARI and its in-country partners (ICOUR and MoFA). Community listing and sampling was undertaken for all the components of the project, led by the socio-economic department of CSIR-SARI. With specific reference to the community seed component, the extension department of MoFA and the Irrigation Company of the Upper East Region (ICOUR) were identified and selected as implementation partners. Seed production and training (on the technique of quality seed production) for farmers and extension agents are the major activities undertaken within this component of the project. It is however worth noting that due to the late start of the project, no activity took place at the Savelugu Hub. This is because rice ecologies within this Hub are

mainly rainfed lowland. At the time the project started, most of the valleys were already too wet. Moreover, rice farmers within this Hub had already established their fields. Therefore, attention was focused on the Navrongo Hub which is mainly an irrigated ecology. Hence, the activities reported herein relate only to the latter Hub. The schematic representation of activities undertaken within the community seed component of the project is shown in Figure 24.

Farmer selection

In collaboration with the extension arm of ICOUR, five farmers were selected from each of three communities sampled for the seed production component (Table 56).

Table 56: List of farmers involved in community seed production in the Navrongo Hub

No.	Name	Community	Collaborating Area Extension Agent
1	Martin Kubeti	Bonia	
2	Amo Kusiamo	Bonia	Miss Ivy Awuni
3	Adinkube Abass	Bonia	
4	Kofi Akwentera	Bonia	
5	Issac Azugah	Bonia	
6	Nkrumah Alaporem	Koronia	
7	Akanyagle Akamma	Koronia	Mr. John Sadongo
8	Akanyetila Aweliya	Koronia	
9	David Atia	Koronia	
10	Amiyire Akambasia	Koronia	
11	Paul Akwabili	Chuchuliga	
12	Agana Akato	Chuchuliga	Mr. Phanuel Akoto
13	James Awini Mari	Chuchuliga	
14	Richard Ajaubulisa	Chuchuliga	
15	Azango Abera	Chuchuliga	

Distribution of inputs

Each of the 15 participating farmers received 20 kg of foundation seed of Gbewaa rice (Jasmine 85) procured from the Ghana Grains and Legumes Development Board (GGLDB), and two 50 kg bags of compound fertilizer (Actyva) and one bag of Urea (for top dressing).

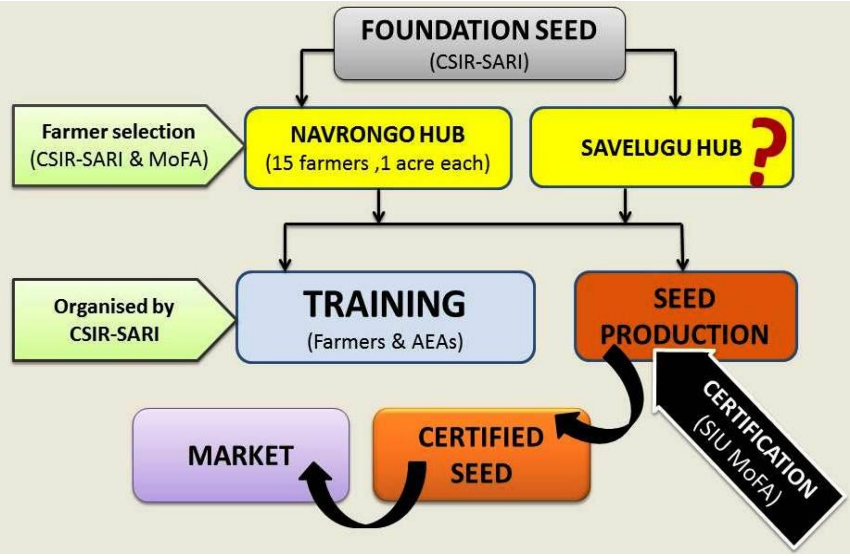

Figure 24: Schematic representation of activities undertaken on the Community-based seed production component

Capacity building

One training program was successfully organized by CSIR-SARI at the Navrongo Hub. On the 20th of September, 2012, the 15 farmers, three Agricultural Extension Agents (AEAs), and one Extension Agronomist at ICOUR (Table 57) were trained in Navrongo on the techniques of quality rice seed production. Two main approaches were used for the training.

The first approach was the use of Participatory Learning and Action Research (PLAR). During this PLAR session, the key morphological stages of the rice plant were made known and their implications for carrying out certain key cultural practices, notably the timing of fertilizer application. The PLAR session demonstrated the use of the cropping calendar and the appropriate timing of good agronomic practices to ensure optimum productivity of the rice crop. The importance of quality seed and what goes into its production were also demonstrated.

The second approach was an interactive PowerPoint and poster presentation on the key steps in quality rice seed production. During this session, participants were taken through the basics of producing rice seed from the nursery stage to the post-harvest and storage. Key factors that could compromise the quality of the seed produced were explained to participants.

Seed production

Each of the 15 farmers successfully established a one-acre rice seed farm. As at the time of compiling this report, CSIR-SARI has coordinated two field inspection visits to the seed farms by staff of the Ghana Seed Inspection Unit of MoFA. About 80% of the fields have been harvested. CSIR-SARI will continue to give technical backstopping to ensure the smooth harvesting of the remaining fields. After all the fields have been harvested, CSIR-SARI will coordinate the final round of the certification process (seed purity and germination test) by the seed inspectors. We estimate that about 20 tonnes of cleaned and certified seed will be available for farmers. This compares favourably with the target of 10 tonnes.

Table 57: List of participants trained on seed production

No	Name	Designation	Community/Organization
1	Martin Kubeti	Farmer	Bonia
2	Amo Kusiamo	Farmer	Bonia
3	Adinkube Abass	Farmer	Bonia
4	Kofi Akwentera	Farmer	Bonia
5	Issac Azugah	Farmer	Bonia
6	Nkrumah Alaporem	Farmer	Koronia
7	Akanyagle Akamma	Farmer	Koronia
8	Akanyetila Aweliya	Farmer	Koronia
9	David Atia	Farmer	Koronia
10	Amiyire Akambasia	Farmer	Koronia
11	Paul Akwabili	Farmer	Chuchuliga
12	Agana Akato	Farmer	Chuchuliga
13	James Awini Mari	Farmer	Chuchuliga
14	Richard Ajaubulisa	Farmer	Chuchuliga
15	Azango Abera	Farmer	Chuchuliga
16	Miss Ivy Awuni	Agricultural Extension Agent	ICOUR, Tono
17	John Sdongo	Agricultural Extension Agent	ICOUR,Tono
18	Hans Akuffo	Extension agronomist	ICOUR,Tono
19	Phanuel Akoto	Agricultural Extension Agent	ICOUR,Tono
20	Siise Aliyu	Breeder	CSIR-SARI
21	Sulemana Alhassan Dana	Technical officer	CSIR-SARI
22	Abdul-Basit Abdul-Rahman	Technical officer	CSIR-SARI

Linking farmers to market

Aside creating awareness on community-based seed production during the MSP meetings and encouraging stakeholders to take advantage the seed produced within the Hub, discussions are far advanced with the following three organizations to procure the certified seed from the farmers: 1. Premier Foods, a private agro-based business organization; 2. The Rice Support Sector Project (RSSP) - a project led by MoFA and implemented within the rice growing ecologies of the three northern regions of Ghana; and 3. Shekinah Agribusiness Centre in Tolon Kumbungu district.

Output 2. Nutrient cycling and use efficiency improved and the potential for inland valley development assessed

Activity 1. Evaluate and promote good agricultural practices (GAP) for integrated soil fertility management (ISFM) options (yield gap assessment and nutrient manager validated)

Objective

The objective of the Yield Gap Study was to use field and household surveys as a means of characterizing constraints to crop production at the individual farmer's field. These include yield-limiting factors such as soil and water, yield-reducing factors such as pests (e.g. diseases, insects and weeds), crop management (fertilizer application, pest management, mechanization), and socio-economic factors (farmer's status, family size, household income, expenses and investment).

Planned activities

The following activities were planned:

- Carry out a diagnostic survey in Northern Ghana and identify two Rice Sector Development Hubs.
- Profile all rice growing communities in the selected Hubs and randomly select 8 communities for yield gap studies.
- Randomly select 10 farmers in each rice growing community and establish a researcher-managed rice field in each community for yield gap assessment.
- Document agronomic and management practices used by rice farmers in the communities.
- Collect routine, pre- and post-harvest datausing a standardized protocol for yield gap assessment.

Achievements

Two research scientists from CSIR-SARI and 15 AEAs were trained by AfricaRice to collect data with smartphones with the major aim of eliminating errors associated with the data transfer process. An automated weather station was established by AfricaRice at Nyangua in the Navrongo Hub to collect meteorological data. Eight communities from the two Hubs were randomly selected for participation in a yield gap study. Field data collection was implemented by CSIR-SARI and MoFA staff.

All households within the selected communities have been profiled and 88 farmers randomly selected for participation in the activity. Soil samples from all the 88 farms have been collected and sent to AfricaRice for analysis.

All the selected farms were geo-referenced and measured. We pegged 200 m^2 (20 m x 10 m) as survey plots and further demarcated three (3) 12 m^2 (3 m x 4 m) within the survey plots as yield plots on all the selected fields. Detailed assessment of agronomic and management practices used by rice farmers in the communities was undertaken. We also collected routine pre-and post-harvest data based on a standardized protocol for yield gap assessment. Yield data have been collected from all communities except Tampola in the Navrongo Hub where harvesting is now on-going.

Measured yields and yield gaps across Hubs

The summaries of yield data from 70 fields and 7 researcher-managed plots across 7 communities within the two Hubs are presented in Figure 25. Farmer's paddy yields within the Navrongo Hub ranged from 0.347 to 5.111 t/ha with a mean of 2.532 t/ha compared to a mean yield of 6.039 t/ha from researcher-managed plots. Average calculated experiment-based yield gap for the Navrongo Hub was 58.1% (Figure 25). Yields in the Savelugu Hub ranged from 0.361 to 6.292 t/ha with a Hub average of 2.019 t/ha. Mean researcher-managed yield within the Savelugu Hub was 2.446 kg/ha. Mean calculated experiment-based yield gap in the Savelugu Hub ranged from 12.5 to 67.8% with a mean of 21% (Figure 24.

Data on agronomic, physical, biophysical and management factors that will explain the recorded yield gaps have been collected and will be used in further analysis. It is noteworthy that the highest yields were obtained from researcher-managed plots in the Navrongo Hub but from farmer-managed plots in the Savelugu Hub.

Agro Met Station at Nyangua, Navrongo hub

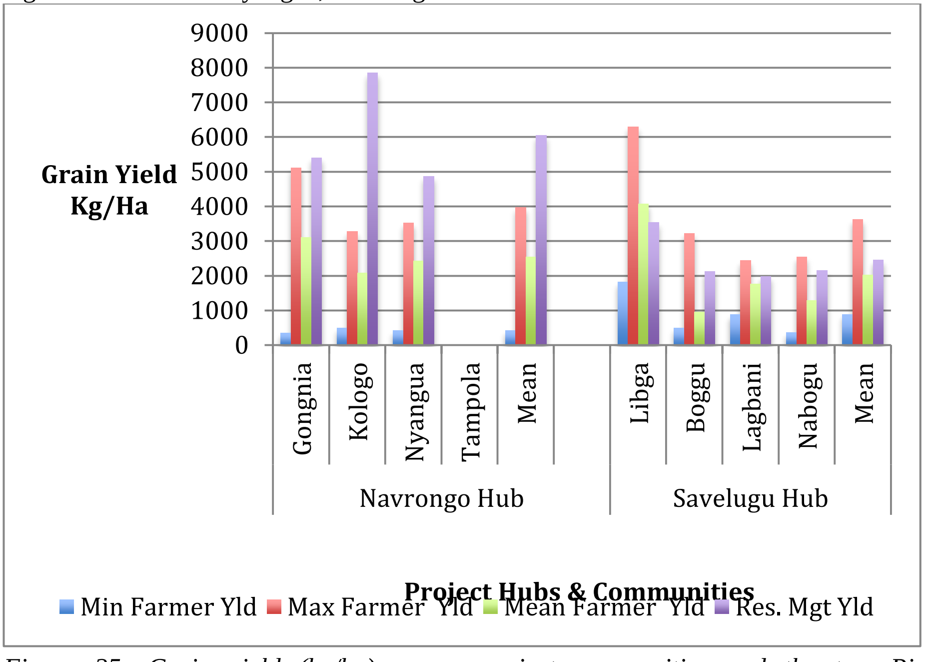

Figure 25: Grain yield (kg/ha) across project communities and the two Rice Sector Development Hubs.

Activities planned for 2013

Complete data collection (appendices 6 and 7 of the protocol) for yield gap studies in the Navrongo Hub. Administer appendices 1 to 7 of the yield gap protocol for each of the farmers involved in the study. Libga (Savelugu Hub) and Gongnia (Navrongo Hub) farms were under irrigation and are therefore late for data collection. All other farms are rainfed and data collection is 80% complete. Upload all data from farmer data sheets (appendices 1 to 7) to smartphone for onward transmission to AfricaRice.

Output 3. Institutional capacities for the promotion of interactive learning and multi-stakeholder innovations through collective action (Multi-stakeholder Platforms (MSPs) enhanced

Activity 1. Conduct diagnostic survey on opportunities and constraints related to collective action and governance of inland valley systems

Background
The diagnostic survey started in July 2012 after AfricaRice had trained CSIR-SARI staff on diagnostic survey methodology and developed the protocol to be used.

Objective
The objective of the diagnostic survey was to have a general understanding of farmers' basic practices on rice farming in the Navrongo and Savelugu Hubs.

Sampling
Purposive sampling method was used to select Key Informants (KIs) who have in-depth knowledge on rice production in the communities involved. Representatives of some identifiable groups in the communities were also selected for Facilitated Discussion Groups (FDGs) to get a broader view and a consensus on rice production. The list of KIs and FDGSs are presented in Table 58.

Table 58. List of Key Informants and Focused Groups selected

No.	Community	KIs	FDGSs
1	Tampola	10	8
2	Upper Nangalkinia	10	18
3	Nyangua	10	23
4	Jegun	10	31
5	Boggu	10	15
6	Libga	10	16

Data collection
Data were collected from 60 KIs and through six FDGSs (Figure 5) in six communities . (Table 58). The instrument used for data collection was the interview guide. The diagnostic survey protocol and interview guide were developed by AfricaRice and adapted by CSIR-SARI.

Training of Field Assistants
The Principal Technical Officers (PTOs) who were contracted to support the Research Scientists were given some basic training at different stages of the project. They were trained

on the use of the interview guide to obtain information from the KIs and FDGSs. The AEAs responsible for the communities were also trained to assist the PTOs.

Data transcription

Two trained PTOs transcribed the voice data after the interview sessions. The transcribed data were then screened by the scientist to ensure the correctness of the transcription.

Preliminary findings from Key Informant interviews

Only results from KIs have been analyzed. Findings from the FDGSs will be reported later.

All the farmers interviewed in the six communities are engaged in farming as their main occupation. Some of them (about 52%) are, however, engaged in other secondary economic activities to support their farming activity. The major off-farm activitieswere trading (9%), animal rearing (13%), masonry 4.55%, butchery 4.55%, and other unspecified minor economic activities (20.46). However, 47.73% of the farmers did not engage in any extra economic activities.

The farmers grew different crops on different plots of lands. The crops grown in the lowlands included rice (90.97%), maize (2.27%), and vegetable (6.82%). The maize is intercropped with the other crops to generate income, especially within the irrigation plots. Vegetables are grown on the bunds to maximize the use of land. While 38.64%, of the rice farmers in both hubs use the irrigation schemes, 61.36% utilized the rainfed lowlands. About 50% of the rice farmers also keep livestock.

Intercropping rice with other crops is a common practice - 89.19% of rice farmers practiced intercropping.. The common practice is to plant maize with the early rains and introduce rice later. In the Navrongo Hub, for example, Tampola, an irrigated rice community, does not intercrop rice while all farmers in Nyangua, a lowland rice community, intercropped rice with mostly maize.

Varieties cropped by farmers

Farmers cultivated different rice varieties, the most important being Tox 3107, GR 18 (Afefe), and Jasmine 85 (Gbewaa Rice), which are cultivated by 68% of the respondents. Other varieties cultivated are Mandi, Anyofula, and Abirkukuo. The distribution of the varieties in the communities and their yield potential is presented in Table 59. Of the 43 respondents, 56% rated their varieties as high yielding, 23% as average and 21% as low yielding. Tox 3107 was considered to be drought-tolerant by 53% of farmers who cultivated it compared to 75% for GR 18, while none of the farmers rated Jasmine as drought-tolerant.

Table 59: Farmers' rating of the varieties based on yield potential

Variety	Communities	No. of Farmers	Farmers' assessment of yield potential			% of farmers
			High	Ave	Low	
	Libga	2	2			
Tox 3107	Boggu	8	6	2		
	Jagum	3	2	1		33
	Tampola	1	1			
Jasmine 85	Nyangua	3		1	2	
(Gbewaa)	Upper Nangalkania	2	2			12
	Boggu	6	3	2	1	
	Libga	2	2			
GR 18/Afefe	Upper Nangalkania	1	1			23
	Jagun	1	1			
Mandi	Jagun	4	2	2		9
Anyofula	Libga	2	2			5
Abirkukuo	Boggu	2			2	
	Jagun	1		1		10
	Libga	2			2	
Other var.	Nyangua	3		1	2	7

Post-harvest activities (storage method, treatment, and priming)

Farmers store the grains for at least a few days before selling. Respondents store their grains in mud silos (15.56%), jute sacks (82.22%) and in the community warehouse (2.22%). Only 16% of respondents treat their paddy before storage.

Use of farm machinery

The use of farm machinery in rice cultivation in the two hubs is high - 77.27% of the respondents reportedly use machinery while 22.73% do not. However, the 22.73% use bullocks to plough their farms, Tractors (93.94% of respondents) and combine harvesters (6.06% of respondents) were the two types of farm machinery reportedly used by the farmers. Only 12.50% of the farmers interviewed used their own farm machinery while 87.50% patronized machine-hiring services (Table 60) - 58.33% of the machine-hiring services were provided by nearby communities and 41.67% were within the local communities.

Table 60: Ownership of tractors in the Savelugu and Navrongo Hubs.

Ownership of machinery		Community						Total
		Boggu	Jegun	Libga	Nyangua	Tampola	Upper Nangarkinia	
Owned	No.	2	0	1	0	0	1	4
	%	22	0	14	0	0	33	12.3
Hired	No	7	6	6	3	4	2	28
	%	78	100	86	100	100	67	87
Total	No.	9	6	7	3	4	3	32
	%	100	100	100	100	100	100	100

While 29% of farmers did not encounter any challenges regard farm machinery, 71% had various challenges (Table 61).

Table 61: Challenges to farm machinery use in the Savelugu and Navrongo Hubs.

Challenge	% of farmers responding
High cost of hiring services	14
Lack of harrowing services	23
Inadequacy of machine available for use	24
Delay in operations and lack of timeliness	10
No challenge	29
Total	100

Agronomic practices

A number of agronomy practices were examined during the interview process. While 71.43% of farmers are bunding their rice fields to control water flow and retain moisture, 28.57% did not. Land leveling after plowing was practiced by 81.82% of farmers - 77.78% of the latter did manual leveling with a hoe, 11.11% harrowed with a tractor, while the remaining 11.11% harrowed using bullocks. While 69% of the respondents employed the services of a tractor, 31% plowed with animal traction.

Transplanting is practiced by 54.55% of farmers, mainly in the irrigated farming communities with the exception of Nyangua. While farmers recognized the usefulness of the practice, they complained that it was labor-intensive and advocated other ways in view of scarcity of labor. Nine percent of farmers prime their rice seed before planting or nursing.

Soil fertility management

Fertilizer application

All the farmers knew the importance of applying fertilizers to improve the yield of their rice crop. Farmers mainly used inorganic fertilizers (Nitrogen [N], Phosphorous [P], and Potassium [K]). The farmers did not produce or use organic fertilizer. Compound (NPK) fertilizer was applied 2 weeks after planting or transplanting by 96.97% of farmers and at 3 weeks after transplanting by 3.03% of farmers. Sulphate of Ammonia was applied at different times after NPK application - two weeks (4% of farmers), 3-4 weeks (21% of farmers), 5 weeks (39% of farmers), or 6 weeks (36%).

Farmer support systems

Support to farmers came from NGOs and the government – 3% received financial support from NGOs whilst 81% received fertilizer subsidy from the government; 16% used only their own resources. Most of the farmers (87%) bought fertilizer from agrochemical stores and 13% from the open market.

Weed control

Manual weeding was done twice by 87.50% of farmers and thrice by 12.50%.

Gender, ethnicity and education of respondents

Figures 26-288 illustrate the variability in gender, ethnicity and educational level of respondents. All respondents in the Savelugu Hub are Dagomba - 8% are women and 92% are men. Most (84%) of the respondents in this Hub have no formal education, 8% have a basic education while the remaining 8% have high school education.

The two ethnic groups in the Navrongo Hub are the Kasim (94%) and Nankani (6%) - 50% are men and 50% women. This indicates that women are involved in rice production in this Hub. While 39% have basic education, 61% have no formal education.

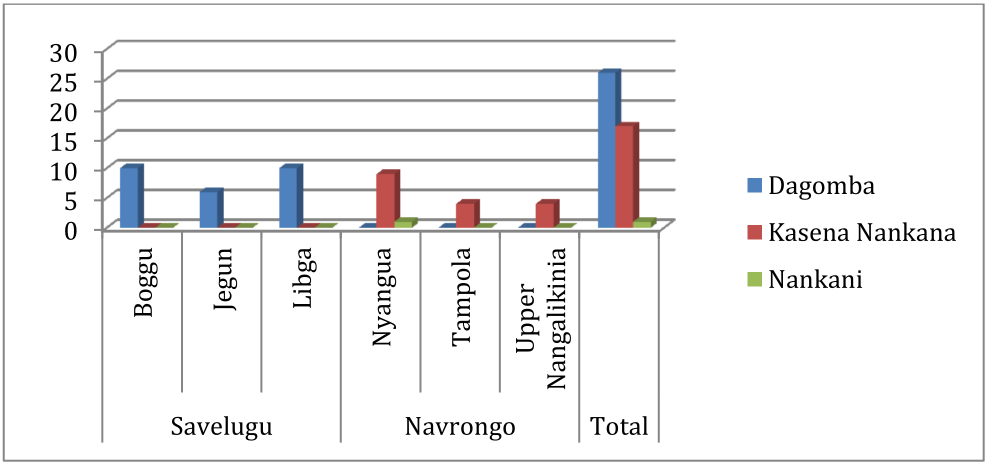

Figure 26: Ethnic grouping of respondents in the Savelugu and Navrongo Hubs

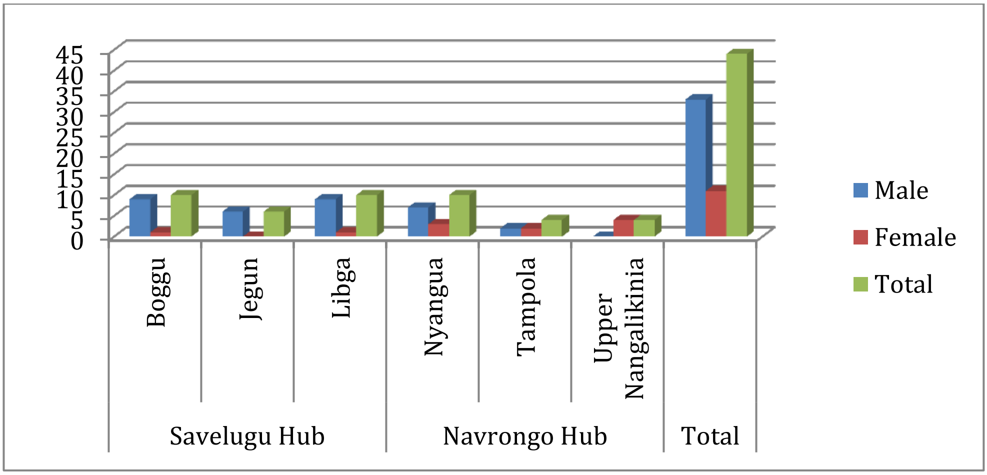

Figure 27: Gender disaggregation of respondents in the Savelugu and Navrongo Hubs

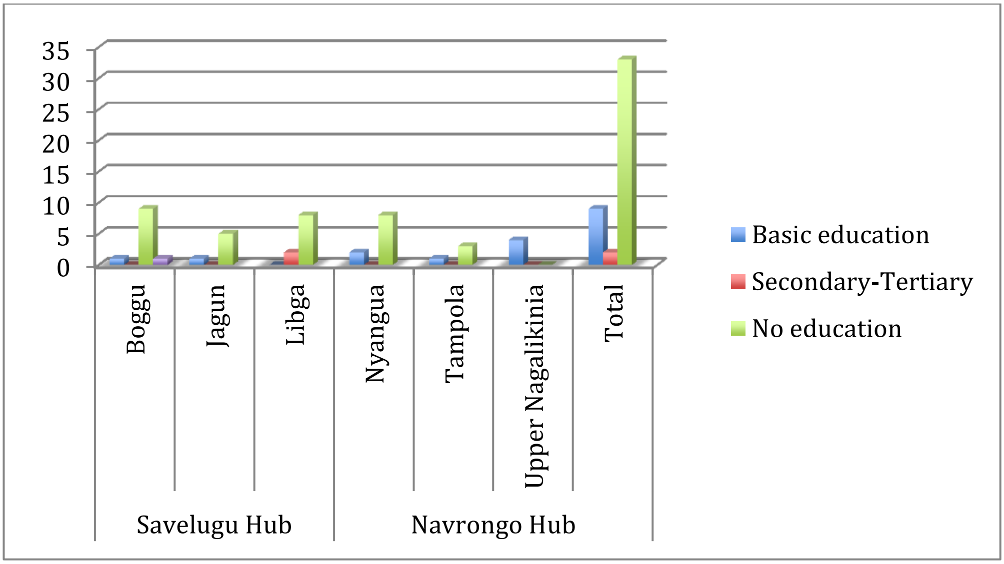

Figure 28: Educational levels of respondents in the Savelugu and Navrongo Hubs

Output 3: Institutional capacities for the promotion of interactive learning and multi-stakeholder innovations through collective action (Multi-stakeholder Platforms (MSPs) enhanced

Activity 2. Establish and operate Rice Sector Development Hubs and MSP process at key sites, including assessment and technical backstopping

Background

The rice value chain comprises a wide range of actors. These include various stakeholders such as input suppliers, farmers, processors, millers, traders, consumers, local authorities, agricultural extension agents, rural banks, and other private and public-sector organizations, such as development and non-governmental organization (NGO) who provides support services. To facilitate organization and prioritization of different actors' interests and activities by providing an opportunity for individuals and groups to come together and openly discuss their respective needs in this project, a Multi-Stakeholder Platform (MSP) approach is being used. This is in line with AfricaRice's Rice Sector Development Hub concept. The MSP facilitates open communication and collaboration among various actors within the rice value chain to promote collective resource management. As indicated above, two Rice Sector Development Hubs have been identified in northern Ghana namely, the Navrongo Hub in the Upper East Region and the Savelugu Hub in the Northern Region. To facilitate communication of actors within these Hubs, an MSP has been established in each Hub, which represents a major rice ecology. The criteria for selecting MSP locations was based on secondary data including population, socio-economic, agricultural, and rice production data, as well as technical reports from MoFA and CSIR-SARI.

Objective

The primary objective of MSP establishment is to serve as a point-of-entry for the identification, validation, operationalization, and monitoring of improved rice technologies and interventions chosen and developed by relevant rice stakeholders. MSPs defines appropriate technologies, and permit stakeholders to participate in the entire process of rice sector development and improvement within the value chain.

The expected outputs were as follows:

1. Identification of of relevant actors;
2. Composition of the MSPs and election of key governing members;
3. Definition of the objectives and rules of operation of the MSP;
4. Development of a coherent action plan; and

"Coaching" of the MSPs to achieve their goals, improve their capacity for development and sustaining the collective group going forward.

Implementation strategies

The responsibility for MSP facilitation was entrusted to CSIR-SARI with technical backstopping from AfricaRice. The process started with a collaborative meeting between CSIR-SARI and AfricaRice researchers to develop the MSP tools and methods in a two-day methodology workshop. The workshop provided the first opportunity to develop the criteria for selecting MSP sites/locations and actors, in addition to enabling partners to finalize a joint workplan for MSP establishment.

Achievements

Identification of relevant actors

Scientists tasked with the formation of the MSP undertook a reconnaissance survey in the Navrongo and Savelugu Hubs in order to identify relevant stakeholders in the rice industry. The identification of the stakeholders was done in consultation with the district directorates of MoFA. A visit was then paid to each potential actor to explain the functions and working of the MSP, the roles they are expected to play and to seek their consent to be a member. Table 62 is a summary of the categories of actors identified.

Launching of MSPs

The launching of the MSP in the two Hubs took place on 25 and 26 June, 2012 in Navrongo, and on 10 and 11 July, 2012 in Savelugu after an initial postponement due to heavy rains. Representatives of all identified stakeholders participated.

The 2-day launching workshop in each Hub afforded all the actors in the platform the opportunity to meet and network for the first time. The actors were briefed on the background and objectives of the MSP, role of the MSP and an overview of MSP processes and methodology (Figure 10). There was a small group session to discuss and document the:

- Role of each stakeholder in the MSP
- Relations between actors
- Vision and mission
- Key executive positions

- Activities to be implemented with timelines.

Table 62: Membership of the multi-stakeholder platforms

Hub	Actor	Number of Actors	Total Membership	Gender	
				Male	Female
Savelugu	FBO	10	500	448	52
	MoFA	1	3	3	0
	Aggregator	2	2	0	2
	Processor	6	6	2	4
	Tractor Services Provider	4	4	4	0
	Agro Input Dealer	2	2	2	0
	Rural Bank	1	1	1	0
	District Assembly	1	1	1	0
	Sub Total	27	519	461	58
Navrongo	FBO	7	379	348	31
	ICOUR	1	3	3	0
	MoFA	1	1	1	0
	Aggregator	2	2	1	1
	Processor	4	4	1	3
	Tractor Services Provider	2	2	2	0
	Agro Input Dealer	2	2	2	0
	Rural Bank	1	2	2	0
	Sub Total	20	395	360	35
Grand Total		47	914	821	93

The vision of the Savelugu MSP is to produce sufficient quality rice that would compete with imported rice in order to increase income levels by 2017 while their mission is to increase the production of quality rice through the adoption of improved farming systems, services and inputs. The short-term goals of the Savelugu MSP are presented in Table 63.

Table 63: Short-term goals of the Savelugu MSP

Goal	Time frame
Election of steering committee members.	15 August 2012
Drafting of constitution,	31 August 2012
Opening of bank accounts	10 September 2012
Meeting of all stakeholders	10-12 October 2012
Identification of warehouses	30 November 2012
Training of tractor operators and farmers on water management	1st week of September 2012
Meeting of all actors to develop plans for 2013	4th week of November 2012

The vision of the Navrongo MSP is to reduce poverty through increased production, processing and marketing of high quality rice by 2017 and their mission is to promote the adoption of improved technologies in order to increase rice production by 50%. The short-term goals of the Navrongo MSP are presented in Table 64.

Table 64: The short-term goals of the Navrongo MSP

Goal	Time frame
Election of executives	August 2012
Regular meetings	Monthly
Acquire fallow land for rice production	April 2013
Seek technical advice from Agricultural Extension Officers	Monthly
Acquire good quality seed of improved rice varieties	April 2013
Timely acquisition of equipment and inputs	April 2013
Timely and proper land preparation	May 2013
Adopt improved rice production technologies	May 2013
Open and operate a cooperative bank	September 2013
Sell the idea of MSP to other stakeholders	July 2013
Train trainers on rice processing	March 2013
Millers to service their machines for quality work	Quarterly
Identify more aggregators	Continuous activity

Monthly meetings

Monthly meetings were held in each Hub after the launching of the MSPs – 6 in Navrongo and 5 in Savelugu. CSIR-SARI provided backstopping by coaching and mentoring the MSPs to achieve their goals. The meetings were also a forum for addressing concerns such as non-availability of subsidized fertilizers, maintenance of irrigation canals, among others.

Problems being addressed by the MSP

Members of the MSP in each Hub brainstormed to agree on the challenges that should be addressed by the platform. Challenges prioritized and currently being addressed by the platforms include:

- Low yields and poor quality of rice produced
- High cost of inputs and machinery
- Late release and inaccessibility of subsidized fertilizers
- Limited equipment for land preparation resulting in late or poor land preparation
- Irregular supply of rice, constraining aggregators
- Inadequate storage facilities
- Pests and diseases
- Non-availability of ready market
- Low capital and high rate of loan delinquency.

Local name of MSP

The platform in each Hub has adopted a local name – the Navrongo MSP adopted *“Mumuna TonTongma Tigsim”* which literally means association of rice workers, while the Savelugu

MSP chose *"Ti-Songmitaba Shinkafa Tuma Lagingu"* literally meaning association of rice workers helping each other.

Election of executives or steering committees

Members of the MSP in each Hub elected leaders who could efficiently steer the affairs of the MSP. Participants were asked to nominate at most three members who are willing to fill the identified positions. After introducing themselves to participants, votes were cast in the absence of the candidates. Elected executives are presented in Table 65.

Table 65: Elected MSP executives

MSP/Hub	Position	Name	Rank	Contact
Navrongo	Chairman	Richard Akoka	Farmer	0242860003
	Vice Chairman	John Tibiru	Korania Chief	0277084280
	Secretary	Kwaku Atigsi Daniel	Village Committee Chairman	0245797637
	Vice Secretary	Augustine C. Kaguah	ICOFA/GRIB	0244144021
	Treasurer	Faustina Abayire	Rice Processor /Parboiler	0541101205
	Organizer	Sebastian Waltia	AEA, MoFA, Kasena Nankani East	0246650023
	Trustee	James Adawina	Bui Chief	0249489083
Savelugu	Chairman	Fuseini Salifu	Farmer	0246169040
	Vice Chair	Alhaji Abdul-Mumin Issahaku	Tractor Service Provider	0244434002
	Secretary	Zakaria Issah Nabila	Farmer	0249151403
	Treasurer	Sulemana Inusah	Banker	0372091143
	Organizer	Peter Nyagri	Tractor Service Provider	0242106846

Official Registration of MSPs

The executives, in consultation with their membership, have initiated the process of formalising or legalising the MSPs by registering them with the Department of Cooperatives. For the platform to be recognised, it must meet the following conditions as espoused by the department. It should:

- Have a membership of at least 10
- Be independent
- Be economically viable
- Have a bank account in a recognized bank
- Have an office accommodation for keeping of records by the secretary
- Be prepared for education and training
- Be helpful to the community
- Be capable of paying the secretary
- Pay a registration fee of GHc 100.00

In order to meet the conditions enumerated above, each MSP levied a membership registration fee GHc5.00. The Navrongo MSP sold shares for GHc10.00, with a maximum of five shares per person. The Savelugu MSP has opened a bank account at the Borimanga Rural Bank while the Navrongo MSP operates an account at the Naara Rural Bank. None of the executives is being paid and a member of the Navrongo MSP has voluntarily offered the platform an office space. After completing the registrations forms, both MSPs have paid their fees and are now awaiting their certificates. Each MSP has therefore been served with the cooperatives bye-laws by the department.

Activities planned for 2013

The following activities have been planned for 2013:

- Update MSPs' action plans and possibly add additional stakeholders (in order to address their challenges and constraints to agricultural production and natural resource management).
- Monthly backstopping/coaching of MSPs.
- Workshop bringing together the two MSPs from each Hub to Tamale for two days.
- Design monitoring and evaluation for mutual learning.
- Conduct training workshop on various themes (themes will be identified based on capacity building needs in order to effectively implement the MSPs' action plan and operate them better.)
- Conduct exchange visits.

Discussion

In spite of the uncertainties at the beginning and the consequent late start of field activities, much positive progress has been made in implementing the approved activities. Because of the delay by the International Food and Policy Research Institute in conducting the baseline surveys, the baseline surveys presented in this report had to be done as a basis for the further activities that were envisaged. Due to inaccessibility of some of the intervention areas caused by flooding, a number of communities are yet to be interviewed in the Savelugu Hub. To complete the entire baseline survey, 40 more man-days/enumerator will be required. The survey will also be extended to Upper West region to prepare the ground for the future.

About 20 tonnes of cleaned and certified seed will be available for farmers. This compares favorably with the target of 10 tonnes. Farmers and extension agents have been trained on seed production and 15 farmers have become seed entrepreneurs. Their successful linkage by the project to the market should ensure the sustainability of the community-based seed system and enhance farmers' access to good quality seed of improved rice varieties.

The grain yield data show that there is great variation in attainable yield within and across communities, Hubs and rice production ecologies. The data show that exploitable yield gaps exist and could be manipulated for increased yields. The readiness of the farmers to cooperate is a great opportunity for the study. The presence of literates, resident in the communities, who can be and were engaged to assist in data collection can ensure timely gathering of accurate data.

Two Rice Sector Development Hubs were successfully established, each with a functional MSP. Improved linkages within the rice value chains as a result of the establishment of MSPs will bring about transparency and trust among value chain actors. A functioning MSP will improve upon farmers’ access to inputs (seed, fertilizer & finance), services and technology, which are the basic ingredients for propelling a sustainable rice production system. Such a system will increase famers’ yield, incomes and food security which are the longer-term objectives of Africa RISING.

Successful intervention in the project sites will be out-scaled by development agencies and the private sector to other areas not covered by the project. CSIR-SARI is in talks with two NGOs namely, ADVANCE and Trias, to support the two MSPs as well implement the concept of MSP in other areas possibly with other crops.
The interest and commitment of stakeholders in this project have been amazing and the project is building on that. The importance of effective communication and inclusiveness of all stakeholders for successful project implementation have also become clearer and a guiding principle.

The Hub concept and MSP are new concepts/approaches being deployed in the target zones. Experiences resulting from working with the MSPs are already being shared at

Effect of bunding and soil fertility management on maize grain yield in the Northern Savanna Zone of Ghana

J. M. Kombiok and Haruna Abdulai

Executive Summary

A set of demonstrations comparing maize yields in bunded plots applied to both organic and in-organic, and non-bunded plots applied to only in-organic fertilizer was set up in a total of 8 districts in Northern, Upper East and Upper West Regions in 2012. The results show that maize yields in the bunded plots were significantly higher than the non-bunded plots in the Upper East Region while in the Northern and the Upper West Regions yields, even though these were still higher but the difference was not significant. The significant difference in maize yields observed in the Upper East Region was attributed to the more erratic nature of the rains than the other regions which did not suffer much from intermittent dry spells during the year's cropping season. The total number of farmers reached with this technology (earth bunding and the application of both organic and in-organic fertilizers) was about 3,687 made up of 1,800 direct beneficiaries and 1,887 farmers indirectly. The direct beneficiaries were those who took part in the demonstrations and were trained in good agricultural practices in maize production. The indirect beneficiaries were those who took part in the various field visits and other field days. In addition, the capacities of these farmers, extension agents of MoFA in the 8 districts have been built in the areas of A-frame construction, use of A-frame to trace contours and bund construction on the field. Framers in these districts have seen the benefits of bunding on the growth and development of the maize crop during years of more dry spells during rainy seasons.

Introduction

Low grain yields of cereals in Northern Ghana have been attributed to poor soils. For the past decade, low soil fertility status of soils has been ranked first among the constraints collated from all the districts of Northern Region at the RELC regional planning sessions. In the Northern Region also, land preparation for crop production is carried out manually by hand hoe, bullock, tractor and to some extent, the slash and burn method (zero tillage) with or without the use of herbicides.

The effect of both organic and in-organic fertilizers separately and in combination to enrich the soil for high grain yields of cereals have been for the past years compared. Results from on-station experiments in Upper-East Region indicate that the best yields of maize were obtained when half the recommended dose of in-organic fertilizer was combined with three tons (3 tons) of manure (organic fertilizer).

The role of integrated soil fertility management (ISFM, i.e. combined application of organic and mineral fertilizers) with different tillage systems/bunding on nutrient (N) and water use efficiency for high maize yields has however been investigated on-station. The results showed significantly high maize grain yields in favour of the bunded fields especially in years of intermittent drought as compared to the plots not bunded but with the same amount of nutrient applied. However, these have not been demonstrated extensively on farmers' fields (On-farm) for adoption.

General Objective

The objective of this work was therefore establish on-farm demonstrations to validate the on-station results obtained in these areas for possible adoption by farmers in northern Ghana.

Specific objectives were :

- To test the effect of integrated soil fertility management and tillage on N and water use efficiency;
- To test the effect of integrated soil fertility management and tillage on the yield of maize in bunded fields
- To train farmers and national extension workers on simple and usable techniques of identifying slopes and the construction of bunds to conserve water and nutrients for crop use

Methodology

In collaboration with Ministry of Food and Agriculture (MoFA) of Ghana in the Northern, Upper East and Upper West Regions, a total of five willing and enthusiastic farmer groups were selected from four (4) districts in the Northern, two (2) each in Upper East and West Regions with very low soil fertility status. These are the Tolon/Kumbungu, West Mamprusi, Bunkpurugu/Yunyoo and the Saboba Districts in the Northern Region, Talensi and Bongo Districts in the Upper East Region and Jirapa and Lawra in the Upper West Region. In all the three regions involving 8 districts, a total of 40 farmer groups participated in the demonstration on the effect of bunding on water conservation and maize yield. Each of the farmers' groups had an average of 45 members.

Location and Number of farmers involved

There were total of forty demonstrations in eight districts:

- Tolon/Kumbungu
- West Mamprusi
- Bunkpurugu/Yunyoo
- Saboba
- Jirapa
- Lawra
- Bongo
- Talensi

In each district, five active farmer based organisations (FBOs) were identified and registered for the demonstrations.

At each site, an acre of land was ploughed and harrowed with a tractor, a bullock or hand hoe. This was divided into two parts along the slope. The recommended fertilizer (2 bags compound and one bag ammonia/acre) was applied to the maize in the first part. The maize variety used as the test crop in the demonstration was Obatampa.

Half rate of organic manure/ha from the farmers' pen (3tons/ha) was used to apply to the second part of the plot and worked in before planting the maize. In addition, half the rate of compound fertilizer and half bag of ammonia/acre was also applied to the same plot at the appropriate periods. The second plot in each case which was treated with both organic and in-organic (half-rates) was bunded. Earth bund was constructed round this second plot in each case to enable the plot retain moisture after rains. The farmers were sensitized to cut open the bunds in the case of frequent rains since maize can not tolerate standing water. The bunds are therefore effective in times of intermittent drought or very low rainfall frequency.

Participatory Promotion and dissemination of contour farming

The cropped area under contour farming (bunding) in the three regions was 40 acres and this represents the plots of the forty farmers (FBO) taking part in the ISFM/contour farming demonstration in 2012. It was observed that up to ten farmers in the West Mamprusi District were farmers practicing contour farming in the area. All the farmers are producing maize within bunds in the district.

Field days were organised several times to all the sites at the vegetative phase of the crop (maize), at about 60 days after planting. The objective of the field day was to visually observe and compare the performance of maize at vegetative phase within the bunds with those outside the bunds. This involved a total of 657 participants (in all the 8 sites) made up of 440 males and 217 females from research, MoFA and farmers within the area (Table 66).

Table 66: Number of farmers benefited from the demonstrations in 2012

Direct Beneficiaries (40 FBOs)	Those met during Field visits (8 sites)	Those at the various Field days (6 sites)	Total
1,800	657	1,230	3,687

A total of 3,687 farmers directly or indirectly benefited from the 2012 demonstartion on ISFM/bunding. This number however, might not be very accurate because some of those we met during the field days and visits were still members of the FBOs at each site.

Every visit to each site showed that there were no distinctive differences between the crops within and those outside the bunds at this stage because the number of days of intermittent drought in some of the sites was just about 5 days and moisture was still adequate for crop growth within both environments. However some of the experienced farmers were of the opinion that the differences would have been well expressed if there was a length of 10 days of no rain after planting the maize. What was very clear was the maize applied with fertilizer and manure was looking greener than those applied with manure alone in both within and outside the bunds at all sites.

Data analysis

Yields of maize were taken from the half acre each of the bunding and non-bunding plots and converted into per hectare basis. These were analysed using the Statistix Program and the differences in maize yields were compared using the T-test.

Results for 2012

Number of farmers reached and Capacity Building.

In all, a total of 1,800 farmers directly participated in the 40 demonstration plots in the three regions (8districts) of Northern Ghana. Apart from taking part in the demonstrations, all the farmers were also taken through all the stages of good agricultural practices (GAP) in maize production. This was broken down into modules, namely site selection and land preparation, Planting and Planting materials, Cultural practices like timely weed control and the application of fertilizer, crop protection measures (Entomology and Pathology) and harvesting and storage of maize.

Also, the capacities of these farmers, extension agents of MoFA in the 8 districts have been built in the areas of A-frame construction, use of A-frame to trace contours and bund construction on the field. This was done by carrying out the training at each site using a resource persons from the MoFA headquarters in the Northern Region of Ghana.

Maize grain yields by Regions

Maize grain yield values as affected by different tillage, fertilization and bunding and non-bunding are presented in Table 67.

Table 67: The effect of bunding and different fertilizer application on the yield of maize in the three regions of Ghana

Region	Mean grain yield kg/ha			
	Manure &fert/bunding		Full fert/No bunding	
Northern	2342.10	a	2024.60	a
Upper East	1661.10	b	1002.20	c
Upper West	873.44	c	843.44	c
LSD(0.05)	360.77		....	

In Northern Region, maize grain yields from the bunded plots fertilized with the combination of both the manure and fertilizer, (half rates of fertilizers/manure and half recommended rates of NPK treatments) were similar to the maize yields from plots not bunded but fertilized with recommended rates of fertilizers (Table 67). However, in the Upper East and West regions, maize yields in the bunded areas were significantly higher than those not bunded.

The fertilizers and manure coupled with bunds would have been responsible for the significant higher grain yields as these supplied more nutrients to the soil and help to raise the organic matter in the soil compared with plots applied with fertilizer alone without bunds (Fig 29).

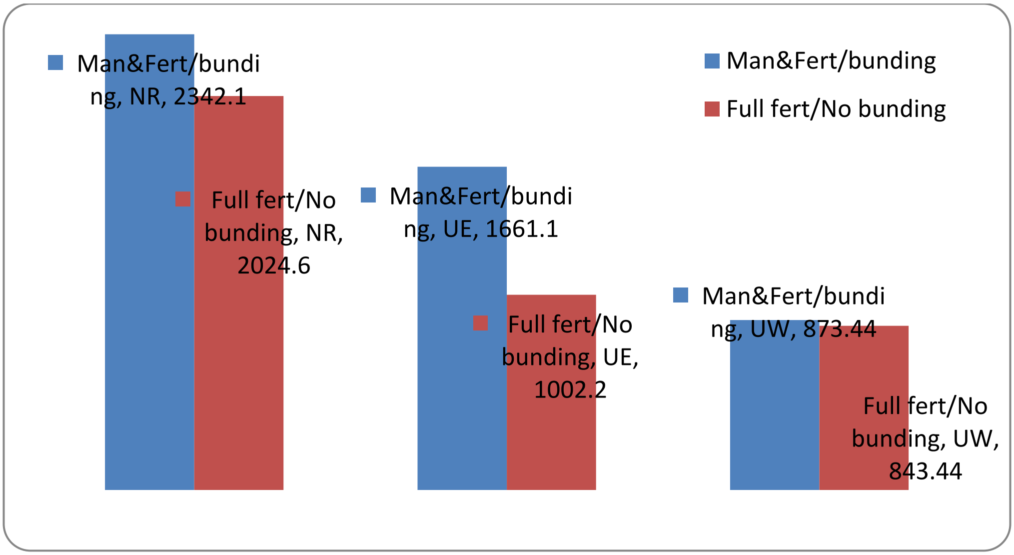

Fig: 29 Yield of maize as affected by bunds and fertilizer application by region.

Additionally, the bunds could have helped to retain moisture and nutrients in the soil for continued plant uptake as the rainfall in the Upper East and West comparably was also less in Quantity and less in frequency than in Northern Region.

Constraints

The only constraint the farmers mentioned related to contour farming was difficulties in making the bunds as it is also difficult to trace the contours to establish the bunds. In a related way, one is not able to predict the nature of the rain in the year and for that matter making bunds in a year with heavy down pour does not give you any better results as the water would have washed the bunds as well suggesting that bunds are most beneficial when rains are scanty and more erratic.

Conclusions and perspectives

From both theory and practice, it is proven that the construction of bunds on slopes helps to store water from rain and improves infiltration for the growth and development of crops which results in higher yields.

The slight increases in maize grain yields in the bunds during an almost even distributed rain this year means that in a year with scanty and erratic rainfall which is common in the area, the construction of bunds or contour farming will assist farmers to increase their grain yields.

For the adoption of contour farming by farmers in the areas of high gradient slopes, carrying out training of trainers involving all extension agents (MoFA and NGOs) will help carry the message forward. This should be backed by assisting some number of farmers in each community to carry out some of the activities.

Yields of Cereals (Maize and Sorghum) and legumes (cowpea and Sorghum) as affected by Jatropha as an intercropping systems

J. M. Kombiok, S. K. Nutsugah,.Afua S. Karikari and H. Abdulai

Executive Summary

A long term field experiment was established in 2010 to study the performance of cereals (maize and sorghum) and legumes (cowpea and soybean) intercropped with Jatropha at Nyankpala. Each of the experiments was laid in RCBD replicated three times with Jatropha spaced at 3m by 2 m while the food crops were sown between every two rows of the Jatropha. Since the establishment of the experiment in 2010, the first yield obtained from the Jatropha was in 2012. The results in 2012 therefore show that yields of both maize and sorghum were significantly reduced by the presence of Jatropha which was attributed to shading by the Jatropha plants. The legumes (cowpea and soybean) however, were not affected by the intercropping system. Similarly, the yield of Jatropha in the sole and when it was intercropped with the food crops were similar suggesting that there was no influence of intercropping on the Jatropha plant.

Introduction

Jatropha has always been used in the Northern part of Ghana as a border plant or as a life fence of gardens and other portions of the house or farms for some time now. It has never been considered as a crop until of late when the issue of its being one of the plants used to produce fuel in some countries. This has however encouraged entrepreneurs and governments of some countries to initiate the establishment of Jatropha plantations with the aim of producing fuel.

With the inception of the EU-Sponsored Jatropha Project which is a community development project, SARI among other things was mandated to carry out field trials involving jatropha. One of the trials was to find out how compatible Jatropha is as an inter crop plant with food crops. This is because farmers in the sub-region practice intercropping widely of which Jatropha will not be left out if it is accepted as a bio-fuel crop. It was therefore based on this reason that it became necessary in 2010 to introduce a long time intercropping systems involving the Jatropha plant and the commonly grown legumes (Soybean and Cowpea) and cereals (Maize and Sorghum). The objective of each of the trials for the past three years has therefore been to assess the performance of some legumes (soybean and cowpea) and cereals (maize and sorghum) in intercropping systems with Jatropha.

Materials and methods

The two sets of trials involving legumes and cereals were established at the Savanna Agricultural Research fields, Nyankpala since 2010 and repeated each year. The Jatropha is permanent planted at a spacing of 3 m by 2m while the cereals and legumes are interplanted each year. Each of the trials was laid in a Randomized Complete Block design (RCBD) and replicated three times. Regular weeding was carried out on both trials to make sure the plants were weed free at most of the stages of crop growth.

Treatments:

a. Jatropha/cereal inter cropping system

Crops: maize, Sorghum and Jatropha
Sole Jatropha spaced at 2 by 3 m
Sole maize
Sole sorghum
Jatropha/ maize
Jatropha/sorghum.
This was replicated three (3) times

b. Jatropha/Legume intercropping system
Crops : Soybean, cowpea and Jatropha
Sole Jatropha spaced at 2 by 3 m
Sole Soybean
Sole Cowpea
Jatropha/ Soybean
Jatropha/Cowpea

Results of intercropping trials in 2012
Cereals: Maize and Sorghum
The grain yields of maize, sorghum and Jatropha as affected by the intercropping systems are presented in Table 68.

Table 68: The performance of maize and sorghum (Cereals)in intercropping systems with Jatropha

Treatment	crop	Yield(kg/ha)	Significant difference level
Sole maize	Maize	1200.00 a	
Jathropha/ maize	Maize	318.67 b	
			Highly significant
LSD (0.05)	-----------------	602.49	
Sorghum	Sorghum	2137.8 a	
Jathropha /sorghum	Sorghum	768.89 b	Highly significant
LSD (0.05)	-----------------	819.08	
Sole jathropha	Jathropha	1495.37 a	
Jathropha /maize	Jathropha	1500.00 a	
Jathropha /sorghum	Jathropha	1412.04 a	Not Significant
LSD (0.05)		317.87	

The results show that maize grain yield in the sole situation was significantly higher than when it was inter cropped with Jatropha. Similarly, there were significant differences in sorghum grain yield between the sole and when sorghum was intercropped with Jatropha. It was observed that the grain yield of sorghum intercropped with Jatropha was significantly lower than the yield obtained from the sole cropping situation.

However, there were significant difference in the yields of Jatropha between the sole and when it was intercropped with either maize or sorghum (Table 67). There were therefore no significant differences among Jatropha yield between the sole and when it was intercropped with any of the cereals. The significantly lower grain yields of both the maize and sorghum obtained from the intercropping systems than the sole could be attributed to competition for light in favour of the Jatropha. It was observed that the Jatropha had developed a lot of lateral branches which were shading these cereals in the intercropping situation.

Legumes: Cowpea and Soybean

Even though cowpea in the sole gave higher grain yield than when it was intercropped with Jatrotha, the difference in yield was not significant (Table 69).

Table 69: The performance of Cowpea and Soybean(Legumes)in intercropping systems with Jatropha

Treatment	crop	Yield(kg/ha)	Significant difference level
Sole cowpea	cowpea	1488.90 a	
Jathropha cowpea	cowpea	1444.40 a	
LSD (0.05)		174.51	N.S
Sole soybean	soybean	1666.70 a	
Jathropha soybean	Soybean	1622.20 a	
LSD (0.05)		493.59	N.S
Sole jathropha	Jathropha	1259.70 a	
Jathropha /cowpea	Jathropha	1328.70 a	
Jathropha/soybean	Jathropha	1148.10 a	
LSD (0.05)		273	N.S

Similarly, there was no significant difference observed between soybean grain yield in the sole and when it was intercropped with Jatropha. The non-significance in the yields of the legumes in the sole and intercropping systems could be due to their earliness to maturity. The legumes matured in three months by which time the shading by the Jatropha plants was not intense while the sorghum and maize took longer time to mature. It was further observed that Jatropha whether it was in sole or intercropped with soybean or cowpea showed no significant difference in yield (Table 69). Grain yield of Jatropha was therefore not affected by intercropping even though Jatropha yield was higher when it was intercropped with cowpea.

For the third year in 2012, with Jatropha giving the first yield, it was generally observed that cropping Jatropha with cereals (maize and sorghum) and also with legumes (cowpea and soybean) significantly reduced the cereal crop yields but the grain yields of legumes were not affected by the presence of Jatropha. However, no influence of these food crops were observed on the yield of Jatropha as the yield in the sole jatropha was similar to the yield when Jatropha was intercropped with both cereal and legume crops. The experiment a long term one and will be repeated every year

SOCIO-ECONOMICS PROGRAMME

Edward Martey, Prince Maxwell Etwire, Alexander Nimo Wiredu, Esther Wahaga

Background

The activities of the Socio-economic Section (SeS) of CSIR-SARI inform research and development (R&D) programs of the all the research groupings including all the Regional Farming Systems Research Groups (RFSRGs) and the Scientific Support Group (SSG). In this report are highlights of specific socioeconomic activities conducted in 2012. The activities include Strategies to Manage Yam Glut in Brong-Ahafo Region, Baseline Studies and Situation and Outlook Analysis for Groundnut in Northern Ghana, Ex-post Impact Study of the AGRA Soil Health Project (SHP), Baseline Surveys for Rice Sector Development Hubs in Northern Ghana, Ex-ante Impact of Rice Research in Ghana and Technology Adoption Survey on Maize and Rice in Northern Ghana.

Other activities carried out during the year under review includes FBO Development, Analysis of the Seed System in Ghana, Socioeconomic Evaluation of Drought Tolerant Maize Varieties, Capacity Building of SME Seed Company Personnel in WCA on Marketing, Multi-stakeholder Platform Processes for Rice-based Systems and Routine Monitoring of Various Projects been Implemented.

This report features synthesis of key findings from all completed studies. It also highlights the progress made so far with on-going studies and a look at the way forward. Some new activities proposed for 2013 are also mentioned.

Strategies to Manage Yam Glut at Peak of Harvest in the Brong-Ahafo Region of Ghana

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Executive Summary

Despite the importance of yam as a high value commodity, annual gluts peaking in July and August has negatively affected producers and traders in Brong-Ahafo Region. The incidence of yam glut has implications on price, future production, harvested yam and income. Most of the producers and traders experience a decrease in price, future yam production, and income. Constraints including agronomic, finance, postharvest and processing were identified. The study also revealed that the most efficient channels were those with the least number of intermediaries. Proposed strategies to manage the glut situation include, varietal development, improvement in post-harvest technologies, market infrastructure and information systems.

Introduction

Yam (*Dioscorea* species) is a high value commodity with the potential to contribute significantly to food security, income, culture and tradition in the Brong-Ahafo region and Ghana as a whole (Hahn et al., 1987). Yam glut is however an annual occurrence in the Brong-Ahafo region that negatively affects both producers and traders in diverse ways. This project was therefore expected to develop strategies to manage yam glut. More specifically the project described the incidence and causes and effect of glut, described and determined the most efficient yam market chain and then proposed strategies for managing yam glut in the region.

Methodology/Approach

The study was participatory, involving all the relevant stakeholders. Data generated from surveys of selected yam communities and markets together with some secondary data provided the basis for analysis of the yam industry. Trend analysis was used to describe the incidence of glut. The efficiencies of the marketing channels were assessed by examining how well the channels respond to consumers and producers demand for services in relation to their preferences.

Results and Discussions

Scientific findings

The causes of yam glut include agronomic, postharvest, utilization and finance. Yam in the domestic market is handled by producers, assemblers, wholesalers and retailers with specific functions. The incidence of yam glut has implication on price, future production, harvested yam and income. Most of the producers and traders experience a decrease in price, future yam production, and income. The channel of distribution also includes an export chain. During the peak of glut (i.e. July-August) yam producers record losses while exporters record the highest margins. The results however shows that yam marketing should not necessary include exporters to make it efficient, reducing the number of intermediaries domestically can help improve the efficiency of the marketing channels significantly.

Conclusions/Recommendations

The study provides evidence and causes of glut. It is therefore recommended that investment in yam improvement should focus on the development of varieties that are marketable and storable. Research should also consider the development of alternate uses for yam as well as the development of appropriate storage technologies. The district offices of the MoFA should be strengthened to serve as market intelligence centres for accessing information on the domestic market and international market for yam. The use of information technology, mass media and mobile phones to access market information should be encouraged. Training on appropriate production practices, particularly harvesting and postharvest practices is also required. There is also the need to develop technologies that would enable the production of yam all year round. There is the need to increase the efficiency of the various channels of distribution by strengthening the linkages between the various actors.

Future activities/The way forward

New proposal will be drafted based on the recommendations of the study.

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Baseline Studies and Situation and Outlook Analysis for Groundnut in Northern Ghana

Edward Martey, A. N. Wiredu, Richard Oteng-Frimpong, S. K Nutsugah, P. M. Etwire, Nicholas Denwar

Executive Summary

The Tropical Legumes II project basically deals with improving the livelihoods of smallholder farmers in drought-prone areas of sub-Saharan Africa and South Asia through grain legume production and productivity. As part of the project, a baseline study was conducted to analyze the current outlook and situation as well as characterize the groundnut production system in northern Ghana. Result of the situation and outlook analysis suggests that West Mamprusi (Northern region), Bawku West (Upper East Region) and Nadowli district (Upper west region) are three (3) major districts in Northern Ghana with the highest area under groundnut cultivation.

The average area under groundnut cultivation ranges from less than one acre to more than 15 acres. Production trends indicate a general positive growth rate in the volume of groundnut production over the entire study period (1990 – 2006) which is accounted for by area and yield.

Introduction

The present study aims at generating situation and outlook analysis and groundnut baseline information in Northern Ghana. Groundnut (*Arachis hypogaea*) is one of the most widely grown tropical legumes in the world. It is grown in about 118 countries and occupies more than 22.6 million ha of land. The average annual production is estimated at about 36.4 million MT, with average yield of about 1610kg per ha. West Africa has experienced approximately 5 million metric tons of groundnuts in the last five years (1997-2001) which represents 60% of the African continent's groundnut production and 15% of world production. The production share of West Africa has dropped from 23 to 15% of world production since 1961. Population growth has been a primary factor in the demand for groundnut products in Africa. Secondly the suitability of groundnut products to other products has also contributed to the high demand. Groundnut production in Northern Ghana is very pronounced and contributes about 92% of total national production. Groundnut production in Ghana nearly tripled from 168,200 tons in 1995 to 420,000 tons in 2005 and was primarily due to increase in the area under cultivation which increased from 180,400 ha in 1995 to 450,000 ha in 2005. Some groundnut studies has revealed that lack of credit support, transport limitations, inefficient groundnut marketing channels and systems, restricted markets and marketing opportunities have contributed to limiting the realization of the potential of the producers especially rural women.

Materials and Methodology

The data for the situation and outlook analysis was obtained from secondary sources (Statistics Research and Information Directorate (SRID) of Ministry of Food and Agriculture (MoFA) of Ghana) as well as review of literature. Primary data for the baseline studies will be obtained through interview of groundnut producing households in Northern Ghana. The data will basically capture the general household structure, household resources, groundnut production profile, institutional arrangements, income and expenditure and food security.

Results and Discussions

Scientific findings

West Mamprusi (Northern region), Bawku West (Upper East Region) and Nadowli district (Upper West region) are three (3) major groundnut producing districts in terms of area in Northern Ghana. It is both a commercial and subsistence venture for majority of the inhabitants. The area under groundnut cultivation ranges from less than one acre to more than 15 acres. It is purely rain-dependent cropping system. Groundnuts are never grown under irrigation and are planted either in rows or staggered on plots and in some locations on mounds to reduce plant population on the fields. Field preparation is most often done using tractors in large holdings whereas in smaller holdings bullock plough or hand hoeing is the preferred method. Seeding is by hand and in most cases farmers use seed from their own stock or purchase from the local market. Harvesting and plucking of groundnut is done manually.

The result of the trend analysis indicates a positive annual growth rate of groundnut production over the entire study period (1990-2006). Comparatively, the production volume of groundnut in the Upper East is higher than that of Northern and Upper west region within the period 1992 – 2011. The production volumes in all the three northern regions witnessed a decline in 2007 and an increase in production beyond 2007 with the exception of Upper East which has been fluctuating. Area under groundnut cultivation for Upper West is the lowest over the entire study period relative to Northern and Upper East Regions. However, Northern Region has witnessed the highest decline in terms of area under cultivation between 2003 and 2007.

Conclusion/Recommendation

The results from the study suggest a positive growth rate in groundnut production in Northern Ghana over the entire study period. Based on the situation and outlook analysis, rural households engaged in groundnut production especially women must be supported with credit facility and improved seed variety.

Future activities/The war forward

The baseline study will commence this year subject to release of funds by ICRISAT. Detailed analysis of the baseline study will be carried out to describe the general groundnut production systems in northern Ghana. This will provide specific guidelines for the project implementation process. Journal articles will also be produced from the baseline database for publication.

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Ex-post Impact Study of the AGRA Soil Health Project (SHP) in Northern Ghana

Edward Martey, A. N. Wiredu, Matthias Fosu, P. M. Etwire, John K. Bidzakin

Executive Summary
The ex-post impact of the AGRA SHP study indicates a high adoption rate of ISFM technologies among maize farmers. However, there is significant variation in the adoption rate across the community categories. The agreement among the ranked preferences for technologies and varieties is low as indicated by the Kendall's coefficient of concordance value of 0.26. Statistically, ownership of livestock and age of the farmer are the most influential significant determinants of ISFM adoption in Northern Ghana. The credit facility of the project must be extended to farmers in other communities.

Introduction
Northern Ghana accounts for over 40 percent of agricultural land in Ghana and considered as the bread basket of the country. The area is however inundated with high levels of food insecurity and poverty. About 80% of the population depends on subsistence agriculture with very low productivity and low farm income. The main reason for the extreme poverty and high food insecurity is the over reliance on rain-fed agriculture under low farm input conditions. In addition, these shortcomings, soil fertility management is sub-optimal. Fertilizer nutrient application in Ghana is approximately 8 kg per ha while depletion rates, which is among the highest in Africa, range from about 40 to 60 kg of nitrogen, phosphorus, and potassium (NPK) per ha per year (FAO, 2005). The escalating rates of soil nutrient mining are a serious threat to sustainability of agriculture and poverty reduction in Ghana. Integrated Soil Fertility Management (ISFM) is the approach promoted by AGRA to improve the soil fertility status of African soils. AGRA has demonstrated its commitment to improving the health of the soils in Northern Ghana by funding the Soil Health Project 005 which was implemented by CSIR-Savanna Agricultural Research Institute between 2009 and 2011 prior to its extension.

Materials and Methodology
Data for the study was obtained at two levels. Focus group discussion was adopted to obtain the community level data by category (Project, counterfactual and control communities). Data captured include access to infrastructure and resources. The second level of data was obtained

from the households. The household data was captured based on the categories (participant, observer and non-participant households) of the households in the study area. Kendall's coefficient of concordance was run to establish the level of agreement among the ranked preference of crop varieties and technologies by the farmers. Regression analysis was also used to establish the factors that determine ISFM technology adoption.

Results and Discussion

Scientific findings

Majority of the communities visited have access to feeder roads with the exception of 1 project community and 4 distant communities. Most of roads are however not tarred. The roads enable access to input and output markets, extension services among others. Members of the communities travel an average distance of 7.95 km to participate in nearby markets in the absence of vehicles. However, the beneficiary communities of the AGRA SHP on the average travel a distance of 9.33 km to the nearby market relative to the near and distant communities. The total number of households across the three community categories is 299 with males forming the majority (241) of the household head.

Crop production was shown to be a year round pre-occupation of the households following the rain-fall pattern which generally begins from March-April and ends in November-December. The crop calendar provides a useful guide for timely execution of the field activities of the project. It also serves as a tool for monitoring of farming activities and provides the targeted farmers the opportunity to fully participate and learn from the project.

The focal crops of the AGRA SHP are maize, cowpea and soybean. Farmers in the project intervention areas either grow one or more of these crops subject to their resource constraint. Maize is largely grown among majority of the farmers. The obatanpa variety of maize is mostly grown by majority of farmers. Generally the percentage use of tools and equipment for maize farming is higher among the observer household relative to the other household categories. About 51% and 54% of the participant and non-participant households respectively cultivate maize on rich soils. Soybean and cowpea cultivation occur mostly on soils with low fertility. The situation is more evident among the observer and non-participants households.

The estimated correlation coefficient value of 0.258 indicates that there is agreement among 26% of the respondents in the ranking of the preferences of crop varieties and technologies by farmers in the Northern Ghana. Among the identified preferences, yield, marketability, grain size and drought tolerance are the four most preferred crop characteristics and technologies. The probit analysis also revealed that farm size, gender, education status, years of farming experience, livestock ownership status, participation status, occupational status and age significantly explains adoption of ISFM technologies in Northern Ghana.

Conclusions/Recommendations

Preferences in the crop varieties and technologies differ among the farmers as indicated by the low level of agreement among the ranked preferences. Uptake of ISFM technologies and improve varieties is increasing among the smallholder maize farmers in Northern Ghana. Maize cultivation is more capital intensive relative to the other focal crops of the project. The beneficiary communities of the project must be scaled up and credit must be extended to other members of the target communities at the right time. Attention must be given to the other focal crops of the project. Training of FBOs and demonstrations must be carried out regularly to enhance farmers' skills.

Future activities/Way forward

The determination of the impact of the project by the use of propensity score matching is on-going. The results of the study will be validated in a stakeholder workshop. Journal articles will be developed and submitted for publication.

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Analysis of the Value Chain of Sweet Potato in Northern Ghana

Edward Martey, Prince Maxwell Etwire, Alexander Nimo Wiredu, Esther Wahaga, Kwabena Acheremu

Executive Summary

The baseline survey basically aims at generating relevant information for characterizing the sweet potato production systems in Northern Ghana. Data collection is completed. Data entry and analysis is underway.

Introduction

PennState University in collaboration with CSIR-SARI has signed a MOU to undertake a study in sweet potato value chain linkages in Northern Ghana. The CSIR-SARI’s socioeconomic unit will work collaboratively with Penn State under the subagreement for the Horticulture CRSP Focus Project “STOPS: Sustainable Technologies for Orange and Purple Sweet potatoes in Ghana”. The subagreement is valid for the life of the project, June 1, 2012 – July 31, 2014. The study will specifically provide baseline information on sweet potato production in Northern Ghana and also assist Penn State graduate students who will work on data analysis and value-chain follow-up analysis.

Materials and Methodology

The study will cover all the three northern regions of Ghana namely, Northern Region, Upper West and Upper East Region. The specific activities to be undertaken are desk studies and field surveys which include focus group discussion and formal interviews. Secondary data will be used to augment the primary data.

Results and Discussions

Scientific findings

Data collection in all the three northern regions is completed. Data entry and analysis are underway.

Way forward/Future

Data entry and analysis will continue

Baseline Surveys for Rice Sector Development Hubs in Northern Ghana

Edward Martey, A. N. Wiredu, P. M. Etwire, Wilson Dogbe, Aliyu Siise, Baba Inusa, Abdulai Lansah, Robert Owusu, Gilbert Yaw Nachim, Aminou Arouna (AfricaRice), Aliou Diagne (AfricaRice)

Executive Summary

The baseline survey basically aims at generating relevant information for characterizing the rice production systems in Ghana. Community and producer (Round 0) data collection for Savelegu is almost complete.

Introduction

Africa Rice Center (AfricaRice) has launched a new strategy to boost rice production in Africa and has initiated the Rice Sector Development Hub concept to drive the agenda. The success of the new strategy depends on the availability of reliable information and knowledge to guide the processes, thus the baseline survey. In Ghana the baseline surveys are being implemented in all the four rice sector development hubs. The baseline surveys are intended to generate relevant information to describe the prevailing socioeconomic conditions in the rice value chains in the hubs.

Materials and Methodology

Basically, data for the study is been generated through focus group discussions and formal interviews with the use of smart phones and tablets to ensure data integrity. The computerized systems are expected to reduce the overall time spent on data entry. Four levels of surveys are being implemented in each of the rice sector development hub. There is the producer level which has been separated into Round 0 and Round 1, the processors (Round 2), the traders (Round 3) and the consumers (Round 4). At each level, respondents are systematically selected from a population of potential respondents. With the aid of semi-structured questionnaires, data describing the characteristics of the respective actors of the rice based production system are collected. Specific data include personal characteristics of the identified actors, characteristics of their rice based activities as well as existing constraints.

Results and Discussions

Scientific findings

Data collection is in progress. Initially, there were some challenges with the use of the smart phones in the data collection. The MLAX software has been upgraded and Google nexus tabs have been provided for the collection of data in the hubs. Communities and producer data (Round 0) is about 90% complete. Data on Producer (Round 1), Processors, Traders and Consumers are yet to be collected.

Way forward/Future

Three (3) additional enumerators will be employed to augment the efforts of the existing six (6) enumerators. The survey in Navrongo has commenced since funds has been provided. Data analysis will also be done concurrently with the data collection with AfricaRice providing technical backstopping.

Ex-ante Impact of Rice Research in Ghana

Alexander N. Wiredu, Edward Martey, P. M. Etwire

Executive Summary

This study attempts to justify the investment in research and development in the rice sector in Ghana. An initial rate of return has been calculated, however, further analysis will have to be done.

Introduction

The need to justify continued investment in research and development in rice has become imperative in the era where allocation of funds for research in general is diminishing. Policy makers and donors need to be convinced about the returns to their investment in rice research. This calls for systematic evaluation of the global impact of rice research on the economy. The project seeks to justify the need for continued funding for rice research in Ghana. It will among other things provide a succinct description of the rice sector in the country and evaluate exe-ante, the impact of research and development on the sector. It will specifically measure the rates of returns to investment in selected research programs.

Methodology/Approach

The study is systemic and iterative in nature. The approach includes participatory process, collation of primary and secondary data collection and econometric modeling. The opinion of stakeholder in the rice production system on the relevant variables to be considered for the study is very crucial. Desk study will also be carried out. The study will basically employ secondary macro-economic data to construct models.

Results and Discussions

Scientific findings

There has been an initial analysis to generate the rate of returns to investment in rice research. Some data has been collected for further analysis.

Future activities/The way forward

There is the need for proper planning to ensure that this activity is adequately attended to due to overconcentration on the baseline survey. Collation of data required for the construction models and analysis will continue. Report and journal articles will be produced.

Technology Adoption Survey on Maize and Rice in Northern Ghana

Alexander N. Wiredu, Edward Martey, P. M. Etwire

Executive Summary

This study investigates the adoption rate of technologies and the constraints faced by rice and maize farmers in Ghana. Data collection is complete. Data cleaning and analysis is underway.

Introduction

This survey aims to understand the constraints of increasing productivity and technological challenges in maize and rice subsectors in various regions in Ghana. The survey will trace the adoption, diffusion and impact of improved agricultural technologies. It also attempts to improve the technologies being developed and promoted and to ensure that they respond to the needs and constraints faced by maize and rice farmers in Ghana.

Methodology/Approach

Data for the study was obtained both at the community and household levels with the use of PDA to ensure data integrity.

Results and Discussions

Scientific findings

Data collection is complete. Data cleaning and analysis are underway.

Future activities/The way forward

Data analysis will continue. Report and journal articles will be produced.

FBO development and M&E for Agricultural Value Chain Mentorship Project (AVCMP)

Prince Maxwell Etwire, W. Dogbe, A. O. Ampofo, Y. Iddrisu, E. Martey, R.K. Owusu, B. Inusah, E.E Awude, E. Doe, A. Krofa, A. Siise, Esther Wahaga

Executive Summary

The CSIR-Savanna Agricultural Research Institute (CSIR-SARI), International Fertilizer Development Center (IFDC), and the Ghana Agricultural Associations Business Information Centre (GAABIC) are grantees implementing the Agricultural Value Chain Mentorship Project (AVCMP) funded by the Danish International Development Agency (DANIDA) through the Alliance for a Green Revolution in Africa (AGRA).

CSIR-SARI is responsible for the implementation of the productivity component of the Project which has the objective of improving entrepreneurial and technical skills of FBOs and their member farmers to upscale ISFM technologies for rice, soybean and maize production. The FBO component is responsible for ensuring that farmers have access to farm inputs.

Introduction

The Alliance for a Green Revolution in Africa (AGRA) has awarded the AVCMP support grant to SARI and its collaborating partners, GAABIC and IFDC. The overall goal of the AVCMP is to contribute towards the Government of Ghana’s objective of achieving food security and becoming an agro-industrial economy by strengthening the capacity of agro-dealers, SMEs, Farmer Based Organizations and farmers in the agricultural sector of Ghana throughout the value chain turning it to a highly productive, efficient, competitive and sustainable system.

Methodology/Approach

As a Value Chain Facility, the implementing partners are applying a holistic and integrated approach to address the problems of inadequate management, business and technical skills, as well as poor access to finance and markets among actors along the maize, rice and soybean value chains. The FBOs are developed through trainings, mentorship and coaching. The FBOs are also being reached through demonstration of proven ISFM technologies, field days, drama, film shows, radio, posters among others.

A survey was initiated to determine the technical efficiency of soybean farms in Saboba and Chereponi districts. In that regard, a light questionnaire was developed, pre-tested and randomly administered to 200 farmers (100 women) in Saboba and Chereponi districts. Half of those sampled were beneficiaries of the project. Data collection is completed. The data is being entered in a statistical software which would be followed by analysis and reporting.

Results and Discussions

Scientific findings

About 14,000 farmers out of the target of 20,000 have been identified and are being primed. Two secondary FBOs are being assisted to develop business plans in order to source long-term finance for their members. FBOs in 4 out of the 16 district were linked to agro-input dealers to access inputs in bulk. Routine monitoring visits were conducted to ascertain the progress of project activities. 244 FBOs were trained in group dynamics and farming as a business.

Future activities/The way forward

The project team intends to prime an additional 6000 farmers to benefit from the project. FBO development and capacity building would continue as well as strengthening linkages with input and output markets.

M&E and Diagnostics of the Seed System in Ghana

Prince Maxwell Etwire, I.D.K Atokple, S.S Buah, A. Abdulai, P. Asungre, S. Karikari, A.N Wiredu, E. Martey

Executive Summary

The importance of seed to any crop-based production system cannot be overemphasized. It is the fundamental unit of any production system since it is the source of life. The objective of the study was to provide an overview of the existing seed systems in Ghana. Stakeholders in the seed industry were interviewed with the aid of a questionnaire. Assessment of the two systems seems to suggest that the formal and informal systems have historically overlapped and there is potential for a hybrid system combining aspects of the two systems to emerge, with more relevance to the realities of smallholder farmers.

Introduction

In Ghana and perhaps Sub Saharan Africa, seed is arguably the most important production factor and perhaps the cheapest input for crop production. Two parallel seed systems exist in Ghana: a formal system established by the state and its technical partners, and a traditional or informal system based on a tradition of exchanges and mutual support among producers within any one zone. Community based seed production systems are also gaining popularity in the country.

Methodology/Approach
The study was undertaken in Ghana and relied mainly on primary data collected through field survey. All the Seed Inspection Units of the Ministry of Food and Agriculture (MoFA) were interviewed. A total of sixty 60 seed producers, 10 seed companies and 20 agro input dealers were surveyed with the aid of a questionnaire. The agro input dealers were identified through snowball sampling and the seed producers and companies were identified through simple random sampling technique. The interviews were conducted face-to-face. The questionnaire covered key areas such as characterization of varieties, production and marketing of certified seeds among others. The study used mainly qualitative analytical tools to generate descriptive statistics such as frequencies and central tendencies.

Results and Discussions
Scientific findings
Prior to the establishment of the formal seed system, farmers relied on informal sources for their seed. The informal seed system continues to play a vital role even though there have been conscious efforts by government and its development partners to strengthen the formal seed sector.

The formal seed system is headed by the Ministry of Food and Agriculture which is hosting the National Seed Committee and the National Seed Services. Research and development of seeds or varieties is however the mandate of research institutions such as those within the Council for Scientific and Industrial Research (CSIR) and the Universities. Once all conditions are accepted by the National Variety Release Committee, the variety is released and the research institute is mandated to produce the breeder seed.

The Grains and Legumes Development Board (GLDB) then acquires the breeder seed to produce foundation seed. Hitherto, GLDB was the only organization mandated to produce foundation seed, but as a result of increasing demand for foundation seed, research institutions are now also allowed to produce foundation seed.
Foundation seeds are then acquired by seed companies and seed growers to produce seeds that are certified for sale to agro-dealers, NGOs and in some cases directly to farmers or grain producers. The Ghana Seed Inspection Division of MoFA is mandated to inspect and certify the production and distribution of foundation and certified seeds.

Future activities/The way forward
The seed systems in Ghana, both formal and informal face some constraints. The study team is therefore seeking to conduct additional analysis in order to identify a cost effective seed delivery system in the country.

Socioeconomic Evaluation of On-Farm Drought Tolerant Maize Varieties

Prince Maxwell Etwire, Abdoulaye T., K. Obeng-Antwi, R.A.L Kanton, M. S. Abdulai, S. S. Buah, H. Haruna, E. Martey, A.N. Wiredu

Executive Summary

Maize is one of the most important food crops in Ghana even though its production has not reached self-sufficiency levels. Drought and Striga infestation are among the most important production constraints of maize in Ghana. Promising high yielding, drought and Striga tolerant maize varieties are being evaluated by CSIR and IITA in participatory on-farm trials and demonstrations. These varieties however need to meet farmers' varietal preferences in order for them to adopt. This study therefore sought to assess farmers' preference for the different drought tolerant maize varieties, and determine factors that influence their choices.

Introduction

Maize (*Zea mays* L.) is one of the most important food cereals in the developing world. It is not only the largest staple crop in Ghana but also the most widely cultivated crop accounting for majority of total cereal production. Additionally, maize is the largest commodity crop in the country second only to cocoa. The importance of maize to the economy of Ghana cannot therefore be overemphasized. The crop is a major source of food, feed and cash for many households in Ghana.

Methodology/Approach

The study used primary data collected through farmer interviews. Questionnaires were developed, tested and administered to maize farmers. Information captured by the questionnaire was mainly on socio-demographic characteristics, preferred maize varieties and reasons for preference.

A multi-stage sampling technique was employed by the study. All the districts and communities were purposively sampled because they hosted an on-farm trial of the Drought Tolerant Maize for Africa (DTMA) Project Phase III. At the community level, farmers were grouped by sex and 30 farmers were sampled through simple random technique. A total of 120 farmers were interviewed in 4 communities in 4 districts. In terms of agro-ecology, 30 farmers were sampled in the transitional zone.
Kendall's coefficient of concordance was used to test the level of agreement between farmers on their preferences and the ordered logistic regression was used to estimate the determinants of farmer's preference.

Results and Discussions

Scientific findings

Analysis of the results indicated that earliness is the most preferred trait required by farmers for their maize varieties. Those varieties with TZE (meaning early maize) in their pedigree received the highest ranking (2.38) in terms of farmer preference. Early and extra early maize varieties enable farmers to have an early harvest which is critical considering the fact that the harvesting period is usually the lean season. These varieties are also usually harvested before the end of the regular season thereby enabling the crop to escape some biotic and abiotic stresses that may affect regular maize production. The second most preferred varieties were the DT category (i.e. drought tolerant varieties) with the various local checks been ranked as the least preferred. Drought tolerant varieties are increasingly becoming important with increasing unreliability and unpredictability of the weather pattern. The Kendell's coefficient of concordance indicates that about 14 percent of the sample agrees with each other on the rankings. Area under maize cultivation, fertilizer usage and family size are the factors that were found to influence farmers' preference for improved maize varieties. These factors should therefore be considered in varietal promotion.

Future activities/The way forward

The preference study will be repeated to validate the findings. Gender issues will also be a key consideration. Adoption monitoring of the uptake of DT varieties is also planned for 2013.

Capacity Building of SME Seed Company Personnel in WCA on Marketing and Selling Directly to Smallholders and Business Management

Prince Maxwell Etwire, Abdoulaye T., Fulton J., Makan F., Martery E

Executive Summary

The project team received funding, from MAIZE CRP which is being implemented by CYMMIT, to train seed companies in Ghana, Nigeria and Mali on marketing and selling directly to smallholder farmers.

Introduction

Access to quality seed by farmers is key to improving productivity of maize in WCA. This will require the existence of a vibrant private seed sector who will deliver the seed to farmers at an effective cost. For sustainable growth, seed companies need to develop tools to allow them to sell directly to the millions of small farmers in WCA that need improved maize seeds.

Methodology/Approach

Organisation of a day's training workshop is the approach adopted by the team to build the capacity of seed companies on effective and efficient marketing.

Results and Discussions

Scientific findings

A training workshop has been organized for seed companies in Nigeria. The capacity of 50 personnel of seed companies were built on techniques of marketing and selling to smallholder farmers.

Future activities/The way forward

Trainings sessions would be organised for seed companies in Ghana and Mali.

Multi-stakeholder Platform (MSP) Processes for Rice-based Systems

Prince Maxwell Etwire, C. M. Raboanarielina, W. Dogbe, E. Martey, J. Yirzagla, R.K Owusu, Esther Wahaga

Executive Summary

In line with AfricaRice's rice sector development concept, two rice sector development hubs have been identified in northern Ghana namely the Navrongo hub in the Upper East Region and the Savelugu hub in the Northern Region. The criteria for selecting MSP locations was based on secondary data including population, socioeconomic, agricultural, and rice production data, as well as technical reports from MoFA and CSIR-SARI.

Introduction

The rice value chain comprises a wide range of actors. These include various stakeholders such as input suppliers, farmers/producers, processors, millers, traders, consumers, local authorities, administrative (extension) partners, and other private and public-sector organizations, such as development and non-governmental organization (NGO) partners who provide support services.

MSP facilitates the organization and prioritization of different actors' interests and activities by providing an opportunity for individuals and groups to come together and openly discuss their respective needs.

Methodology/Approach

The establishment of a MSP is a dynamic iterative process involving mentoring and coaching through regular technical backstopping visits.

Results and Discussions

Scientific findings

Monthly MSP meetings have been facilitated, executives have been elected, registration process has commenced and activities are being implemented to help MSPs achieve their short term goals.

Future activities/The way forward

The team will continue with monthly meetings and capacity building of MSPs to be self-sustaining.

ENTOMOLOGY PROGRAMME

Mumuni Abudulai, Jerry Asalma Nboyine and Afia Serwaa Karikari

Executive Summary
Three projects spanning around three crop commodities were executed under the entomology program of the Northern Region Farming System Research Group in 2012.
Peanut Entomology: Three activities were carried out under the broad title "Improved West African peanut production for enhanced health and socioeconomic status through the delivery of research-based production system in Ghana. *Field screening of peanut genotypes* and cultivars for resistance to leaf spot diseases; *Field evaluation of pre- and post- emergence herbicides* for weed control in peanut in northern Ghana.
Participatory integrated pest management of peanut in northern Ghana
Soybean Entomology: Effect of planting date and soybean cultivar on incidence of insect pests, damage and yield of soybean
Cowpea Entomology: Two activities were carried out under the title "Evaluation of Planting Date, Cultivar and Insecticide Spraying Regime for Control of Insect Pests of Cowpea in Northern Ghana". *Evaluation of planting date*, cultivar and insecticide application for control of insect pests of cowpea in northern Ghana; *Evaluation of insecticide spraying* regime and cultivar for control of insect pests of cowpea
Cotton Entomology: a) Field evaluation of insecticides for control of insect pests in cotton, with special reference to the bollworm complex, and impact on nontarget arthropods

The experimental procedures and result highlights and discussions are discussed in the succeeding pages.

Improved West African peanut production for enhanced health and socioeconomic status through the delivery of research-based production system in Ghana

Mumuni Abudulai, Jerry Asalma Nboyine

Field Screening of Peanut Genotypes for Resistance to Leaf spot Diseases

Introduction
Peanut or groundnut is important as a food and cash crop in Ghana. About 439,030 MT was produced on 464,710 hectares in 2003 (SRID 2004). However, peanut yields in Ghana are low averaging less than 1000 kg/ha compared to an average of 2500 kg/ha obtained in developed countries such as the United States of America. Early and late leaf spot caused respectively by *Cercospora arachidicola* S. Hori and *Cercosporidium personatum* Berk. & M.A. Curtis, are major diseases of peanut that can reduce yield by as much as 50% (Shokes and Culbreath 1997). The principal recourse for control is the use of fungicides. However, in Ghana few farmers currently carry out control for these diseases in their peanut farms due largely to lack of resources to use recommended chemical control. The objective of this study was to field screen peanut genotypes and cultivars for resistance to early and late leaf spot diseases. This

will enable us to identify resistant cultivars that are better adapted to the farming conditions of northern Ghana.

Materials and Methods

Field tests were conducted at Nyankpala in 2012 to evaluate 21 peanut genotypes and cultivars for resistance to early and late leaf spot diseases. Eleven of the genotypes and cultivars were obtained from the breeding program in CSIR-SARI while the remaining nine were obtained from our collaborators in Burkina Faso (Table 70).

Table 70. List of peanut genotypes and cultivars and source for the study in Nyankpala, 2012.

Entry	Identity of genotype or cultivar	Source
1	NC 7	Tamale-Ghana
2	Nkatiesari	Tamale-Ghana
3	ICGV IS96814	Tamale-Ghana
4	ICGV-20 x F-Mix-39	Tamale-Ghana
5	ICGV-IS-92093	Tamale-Ghana
6	F-Mix x Sink 24	Tamale-Ghana
7	Chinese	Tamale-Ghana
8	F-mix	Tamale-Ghana
9	Doumbala	Burkina Faso
10	TS-32-1	Burkina Faso
11	PC 7979	Burkina Faso
12	GM 204 (123)	Burkina Faso
13	ICGV 86124	Burkina Faso
14	ICGV 97188	Burkina Faso
15	ICGV 86024	Burkina Faso
16	ICGV 86015	Burkina Faso
17	GM 656	Burkina Faso
18	GM 155	Burkina Faso
19	GM 120	Burkina Faso
20	GM 663	Burkina Faso
21	GM 324	Burkina Faso

The experimental design was a randomized complete block with three replicates of each genotype and cultivar. Plot sizes were four rows 4 m long by 2 m wide. Leaf spot disease ratings were conducted at harvest using the Florida scale of 1-10 based on visual observations (Chiteka et al. 1997). The genotypes were also assessed for defoliation at harvest.

Summary of Results and Discussions

CGV IS 98814, F-Mix x Sink 24, ICGV 86015, GM 656, GM 155, GM 120, GM 663, GM 324 and ICGV 86024 recorded the least scores for early leaf spots and therefore exhibited the greatest resistance to early leaf spots (Table 71). .Similarly, the GM genotypes and ICGV 86024 and ICGV IS96814 had the least scores for late leaf spots and were the most resistant to late leaf spots compared to the other genotypes and cultivars. The highest score of both early and late leaf spots were recorded for the susceptible cultivars Chinese, Doumbala among others.

Table 71. Effect of peanut lines and cultivars on severity of leaf spot diseases, number of pods per plant , haulm weight and pod yield at Nyankpala.

Treatment	Disease score		Pods per plant	Haulm weight (Kg/Ha)	Pod Yield (Kg/Ha)
	ELS @ 90DAP	LLS @ 90DAP			
NC 7	4.77a	5.77a	**22.10ab**	833.3abc	958.3
Nkatiesari	4.40a-d	5.33a-d	17.10bcd	708.3b-e	541.7
ICGV IS96814	**3.40f**	4.40fg	17.68bcd	708.3b-e	1166.7
ICGV-20xF-Mix-39	4.40a-d	5.60abc	15.43bcd	708.3b-e	708.3
ICGV-IS-92093	4.60ab	5.47abc	17.53bcd	**958.3a**	958.3
F-Mix x Sink 24	3.80def	4.87def	16.87bcd	791.7a-d	791.7
Chinese	5.8a	6.67a	9.53e	583.3d-g	542.4
F-mix	4.43abc	5.20cde	15.00cd	833.3abc	1208.3
Doumbala	4.20a-e	5.27bcd	16.13bcd	375g	791.7
TS-32-1	4.60ab	5.53abc	14.23d	541.7efg	625.0
PC 7979	4.13b-e	5.20cde	18.07 bcd	791.7a-d	1041.7
GM 204 (123)	4.67ab	5.57abc	13.50d	791.7a-d	791.7
ICGV 86124	4.53ab	5.53abc	16.13bcd	625.0c-f	791.7
ICGV 97188	4.57ab	5.73ab	16.80bcd	583.3d-g	1250.0
ICGV 86024	**3.40f**	4.57fg	16.23bcd	750.0a-e	916.7
ICGV 86015	**3.87c-f**	4.87def	15.13cd	583.3d-g	833.3
GM 656	**3.40f**	**4.30g**	**20.97abc**	625.0c-f	791.7
GM 155	**3.60ef**	4.53fg	12.90d	458.3fg	683.3
GM 120	**3.73ef**	4.77efg	13.47d	**875.0ab**	875.0
GM 663	**3.67ef**	4.67fg	**26.53a**	666.7b-f	708.3
GM 324	**3.87c-f**	4.87def	17.63bcd	**983.3a**	791.7
P>F	<0.0001	<0.0001	0.0470	0.0006	0.1396
CV(%)	9.12	5.85	23.87	20.62	15.70

The greatest number of pods per plant was recorded on GM 663, GM 656 and NC 7 while the least number of pods per plant was recorded on chinese. GM 324 and ICGV-IS-92093 also produced the greatest haulm weight while the least haulm weight was recorded on Doumbala. Pod yield was not significantly different among the cultivars

Field Evaluation of Pre- and Post- Emergence Herbicides for Weed Control in Peanut

Introduction

Peanut production in Ghana is constrained by weeds, mainly because of its slow initial growth. Weed interference especially within the first six weeks after planting result in significant loss in yield. Yield loss due to weed interference was estimated to be between 50 to 80% in West Africa (Akobundu 1987; Dzomeku et al 2009). Farmers in Ghana use both manual hand weeding and herbicides for control of weeds in crops. Pendimethalin is the most commonly used herbicide in peanut. The objective of the present study was to evaluate various pre- and post- emergence herbicides for weed control in peanut.

Materials and Methods

Field experiments were conducted at Nyankpala to evaluate the efficacy of four herbicides applied sole or in alternation and/or with supplementary weeding (Table 72) for control of weeds in peanut. Unweeded control and farmers' practice of two hand weedings were included as checks.

Table 72. Pre and post emergence herbicide treatments applied to peanut fields in Nyankpala, 2012

Treatments	Time of application
Pendimethanlin (Pre-E)	Pre-E + HW 4 WAP
Gallant Super (Post-E)	4 WAP + HW 6 WAP
Agil (Post-E)	4 WAP + HW 6 WAP
Basagram (Post-E)	4 WAP + HW 6 WAP
Pendimethalin + Gallant	Pre + 4 WAP
Pendimethalin + Agil	Pre + 4 WAP
Pendimethalin + Basagram	Pre + 4 WAP
Pendimethalin alone	Pre-E-
Gallant alone	4 WAP
Agil alone	4 WAP
Basagram alone	4 WAP
Weedy check	Control
Farmers method (2 HW)	3 WAP + 6 WAP

HW – Hand weeding, WAP – weeks after planting

Data were collected on weed species present and their dominance on the field before and after treatment application, Weed biomass, number of pods per plant, pod yield and haulm weight were taken at harvest.

Summary of Results and Discussions

The results showed that all the herbicide treatments significantly improved yield over the weedy check. On treated plots, yield was higher with the farmer's practice of two hand weedings at 3 and 6 WAP, application of the pre-emergence herbicide pendimethalin with one supplementary hand weeding at 4 WAP, and also with pendimethalin treatment followed with a post-emergence herbicide at 6 WAP than a post-emergence herbicide treatment alone. Weed biomass was the highest in the weedy check and in the gallant alone treatment and lowest in the pendimethalin plus a supplementary hand weeding, gallant or agil or basagram treatment with a supplementary hand weeding and in the farmers practice of two hand weedings. Peanut haulm weight was negatively and significantly correlated with weed biomass, but not with pod yield.

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Participatory Integrated Pest Management in Peanut

Introduction

Peanut or groundnut is important as a food and cash crop in Ghana. About 439,030 MT was produced on 464,710 hectares in 2003 (SRID 2004). However, peanut yields in Ghana are low averaging less than 1000 kg/ha compared to an average of 2500 kg/ha obtained in developed

countries such as the United States of America. Soil arthropod pests and diseases are the main causes for the poor yields. Major soil arthropod pests include termites, white grubs, millipedes and wireworms while early and late leaf spots are the major diseases of peanut in Ghana. Yield losses up to 70% have been attributed to these pests in West Africa.
Farmers generally do not carry out any control for these pests in their peanut farms due largely to inadequate knowledge about these pests and their control. Some farmers would even mistake leaf spots disease for signs of maturity. This poor knowledge is due to inadequate extension service delivery system and the fact that technologies are generally developed in isolation of farmers. Farmer participatory IPM is one approach that can build the capacity and confidence of farmers to enable them make informed decisions about their farm operations. Farmer participatory IPM recognizes the indigenous knowledge of farmers and puts farmers at the forefront of technology generation (van Huis and Merrman 1997). This empowers farmers with the capability and capacity to make good choices for sustainable crop production.
The objective of this study was to improve peanut yields for farmers through integrated pest management (IPM) -based farmer participatory research through Farmer Field School.

Materials and Methods
The study involved group training of farmers in peanut crop and pest management. Participating farmers were selected from Sung and Zankali in the Karaga district of the northern region, with the assistance of staff of the Ministry of Food and Agriculture. The farmers grew and monitored the peanut crop throughout the season. The two treatments studied were 1) Farmers' practice (FP) and 2) IPM. Proven crop management practices, e.g. at-pegging treatment of soil with chlorpyrifos for control of soil pests and fungicide treatments for control of leaf spot diseases were imposed on IPM plots. Farmers at each training location worked in five groups representing five replications, and each group tested the two treatments on their plots. The training sessions were interactive and held once every two weeks. Components of the training included learning crop growth habits, preventive measures for soil arthropod pests and diseases such as maintaining good farm hygiene, skills in arthropod pests and diseases identification and their management. Also, special topics on relevant areas of peanut production were held to further build capacity of farmers.

Summary of Results and Discussions
Twenty (20) men and eight (8) women were trained at Sung while 12 men and 8 women were trained at Zankali for a total of 32 men and 18 women. Farmers identified soil pests and leaf spot diseases and learnt control practices as well as best agronomic practices to minimize pest attack. A few of the farmers now control leaf spot diseases with fungicides.

Effect of Planting Date and Cultivar on Insect Pest Incidence, Damage and Yield of Soybean

Mumuni Abudulai, Jerry Asalma Nboyine

Introduction
Soybean was said to be free from insect pests attack in the earlier years of its introduction in Africa (Jackai et al. 1984). However, with the increased popularity of the crop over the years

and increased area of cultivation, insect pests have now become important as damage by insects have been widely reported (Abudulai et al 2012; Jackai et al., 1988, 1990). A study conducted at Nyankpala in northern Ghana revealed that *Spodoptera* spp., *Zonocerus variegatus* L. *Sylepta derogata* F. and a complex of pod-sucking bugs (PSBs) including *Nezara viridula* L, and *Riptortus dentipes* F. attack the crop (Abudulai 2012). Yield losses due to these insects are up to 30% in unprotected soybean fields in Ghana (Abudulai et al.2012) and up to 60% in Nigeria (Anyim 2003). Much of the yield lost is attributed to attack by the pod-sucking bugs (PSBs) complex that is the most important insect pests of soybean in Africa (Jackai and Singh (1987). PSBs feed on developing pods and seeds resulting in pod and seed abscission as well as seed shriveling and decay (Abudulai et al. 2012).

Despite the importance of these pests, farmers seldom control pests on their soybean fields resulting in poor yields. Insecticide control is the recommended practice for these insects in soybean. However, majority of soybean farmers are peasants and cannot afford insecticide control. The objective of this study therefore was to exploit host plant resistance in existing soybean cultivars and different planting dates for sustainable pest management in soybean.

Materials and Methods

Field experiments were conducted at Nyankpala in the Northern Region. The factorial experiment comprised four soybean cultivars of different maturity groups and four planting dates that were protected or unprotected against insect pests. The experimental design was a split split with four replications. The soybean cultivars tested included TGX 1799-8F (early maturity), TGX 1834-5F (medium maturity), Jenguma (medium maturity) and Salintuya II (late maturity). They were planted at two weeks intervals starting from 18 June 2012. June is the normal planting time for soybean in the Northern Region. Plots consisted of six row 5 m long. Inter and intra row distances of 0.60 m and 0.05 m were maintained.

Data collection

Insects were sampled on plants beginning two weeks (V2) after planting of each maturity group and planting date using the beet cloth method of Kogan and Herzog (1980). Data on pests' incidence and densities were recorded until harvest (V8) (Fehr and Caviness 1977). Defoliation by leaf eating insects were estimated in each plot by randomly selecting two trifoliate leaves on 10 plants to assess the percent leaf surface missing using a scale of 5-100%. At maturity, pods were harvested for yield data from the middle four rows. A sample of 100 pods was examined for characteristic pod and seed damage by PSBs, which was shriveling and decay of pods and seeds. The pods were shelled to determine seed damage. All data were analyzed using SAS (SAS Institute 1998).

Summary of Results and Discussions

There was a 3-way interaction effect of planting date, variety and spraying regime on percentage pod damage. Pod damage was lower on sprayed plots than unsprayed plots. Across varieties, pod damage was lower when soybean was planted on 16 July than at other planting dates. TGX 1834-5F sustained significantly less pod damage than the other varieties in all spraying regimes. There was also a significant planting date by spraying regime interaction on percentage defoliation. On both sprayed and unsprayed plots, defoliation was lowest at the first planting date of 18 June and highest at the third planting date of 16 July. Defoliation was lower on sprayed than unsprayed plots and also at the first planting date of 16 June. There was a significant effect of planting date by variety interaction on percentage seed damage. For Jenguma and Salintuta 2, seed damage was lower at the first planting date of 18 June whereas for TGX 1779-8F and TGX 1834-5F, damage was lower at the third planting date of 16 July. Seed yield was significantly affected independently by planting date, variety and also by spraying regime. Across spraying regimes, yield was highest at the first planting date of 18 June and lowest at the second and forth planting date of 2 July and 30 July, respectively. Also, higher yields were recorded on sprayed than unsprayed plots. For the varieties, yield was highest with TGX 1834-5F and lowest with Jenguma.

Evaluation of Planting Date, Cultivar and Reduced Insecticide Treatment for Management of Cowpea Insect Pests in Northern Ghana

Mumuni Abudulai, Jerry Asalma Nboyine

Introduction

Cowpea, *Vigna unguiculata* (L) Walp, is a major staple crop in Ghana. The leaves, green pods, green peas and the dry grain are eaten as food and the haulms are fed to livestock. Cowpea constitutes the cheapest source of dietary protein for majority of people in Africa who lack the necessary financial resources to acquire animal protein (Tarawali et al., 1997). Sale of the grain also provides income to farmers and traders in Ghana. As a leguminous crop, cowpea also fixes atmospheric nitrogen into the soil which is of major importance in African farming where most of the lands are exhausted and farmers lack the needed capital to purchase chemical fertilizers. Moreover, cowpea is shade-tolerant and therefore compatible as an intercrop in the mixed cropping systems widely practiced by small holder farmers (Singh and Sharma, 1996).

Despite its importance, cowpea yields on farmers' field are low averaging less than 500 kg ha^{-1}. The major cause of the low yields is problem of insect pests that attack the crop throughout its growth, although the most important insect pests are those that attack the crop from flowering (Jackai et al. 1992). Insecticide application is the recommended practice for control of insect pests on cowpea. However, most farmers in Ghana are resource-poor and require pest management strategies that are cost-effective and sustainable. The use of insecticides must be minimized because of high cost and harmful effects on the environment. The objective of this study was to identify the appropriate combination of planting date and insecticide spray regime for the control of insect pests of cowpea in northern Ghana.

Materials and Methods

Two experiments were conducted each at Tingoli in the Tolon-Kumbungu district and Malzeri in the Yendi district of the Northern Region In Experiment 1, the treatments consisted of four planting dates and 6 cowpea cultivars of maturity periods ranging from early to late, which were sprayed with insecticide or unsprayed. The experimental design was a split-split-plot in a randomized complete block design with three treatment replications. Insecticide spray constituted the main plots, planting date as sub-plots and cowpea cultivars as sub-sub-plots. The six cowpea cultivars used were IT99 K-573-1-1 and IT99 K-573-3-2-1 obtained from IITA, Bawutawuta, Songotra and Padi Tuya obtained from the breeding program at CSIR-

SARI and a farmer's variety. Planting dates were mid-July, late-July, mid-August and late-August. Sub-sub-plots consisted of 4 rows 5 m long spaced at 0.60 between rows and 0.20 m between plants in a row. The replicates and main plots were separated by 2 m alleys while the sub and sub-sub plots were spaced 1 m apart. In Experiment 2, the treatments comprised six cowpea cultivars as in Experiment 1 and four insecticide spray regimes. The insecticide spray regime treatments consisted of 1) no spray (untreated control), 2) spraying once at 50% flowering, 4) two sprays, one at flower bud initiation and a second at early podding and 4) three sprays, one each at flower bud initiation, 50% flowering and 50% podding. The experimental design was a split-plot in a randomized complete block with insecticide spray regime as the main plots and cowpea cultivars as sub-plots. The treatments were replicated four times. Sub-plots consisted of 4 rows 5 m long spaced at 0.60 between rows and 0.20 m between plants in a row. The replicates and main plots were separated by 2 m alleys while the sub-plots were spaced 1 m apart.

Data collection.

Data were collected on agronomic parameters such as percent germination and days to 50% flowering and maturity. Insect pests were sampled from the two middle rows of each plot. Populations of thrips and *Maruca vitrata* were estimated beginning at flower bud formation until 50% podding by picking 20 flowers from the two middle rows to the laboratory to count the insects. Populations of pod-sucking bugs (PSBs) were estimated by counting nymphs and adults in the two middle rows of each plot. Pod damage by PSBs and *Maruca* were estimated from a sub-sample of 100 pods after harvest. Data also were taken on yield parameters such as number of pods per plant, number of seeds per pod, haulm and seed yield.

Summary of Results and Discussions

Experiment 1: Evaluation of planting date, cultivar and insecticide spraying regime for control of insect pests of cowpea in northern Ghana,

Nyankpala

The 3-way interaction of spraying regime, planting date and variety was significant for number of thrips per 20 flowers. Thrips populations were lower on sprayed than unsprayed plots for all the varieties and planting dates. Thrips populations were lower at the first and third planting dates of 13 July and 10 August. Populations were higher at the on unsprayed plots at the last planting date of 17 August. On unsprayed plots, IT99K-573-1-1 and IT99K-5-2-1 sustained a lower damage than the other varieties.

There was a significant interaction effect of planting date and vasriety on percentage pod damage. Bawutawuta sustained the least pod damage when planted at the first planting date of 13 July than at other planting dates. Similarly, IT99K-573-1-1 sustained the least pod damage when planted at the second planting date of 27 July

There was a significant interaction effect of spraying regime and planting date on seed yield. Higher yields were recorded for cowpea planted on 13 July and 27 July while the lowest yield was recorded for the last planting date of 24 August, for both sprayed and unsprayed plots. Yield was higher on sprayed plots than unsprayed plots.

Experiment 2: Evaluation of insecticide spraying regime and cultivar for control of insect pests of cowpea in northern Ghana,

Nyankpala

There was a significant interaction effect of spraying regime by cowpea cultivar on the number of pods per plant. Generally, the number of pods per plant was lowest on untreated plots than treated plots. IT99k-573-1-1 and Padituya had the least number of pods when sprayed only once at flowering than other cultivars. The number of pods was lowest on untreated or plots sprayed only once. Similarly, the number of seeds per pod and yield were generally lowest on untreated plots for all cultivars. Yield was highest when plots were sprayed twice at budding and podding ot thrice at budding, flowering and podding.

Field Evaluation of Insecticides for Control of Insect Pests in Cotton, with Special Reference to the Bollworm Complex, and Impact on Nontarget Beneficial Arthropods

Introduction

Cotton is attacked in the field by a plethora of insect pests. Among these, the bollworm complex comprising the American bollworm, *Helicoverpa armigera* (Hubner); Spiny bollworm, *Earias* spp.; Pink bollworm, *Pectinophora gossypiella* **Saunders;** Sudan bollworm, *Diparopsis watersii* (Rothschild); and the False codling moth, *Thaumatotibia* (=*Cryptophlebia*) *leucotreta* Meyrick are the most destructive insect pests of cotton in Ghana and in the West African sub-region (Abudulai et al 2007). The adults of these insects invade cotton fields for oviposition from the late vegetative stage. The emerging larvae, which are the destructive stage, damage plant terminals and also chew into squares and developing bolls, resulting in abscission of these floral parts and loss in seed cotton yield. The feeding damage also predisposes the fruiting structures to infection by rot organisms. Also, the cotton stainer, *Dysdercus* sp., and other hemipteran bugs feed on the seed in open bolls affecting seed quality for germination while the extreta of these insects stain the lint. Other insect pests include aphids, *Aphis gossypii* Glover; whiteflies, *Bemisia tabaci* Gennadius; leafhoppers, *Jacobiella* (*Empoasc*a) *facialis* Jacobi that suck the sap from developing leaves and growing terminals causing leaves to curl or crumble. They also transmit viral diseases and excrete honey dew that contaminates lint. Moreover, the leaf worm, *Spodoptera littoralis* Boisduval; the looper, *Anomis flava* (Fabricius) and the leaf roller, *Haritalodes* (=*Sylepta*) *derogata* (Fabricius) are important defoliators in cotton.

The management of these insect pests is an integral part of an economic cotton production system. Insecticide application is the most common and also the most effective means of control for these insect pests in cotton in Ghana and many other cotton growing areas. Various insecticides with different chemistries are used for control. In Ghana, endosulfan, an organochlorine insecticide was one of the most effective and widely used insecticides for pest control in cotton, until 2006 when it was banned because of abuse and hazards to the environment. There is therefore the urgent need for an effective but less toxic insecticide as a suitable alternative and a replacement for endosulfan. The objective of the present study was to evaluate insecticides against cotton insect pests with particular reference to the bollworm complex. The ultimate aim was to find the most potent insecticide(s) or their combinations as a replacement for endosulfan.

Materials and Methods

The experiments were conducted at the research farm of the CSIR-Savanna Agricultural Research Institute near Nyankpala and on a farmer's field at Walewale in the northern region of Ghana in the 2012 cropping season. Both Nyankpala and Walewale are important cotton growing areas in Ghana. The treatments included alternate applications of the insecticides, Tihan 175 O-Teq, Thunder 145 O-Teq, Oberon, Belt Expert and Polytrin C with or without seed treatments with the fungicide/insecticides, Apron star 42 WS or monceren as listed in Table 73. The treatments rates used for the various chemicals are also listed in Table 74. All treatments were replicated four times in a randomized complete block design. Plots consisted of 10 rows 10 m long, with spacing of 0.75 m between rows and 0.30 m between plants in a row. The plots were planted to the cotton cv FK 37 at Nyankpala on 25 June 2012 and at Walewale on 29 June 2012. Plots were weeded twice at four and six weeks after planting. The plants were fertilized with 250 kg ha^{-1} Activa compound fertilizer after the first weeding and with 125 kg ha^{-1} Sulfan (Ammonium sulphate) after the second weeding.

Table 73. Insecticide treatment schedule- 2012

Insecticide Treatments
Monceren - Tihan (1st 2nd sprays) – Oberon (3rd spray) –Thunder (4th spray) – Oberon (5th spray) – Thunder (6th spray)
Monceren - Tihan (1st 2nd sprays) – Oberon (3rd spray) –Thunder (4th 5th 6th spray)
Belt Expert (1st 2nd 3rd 4th 5th 6th sprays)
Monceren – Belt Expert (1st 2nd 3rd sprays) – Thunder (4th 5th 6th spray)
Monceren - Tihan (1st 3 sprays) + Thunder (4th-6th sprays)
Apron star - Tihan (1st 2nd sprays) – Polytrin C (3rd 4th spray) –Thunder (5th 6th spray)
Untreated control

Table 74. Active ingredients and treatments rates used for the various chemicals

Pesticide	Acive ingredient	Dosage/Rate
Monceren (seed treatment)	Imidacloprid +pencycuron + Thiram	0.375 L/100 kg seed
Apron Star 42 WS (seed trt)	Thiamethoxam + Metalaxyl-M + Difenoconazole	250 g/100 kg seed
Tihan 175 O-Teq	Spirotetramat + Flubendiamide	200ml/ha
Thunder 145 O-Teq	Imidacloprid + betacyfluthrin	200ml/ha
Oberon	Spiromesifen	250ml/ha
Belt Expert	Flubendiamide +Thiaclopride	150ml/ha
Polytrin C	Profenophos + Cypermitrin	500ml/unit or 1L/ha

Insecticide applications begun at 35 days after planting (DAP), which was during the late vegetative or square initiation stage and was continued at two weeks intervals for a total of six sprays in the season. The treatments were applied according to the rates recommended on the label using a CP-15 knapsack sprayer with water delivery rate of 225 l $ha^{-1.}$

Summary of Results and Discussions

Nyankpala Tests

Effect of treatments on insect pest densities

Irrespective of the insecticide treatment used, number of bollworms per plant was significantly (P<0.05) lower in treated plots than untreated control plots i.e treatment 7. The numbers of bollworms did not differ significantly among the insecticide treatments. The highest number of cotton stainers per plant was recorded in treatment 1, but this number was not higher than those recorded for treatment 3. The number of cotton stainers per plant was significantly lower (P<0.05) in the insecticide treatments 2, 4, 5, 6 and 7 compared to treatment 1.

Effect of treatments on nontarget organisms

Significantly higher numbers of spiders per plant were observed in untreated control (treatment 7) than those that received insecticide treatments, except those for treatment 3. The numbers of ladybird beetles per plant was significantly higher in treatment 2 compared with treatment 6. However, the numbers of ladybird beetles in the other treatments were not lower than those for treatment 2. Significantly higher numbers of lacewings per plant were recorded in treatment 6 compared with the other treatments. However, the numbers of lacewings in the other insecticide treatments and control did not differ significantly from one another.

Walewale Test

Effect of treatments on insect pest densities

Insecticide treated plots recorded significantly lower (P<0.05) numbers of bollworms per plant compared with untreated control. There was no difference in the number of bollworms per plant among the different insecticide treatments. The number of cotton stainers per plant ranged from 29.9 to 46.6, but no statistical differences were detected among the treatments).

Effect of treatments on nontarget organisms

There was no statistical difference in the numbers of spiders per plant among the different treatments. For lady bird beetles, treatments 1 and 3 (Monceren-Tihan 175OD ($1^{ST}2^{ND}$ Sprays)-Oberon 3^{rd}-Thunder 4^{th}-Oberon 5^{th}-Thunder 6^{th} Spray and Belt expert only respectively) had the least number of beetles per plant while treatment 7 (Untreated control) had the greatest number of beetles per plant. There was no difference (P>0.05) between the number of lady bird beetles per plant on the control plots and those of treatments 2, 4, 5 and 6. Lacewings were recorded only in treatment 3 and 6.

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Nutrition versus Attack: Case Studies

Afia S. Karikari, W. Dogbe, M. Mawuenyah, E. Kuwornu

Introduction

Rice and sorghum crops are important staple food in Ghana and its consumption keeps increasing as a result of population growth, urbanization and change in consumer habits (MOFA, 2009) especially in the northern region of the country. Insects are common in cereal cropping systems especially in northern Ghana. Some feed on the crops but seldom cause yield loss. Other species, however, can become pests and cause significant production losses. They cause damage to the plants by feeding on leaves, stems and developing grains.Agroecologists contend that links between healthy soils and healthy plants is fundamental to ecologically based pest management. Hence, one of the means of ecological pest management is to improve plant health via improving and providing optimal physical, chemical and biological properties of soils (Altieri and Nicholls, 1999).

Studies suggest that the physiological susceptibility of crops may be affected by form of fertilizer used (Sohail *et al*., 2003). Many evidences have been highlighted where comparison between conventional versus organic fertilizers have shown high number of herbivores insects on conventionally managed plots than organically farmed crops (Magdoff, 1992; Altieri, 1994). There is possibility of changing the preference of insects by optimal plant nutritional requirement by altering the fertilizer level of a soil (Hendrix *et al*., 1990; Phelan *et al*., 1996) because by modifying the nutrient composition of crops, fertilizer practices can influence plant defenses.

The current study sought to evaluate the effect of different fertility rates on the incidence of insect pests, in northern region using rice and sorghum as case studies.

Nutrition versus Attack: RSSP's Direct Mulch Cropping Systems Experience: Case Study 1:

Objective:
To assess the effect of 3 fertilizer rates and different direct mulching combinations on insect pests' infestation in lowland and midland rice ecosystems.

Materials and Methods
In the 2 ecologies, the experiments were laid out in 2 blocks: one with strips of rice intercropped with the DMC cover crops and one with only the cover crops mixtures. The treatments were divided into three subplots representing three fertilizer levels (F0, F1, and F2). The DMCs and fertilizer rates are as follows:

Lowland:
DMC 9: Rice is planted in June. Stylosanthes guianensis is broadcasted in the rice at the end of the rainy season when the water has withdrawn from the field.

DMC 10: Rice is planted in June. A mixture of Braccharia ruziziensis and Stylosanthes g. is broadcasted at the end of the rainy season when the water has withdrawn from the field.

DMC 11: Rice is planted in June. A mixture of Braccharia ruziziensis, Centrosema and Sesbania is broadcasted at the end of the rainy season when the water has withdrawn from the field.

DMC 12: Rice is planted in June. Cowpea and water melon are planted at the end of the rainy season when the water has withdrawn from the field.

DMC 13: Rice is planted in June. A mixture of Sorghum, Sesbania, Centrosema, Finger millet and Crotalaria Juncea is broadcasted at the end of the rainy season when the water has withdrawn from the field.

Control: Conventional rice production with Nabogo rice.

Midland:

DMC 4 : Rice and stylosanthes g. are planted within the same day in June.

DMC 5 : Rice is planted in June. Stylosanthes guianensis will be broadcasted in the plot after the flowering stage of rice.

DMC 6 : Rice is planted in June. Stylosanthes guianensis will be planted in hole in the plot after the flowering stage of rice.

DMC 7 : Rice is planted in June. A mixture of Braccharia ruziziensis, Sesbania, Centrosema, Crotalaria juncea is planted in the field at flowering stage of rice.

DMC 8 : Rice is planted in June. Cow pea and water melon are planted at the time water has withdrawn from the field. The variety of cow pea is a short duration variety that can produce grains for consumption. The crop will use the final moisture in the soil at the end of the rainy season.

Control: Conventional rice production system with Gbewaa rice.

The three fertilizer rates used for the 2 ecologies are as follows:
F0 = No fertilizer
F1 = 42.0 kgN/ha + 29.4 kgP/ha + 22.5 kgK/ha
F2 = 123.0 kgN/ha + 58.8 kgP/ha + 45.0 kgK/ha

The treatments were laid out differently in terms of the DMC+ rice combinations and the number of repetitions but the fertilizer rates were the same for the two ecologies (Figs 30 and 31). The lowland trial was repeated 4 times (Fig 30) and the midland was repeated threetimes (Fig 31). The data was collected from the Nyankpala rice fields, fortnightly during tillering to maturity to identify and record the insects and score their damage.

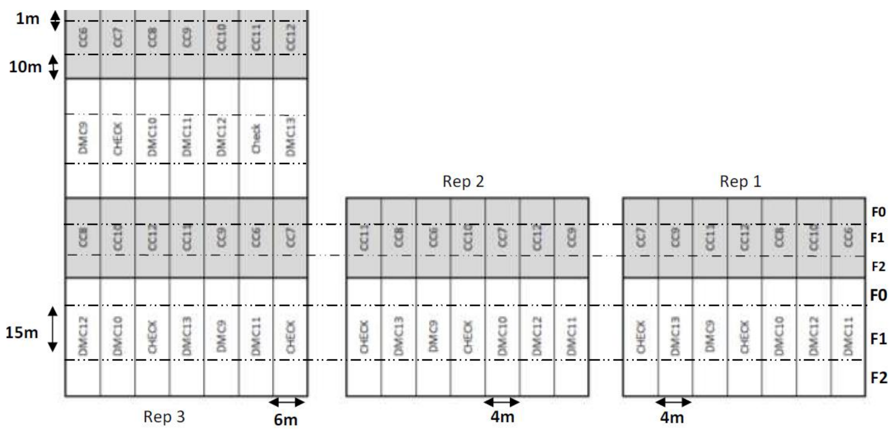

Fig 30: Layout of DMC experiment in the lowland ecology

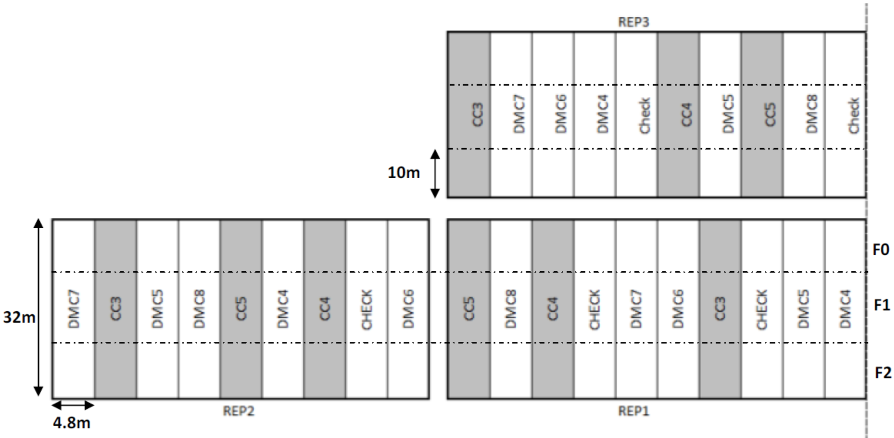

Fig 31: Layout of DMC experiment in the midland ecology

Results and Discussion

Insects found in the ecologies

Insects identified within the rice ecologies were grasshoppers (GH), stemborers (SB), shootflies (SF), leafminers (LM), leaf-folders(LF), spittle bugs (SPB) and others (OT). The others were insects that were found in very minor and isolated cases. These were gall midges, flea beetles, sucking bugs, planthoppers. The tillering stage of the midland ecology recorded a population hike of gall midges accounting for a higher incidence of OT (Table 75). The midland ecology significantly ($P<0.001$) recorded higher number of insect incidence than the lowland. This is probably due to the aromaticity of Gbewaa rice which was the variety used for the midland variety.

The maturity stages were recording the highest incidence of the 3critical pests.

Fertility levels versus insect incidence

Even though most of the insects did not show significant differences in incidence among the 3 fertility levels the different insects showed different reactions to the fertilizers (Tables 2a&b). For instance it could be observed that leafminer (LM) attack was higher than the spittle bugs (SPB) but within the different levels of fertilizer under LM, the differences were not so wide.

Table 75: Incidence of the identified insects

Ecology	Growth Stage	Order of Prominent Insects	Incidence (%)
Lowland	Tillering	LM> SB> GH	23: 18: 14
	Panicle Initiation	LM> SB> GH	31: 20: 18
	Maturity	LM> SB> GH	40: 22: 15
Midland	Tillering	OT> LM&SB> GH	30: 19: 14
	Panicle Initiation	LM> GH> SB	36: 19: 18
	Maturity	LM> GH> SB	38: 20: 17

Table 76a: Fertilizer rates versus insect incidence in lowland ecology

Fertilizer	Incidence of Insects (%)						
Rates	GH	LM	SB	SF	LF	SPB	OT
F0	3.58	4.58	3.49	2.13	2.60	1.55	2.61
F1	3.48	4.43	3.37	2.40	2.65	1.49	2.49
F2	3.27	4.24	3.31	2.10	2.61	1.66	2.39
LSD	0.36	0.34	0.35	0.64	0.34	0.36	0.37
SED	0.16	0.16	0.16	0.29	0.15	0.16	0.17

Table 76b: Fertilizer rates versus insect incidence in midland ecology

Fertilizer	Incidence of Insects (%)						
Rates	GH	LM	SB	SF	LF	SPB	OT
F0	3.31	4.17	2.94	1.91	1.63	1.26	2.82
F1	3.21	4.09	3.20	1.96	1.88	1.191	2.31
F2	3.28	4.19	3.20	2.08	1.70	1.151	2.66
LSD	0.16	0.37	0.47	0.30	0.22	0.27	1.02
SED	0.07	0.17	0.21	0.13	0.10	0.12	0.47

Direct Mulch Cropping (DMCs) Versus Insect incidence
Within the **lowland** ecology, P-values showed non-significant figures for all the DMC treatments. This means that the different DMC treatments did not influence the incidence of the insects.

In the **midland** but for two of the insects, again the DMCs did not affect the feeding behavior of the insects. The two affected insects are leaf folders and shootflies. For the leaf folders, at $P<0.025$, DMC6 had the highest insect incidence of 2.114 and the control recorded the least incidence of 1.387. Tillering was the stage with the highest incidence of insects under DMC6. In the case of the shootflies, DMC7 and DMC6 recorded the highest incidence ($P<0.04$) of 2.29 and 2.20 respectively, and again the control recorded the least; 1.418 and the highest record was at the tillering stage.

Nutrition versus Attack: SARI-CORAF Strengthening Seed System Research and Development Experience: Case Study 2:

Afia S. Karikari, I.D.K. Atokple, S.S. Buah, A. L. Abdulai, P. M Etwire, P. Asungre

Objective:
To assess the effect of three fertilizer levels on insect pest infestation of some sorghum varieties.

Materials and Methods
The experiment was conducted in Yendi and Savelugu. The varieties used were Kapaala, Dorado and Kadaga (farmer variety).

The fertilizer levels:
Three fertilizer rates (Recommended rate, Higher rate and no fertilizer (control) were used as shown below:

- Recommended rate of fertilizer (RR) = 250 kg NPK +125 kg SA/ha
- Higher rate of fertilizer (HR) (250 kg NPK + 250 kg SA/ha).
- No fertilizer (NR)

The crop was sampled during four (4) critical stages of growth namely emergence, pre-flowering (vegetative) flowering and maturity. Within each district of the 3regions, there were 2 replications of 12 plots per rep for data collection. At each critical stage, each district was visited to record insect species visiting the various varieties and their damage symptoms.

Results and Discussion
Insect Pests Identified on the Sorghum Varieties
All three sorghum varieties attracted various insects throughout the growing season. Major insect pests that attacked the crops within the two municipalities were grasshoppers (GH) stemborers (SB), leafminers (LM), spittle bugs(SPB) sorghum midges (SM), headbugs (HB) and others (OT). The others were insects that were found in very minor and isolated cases. These were beetles and planthoppers. Leafminers grazed (mined) the leaf surfaces and also created patterns on the leaf surfaces of the crops. Grasshoppers were found chewing the sorghum leaves and stemborers were identified by deadhearts and the characteristic holes created on the leaf surfaces as a result of the larval feeding. The damage symptoms of leafminers, grasshoppers and stemborers were found throughout the growing period of the crops.

Sorghum midges and headbugs were the most serious pests found on the sorghum during the reproductive stage. In relation to leafminers, stemborers and grasshoppers, sorghum midge and headbugs had relatively lower incidence (Tables77 and 78). However the effect of their infestations was very severe causing almost 100% yield loss. Several larvae of the midge were found in the glumes which resulted in many chaffy florets as in severe blast infestation. The headbugs on the other hand caused a lot of shriveled grains and mould infestation. Kapaala and Dorado varieties were found to be the most affected, probably due to the fact that they had more compact heads than Kadaga (the farmer variety). This confirms the observation in an earlier study by Tanzubil and (Dekuku1991).

Fertilizer rates versus insect incidence
The insect pests seemed to be exhibiting variable incidence intensity under the three fertility levels. Judging from the LSD (0.05) values, with regards to the different types of insects, there were significant differences observed in the effects of the different fertilizer rates on pests' incidence (Tables 77a & b). However for the same insect species, there were no significant differences seen in the effects of the different fertilizer rates on the insect pests' incidence. Nonetheless, the recommended fertilizer rate (RR) seemed to have some effect on headbug (HB) incidence.

Varieties versus Incidence

Similar pattern of results described above, was observed under the variety and pest incidence correlation (Table 77). Leafminers maintained their dominance over the other insects in terms of their incidence on the three sorghum varieties. Headbug incidence was however significantly higher in the two improved varieties (Dorado and Kapaala) than the farmer variety.

Fertility levels versus insect incidence

Table 77a: Fertilizer rates versus insect incidence on sorghum in Yendi

Fertilizer	Incidence of Insects (%)						
Rates	GH	LM	SB	HB	SM	SPB	OT
NR	4.22	5.59	4.12	1.68	1.65	2.96	2.88
RR	4.28	5.28	3.89	2.48	1.70	2.50	2.63
HR	4.32	5.24	3.82	1.91	1.73	2.45	3.19
LSD	0.66	0.57	0.88	0.82	0.53	1.04	1.28
SED	0.30	0.26	0.40	0.37	0.24	0.47	0.59

Table 77b: Fertilizer rates versus insect incidence on sorghum in Savelugu

Fertilizer	Incidence of Insects (%)						
Rates	GH	LM	SB	HB	SM	SPB	OT
RR	4.28	5.14	4.53	1.250	1.185	2.47	1.92
HR	4.71	5.54	4.51	1.000	1.076	2.12	1.94
LSD	0.890	0.389	0.807	0.306	0.243	0.457	0.507
SED	0.364	0.159	0.330	0.125	0.099	0.187	0.207

Varieties versus Incidence (Note only results from Yendi presented since they were similar to that of Savelugu)

Table 78: Three sorghum varieties versus insect incidence on sorghum

Varieties	Incidence of Insects (%)						
	GH	LM	SB	HB	SM	SPB	OT
Dorado	4.00	5.37	3.80	2.49	1.78	2.75	3.49
Kadaga	4.48	5.39	4.20	1.18	1.54	2.58	2.44
Kapaala	4.35	5.35	3.84	2.40	1.76	2.57	2.78
LSD	0.47	0.48	0.73	0.97	0.63	0.61	0.98
SED	0.23	0.23	0.36	0.48	0.31	0.30	0.48

General Conclusions

The general conclusions for the Nutrition versus attack case studies are enumerated as follows:

- Leafminers, Stemborers and grasshoppers were the 3 most important pests found in the cereal cropping systems of northern region.
- The different insects in the cereal cropping systems responded differently to the different fertilizers and rates.

- In the rice ecologies, type of direct mulch crops and intercrop seem to affect the incidence of shootflies and leaf folders.
- Midges and headbugs are a real danger to sorghum production and calls for interventions like exploring the possibility of a biological control agent.
- Dorado and Kapaala seem to be more susceptible to the most critical pests than Kadaga.

Way forward

The way forward is to explore and develop management strategies for the identified critical pests of the cereal crops.

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Insect Pollinators of Jatropha curcas: GHAJA Project

A.S. Karikari, J.M. Kombiok

Objective: To assess the pollinators of Jatropha curcas in the Northern region of Ghana

Introduction: Insect pollinators had been found to be very effective in the pollination of *Jatropha curcas.* Some insects that have been identified to be the major pollinators of jatropa are the common wasps, *Vespa and Vespula spp*, fire ant, *Solenosis geminate* (Hill, 1987), stingless bees, *Trigona iridipennis*, the honey bees *Apis mellifera*, etc ((Wille,1983). This knowledge is however non-existent in Ghana. This study therefore sought to identify the pollinators of *J. curcas* in the northern region of Ghana.

Materials and Methods: The study was conducted from jatropha farms at Wungu in Walewale (Latitude 10º19.236'N, Longitude 000º50.376'W) and Savanna Agriculture Research Institute (SARI) Experimental Field in Nyankpala (Latitude 09º23.149'N, Longitude 001º00.182'W). Five plants were randomly selected in each farm. Each plant was observed for 10mins to identify and record the pollinator activities.

Results and Discussions: Some identified probable insect pollinators of *Jatropha curcas*

Common / scientific names and family of insects	Order of abundance
Honey bee: *Apis mellifera* (Apidae)	1
Carpenter ant: *Camponosus compressus* (Hymenoptera: formicidae)	2
Stingless bee: *Trigona spp* (Hymenoptera)	3
Wasp: *Vespa spp* (Hymenoptera: vespidae)	4
Blue bottle fly: *Calliphora vomitoria* (Diptera)	4
Paper wasp: *Polistes spp* (Vespidae)	5

Conclusion:
J. curcas seems to have substantial pollinators and this is very good for the enhanced yield and the biodiesel industry as a whole. However further studies need to be undertaken to confirm the identified insects as true pollinators and not robbers.

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UPPER EAST REGION FARMING SYSTEMS RESEARCH GROUP (UER-FSRG)

General introduction:
The Upper East Region Farming Systems Research Group (UE-FSRG) was established in May 1993 and based at the Manga Agricultural Research Station about 4 km South-East of the Bawku Municipal. The Team currently has a membership of five Research Scientists made up of two Agronomists, 1 Entomologist, 1 Postharvest specialist and 1 Socio-economist. The Team also has two Research Scientists on study leave. The Team also has four Technicians and four supervisors. The Group has oversight responsibility for the Co-ordination of Research, Extension and Farmer Linkage Committees (RELC) activities in the Upper East Region. The Team also coordinates a number of projects jointly with colleagues at Nyankpala on the AGRA Soil Health Project, Rice Sector Support Project, Sustainable Natural Resource Management (SANREM) and the USAID Feed the Future Project. The Team also provides backstopping to technical staff of non-governmental organizations such as the CARE International Climate Change Project, NORTHFIN Foundation onion bulb size improvement Project in the Bawku West District, Garu Presbyterian Agriculture Station, Bawku East Women Development Association and Action-Aid Ghana for the improvement of food security in the region.

Research Extension Farmer Linkage Committee of the Upper East Region (RELC-UER):

For the year under review no significant RELC activities have been undertaken due to lack of funding. However all the 7 districts and 2 Municipal Assemblies were able to conduct their respective district and municipal planning sessions. Also WAAPP organised a Regional RELC Planning Session with a view to identifying production constraints for root and tuber crops in the region.

AGRONOMY
The overall objective of the agronomy section of the UE-FSRG is to identify production constraints and missed opportunities and to develop appropriate and cost effective agronomic technologies to address these constraints with a view to increasing and sustaining food crops production and productivity at the farm level. To achieve this noble objective a number of trials were conducted both on-station and on-farm during the year under review. Some of the results of the studies are presented below:

Evaluation of Pearl millet varieties and hybrids for adaptation to the semi-arid agro-ecology of northern Ghana.

Roger A. L. Kanton (PhD Agronomy), Team Leader, Julius Yirzagla (MPhil. Agronomy),

Executive Summary
A field trial was conducted at the Manga Agricultural Station near Bawku in the Upper East Region to evaluate 6 varieties and 3 hybrids of pearl millet or early millet [*Pennisetum glaucum* (L.) R. Br.] for adaptation to the Sudan savanna agro-ecology of northern Ghana. The varieties are; Arrow; Bongo Short Head; Bristle millet; Soxsat; Tongo Yellow and the farmers' variety and the hybrids are: GB 8735; ICTP 8203 and TABI-B9. The experiment was

established as a randomized complete block design with 4 replicates. Plot dimensions were 6 ridges at 0.75m apart and 5m long. All standard agronomic practices and data as recommended for pearl millet production in Ghana were strictly adhered to. The results indicate highly significant ($P<0.001$ differences among genotypes for most of the traits recorded. The local landrace Mnaga Nara was the earliest to attain 50% flowering; whilst Soxsat was the latest. Downy mildew incidence at 30 days after sowing least on Sosat-C88 and ICTP 8203 and highest on the farmers' variety and TABI-B9 and at maturity was least on Soxsat and highest on Tongo Yellow. TABI-B9 Bristle millet and Sosat-C88 produced the tallest plants whilst the farmers' variety; Bongo Short Head and GB 8735 produced the shortest plants. Bongo Short Head produced the broadest spikes whilst TABI-B9 the longest spikes. Pearl millet harvest indices were generally low with Arrow; and ICTP 8203 producing the highest and GB 8735; Bongo Short Head and the farmers' varieties the lowest. ICTP 8203; Sosat-C88 and Bristle millet recorded superior grain yields compared to the other genotype evaluated. However, the farmers' variety; GB 8735 and TABI-B9 recorded the lowest grain yields compared to the trial mean. Soxsat and TABI-B9 produced superior straw yield compared to the other genotypes whilst Tongo Yellow; the farmers' variety; Arrow and GB 8735 produced appreciably lower straw yields. ICTP 8203; Sosat-C88 and Bristle millet were the most efficient in rainfall water capture and use.

Introduction

Millet [*Pennisetum glaucum* (L.) R. Br.] is one of the most important cereal crops in the Upper East Region. The importance of the crop is most pronounced in the region where it serves as a hunger-breaker immediately after the long dry season. Most farm-families would have exhausted their scanty harvest and even have difficulties in purchasing seed for the cropping season. Pearl millet is the only cereal that reliably provides grain and fodder under dryland conditions on shallow and sandy soils with low fertility and low water holding capacity. The only cereal crop that can be sowed and harvested within 3 months in the region is pearl millet. Regrettably there has not been any improved pearl millet crop varieties since Ghana's independence. The most important characteristic of millet is their unique ability to tolerate and survive under adverse conditions of continuous or intermittent drought as compared to most other cereals like maize and sorghum (LCR, 1997). The only pearl millet variety that was bred during the colonial era and released was Manga Nara, which is currently been cultivated extensively in the region. The SARI engaged a millet breeder in the 1990s, who bred for early maturing, insects pests and diseases resistant pearl millet varieties, which are being evaluated for subsequent release for mass production in Ghana. Adoption of improved pearl millet varieties tends to be slow in some regions due a complex of factors such as seed availability, variety performance or household preferences (Ndjeunga and Bantilan, 2005). The ability of pearl millet to reliably produce on marginal lands and under low rainfall makes it attractive choice for sandy, low fertility and acidic soils (Menezes *et al*. 1997). There are 2 schools of thought in plant breeding: one is of the view that selecting for broad adaptation has greater gains and stability whilst the other believes that developing crops such as pearl millet that are grown as landraces and also are produced in marginal areas site-specific breeding is of the essence (Ceccreli, 1996 and Omanya *et al*. 2007). The introduction of 4 promising pearl millet varieties is therefore welcome news to the anxious peasant farmers of the region, who over the years have always ranked the lack of early maturing and insect pest and disease resistant or tolerant crops as the most important constraint rated after only low soil fertility. However there is a paucity of information regarding the optimal spacing, plant population density and Nitrogen fertilizer for these promising varieties. Plant density is one of the most important factors affecting plant productivity (Ali, 2010). The objective of the current study is to test the performance of pearl millet varieties and hybrids for their response to agro-ecological conditions in the region.

Materials and methods

Field trial was established at the Manga Agricultural Research Station near Bawku in the Sudan savanna agro-ecological zone of Ghana. The soil in the area is sandy loam with below average plant nutrients as presented in Table 79. The study evaluated 9 pearl millet varieties/hybrids comprising of 3 bio fortified hybrids, 4 improved millet varieties from the CSIR-SARI Pearl Millet breeding and a local landrace called Manga Nara. The experiment was established in a randomized complete block design with 4 replicates. Plot dimensions were 4.5m x 5m long on ridges made by bullocks with a spacing of 0.75m apart and the spacing between hills was 0.30m. Cow dung was applied to the field just before disc harrowing with a tractor. The land was prepared by tractor and the ridges were made by bullock. Pearl millet seeds were sowed using 3 to 4 seeds per hill and thinned to 2 plants per hill at exactly 2 weeks after sowing (WAS). 1 weeding was done 2 weeks after sowing prior to the first fertilizer application. The second fertilizer application was done 2 weeks after the first fertilizer was applied. The fertilizer was applied at the rate of 80 kg N/ha and 40 kg /ha each of P_20_5 and K_20 immediately after thinning using NPK 15-15-15 and top-dressing done on 27th July using ammonium sulphate. Half the N (40 kg N/ha) and all the P_20_5 and K_20 was applied in the form of compound fertilizer. R**e-**shaping was done on 30th July 2012 to prevent root lodging using bullocks as recommended for cereals in Ghana. All recommended data for pearl millet production was taken. After harvest the data was subjected to standard statistical analysis and means separated using the standard error of 2 means.

Results

The soils of the experimental site are mainly sandy, and also acidic, with high levels of potassium. However, all the other plant growth requirements are below average for increased maize production (Table 79). The farmers variety, Manga Nara was the earliest to attain 50% flowering whilst Sosat-C88 was the latest to attain 50% flowering.

Table 79. Some physical and chemical properties of the surface (0-15 cm) soil at the experimental site at Manga Agricultural Research Station, 2012.

Soil physical and chemical properties	Experimental site at Manga
Sand (%)	80.4
Silt (%)	16
Clay (%)	3.6
Soil texture	Loamy sand
Soil pH	4.64
Organic carbon (%)	0.35
Total nitrogen (%)	0.06
Available P (mg kg^{-1})	13.58
Exchangeable cations cmol (+) kg^{-1})	xxx

Ca	0.07
Mg	0.05
K	65.70
CEC [cmol (+) kg^{-1}]	3.28

The farmers' variety attained 50% flowering significantly earlier than the rest of the varieties/hybrids tested. Similarly Tongo Yellow; GB 8735; Bongo Short Head and Arrow also attained 50% flowering significantly earlier than Soxsat and TABI-B9 (Table 80). The tallest plants were produced by TABI followed closely by Bristled head with the farmers' variety producing the shortest plants followed by Bongo short head and GB 8735 (Table 79). The tallest plants were produced by TABI-B9 followed closely by Bristle millet and then Sosat-C88, whilst the shortest plants were recorded by the farmers' variety; Bongo Short Head (BSH) and GB 8735 (Table 80). TABI-B9; Bristle millet and Sosat-C88 produced significantly (P<0.001) taller plants compared to the rest of the varieties/hybrids evaluated in the study. There were no significant differences among treatments with regards to the number Panicles harvested. However, ICTP recorded the highest number of panicles at harvest followed by TABI-B9 and Sosat-C88. GB 8735 recorded the least number of heads at harvest. Only ICTP 8703 and TABI-B9 recorded heads that were above the trial mean. Downy mildew incidence at 30 days after sowing was highest in GB 8735 and on the farmers' variety, whilst Sosat-C88 recorded the least level of infection followed by ICTP 8703. The local improved varieties had lower levels of infection as compared to that recorded for the trial mean. At maturity the level of downy mildew incidence was similar to that observed at 50 days after sowing, with GB 8735 recording the highest level of incidence followed by Tongo Yellow; whilst Sosat-C88 and ICTP 8703 again recorded the least levels of infection (Table 80).

Table 80. Effect of millet variety on the growth and development of pearl millet in a semi-arid agro-ecology in the 2012 cropping season.

Millet variety	Days to 50% flowering	Plant Height (cm)	Head count at harvest	Downy mildew at 30 days	Downy mildew at maturity	No. of chaffy heads
Arrow	50	202.5	125	6.75	23.3	102
Bongo short head	49	189.6	125	7.25	29.3	107
Bristled millet	53	243.8	114	5.75	21.3	90
GB 8735	48	191.3	100	17.25	34.0	116
ICTP 8203	51	215.6	174	4.0	9.5	79
Sosat-C88	58	228.5	130	0.25	1.75	73
TABI-B9	55	246.7	145	11.0	23.3	71
Tongo Yellow	46	212.4	124	9.25	30.3	95
Farmers variety	43	185.7	128	11.75	23.1	143
Mean	50.3	212.9	129.6	8.14	22.3	97
s.e.d.	1.40	6.61	23.48	2.01	2.19	21.87
C.V. (%)	3.9	4.40	25.60	34.8	13.9	31.90

There were significant (P<0.001) differences among the varieties/hybrids with regards to the number of chaffy heads recorded at harvest with the farmers' variety recording significantly the highest number whilst TABI-B9 and Sosat-C88 recorded the lowest numbers of chaffy heads. TABI-B9; Sosat-C88 and CTP 8703 recorded significantly fewer number of chaffy heads compared to that recorded by the farmers' variety (Table 80).

There were significant (P<0.001) differences among varieties/hybrids with regards to spike length with TABI-B9 producing the longest spikes followed closely by Bristle millet whilst Bongo Short Head and the farmers' varieties produced the smallest spikes at harvest. The spiked produced by all the varieties/hybrids were significantly longer than those produced by Bongo Short Head and the farmers' variety (Table 81). Spike girth however, followed a different trend compared to their length counterparts with the Bongo Short Head producing the broadest spikes and TABI-B9 the smallest. Bongo Short Head produced significantly broader spikes than the rest of the varieties/hybrids tested. Similarly, Sosat-C88; the farmers' variety; Tongo Yellow and GB 8735 also produced significantly broader spikes as compared to those produced by TABI-B9; ICTP 8203; Bristle millet and Arrow. Harvest index of millet was generally very low as compared to those reported for other cereals such as maize; rice and sorghum, with Arrow; ICTP 8203 and Tongo Yellow recording the highest harvest indices whilst GB 8735 recorded the lowest. Arrow; ICTP 8203 and Tongo Yellow recorded significantly (P<0.001) greater harvest indices compared to those recorded by GB 8735. It was found that 1000-grain weight of pearl millet was similarly very low as compared to its dry cereal counterparts with Bristle millet and Tongo Yellow recording the heaviest grain than those produced by TABI-B9 and Arrow. Grain yield of pearl millet was significantly (P<0.01) influenced by variety/hybrid with ICTP 8203 producing the highest grain yield and followed closely by Sosat-C88 and Bristle millet whilst the farmers' variety and GB 8735 produced the lowest grain yield. ICTP 8203 produced significantly greater grain yield than all the treatments except Sosat-C88 and Bristle millet. Sosat-C88 also significantly out-yielded the farmers' variety; GB 8735; and TABI-B9. Bristle millet significantly out-performed the farmers' variety and GB 8735. All the varieties/hybrids evaluated produced grain yield greater than trial mean of 1 metric ton with the exception of GB 8735; TABI-B9 and the farmers' variety. Sosat-C88 produced the highest straw yield followed closely by TABI-B9 whilst, Tongo Yellow produced the lowest (Table 81). Sosat-C88 produced superior straw yield than the rest of the treatments except TABI-B9. All the varieties/hybrids significantly out-yielded the Tongo Yellow.

Table 81. Effect of millet variety on grain yield and its components of millet in a semi-arid agro-ecology in the 2012 cropping season.

Millet variety	Spike length (cm)	Spike girth (mm)	Harvest index	1000-grain weight (g)	Grain yield (kg/ha)	Straw yield (t/ha)	Rainfall use efficiency (kgha^{-1} mm^{-1})
Arrow	21.3	73.5	0.09	9.2	1039	15.8	1.84
Bongo short head	13.6	114.5	0.07	9.5	1046	21.7	1.85
Bristled millet	30.5	77.0	0.08	11.5	1255	22.9	2.22
GB 8735	24.3	90.0	0.06	9.8	756	19.3	1.34
ICTP 8203	26.2	77.0	0.09	8.4	1492	23.8	2.64
Sosat-C88	22.6	98.5	0.07	7.1	1307	30.1	2.31
TABI-B9	33.9	68.5	0.07	6.2	922	28.3	1.63
Tongo Yellow	20.5	91.0	0.09	11.4	1027	11.8	1.82
Farmers variety	15.9	96.5	0.07	10.0	713	15.1	1.26

Mean	23.8	87.4	0.08	9.21	1062	21.5	1.88
s.e.d.	2.11	3.60	0.01	0.92	184.7	1.70	0.327
C.V. (%)	12.5	5.81	21.30	14.2	24.6	11.1	24.60

All the varieties/hybrids with the exception of Tongo Yellow; Arrow; farmers' variety and GB 8735 produced lower straw yield compared to that obtained by the trial mean. Rainfall use efficiency (RUE), which is a measure of how efficient the genotype uses rain water was significantly ($P<0.01$) affected by genotype with ICTP 8203 recording the highest RUE followed closely by Sosat-C88 and Bristle millet. ICTP 8203 recorded significantly greater RUE than that recorded for the farmers' variety; GB 8735; Tongo Yellow and Arrow (Table 81). Only ICTP 8203; Sosat-C88 and Bristle millet recorded RUE values greater than the trial mean.

Discussions

There were strong positive correlations between plant height and spike length with pearl millet grain yield. Similar results were reported by Wilson *et al*., (2008) in an evaluation of pearl millet varieties across seven countries in West Africa. The low incidence of downy mildew on Sosat-C88 and ICTP 8203 could be ascribed to their resistance to the disease, whilst the farmers' variety and the other locally improved varieties are highly susceptible to the disease. These findings are corroborated with those of Wilson *et al*. (2008), who reported lower incidence of downy mildew on Sosat-C88 and higher level of incidence on the local improved open pollinated varieties of Bongo Short Head; Tongo Yellow and the farmers' variety Manga Nara. Days to 50% flowering influenced pearl millet grain yield with higher grain yield being associated with longer days to attainment of 50% flowering. This could be due to longer periods of utilization of plant growth resources such as nutrients; soil moisture and solar radiation. Days to flowering had the least consistent correlation with grain yield (Wilson *et al*. 2008). The higher yields associate with ICTP 8203; Sosat-C88 and Bristle millet was due to their low numbers of chaffy heads recorded for these varieties as against the higher numbers of chaffy heads recorded for the farmers' variety; GB 8735; Bongo Short Head and Arrow. The higher yielding varieties recorded greater harvest indices indicating the superior conversion of dry matter to generative the expense of vegetative organs as reflected in the greater harvest indices associated with the higher yielding varieties compared to their lower yielding counterparts. The higher grain yields associated with the top 4 high yielding varieties comprising ICTP 8203; Sosat-C88; Bristle millet; Bongo Short Head and Arrow could be attributed to their relatively higher rain water use efficiencies thereby resulting in better resource capture and use such as nutrients and solar radiation with a resultant higher rates dry matter accumulation as reflected in their superior grain yields as compared to low yielding counterpart like the farmers' variety; GB 8735; variety and TABI-B9 that had the lowest rain water use efficiencies as reflected in their lower grain yields. Straw yield followed a similar trend like grain yield with the better performers also producing superior straw yields compared to their lower yielding counterparts. This could be ascribed to poor capture and use of plant growth factors by these varieties.

Conclusion

These preliminary results have clearly shown the superiority of ICTP 8203; Sosat-C88: Bristle millet; Bongo Short Head; Arrow and Tongo Yellow. These varieties would be tested in the 2013 rainy season and if they are consistent in their superior grain yield they would be recommended to the National Variety Release and Technical Committee for release. This will enable pearl millet farmers to increase both yield and areas of cultivation of the crop, which has lost grounds to maize cultivation in recent times due to the lack of high yielding and insect pests and disease resistant varieties. There is also the need to breed for downy mildew resistance in the local improved varieties, which all have appreciably higher levels of the disease in the present study.

Determination of optimal sowing dates for pearl millet in a semi-arid agro-ecology in northern Ghana.

Executive Summary

A field trial was conducted at the Manga Agricultural Station near Bawku in the Upper East Region to evaluate 4 sowing dates for pearl millet or early millet [*Pennisetum glaucum* (L.) R. Br.] for enhanced and stable yields in the Sudan savanna agro-ecology of northern Ghana. The experiment was established as a randomized complete design with 4 replicates. Plot dimensions were 6 ridges at 0.75m apart and 5m long. All standard agronomic practices and data as recommended for pearl millet production in Ghana were strictly adhered to. The results indicate a highly significant ($P<0.001$) interaction effect for most of the traits recorded for pearl millet. For Bongo Short Head a delay in sowing date hastened attainment of 50% flowering whereas, whereas the converse was the case for Bristle; Tongo Yellow and Arrow. Pearl millet plant height increased with delay in sowing date except for the last sowing date. Sowing Bristle millet at the third sowing date produced the tallest plants whilst the third sowing date of Bongo Short Head produced the shortest plants. Generally Bristle millet and Tongo Yellow produced the tallest plants. Millet harvest index decreased with delay in sowing date. Bongo Short Head sowed on the first and second dates produced the highest harvest indices. Bongo Short Head and Tongo Yellow recorded the highest harvest indices whilst Arrow recorded the lowest. Generally grain yield of pearl millet declined with delay in sowing date. Bongo Short Head recorded a mean yield increase of 133% over that recorded by Arrow; 128% over Bristle millet and 41% over Tongo Yellow. Similarly Tongo Yellow recorded mean grain yield increments of 67% and 63% over Arrow and the Bristle millet respectively. Generally, millet straw yield marginally increased with delay in sowing date. However, the highest straw yield was recorded by Tongo Yellow at the first sowing date followed by the third and fourth sowing dates of Tongo Yellow and third sowing date of Arrow and last sowing date of Bongo Short Head. Bristle millet at the first and third sowing dates recorded the lowest straw yields in the study.

Introduction

Pearl millet [*Pennisecum glaucum* (L.) R. Br] is the only cereal that reliably provides grain and fodder under dryland conditions on shallow and sandy soils with low fertility and low water holding capacity. While pearl millet farmers have managed to feed their under harsh conditions for centuries, population growth is outstripping their capacity to meet new demand with ancient practices and landraces. However, due to climate change farmers have found it very difficult to determine the most optimal time of sowing of this very important cereal crop as it is always the first crop to be sowed as it matures earlier than any other cereal crop thereby serving as a hunger-breaking crop. The Upper East Region usually experiences a 4 to 5 months net food deficit annually and it is the only crop that is harvested early to enable farm families to feed themselves whilst waiting for the other cereal and grain legume crops, which are normally harvested around November to December. Therefore the determination of a suitable time of sowing is both crucial and critical towards assuring of farm families their food security. Planting at different dates may result in differences in grain yield, infestation by disease pathogens and percentage germination (Assiedu, Owusu-Akyaw, and Fenteng, 1989). One of the major constraints to early millet production is unreliable rainfall and lack of suitable improved varieties. In northern Ghana, rainfall is highly erratic in on-set and distribution; therefore, strategies need to be developed for optimal use of available moisture for enhanced crop production. Farmers participating in the Annual Review and Planning Sessions of the Upper East Region Research, Extension and Farmers Linkage Committee (RELC) meetings have complained of the lack of and optimal time to sow pearl millet. Most of the farmers therefore gamble with the sowing date and often rush out to sow the crop at the first drop of rains in the region resulting in massive crop failures as the rains draw back thereby leaving farmers to their fate and sometime the farmers have no reserve seed to refill or re-sow after prolonged periods of drought. The objective of this study was to evaluate various sowing dates and to determine the optimal date for increased and stable pearl millet production and productivity in the region.

Materials and method

Field trial was established at the Manga Agricultural Research Station near Bawku in the Sudan savanna agro-ecological zone of Ghana. The soil of the area is sandy loam with below average plant nutrients. The study evaluated 9 pearl millet varieties/hybrids comprising of 3 bio fortified hybrids, 4 improved millet varieties from the CSIR-SARI Pearl Millet breeding P and a local landrace called Manga Nara. The experiment was established in a randomized complete block design with 4 replicates. Plot dimensions were 4.5m x 5m long on ridges made by bullocks with a spacing of 0.75m apart and the spacing between hills was 0.30m. Cow dung was applied to the field just before disc harrowing with a tractor. The land was prepared by tractor and the ridges were made by bullock. Pearl millet seeds were sowed using 3 to 4 seeds per hill and thinned to 2 plants per hill at exactly 2 weeks after sowing (WAS). One weeding was done 2 weeks after sowing prior to the first fertilizer application. The second fertilizer application was done 2 weeks after the first fertilizer was applied. The fertilizer was applied at the rate of 80 kg N/ha and 40 kg /ha each of P_20_5 and K_20 immediately after thinning using NPK 15-15-15 and top-dressing done on 27th July using ammonium sulphate. Half the N (40 kg N/ha) and all the P_20_5 and K_20 was applied in the form of compound fertilizer. R**e-**shaping was done on 30th July 2012 to prevent root lodging using bullocks as recommended for cereals in Ghana. All recommended data for pearl millet production was taken. The millet was harvested on the 2012 and the data was subjected to standard statistical analysis and means separated using the standard error of 2 means.

Results

There was a significant (P<0.01) interaction between variety and sowing date with respect to the number of days taken by pearl millet to attain 50% flowering (Table 82). Bongo Short Head at all sowing dates attained 50% flowering significantly earlier than rest of the varieties at the contrasting sowing dates. For Arrow the second sowing date took significantly a longer time to attain 50% flowering compared to the rest of the sowing dates. In contrast for Bristle millet the second sowing date attained 50% flowering significantly earlier than the other sowing dates. For Bongo Short Head the late sowing dates attained 50% flowering significantly earlier than the first sowing date (Table 82).

Table 82. Effect of sowing date on number of days taken to attain 50% flowering in pearl millet varieties in the 2012 rainy season in a semi-arid agro-ecology in northern Ghana.

Sowing date	Arrow	Bristle millet	Bongo Short Head	Tongo Yelow	Mean
D1	46	47	45	46	46.0
D2	47	46	44	47	46.0
D3	46	47	44	46	45.8
D4	46	47	44	46	45.7
Mean	46				
s.e.d.	0.38				
C.V. (%)	1.2				

There was a significant (P<0.001) variety by sowing date interaction. Generally millet plant height increased with delay in sowing date except for the last sowing date. The tallest millet plants were produced by Bristle at the third sowing date followed by Tongo Yellow at the first sowing date. The plants produced by Bristle; Tongo Yellow except for the last sowing date and Arrow were significantly taller than those produced by Bongo Short Head at all the sowing dates. For Bongo Short Head and Tongo Yellow there was a reduction in plant height with a corresponding delay in sowing date except for the last sowing date (Table 83). For Arrow and Bristle there was an increase in plant height with delay in sowing except for the last sowing date.

Table 83. Effect of sowing date on plant height (cm) of pearl millet varieties in the 2012 rainy season in a semi-arid agro-ecology in northern Ghana.

Sowing date	Arrow	Bristle millet	Bongo Short Head	Tongo Yellow	Mean
D1	219	212	165	239	209
D2	224	235	162	227	212
D3	226	247	155	236	216
D4	213	214	170	193	198
Mean	221	227	163	224	
s.e.d.	24.72				
C.V. (%)	16.8				

Pearl millet harvest index decreased significantly (P<0.001) with delay in sowing date**.** Sowing date, millet variety and their interaction significantly affected the harvest index of pearl millet.

The highest harvest index was recorded by Bongo Short Head at the first and second sowing dates whilst the lowest was recorded for Arrow at the second and last sowing dates (Table 84). Bongo Short Head generally recorded the highest harvest indices followed by Tongo Yellow. The lowest harvest index was recorded by Arrow. Mean increase in harvest index recorded by Bongo Short Head over that recorded for Arrow and Bristle were 114% and 88% respectively.

Table 84. Effect of sowing date on harvest index of pearl millet varieties in the 2012 rainy season in a semi-arid agro-ecology in northern Ghana.

Sowing date	Arrow	Bristle millet	Bongo Short Head	Tongo Yellow	Mean
D1	0.07	0.09	0.17	0.12	0.11
D2	0.06	0.07	0.17	0.10	0.10
D3	0.08	0.07	0.14	0.10	0.10
D4	0.06	0.07	0.11	0.11	0.09
Mean	0.07	0.08	0.15	0.11	
s.e.d.	0.0113				
C.V. (%)	15.9				

Sowing date, pearl millet variety and their interaction effects significantly (P<0.001) affected pearl millet grain yield. The first sowing date produced the highest grain yield whilst the last sowing date produced the lowest grain yield. Variety influence on millet yield was significant (P<0.001) with Bongo Short Head producing the highest grain yield followed closely by Tongo Yellow whilst Arrow produced the lowest yield (Table 85). Bongo Short Head at the first and second sowing dates produced significantly higher grain yield than any of the other sowing dates for all the varieties and also Bongo Short Head at the third and fourth sowing dates. Similarly Bongo Short Head at the third and Tongo Yellow at the first sowing dates produced superior grain yields as compared to the rest of the treatments. The last sowing date of Bongo Short Head significantly out-yielded all the sowing dates for Arrow and the Bristle millet (Table 84). All the sowing dates of Tongo Yellow also significantly out-yielded all the sowing dates of Arrow except the third sowing date and the other sowing dates of Bristle millet with the exception of the first sowing date. The third sowing date of Arrow and the first sowing of Bristle millet significantly out-yielded the first sowing date of Arrow. Bongo Short Head recorded a mean yield increase of 133% over that recorded by Arrow; 128% over Bristle millet and 41% over Tongo Yellow. Similarly Tongo Yellow recorded mean grain yield increments of 67% and 63% over Arrow and the Bristle millet respectively.

Table 85. Effect of sowing date on grain yield (kg/ha) of pearl millet varieties in the 2012 rainy season in a semi-arid agro-ecology in northern Ghana.

Sowing date	Arrow	Bristle millet	Bongo Short Head	Tongo Yellow	Mean
D1	967	1250	2817	2050	1771
D2	850	950	2700	1450	1488
D3	1300	983	2150	1567	1500
D4	933	950	1767	1650	1325
Mean	1013	1033	2359	1679	
s.e.d.	178.8				

C.V. (%)	16.6

Straw yield of pearl millet was not influenced significantly by sowing date; millet variety or their interaction. Generally, millet straw yield marginally increased with delay in sowing date. However, the highest straw yield was recorded by Tongo Yellow at the first sowing date followed by the third and fourth sowing dates of Tongo Yellow and third sowing date of Arrow and last sowing date of Bongo Short Head (Table 86). Bristle millet at the first and third sowing dates recorded the lowest straw yields in the study.

Table 86. Effect of sowing date on straw yield of pearl millet varieties in the 2012 rainy season in a semi-arid agro-ecology in northern Ghana.

Sowing date	Arrow	Bristle millet	Bongo Short Head	Tongo Yellow	Mean
D1	13.2	12.2	13.5	15.0	13.5
D2	13.5	13.7	13.5	13.0	13.4
D3	14.0	12.8	13.0	14.0	13.5
D4	13.8	13.5	14.0	14.0	13.8
Mean	13.6	13.1	13.5	14.0	
s.e.d.					
C.V. (%)					

Discussion

Optimal time of sowing of improved pearl millet varieties is very critical for increased and stable grain yields. It is assumed that the season for improved cultivars can be tailored to most assured rainfall periods and avoid soil moisture stress. Though some cultivars have shown this flexibility for time of planting, the yield losses observed in delayed plantings are significant (IER, 1990). Early-sown sorghum produced significantly (P<0.05) taller plants than their lately sown counterparts (Kanton, *et al*. 2007). Similarly, Narwal *et al*. (1996) reported that delay in sowing time decreased plant height of sorghum. This find sharply contrasts the findings of the current study in, which pearl millet sowed on the first day produced shorter plants than their lately sown counterparts most of the varieties. This could be ascribed to better rainfall distribution during the course of the season thereby resulting in improved soil moisture conditions as reflected in the better plant height with the second and third sown dates.

The first sowing date produced the highest grain yield whilst the last sowing date produced the lowest grain yield. Similar, results were reported by Kanton, et al. (2007) and Patel & Patell, (1989). The superior performance of the early sown pearl millet might be ascribed to favourable weather conditions that prevailed during the growth and development of the crop. The lately sown millet suffered from reduced rainfall during critical stages of crop growth such as at flowering and grain filling, towards the end of October when the rains were receding, resulting in low grain yields.

Effects of contrasting sources of organic and inorganic fertilizers on the growth, development, yield and its components of maize in a dry agro-ecology in northern Ghana.

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Executive Summary
Declining maize yields due to a myriad of factors such as inherently poor soils, continuous cropping of cereal after cereal, high cost and unavailability of chemical fertilizers, continuous crop residue removal and soil erosion and run-off have all had their toll on low soil fertility and reduced maize yields in northern Ghana. To address this negative trend a field trial was conducted at the Manga Agricultural Research Station in the Upper East Region of Ghana, which represents a Sudan Savanna agro-ecology in the country. The experiment was established as a complete block design with 4 replications with plot dimension of 4.5 m x 5 m. The experimental treatments comprised of available sources of both organic and chemical fertilizers currently being used by peasant farmers in Ghana. The experimental factors studied were nitrogen fertilizer rates: 0 kg N/ha; 40 kg N/ha and 80 kg N/ha; length of tied ridges were: 2 m and 4 m wide and crop residue management practices were: total crop residue removal; 50% crop residue removal; 100% crop residue retention and 50% crop residue retention. The trial was established as a randomized complete block design with 4 replications. The results of this study revealed that the chemical fertilizers with micro nutrients such as S, Zn and Mg produced taller plants with superior stem dimensions and also produced tassels and silk significantly earlier than their counterparts. They also produced the highest grain and straw yields, due to higher cob numbers, bolder grain and higher harvest indices. Poultry manure and sheep manure were the best amongst the organic sources evaluated.

Introduction
Maize (*Zea mays* L.) is now an important food crop in the Upper East Region, both in terms of the mouths it feeds and also in terms of areas devoted to its cultivation fast out stripping the traditional staple crops of millet and sorghum contrary to what used to pertain in the region before the mid-2000. However, low soil fertility has always been identified by farmers in the 3 northern regions of Ghana as the number one constraint to increased and stable cereal productivity and production in the savanna agro-ecologies. Loss of soil organic matter, plant nutrients, low water infiltration and low water holding capacity of soils are among the factors that have resulted in poor soil productivity (FAO-RAF, 2000). The use of organic manure and compost has been shown to improve the soil organic matter content (Adani, *et al*., 2007; Soumare *et al*., 2003), water infiltration and retention (Agassi et al., 2004; Bationo *et al*., 1998) and the available water content of soils by 58-86% (Celik *et al*., 2004). Increasing population has placed too much pressure on the limited land resources thereby leading to continuous cropping particularly of cereals after cereals (Anane-Sakyi *et al*. 2005). Though farmers use various improved maize varieties with high yield potential, grain yield has been observed to be very low, rarely exceeding 1.00t/ha in farmers' fields (Abunyewa and Mercer-Quarshie. 2004). Sarfo *et al*. (1998) concluded that for most crops, the best type, rate and time of application are not known and that this constitutes a constraint to the use of fertilizer. Earlier attempts by the Ministry of Food and Agriculture, Global 2000 and other non-governmental organisations, who

started the promotion of maize production, supported farmers with highly subsidized fertilizers. These endeavours appreciably increased maize yield to about 1.2 t ha^{-1} as against the average maize yield of 0.6 t ha^{-1} under peasant farmers' practice of using 200 kg ha^{-1} of NPK (UER-IFAD/LACOSREP, 1992). Average maize yields per unit of land have fallen in Africa since the 1970s partly because maize production has expanded into drought prone areas, semi-arid areas and partly due to declining soil fertility (Gilbert *et al*. 1993). Best fertilizer application for savanna soils is a combination of organic and inorganic fertilizers (Dennis *et al*. 1994). Application of organic manure and/or compost has been proven to improve soil organic matter content (Adani *et al*., 2007; Sounare *et al*., 2003) and the available water content of soils by 58-86% (Celik *et al*., 2004). Increase in wheat yield from 1190 kg ha^{-1} in the control to 1520 kg ha^{-1} due to the application of Municipal solid waste compost, because of availability of water in the rooting zone attributable to reduction in evaporation (Agassi *et al*., 2004). The objective of the current study is to determine the most optimal source of organic and inorganic sources of fertilizer for increased and stable maize production in the Savanna agro-ecologies of northern Ghana.

Materials and methods

The experiment was conducted at the Manga Agricultural Research Station near Bawku, in the Upper East Region (11^o 01' N, 00^o 16' W, 249 m above sea level). The mean annual rainfall of the experimental site was mm, it is monomodal, starting in June and ending in October. The field was a flat land and the soil is Plinthic Lixisol (FAO-UNESCO, 1988) classification and developed from granite. The soil is deep to moderate deep and well drained. The mean physical and chemical properties of the surface soil taken at a depth of 0-15 cm before sowing are presented in Table 87. The experimental factor was different sources of organic and chemical fertilizers. Sources of organic fertilizers are: Cowdung, Poultry dropping, Goat dropping, Sheep dropping, Compost, Town waste and Fertisoil and the sources of the chemical fertilizers are: 15:15:15; 21:10:10:2S; Actyva (23:10:5:3S:2Mg:0.3Zn). The experimental design was a randomised complete block with 4 replicates. Plot size for each treatment will be 4.5 m x 5 m. The test crop was maize variety CSIR-Abontem, an extra early maturing variety, which is drought tolerant, *striga hermonthica* resistant and has quality protein. Maize was hand sowed by dibbling on 11th July 2012, on ridge seedbeds made by bullocks at 0.75 m wide and maize seeds sowed at 0.40 m between hills at a depth of 5 cm using 3 to 4 seeds per hill and thinned to plants per hill at exactly 2 weeks after sowing (WAS). The various sources of organic fertilizers were applied at the rate of 5 t/ha before sowing. Basal chemical fertilizers was applied at the rate of 60 kg N; 60 kg P_2O_5/ha as triple super phosphate (TSP) and 60 kg K_2O/ha as Muriate of Potash (MOP). Half of the nitrogen fertilizer, 30kg N/ha all of the P and K were applied at 2 weeks after sowing, dibbling at 3 to 5 cm from the maize plants and placing the fertilizer into holes and closing as the foot as recommended. Top-dressing with S/A at the rate of 40 kg N/ha for all treatments at 2 weeks after the first fertilizer application as recommended for maize cultivation in Ghana. The first weed control was through the use of a herbicide at recommended rate on the 12th July 2012 and the second weed control was done by hand on 13th August 2012. The ridges were re-shaped to control any remnant weeds and also control root lodging at mid-season. Data on maize growth, development, yield and yield components were taken throughout the season. Maize was harvested on 17th July 2012 and sun dried to about 14% moisture content. No major insect pests and disease was observed during the season. The data was subsequently subjected to standard statistical analysis using GenStat release 14, statistical package and where there were significant differences at the P<0.05 confidences level means were separated using the least significant difference procedure.

Table 87. Some physical and chemical properties of the surface (0-15 cm) soil at the experimental site at Manga Agricultural Research Station, 2012.

Soil physical and chemical properties	Experimental site at Manga
Sand (%)	80.4
Silt (%)	16
Clay (%)	3.6
Soil texture	Loamy sand
Soil pH	4.64
Organic carbon (%)	0.35
Total nitrogen (%)	0.06
Available P (mg kg^{-1})	13.58
Exchangeable cations cmol (+) kg^{-1})	
Ca	0.07
Mg	0.05
K	65.70
CEC [cmol (+) kg^{-1}]	3.28

Results

The soils of the experimental site are mainly sandy, and also acidic, with high levels of potassium. However, all the other plant growth requirements are below average for increased maize production (Table 87). The application of external sources of fertilizer either organic or inorganic or both is therefore essential for increased and stable maize grain production.

The highest maize stem girth was recorded by maize plants fertilised with sheep droppings followed by maize plants fertilised with 15:15:15 and then 21:10:10:2S, whilst the lowest maize stem girth was recorded for maize fertilised with compost. Generally maize fertilised with chemical fertilizer recorded bigger maize stems as compared to their organic counterparts Table 88). The tallest maize plants were produced by plants treated with 21:10:10:2S, followed closely by Actyva (N_{23}:P_{10}:K_5:3S:2MgO:0.3Zn) and 15:15:15 with the shortest plants produced by plants fertilised with goat dropping. Maize plant fertilised with 21:10:10:2S, Actyva, 15:15:15 and Poultry manure were significantly (P<0.01) taller as compared to their counterparts that received fertilizer from goat dropping, fertisoil and compost. Maize plants fertilised with chemical fertilizer were generally superior to their organic counterparts. Maize plants that were fertilised with Actyva were the first to tassel followed closely by fertisoil, cowdung, 15:15:15 and Urea, whilst those fertilised with compost and town waste took the longest time to tassel (Table 88). All the treatments tasselled significantly (P<0.001) earlier than maize fertilised with compost or town waste. The earliest maize plants to produce silk were maize plants that were fertilised with Poultry manure followed by Actyva, 21:10:10:2S, Urea, fertisoil and sheep dropping. Maize plants fertilised with compost and town waste took a significantly (P<0.001) longer time to produce silk than the rest of the treatments.

Table 88. Effect of sources of fertilizers on maize growth and development in a dry agro-ecology in northern Ghana, during the 2012 cropping season

Source of fertilizer	Stem girth (cm) 10 WAS	Plant height (cm)	Days to tasselling	Days to silking	Root lodging
Cowdung	11.60	145.40	47.25	51.75	14.25
Goat dropping	10.64	126.2	48.25	52.75	19.00
Sheep dropping	15.47	141.20	47.00	51.50	14.00
Poultry manure	11.68	152.70	46.00	49.25	15.50
Compost	9.61	138.5	52.25	58.75	19.75
Town waste	11.17	147.1	51.25	59.00	22.00
Fertisoil	10.36	138.80	47.00	51.25	13.00
15:15:15	13.99	155.40	47.50	51.25	10.25
21:10:10:2S	12.67	159.30	48.00	51.00	12.25
23:10:5:3S: 2Mg:0.3Zn	12.38	156.60	46.75	50.50	15.75
Urea	10.85	151.70	47.75	51.00	22.25
Mean	11.86	146.50	48.09	52.55	15.75
s.e.d.	2.435	7.86	0.970	1.044	4.413
LSD	4.973	16.06	1.980	2.132	9.012
C.V. (%)	15.3	12.10	3.5	3.8	13.90

Maize plant that were fertilised with poultry manure produced silk significantly earlier than those produced by maize fertilised with town waste, compost and goat dropping. The highest number of maize plants that had undergone root lodging were maize plants that were fertilised with Urea, and town waste, whilst the least lodged plants were those fertilised with 15:15:15, Actyva and 21:10:10:2S. Generally maize that were fertilised with chemical fertilizers with the exception of urea produced fewer root lodged plants than their counterparts that were fertilised with organic sources. Fertisoil, cowdung and sheep manure produced the least root lodged plants among the organic sources.

There were no significant differences amongst treatments. However, the highest number of cobs was produced by maize plants that were fertilised with Actyva followed by sheep dropping, whilst the least was recorded under goat dropping and cowdung. The 1000-kernel weight of maize was significantly ($P<0.001$) affected by treatment effects, with maize plants fertilised with 21:10:10:2S followed closely by 15:15:15 and Actyva, whilst maize fertilised with town waste and compost recorded the lowest kernel weight (Table 89). Generally, all chemical fertilizer treatments with exception of Urea have recorded higher kernel weight in excess of 200 g. Maize fertilised with poultry manure produced the highest grain weight amongst the organic sources of fertilizer. Harvest index of maize was not significantly affected by source of fertilizer, however the highest harvest index was recorded b maize fertilised with Urea followed closely by maize fertilised with poultry dropping and Actyva. The lowest harvest index was recorded for maize produced when fertilised with Goat dropping and Fertisoil. Maize grain yield was significantly ($P<0.001$) influenced by maize fertilised with Actyva producing the highest grain yield followed by 15:15:15. The lowest grain yield was produced by maize fertilised with goat dropping (Table 89). Maize grain yield under goat dropping, town waste, compost, fertisoil and cowdung were less than that recorded for the trial mean. Generally the chemical fertilizer treatment plots recorded greater maize grain yields compared to their organic source counterparts. However, maize fertilised with poultry manure produced the highest grain yield among the organic sources.

Table 89. Effect of sources of fertilizers on maize growth and development in a dry agro-ecology in northern Ghana, during the 2012 cropping season

Source of fertilizer	No. of ears at harvest	1000-grain weight (g)	H.I.	Grain yield (kg/ha)	Straw yield (kg/ha)	Rainfall use efficiency
Cowdung	39.75	183.80	0.303	1973	2333	2.4
Goat dropping	38.50	164.50	0.285	1407	1750	1.7
Sheep dropping	44.00	179.00	0.317	2350	2667	2.9
Poultry manure	42.75	190.50	0.376	2437	2083	3.0
Compost	41.50	159.50	0.292	1657	1833	2.0
Town waste	42.25	155.80	0.299	1600	1917	2.0
Fertisoil	41.75	178.00	0.285	1740	2083	2.1
15:15:15	41.25	210.00	0.305	3063	3417	3.8
21:10:10:2S	43.75	211.00	0.290	2893	3417	3.7
23:10:5:3S: 2Mg:0.3Zn	44.25	203.20	0.341	3597	3844	4.4
Urea	43.50	181.80	0.415	2437	1667	3.0
Mean	42.11	182.50	0.391	2287	2455	2.81
s.e.d.	2.807	11.11	0.0581	410.5	311.1	0.505
LSD	5.732	22.69	0.1187	836.1	439.9	1.03
C.V. (%)	1.3	10.40	12.90	33.0	27.60	25.4

Maize straw yield followed a similar trend like maize grain yield with Actyva recording the highest straw yield followed by 21:10:10: 2S and 15:15:15. Poultry dropping recorded the highest straw yield amongst the organic sources followed by sheep dropping. General, the chemical sources of fertilizer produced higher straw yields as compared to their organic counterparts with the exception of Urea, which produced the lowest straw yield. Rainfall use efficiency (RUE) varied considerably amongst treatments with Actyva (N23:P10:K5:3S:2Mg:0.3Zn) recording the highest RUE followed closely by 15:15:15 and 21:10:10: 2S whilst the least Rue was recorded by Goat manure. Generally rainfall use efficiency increased with the inorganic sources of fertilizer than with the organic sources. The inorganic sources of fertilizer recorded a mean increase in RUE of 59.7% over the organic sources (Table 89).

Discussion

The chemical fertilizer treated plots produced maize tassels and silk much earlier than their organic counterparts, which is very important in maize production particularly in semi-arid conditions. Improving maize yields depends on both genetic and environmental factors. Besides climatic influence, soil fertility plays a critical role in crop production. With the introduction of improved maize varieties the low maize yields being recorded in the semi-arid agro-ecology could be attributed to primarily climatic factors especially rainfall, low soil fertility and inappropriate agronomic practices. And since climatic factors are not easy to manipulate, it would be prudent to concentrate every effort on improving upon soil fertility and water conservation. The taller plants produced under the chemical fertilised treatments might have given these plants better exposure to capture solar radiation for assimilation of dry matter as reflected in the superior grain yield obtained by these treatments.. The superior maize growth and development under chemical fertilizer treatment could be ascribed to the readily available nutrients supplied by these sources as compared to their organic counterparts, which require time to undergo decomposition and mineralisation before being made available for plant absorption. In the present study treatments that recorded higher number of cobs harvested, 1000-grain weight and harvest index, gave the best grain and straw yields, indicating that they are the major yield determinants in the study. The maize harvest indices reported in this study are far greater than those reported by Nyalemegbe *et al*. (2012). Poultry manure and sheep dropping gave the best grain and straw yields in the study probably due to their high nutrient concentration as compared to the other organic sources. Abdelrazzag (2002) found that increasing the rate of sheep manure and poultry manure increased N content of onion significantly. Many chemical fertilizer manufacturers are known not to contain micronutrients vital for crop growth and development and since the deficiency of these nutrients have been reported for some tropical soils, there is need to apply nutrient sources that will reduce or eliminate such deficiencies (Addediran *et al*., 2007). Because of its greater solubility in the soil the inclusion of micronutrients in its formulation, the Actyva fertilizer brought about higher growth and yield of maize compared with equivalent application of the compound fertilizer in use 16:16:16 NPK fertilizer (Nyalemegbe *et al*., 2012). The highest grain yield associated with Actyva and 21:10:10:2S might be ascribed to its superior formulation that includes all the major and micro micronutrients such as S, Mg and Zn which are lacking in the other chemical fertilizers. It has been shown that the absence of some essential elements such as Mg and Zn in most chemical fertilizers may be partly responsible for the low yield of maize in the semi-arid zones of northern Ghana Abunyewa *et al*., (2004). Although organic fertilizers are useful for ameliorating physical and chemical properties of the soil, inorganic fertilizers are popular for their ease of application, early crop response, and ease of transportation as they are less bulky (Nyalemegbe *et al*., 2012). The higher grain yield obtained by Actyva and 21:10:10:2S, which contain essential plant nutrients such as S, Mg and Zn, which are lacking in most fertilizer formulations, suggests that micronutrients are lacking in our soils though essential for increased and stable maize production and productivity. Rainfall use efficiency was highest with the organic sources probably because the inorganic sources provided plant nutrients much more readily than organic counterparts thereby resulting in better root development leading to better capture of environmental resources such as water. The rainfall use efficiency reported here for maize are comparable and in some instances superior to those reported for maize by Neil (2009).

Conclusion

The inorganic fertilizer sources produced plants that tasselled and silked significantly earlier than their organic counterparts. They also produced taller plants with bigger stems than their organic counterparts. The preliminary results indicated that the inorganic sources produced superior maize plants as compared to their organic counterparts. The inorganic sources also produced superior grain and straw yields than their organic counterparts. Poultry manure and sheep dropping were the best sources of fertilizer among the organic sources evaluated. The study would have to be repeated in the 2013 cropping season so as to confirm or reject these preliminary results that would eventually lead to a recommendation of the most optimal source of fertilizer for increased and stable maize production and productivity in Ghana at economically affordable rate to our peasant farmers.

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Effects of tied ridges, rates of nitrogen and crop residue management on the growth, development, yield and its components of maize in a dry agro-ecology in northern Ghana

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Executive Summary
Declining maize yields due to a myriad of factors such as inherently poor soils, continuous cropping of cereal after cereal, high cost and unavailability of chemical fertilizers have all contributed to the above phenomenon. To address this negative trend, a field trial was conducted at the Manga Agricultural Research Station in the Upper East Region of Ghana, which represents a Sudan Savanna agro-ecology in the country. The experimental factors were comprised of length of tied ridging with 3 levels: open ridges; tying of ridges at 2m and 4m long; the second factor was rates of nitrogen with 3 levels: 0N; 40N and 80N ha^{-1} and the third factor was residue management also with 3 levels: 100% crop residue removal; 50% crop residue removal and 100% crop residue retention. The study was established as a factorial in a randomized complete block design with 4 replicates. Plot dimensions comprised of 6 ridges at 0.75 m wide and 5 m long, with data taken from the middle 4 ridges. Grain yield was similarly not significantly affected by an interaction of length of tied ridging and rate of N application. However, there were significant ($P<0.001$) differences with regards to rate of N applied, with the highest level recording significantly higher grain yield than the non-fertilised and 40 kgN/ha. Similarly the 40 kg Nha-1, recorded significantly greater grain yield than the non-fertilised treatment. Maize straw yield was similarly significantly affected by rate of N applied. The highest straw yield was obtained when 80 kgN/ha was applied and the lowest when no fertilizer was applied. The highest N rate significantly out-yielded all the other treatments. Generally all traits of maize measured have clearly shown the superiority of higher rates of nitrogen on the performance of maize.

Introduction
Maize (*Zea mays* L.) is now an important food crop in the Upper East Region, both in terms of the mouths it feeds and also in terms of areas devoted to its cultivation fast out stripping the traditional staple crops of millet and sorghum contrary to what used to pertain in the region

before the mid-2000. However, poor soil fertility and unreliable rainfall both in amount and distribution have always been identified by farmers in the 3 northern regions of Ghana as the number one constraint to increased and stable cereal productivity and production in the savanna agro-ecologies. On a global scale irrigated agriculture uses about 72% of available fresh water resources (Geerts and Raes, 2009). The rapid increase in world population and the corresponding demand for extra water by sectors such as industries and municipal forces the agriculture sector to use its irrigation water more efficiently on one hand and to to produce more food on the other hand (Andarzin, *et al*., 2011). Defining optimum strategies in planning and management of available water resources in the agricultural sector is becoming a national and global priority (Smith, 2000). Loss of soil organic matter, and nutrients, low water infiltration and water holding capacity of soils are among the factors that have resulted in poor soil productivity (FAO-RAF, 2000). The use of water for agricultural production in water scarcity regions requires innovative and sustainable research, and appropriate transfer of technologies (Pereira, *et al*., 2002). Water scarcity may be due to different causes, relative to different regimes, nature produced and man-induced (Vlachos and James, 1993) and (Pereira, 1990). Several soil and water practices such as tillage, stone bunds, stone walls earth bunds, and dykes have often been employed to enhance soil water infiltration, storage and availability, Zougmore *et al*., 2004). Mando, (1997) reported that high inter-annual variability and erratic rainfall distribution in space and time, exacerbated by with water loss through run-off, soil evaporation, drainage below root zone as some of the factors responsible for low water-use efficiency and crop production. Retention of crop residues in the field and using pearl millet-legume rotational system have been suggested as ways to simultaneously increase yields and replenish soil nutrient levels (Coulibaly *et al*., 2000). Crop residue application in West Africa has resulted in increased pearl millet grain yields (Mulchlig-Versen *et al*., 1997) reduced crusting enhanced seedling growth and improved N, P, and K nutrition of seedlings (Mulchlig-Versen *et al*., 1997) and enhanced root growth (Bababe, 1997, Hafner *et al*., 1993). Crop residue trapped wind-blown dust with nutrient-levels (Bationo, *et al*., 1993) and higher soil pH and lower Al and Mn levels (Bationo *et al*., 1993, Kreszschmar *et al*., 1991 and Hafner *et al*., 1993). Studies on crop residue concluded that the highest gross marginal returns for land was mulching with crop residues but the highest gross marginal returns for total labour was using residues for livestock feeding and for weeding labour was burning residues (Lamers and Bruentrup, 1996). The toxic potential substances, mainly phenolics which are set free during decomposition of maize crop-residues has been discussed in recent literature (Horst and Hardter, 1994). Whereas from their studies Breakwell and Turco (1989) and Krogmeier and Bremner (1989) concluded that substances produced during decomposition of maize residues are not toxic to maize, Yakle and Cruse (1984) and Martin *et al*, (1990) presented evidence for phytotoxicity. The objective of this study is to determine the optimal length of tied ridging, nitrogen fertilizer rate and crop residue management for increased and stable maize production in the Savanna agro-ecologies of northern Ghana.

Materials and methods

The experiment was conducted at the Manga Agricultural Research Station near Bawku, in the Upper East Region (11^o 01' N, 00^o 16' W, 249 m above sea level). The mean annual rainfall (2011-2012) of the experimental site was 1,200 mm, it is mono-modal, starting in June and ending in October. The field was a flat land and the soil is Plinthic Lixisol (FAO-UNESCO, 1988) classification and developed from granite. The soil is deep to moderate deep and well drained. Soil organic carbon was determined by Walker-Black wet oxidation, available Potassium (K) ammonium Acetate (Toth and Prince, 1949), Available Phosphorus (P) by Bray and Kurz, 1945. Particle size distribution by Bouyoucos (Hydrometer) Method and Total Nitrogen by Kjeldals' method. The mean physical and chemical properties of the surface soil taken from 0-15 cm before sowing are presented in (Table 90). The experimental treatments are: Open ridges; Tied ridges at 2m and 4m intervals and N-rates at 0 kg N/ha; 40 kg N/ha and 80 kg N/ha and crop residue management practices are: Total crop residue removal; removal of 50% crop residue and retention of 50% crop residue and retention of 100% crop residue. The test crop was maize variety CSIR-Aburohema a relatively new drought tolerant, striga resistant and quality protein medium maturity maize variety. The experimental design was a randomised complete block with 4 replicates. The experimental plot dimension was 4.5 m x 5 m. Maize was sowed on 9th July 2012 on ridges made by bullocks at 0.75 m wide and maize seeds sowed at a depth of 3 to 5 using 3 to 4 seeds per hill spaced at 0.40 m between hills and thinned to plants per hill at exactly 2 weeks after sowing (WAS). Basal inorganic fertilizers was applied by hill placement method at 2 weeks after sowing at the rate of 60 kg N, 60 kg, 60 kg P_2O_5/ha as triple super phosphate (TSP) and 60 kg K_2O/ha as Muriate of Potash (MOP) at sowing. Top-dressing with S/A at the rate of 40 kg N/ha for all treatments at 2 weeks after the first fertilizer application except the control plot as recommended for maize cultivation in Ghana. Two manual weeding at 2 and 6 weeks after planting and ridges were re-shaped to control any remnant weeds and also control root lodging at mid-season. Data on insect pests and diseases were also taken during the course of the season. Maize was harvested on the 30th October 2012 at maturity when all leaves and stems have turned brown. Yield and its components were subjected to analysis of variance (ANOVA) and means separated by the least significant difference at 5% using GenStat Release 14.

Results

The soils of the experimental site are mainly sandy, and also acidic, only potassium is above the average for sandy soils. However, all the other plant growth requirements are below average for increased maize production (Table 90). The application of external sources of fertilizer either organic or inorganic or both is therefore essential for increased and stable maize grain production. There was no significant interaction between length of tied ridges and rate of nitrogen fertilizer applied. However, maize stand count at establishment and mid-season was significantly ($P<0.01$) affected by the rate of nitrogen fertilizer applied. The highest stand count at harvest was obtained when 40 kg N ha^{-1} was applied whilst the lowest when no fertilizer was applied (Table 91). There was no significant interaction effect on number of days taken by maize to tassel however, the effect of N was significant ($P<.001$) with increase in N rate reducing the number of days taken to tassel.

Table 90. Some Physical and Chemical Properties of the surface (0-15 cm) soil at the Experimental site at the Manga Agricultural Research Station, 2012.

Soil properties	*Experimental site at Manga*
Sand (%)	78.4
Silt (%)	16
Clay (%)	5.6
Soil texture	Loamy sand

Soil pH (H_20)	4.35
Organic carbon (%)	0.39
Total nitrogen (%)	0.06
Available P (mg kg^{-1})	20.25
Exchangeable cations cmol (+) kg^{-1})	
Ca	0.08
Mg	0.04
K	39.00
CEC [cmol (+) kg^{-1}]	4.28

Table 91. Effect of rate of nitrogen fertilizer and length of tied ridging on the growth and development of maize in a semi-arid agro-ecology in northern Ghana in the 2012 cropping season.

Nitrogen Rates (kg/ha)	Stand count at mid-season	Days to tassel	Days to silking	Maize stem girth (mm)	No. of root lodged plants	Plant aspect	Ear aspect
0N	39	53	58	8.22	3.6	4.9	4.9
40N	43	51	54	10.75	5.8	3.3	3.4
80N	41	48	53	11.31	4.0	2.7	2.8
Mean	41	51	55	10.09	4.47	3.63	3.7
s.e.d.	1.22	0.365	0.374	0.341	0.903	0.109	0.119
C.V. (%)	12.6	3.0	2.9	14.3	32.3	12.8	13.6

Maize under the highest N- rate tasselled significantly earlier than their counterparts under the other rates of N. Similarly maize under 40 kg N ha-1 tasselled significantly earlier than non-fertilised counterparts. Maize stem girth was in influenced significantly by length of tied ridging and rate of nitrogen applied. However, maize stem girth increased significantly ($P<0.001$) with a commensurate increase in rate of N. Number of maize plants that suffered from root lodging however, increased with increase in N application. The non-fertilised treatment gave fewer lodged plants compared to their fertilised counterparts. Plant aspect, which is a visual measure of attractiveness of the maize plant or ear, was scored on a 1 to 5 scale with 1 being excellent and 5 worst. It can be seen that the fertilised maize plants produced both health looking plants and well formed cobs as compared to the non-fertilised plants.

Number of maize ears at harvest was not influenced significantly by length of tied ridging and rate of nitrogen. However, with the highest N rate produced significantly greater cobs than the other treatments, with the 40 kg N ha^{-1} also producing significantly superior cobs compared to the non-fertilised treatment. Maize ears per plant followed a similar trend with the higher rate of nitrogen producing superior cobs as compared to their non-fertilised counterparts. There were significant differences among the treatments with the highest rate giving the best cobs followed by the 40 kg N ha^{-1}, which also produced superior cobs over the non-fertilised treatment. 1000-kernel weight was not significantly influenced by length of tied ridging and N interaction effect, however the rate of N significantly ($P<0.01$) influenced the weight of maize kernels, with the fertilised treatments producing superior kernels over their non-fertilised treatment. Harvest index of maize was significantly affected by rate of N applied and not interaction between length of tied ridges and rate of nitrogen. The fertilised treatments produced significantly bolder kernels compared to those obtained by the non-fertilised treatment. Grain yield was similarly not significantly affected by an interaction of length of tied ridging and rate of N application. However, there were significant (P<0.001) differences with regards to rate of N applied, with the highest level recording significantly higher grain yield than the non-fertilised and 40 kgN/ha. Similarly the 40 kg Nha-1, recorded significantly greater grain yield than the non-fertilised treatment. Maize straw yield was similarly significantly affected by rate of N applied. The highest straw yield was obtained when 80 kg N ha-1 was applied and the lowest when no fertilizer was applied. The highest N rate significantly out-yielded all the other treatments (Table 92). Generally all traits of maize measured have clearly shown the superiority of higher rates of nitrogen on the performance of maize.

Table 92. Effect of rate of nitrogen fertilizer on the growth and development of maize in a semi-arid agro-ecology in northern Ghana in the 2012 cropping season.

Rate of Nitrogen (kg/ha)	No. of ears harvested	No. of ears/ plant	1000-kernel weight(g)	Harvest index	Grain yield (kg/ha)	Straw yield (kg/ha)
0N	34	0.92	164	0.26	277	941
40N	62	1.47	189	0.40	1161	1826
80N	70	1.76	196	0.44	1677	2222
Mean	55	1.38	183	0.37	1039	1663
s.e.d.	2.13	0.710	3.52	0.034	72.2	125.6
C.V. (%)	16.20	21.8	1.70	39.00	29.5	32.0

There was a significant (P<0.001) length of tied ridging by rate of nitrogen fertilizer on maize grain yield. The highest maize grain yield was recorded at a tie ridging of 4m at a nitrogen level of 80 kg ha^{-1} and lowest when ridges were not tied and also when no fertilizer was applied (Table 93) . Application of nitrogen at 80 kg N ha^{-1} resulted in a 505% increase over when no fertilizer was applied and about 168% increase over when 40 kg N ha^{-1} was applied. However, there was no significant mean increase in maize grain yield due to tied ridging. There was a marginal increase in maize grain yield when ridges were tied at 4 m long as compared to their open ridge counterparts or when ridges were tied at 2 m long.

Table 93. Effects of length of tied ridges and nitrogen fertilizer rate on the grain yield of maize in a semi-arid agro-ecology in northern Ghana during the 2012 cropping season

Length of Ridge	N Rates (kg/ha)			
	0 N	40 N	80 N	Mean
Open Ridge	381	1107	1626	1038
2 m	233	1233	1604	1023
4 m	218	1143	1802	1054
Mean	277	1161	1677	
s.e.d	125.1			
C.V. (%)	29.5			

Discussion

The soils of the experimental site are very poor and very representative of the soils of the region. The soils are also acidic with only high levels of potassium, which is reported to be non-limiting in the soils of the region. The year under, which this study was carried out in a dry year and the season also started rather later. As of August 2012, there were no heavy rains to make the effect of tie ridges felt as there was not enough rain water to harvest for crop use. Grain yield of maize in tied ridges was increased by 22 to 85% compared to sowing on flat land, Nyakatawa *et al*. (1996). Siddique *et al*., (1990) investigated crop water productivity of old and new wheat cultivars and found that older cultivars have lower crop water productivity values due to lower harvest index. In rice production crop water productivity increased throughout the years due to developments in the new plant types with a higher ratio of photosynthesis to transpiration and due to a decrease in growth period (Peng *et al*., 1998) and (Tuong, 1999). Water stress at tillering and stem elongation can affect leaf growth and stomata conductance, canopy cover development and initiation of spikelets and florets, which resulted in decreasing biomass production and final grain yield (Steduto *et al*., 2009; Hsiao, *et al*., 2009). Growing maize in furrows of tied ridge designed to conserve and concentrate rain water into the root zone under rainfed conditions generally gave significant grain yield increases over the tradition farmers' practice of planting on the flat. Grain yield of maize under tied ridges increased from 22 to 85% compared to sowing on the flat. Jone *et al*. (1989) reported a grain yield increase of 45% due to tied ridging on vertisols. Grain yield of sorghum and straw yields of both sorghum and maize were however, less affected by tied ridges Nyakatawa *et al*. (1996). Roth *et al*., (1986) reported that the use of tied ridges technology in combination with inorganic fertilizer gave the highest returns per unit of land and labour invested among the treatments that were evaluated in Burkina Faso. Nyamudeza *et al*., (1992 reported that tied ridges did not significantly affect sorghum yields in years with adequate rainfall. Tied ridges may not have any yield benefits in very wet years (Nyakatawa *et al*., 1996). In years of very low and poorly distributed rainfall, there was not enough rainfall to cause significant concentration of rain water in the furrows at the times it was most needed by the plants (Nyakatawa *et al*., 1996).

Conclusion

Maize grain and straw yield were significantly increased with increase in nitrogen fertilizer rate. The effect of tied ridging was not as much as anticipated due to the combination of the late arrival and early cessation of the rains. There was therefore no increase in grain yield under tied ridges as would have been anticipated in a normal year. The effect of crop residue management would be realised during the next cropping season as this treatment has just been applied after harvest. The study is a long-term one and would have to be repeated for a couple of years so as to enable us draw definitive conclusions to enable offer the right recommendations to maize farmers in the northern Ghana.

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Effect rates of nitrogen fertilizer on the growth, development, yield and its components of Extra-early, Early and Medium maize maturity groups in a dry agro-ecology in northern Ghana.

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Executive Summary

Declining maize yields due to a myriad of factors such as inherently poor soils, continuous cropping of cereal after cereal, high cost and unavailability of chemical fertilizers have all contributed to the above phenomenon. To address this negative trend a field trial was conducted at the Manga Agricultural Research Station in the Upper East Region of Ghana, which represents a Sudan Savanna agro-ecology in the country. The current study seeks to address the contentious issue of optimal nitrogen fertilizer rate for increased maize production in Ghana. The experimental treatments comprised of various levels of nitrogen: 0 kg N/ha; 40 kg N/ha; 80 kg N/ha; 120 kg N/ha and 160 kg N/ha for the three maturity maize groups. The results of this study revealed that The highest grain yield was recorded when 120 kg N ha^{-1} was applied followed by 80 kg N ha^{-1} whilst the lowest, when no fertilizer was applied. Grain yield recorded at 120 kg N ha^{-1} was significantly ($P<0.001$) higher than the rest of the treatments except 80 kg N ha^{-1}. Generally maize grain yield increased with increase in rate of N applied. Maize yield when N was applied above 40 kg ha^{-1} was generally higher than that obtained by the trial mean. The highest straw yield was obtained when 40 kg N ha^{-1} was applied and the lowest when no fertilizer was applied. Maize straw yield produced when 40 and 120 kg N ha^{-1} was applied was significantly higher than that obtained when no fertilizer was applied or when 160kg ha^{-1} was applied. Generally grain yield and its components increased with an increase in the level of nitrogen applied. Nitrogen use efficiency (NUE) was significantly ($P<0.001$) influenced by the rate of nitrogen applied. Maximum NUE was obtained at 40 kg N ha^{-1} followed by 80 kg N ha^{-1} and the least at 160 kg N ha^{-1}. Generally the highest rates of nitrogen recorded the lowest nitrogen use efficiencies. The NUE at 40 kg N ha^{-1} was significantly greater than those obtained for all the treatments. The highest N rate recorded significantly the lowest NUE. Rainfall use efficiency (RUE) varied considerably for maize as a result of treatment effect. The highest RUE was obtained at 120 kg N ha^{-1} followed closely by 80 kg N ha^{-1}, whilst the lowest was recorded when no fertilizer was applied.

Introduction

Maize (*Zea mays* L.) is now an important food crop in the Upper East Region, both in terms of the mouths it feeds and also in terms of areas devoted to its cultivation fast out stripping the traditional staple crops of millet and sorghum contrary to what used to pertain in the region before the mid-2000. However, low soil fertility and unreliable rainfall pattern both in amount and distribution have always been identified by farmers in the 3 northern regions of Ghana as the number one constraint to increased and stable cereal productivity and production in the savanna agro-ecologies. Loss of soil organic matter, and nutrients, low water infiltration and water holding capacity of soils are among the factors that have resulted in poor soil productivity (FAO-RAF, 2000). Increasing population have placed too much pressure on the limited land resources thereby leading to continuous cropping particularly of cereals after cereals (Anane-Sakyi *et al*. 2005). IFDC (1998) reported that the annual rate of nutrient depletion from soils of Ghana between 1993 and 1995 in kilogrammes of $N+P_2O_5+K_2O$ per hectare was 51-100 with average annual rate of nutrients required to achieve optimum levels of production being greater than 80.Though farmers use various improved maize varieties with high yield potential, grain yield has been observed to be very low, rarely exceeding 1 t ha^{-1} in farmers' fields (Abunyewa and Mercer-Quarshie. 2004). Earlier attempts by the Ministry of Food and Agriculture, Global 2000 and other non-governmental organisations, who started the promotion of maize production, supported farmers with highly subsidized fertilizers. These endeavours appreciably increased maize yield to about 1.2 t ha^{-1} as against the average maize yield of 0.6 t ha^{-1} under peasant farmers' practice of using 200 kg ha^{-1} of NPK (UER-IFAD/LACOSREP, 1992). The objective of this study is to determine the nitrogen fertilizer rate and crop residue management for increased and stable maize production in the Savanna agro-ecologies of northern Ghana.

Materials and method

The experiment was conducted at the Manga Agricultural Research Station near Bawku, in the Upper East Region (11^o 01' N, 00^o 16' W, 249 m above sea level). The mean annual rainfall (2011-2012) of the experimental site was 1,200 mm, it is mono-modal, starting in June and ending in October. The field was a flat land and the soil is Plinthic Lixisol (FAO-UNESCO, 1988) classification and developed from granite. The soil is deep to moderate deep and well drained. Soil organic carbon was determined by Walker-Black wet oxidation, available Potassium (K) ammonium Acetate (Toth and Prince, 1949), Available Phosphorus (P) by Bray and Kurz, 1945. Particle size distribution by Bouyoucos (Hydrometer) Method and Total Nitrogen by Kjeldals' method. The mean physical and chemical properties of the surface soil taken from 0-15 cm before sowing is presented in Table 94 for the on-station trial.. The experimental factors studied were extra early varieties and different rates of nitrogen, The extra early maize varieties are: 99 TZEE Y STR; TZEE W Pop STR QPM C0; 2000 SYN EE STR; 2004 TZEE W Pop STR C4 and for the farmers' variety the newly released CSIR-Abontem was used. The Nitrogen rates used are: 0N; 40 kg N/ha; 80 kg N/ha; 120 kg N/ha and 160 kg N/ha. The experimental design was a factorial established in a randomised block with 4 replications. The plot dimensions used are 4.5 m x 5m. The trial field was harrowed by a tractor on the 19^{th} of July 2012, and bullocks were used to ridge the field 2 days after harrowing. Maize was sowed on the 7th of July 2012 on ridges made by bullocks at 0.75 m wide and maize seeds sowed at 0.40 m between hills using 3 to 4 seeds per hill and thinned to plants per hill at exactly 2 weeks after sowing (WAS). Basal inorganic fertilizers was applied by hill placement method at 2 WAS. Straight fertilizers were used in the study. Urea was the source of basal nitrogen whilst triple super phosphate and Muriate of potash were the sources of phosphorus and potassium respectively. Half of the compound fertilizer was applied at 2 WAS immediately after thinning to recommended plant population whilst the entire triple super phosphate (TSP) in the form of 60 kg P_2O_5/ha and also the whole amount of the Muriate of Potash (MOP) in the form of 60 kg K_2O/ha as were applied together with the basal nitrogen. For top-dressing of the remaining half of nitrogen ammonium sulphate popularly called sulphate of ammonia (S/A) was used. Two manual weeding at 2 and 6 WAS were carried out and ridges were re-shaped to control any remnant weeds and also control root lodging at mid-season approximately 2 months after sowing. Agronomic data on maize growth, development, yield and its components as recommended in Ghana were taken during the cause of the trial.

Maize was harvested at physiological maturity on the 23rd of October 2012. The maize plants were cut from above ground level and cobs removed from the stems, weighed. The cobs were then dehusked and also weighed and then dried to permanent weight and hand shelled and yields taken for analysis. Maize samples were taken for 100-grain weight measurements. Data on insect pests and diseases were also be taken during the course of the season. The agronomic data were then subjected to standard statistical analysis and where mean values were found to be statistically significant, means were separated using the least significant difference at the (P<0.05) level..

Table 94. Some physical and chemical properties of the surface (0-15 cm) soil at the experimental site at the Manga Agricultural Research Station, 2012.

Soilphysical and chemical properties	Experimental site at Manga
Sand (%)	84.56
Silt (%)	12
Clay (%)	3.44
Soil texture	Loamy sand
Soil pH	4.05
Organic carbon (%)	0.35
Total nitrogen (%)	0.05
Available P (mg kg^{-1})	11.13
Exchangeable cations cmol (+) kg^{-1})	
Ca	0.07
Mg	0.30
K	20.50
CEC [cmol (+) kg^{-1}]	2.93

Results

The soils of the experimental site are mainly sandy, and also very acidic, only the levels of potassium are moderate. However, all the other plant growth requirements are below average for increased maize production (Table 95). The application of external sources of fertilizer either organic or inorganic or both is therefore essential for increased and stable maize grain production. Maize 1000-kernel weight increased with increase in N applied, with 120 kgN/ha recording the heaviest kernels whilst the non-fertilised treatment recorded the lowest. 1000-kernel weight obtained at 120 kg ha-1 was significantly (P<0.001) higher than that recorded for the rest of the treatments. Similarly all the other treatments recorded significantly heavier kernels than the non-fertilised maize treatment. Harvest index of maize, which is a measure of the conversion efficiency of assimilates from vegetative to generative organs increased with increase in N application with 120kgN/ha recording the boldest kernels followed closely by 80 kg N ha^{-1} with the non-fertilised treatment producing the smallest kernels. Generally maize grain yield increased with a commensurate increase in N rate. The highest grain yield was recorded when 120 kgN/ha was applied followed by 80 kgN/ha whilst the lowest was when no fertilizer was applied. Grain yield recorded at 120 kgN/ha was significantly (P<0.001) higher than the rest of the treatments except 80 kg N ha^{-1}. Generally maize grain yield increased with increase in rate of N applied. Maize yield when N was applied above 40 kg ha^{-1} was generally higher than that obtained by the trial mean. The highest straw yield was obtained when 40 kg N ha^{-1} was applied and the lowest when no fertilizer was applied. Maize straw yield produced when 40 and 120 kg N ha^{-1} was applied was significantly higher than that obtained when no fertilizer was applied or when 160kg ha^{-1} was applied. Generally grain yield and its components increased with an increase in the level of nitrogen applied.

Table 95. Effect of rates of nitrogen fertilizer on yield and its components of extra-early maturity maize in a semi-arid-agro-ecology in northern Ghana in the 2012 cropping season

Fertilizer rate (kg/ha)	1000-grain weight(g)	Harvest index	Grain yield (kg/ha)	Straw yield (kg/ha)	N use efficiency (kg kg^{-1})	Rainfall use efficiency (kg ha^{-1} mm^{-1})
0 N	169	0.14	351	1417	18.2	0.43
40 N	186	0.35	1170	2160	29.3	1.44
80 N	193	0.44	1552	1977	19.4	1.91
120 N	212	0.48	1877	2103	15.6	2.31
160 N	190	0.42	1384	1697	8.7	1.70
Mean	190	0.37	1267	1871	18.2	1.56
s.e.*d*.	7.67	0.037	195.40	222.2	2.64	0.240
CV (%)	12.80	31.9	48.8	39.60	45.0	48.8

Nitrogen use efficiency (NUE) was significantly ($P<0.001$) influenced by the rate of nitrogen applied. Maximum NUE was obtained at 40 kg N ha^{-1} followed by 80 kg N ha^{-1} and the least at 160 kg N ha^{-1}. Generally the highest rates of nitrogen recorded the lowest nitrogen use efficiencies (Table 95). The NUE at 40 kg N ha^{-1} was significantly greater than those obtained for all the treatments. The highest N rate recorded significantly the lowest NUE. Rainfall use efficiency (RUE) varied considerably for maize as a result of treatment effect. The highest RUE was obtained at 120 kg N ha^{-1} followed closely by 80 kg N ha^{-1}, whilst the lowest was recorded when no fertilizer was applied. The RUE at 120 kg N ha^{-1} was significantly ($P<0.001$) greater than those recorded for the rest of the treatments (Table 95). Generally, rainfall use efficiency increased with increase in N rate applied except for the highest rate of N.

Maize ears per plant were significantly influenced by rate of nitrogen. The highest ears per plant were recorded at 80 kg N and 160 kgN/ha whilst the lowest was recorded by the unfertilised treatment. All the treatments produced significantly higher ears per plant compared to the unfertilised treatment (Table 96). The highest straw yield was recorded when 80 kgN/ha was applied followed by the 160 kg and 120 kgN/ha. All the N rates above 40 kg N ha^{-1}, significantly out-yielded the unfertilised treatment 40 kgN/ha. The highest nitrogen use efficiency (NUE) was recorded when 40 kgN/ha was applied followed by the 80 kgN/ha, whilst the lowest was recorded at 160 kgN/ha.

Table 96. Effect of rates of nitrogen fertilizer application on grain yield and its components in a semi-arid agro-ecology in northern Ghana in the 2012 cropping season.

Rate of N (kg/ha)	Ears/plant	Straw yield (kg/ha)	Nitrogen use efficiency (kg kg^{-1})	Rainfall use efficiency (kg ha^{-1} mm^{-1})
0 N	0.8	2233	30.1	0.69

40 N	1.4	3367	43.8	2.16
80 N	1.6	4017	35.0	3.50
120 N	1.5	3550	23.3	3.40
160 N	1.6	3650	18.4	3.63
Mean	1.39	3363.4	30.2	2.64
s.e.d.	0.104	270.9	3.05	0.253
C.V. (%)	23.7	25.50	31.9	29.8

There was a significant (P<0.09) interaction between maize variety and rate of nitrogen fertilizer applied. Generally maize harvest index increased with increase in N rate applied (Table 97). The highest N rate had a 52% increase in harvest index over the no fertilizer treatment. The highest harvest indices were recorded when 160 kg N/ha was applied to TZE Comp 3 DT C2F2 and TZE-W DT STR C4, which was significantly higher than those recorded for all the treatments when no fertilizer was applied; for all the N rates for the farmers' variety; for all the varieties when 40 kg N per ha was applied except for rates TZE Comp 3 DT C2F2 and for the CSIR-Omankwa when 80 kg N was applied per ha (Table 97). TZE Comp 3 DT C2F2 recorded the highest mean harvest index followed closely by TZE-W DT STR C4 with the farmers' variety recording the lowest.

There was a significant (P<0.001) maize variety by rate of nitrogen applied effect on maize grain yield. Rates of nitrogen above 40 kg N/ha produced greater maize grain yields compared to those obtained by 40 kg N ha^{-1} and when no fertilizer was applied. The highest grain yield was recorded when 160 kg N ha^{-1} was applied followed closely by when 80 kg N/ha was applied (Table 98). However, maize grain yield across the nitrogen fertilizer rates was highest, above 3.0 t ha^{-1} at 120 kg N ha^{-1} compared to the rest of the rates. Similarly TZE Comp 3 DT C2F2 recorded the highest grain yield followed by TZE-W DT STR C4 and then the latest released maize variety CSIR-Aburohemaa, whilst the farmers' variety recorded less than 1.0 t ha^{-1}. Generally, all the improved maize varieties, with the exception of the farmers' variety responded well with increase in nitrogen fertilizer application.

Table 97. Interaction effect of maize variety by rate of nitrogen fertilizer on harvest index of maize varieties evaluated in semi-arid agro-ecology in northern Ghana during the 2012 cropping season

Maize variety	0 N	40N	80N	120N	160N	Mean
CSIR-Aburohemaa	0.19	0.32	0.43	0.46	0.45	0.37
CSIR-Omankwa	0.13	0.35	0.37	0.45	0.46	0.36
TZE Comp 3 DT C2F2	0.28	0.47	0.48	0.48	0.50	0.44
TZE-W DT STR C4	0.17	0.35	0.47	0.48	0.50	0.39
Farmers' variety	0.10	0.21	0.27	0.20	0.23	0.20
Mean	0.17	0.34	0.40	0.41	0.43	
s.e.d.	0.048					
C.V. (%)	20.30					

Table 98. Interaction effect of early maize varieties by rate of nitrogen fertilizer on grain yield of maize varieties evaluated in semi-arid agro-ecology in northern Ghana during the 2012 cropping season

Maize variety	0 N	40N	80N	120N	160N	Mean
CSIR-Aburohemaa	1063	1687	3120	3070	3370	2462
CSIR-Omankwa	297	2180	2563	3047	2963	2210
TZE Comp 3 DT C2F2	870	2170	3677	3747	3200	2733
TZE-W DT STR C4	480	1823	3360	3107	3980	2550
Farmers' variety	133	933	1520	983	1230	960
Mean	568.6	1758.6	2848	2791	2949	
s.e.d.	460.1					
LSD(0.001)	917.2					
C.V. (%)	29.80					

It is interesting to note that the newly released CSIR-Aburohemaa responded best at the 0 kg N ha^{-1} followed by TZE Comp 3 DT C2F2. TZE Comp 3 DT C2F2 gave consistently higher grain yields across all the N levels compared to rest of the treatments thereby indicating that this variety is very plastic to all the N rates evaluated in the current study

Discussion

The earlier attainment of tasseling and silking by maize plants that received higher rates of nitrogen could be attributed to the better supply of plant nutrients under these treatments compared to the non-fertilised or lower N rate treatment. Generally, plants that receive better growth factors usually take fewer days to attain both growth and development stages compared to those that received less of these growth factors. Similarly the bigger maize plants reported for the higher N rates treatments could also be due to superior grow conditions afforded by the higher N rate treatments, leading to better capture of plant growth resources such as water due to better root development and taller plants resulting in better capture of radiation as reflected in the overall plant performance under the higher N rate treatments. The relatively higher harvest index of maize crops for the higher N rate treatments compared to the non-fertilised or lower N rate may be attributed to the higher nitrogen uptake (Adamptey *et al*., 2010). Sinclaire (1998) reported high harvest index to be associated with high N levels in maize crops. Adamtey *et al*., (2010) reported low grain maize yields for soils that received no fertilizer and ascribed it to reduced plant growth as a consequence of low nutrient (especially, N) supply and uptake. This observation has been confirmed by the results of the current study in, which the non-fertilised maize recorded abysmal grain yields. Inorganic fertilizer increased grain yield of maize by 35 to 115% and that of sorghum by 59 to 100% (Nyakatawa *et al*., 1996). Similar results were reported by Ngambeki *et al*. (1991) who reported grain yield increases of up to 183% in maize due to application of inorganic and organic fertilizers. The higher maize grain yields reported with higher levels of N are supported by the findings of Gentry *et al*. (2201) who reported a significant positive relationship between grain yield and soil inorganic N. The results of the study showed that application of 120kgN/ha + 0kgP/ha and 60kgN/ha + 40kgP/ha significantly increased the growth of maize than other treatments (Onasanya, *et al*., 2009). The low nitrogen use efficiency associated with the highest nitrogen rates could be ascribed to leaching as the soils of the area are sandy loamy soils, which are characterised by low nutrient holding capacity and any excess nitrogen could be leached beyond the rooting zone of crop plants. Rainfall use efficiency reported here are lower than those reported by Neil (2009) for maize. Results of the economic analysis have corroborated those of their agronomic counterparts, indicating that beyond the 120 kg N ha^{-1} rate the excess nitrogen might be leached beyond the rooting zone of maize thereby rendering none productive for maize use.

Conclusion

Generally grain yield and its components increased with an increase in the level of nitrogen applied. Nitrogen use efficiency (NUE) was significantly ($P<0.001$) influenced by the rate of nitrogen applied. Maximum NUE was obtained at 40 kg N ha^{-1} followed by 80 kg N ha^{-1} and the least at 160 kg N ha^{-1}. Generally the highest rates of nitrogen recorded the lowest nitrogen use efficiencies. The NUE at 40 kg N ha^{-1} was significantly greater than those obtained for all the treatments. The highest N rate recorded significantly the lowest NUE. Rainfall use efficiency (RUE) varied considerably for maize as a result of treatment effect. The highest RUE was obtained at 120 kg N ha^{-1} followed closely by 80 kg N ha^{-1}, whilst the lowest was recorded when no fertilizer was applied. However, since these results are preliminary ones it would be imperative that we repeat this study so as to confirm or reject these current results, so that we can recommend to maize farmers in Ghana for increased and stable maize production.

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Effect rates of nitrogen fertilizers on the growth, development, yield and its components on extra-early; early and medium maturity groups of drought tolerant maize varieties in the Upper East Region of Ghana.

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Results

The soils of the experimental site was mainly sandy, and also very acidic, only the levels of potassium are moderate. However, all the other plant growth requirements were below average for increased maize production (Table 99). The application of external sources of fertilizer either organic or inorganic or both is therefore essential for increased and stable maize grain production. Days taken by maize to tassel was significantly ($P<0.001$) influenced by quantity of nitrogen fertilizer applied. The earliest maize plants to tassel were those that received 80 kg and 120 kg N/ha whilst those that were not fertilised were the latest to tassel (Table 99). All the maize that received fertilizer tasselled significantly earlier than their non-fertilised counterparts. Generally fertilizer application reduced the days taken by maize to tassel. Days taken by maize to produce silk followed a similar trend like their counterparts in tasseling, with nitrogen rate of 80 kg N/ha being the earliest to produce silk whilst the non-fertilised treatment the latest to produce silk. All the fertilised treatments produced silk significantly earlier than their non-fertilised counterparts (Table 99). Maize plants were also score for some phenotypic traits such as plant and ear aspects, on a scale of 1 to 5, with 1 representing excellent and 5 poor for both traits. Maize plant that were fertilised produced both healthier plants and bigger cobs than their non-fertilised counterparts (Table 99). Maize ears at harvest was significantly (P<0.001) influenced by treatment effect. The highest cob number was recorded at 80 kg N ha^{-1} followed closely by 160 kg/ ha, whilst the lowest was recorded at 0 kg N /ha (Table 99). All the fertilizer treated plots recorded higher cobs compared to the trial mean.

Table 99. Effect of rates of nitrogen fertilizer application on grain yield and its components of extra-early maturity maize variety in a semi-arid agro-ecology in northern Ghana in the 2012 cropping season.

N Rate (kg/ha)	Days to tassel	Days to silk	Plant aspect	Ear aspect	No. of ears harvested
0 N	54.9	62.6	4.7	4.9	19
40N	52.2	56.9	3.8	4.0	32
80N	51.7	55.8	3.5	3.3	37
120N	51.9	56.3	3.2	3.4	33
160N	52.1	56.1	3.1	3.2	36
Mean	52.6	57.5	3.7	3.8	31.40
s.e.d.	0.49	0.56	0.194	0.18	2.37
C.V. (%)	2.9	3.1	17.0	15.1	23.90

Maize ears per plant were significantly influenced by rate of nitrogen. The highest ears per plant were recorded at 80 kg N and 160 kg N /ha whilst the lowest was recorded by the non-fertilised treatment. All the treatments produced significantly higher ears per plant compared to the treatments that were not given fertilizer (Table 99). The highest straw yield was recorded when 80 kg N/ ha was applied followed by the 160 kg and 120 kg N /ha. All the N rates above 40 kg N/ha, significantly out-yielded the non-fertilised treatment 40 kg N/ ha. The highest nitrogen use efficiency (NUE) was recorded when 40 kg N/ ha was applied followed by the 80 kg N /ha, whilst the lowest was recorded at 160 kg N /ha. Generally, nitrogen use efficiency decreased with an increase in N rate applied. Rainfall use efficiency (RUE) varied considerably among treatments with the highest N rate recording the highest RUE followed closely by 80 kg and 120 kg N /ha). Fertilizer rate from 80 to 120 kg N ha-1 recorded significantly (P<0.001) greater RUE values as compared to those obtained for the unfertilized and 40 kg N /ha. The 40 kg N /ha gave higher RUE than the unfertilized treatment. Generally RUE increased with increase in N rate (Table 100).

Results of early maize maturity varieties

There was a significant (P<0.001) maize variety x rate of nitrogen interaction on maize grain yield. Rates of nitrogen above 40 kg N/ha produced greater maize grain yields compared to those obtained by 40 kg N /ha and when no fertilizer was applied. The highest grain yield was recorded when 160 kg N /ha was applied followed closely by when 80 kg N/ha was applied (Table 101).

Table 100. Effect of rates of nitrogen fertilizer application on grain yield and its components in a semi-arid agro-ecology in northern Ghana in the 2012 cropping season.

N Rate (kg/ha)	Ears/plant	Straw yield (kg/ha)	Nitrogen use efficiency (kg /kg)	Rainfall use efficiency (kg/ha^{-} /mm)
0N	0.8	2233	30.1	0.69
40N	1.4	3367	43.8	2.16
80N	1.6	4017	35.0	3.50
120N	1.5	3550	23.3	3.40
160N	1.6	3650	18.4	3.63
Mean	1.39	3363.4	30.2	2.64
s.e.d.	0.104	270.9	3.05	0.253
C.V. (%)	23.7	25.50	31.9	29.8

Table 101. Interaction effect of maize variety x rate of nitrogen fertilizer on grain yield of maize varieties evaluated in semi-arid agro-ecology in northern Ghana during the 2012 cropping season

Maize variety	0 N	40N	80N	120N	160N	Mean
CSIR-Aburohemaa	1063	1687	3120	3070	3370	2462
CSIR-Omankwa	297	2180	2563	3047	2963	2210
TZE Comp3 DT C2F2	870	2170	3677	3747	3200	2733
TZE-W DT STR C4	480	1823	3360	3107	3980	2550
Farmers' variety	133	933	1520	983	1230	960
Mean	568.6	1758.6	2848	2791	2949	
s.e.d.	460.1					
LSD(0.001)	917.2					
C.V. (%)	29.80					

However, maize grain yield across the nitrogen fertilizer rates was highest, above 3.0 t /ha at 120 kg N /ha compared to the rest of the rates. Similarly TZE Comp 3 DT C2F2 recorded the highest grain yield followed by TZE-W DT STR C4 and then the latest released maize variety CSIR-Aburohemaa, whilst the farmers' variety recorded less than 1.0 t ha^{-1}. Generally, all the improved maize varieties, with the exception of the farmers' variety responded well with increase in nitrogen fertilizer application. It is interesting to note that the newly released CSIR-Aburohemaa responded best at the 0 kg N ha^{-1} followed by TZE Comp 3 DT C2F2. TZE Comp3 DT C2F2 gave consistently higher grain yields across all the N levels compared to rest of the treatments thereby indicating that this variety is very plastic to all the N rates evaluated in the current study.

Results of medium maturity group maize varieties

Harvest index of maize, which is an indication of conversion of dry matter from vegetative to generative organs of the plant, was also influenced significantly by the application of nitrogen fertilizers. The highest harvest index was recorded for plants that received 120 kg N/ha and the least recorded for maize plants that received no fertilizer. All the fertilised treatment produced significantly greater harvest indices compared to the no fertilizer treatment (Table 102). Similarly maize grain yield was significantly ($P<0.001$) affected by level of nitrogen fertilizer applied. The highest grain yield was obtained when 120 kg N/ha was applied whilst the lowest when no fertilizer was applied. All fertilised maize treatments significantly out-yielded the 0 kg

N/ha treatment. Generally maize grain yield increased with increase in nitrogen fertilizer applied except when more than 120 kg N/ha was applied. Maize straw yield, which is an essential component of the farming system of the region did not follow a trend, with nitrogen fertilizer application of 40 kg N/ha recording the highest straw yield and the 120 kg N/ha the least. Forty kilogram nitrogen per hectar produced significantly (P<0.001) higher straw than the other treatments except for the non-fertilised treatment (Table 102).

Table 102. Effect of rates of nitrogen fertilizer application on the yield and its components of medium maturing maize varieties in a semi-arid agro-ecology in northern Ghana in the 2012

N rate (kg/ha)	Harvest index	Grain yield (kg/ha)	Straw yield (kg/ha)	Nitrogen use efficiency (kg kg^{-1})	Rainfall use efficiency (RUE, kg ha^{-1} mm^{-1}
0N	0.22	659	2593	22.5	0.81
40N	0.36	1441	3213	36.0	1.77
80N	0.50	2015	2027	25.2	2.48
120N	0.56	2052	1640	17.1	1.52
160N	0.45	1846	2273	11.5	2.27
Mean	0.42	1603	2349	22.5	1.97
s.e.d.	0.060	269.5	386.9	3.62	0.33
CV (%)	45.40	53.2	52.10	51.0	53.1

Nitrogen was most efficiently used when applied at the rate of 40 kg N /ha followed closely by the 80 kg/ ha rate. The least efficient rate was when N was applied at the highest rate of 160 kg N/ ha. The unfertilised treatment was more efficient in nitrogen use than the highest rates of N, at 120 and 160 kg N/ ha. Generally nitrogen use efficiency declined with an increase in rate of N applied (Table 102). However, rainfall use efficiency (RUE), followed a contrasting trend with the highest 80 kg N /ha recording the highest RUE followed closely by the highest N rate of 160 kg N /ha. Generally, RUE increased with increase in rate of nitrogen applied (Table 102). The RUE obtained at 80 kg and 160 kg N /ha were significantly (P<0.001) greater than those recorded for the unfertilised treatment and when N was applied at the rate of 40 kg /ha.

Discussion

Generally the time taken by maize to produce tassels and silk reduced with an increase in rate of N applied. This might be ascribed to the better nutrition under higher N rates thereby leading to better plant performance resulting in earlier attainment of development stages. The maize plants and their ears were also very attractive under the higher N rates compared to the non-fertilised or lower N rates thereby resulting in their being attractive phenotypically and receiving higher scores. The higher N rate treatments afforded better nutrients uptake for maize and subsequently resulted in healthier plants that gave well filled cobs as compared to the non-fertilised treatment, which produced stunted plants, which could not produce sufficient assimilates to give good cobs. This observation has been confirmed by the results of the current study, in which the non-fertilised maize recorded abysmal grain yields. Inorganic fertilizer increased grain yield of maize by 35 to 115% and that of sorghum by 59 to 100% (Nyakatawa *et al*., 1996). Similar results were reported by Ngambeki *et al*. (1991) who reported grain yield increases of up to 183% in maize due to application of inorganic and organic fertilizers. The higher maize grain yields reported with higher levels of N are supported by the findings of Gentry *et al* who reported a significant positive relationship between grain yield and soil inorganic N. The results of the study showed that application of 120kgN/ha + 0kgP/ha and 60kgN/ha + 40kgP/ha significantly increased the growth of maize than other treatments (Onasanya, *et al*., 2009). The low nitrogen use efficiency associated with the highest nitrogen rates could be ascribed to leaching as the soils of the area are sandy loamy soils, which are characterised by low nutrient holding capacity and any excess nitrogen could be leached beyond the rooting zone of crop plants. Rainfall use efficiency reported here are lower than those reported by Neil (2009) for maize. Results of the economic analysis have corroborated those of their agronomic counterparts, indicating that beyond the 120 kg N/ha rate the excess nitrogen might be leached beyond the rooting zone of maize thereby rendering none productive for maize use. The decline in nitrogen use efficiency is consistent with those generally reported in literature. This condition could be ascribed to loss of excess nitrogen applied through leaching and run-off, leading to that nitrogen not being available for crop use. However, the better capture and use of rainwater could possibly be due to the better root establishment under the higher fertilised treatment with a resultant increase in root volume and index as reflected in the better exploitation of water resources in the soil leading to the superior maize yields reported. These results are consistent with those reported by Neil, (2009). The economic studies also confirm the above agronomic assertion that the highest N rates used in the current study might not be useful due to leaching or run-off effects on the excess fertilizer applied and also due the sandy nature of the soils resulting in poor nutrient and moisture retention for crop growth and development.

Conclusion

Generally grain yield of maize increased appreciably with increase in N rate applied, with highest grain yield being produced when 160 kg N/ha was applied to maize variety TZE-W DT STR C4, followed closely by TZE Comp 3 DT C2F2 and the least when no fertilizer was applied to the farmers' variety. Maize grain yield increased with increase in rate of N applied. TZE Comp 3 DT C2F2 produced the highest grain yield followed by TZE-W DT STR C4 with the farmers' variety producing the lowest grain yield. The highest straw yield was recorded when 80 kg N/ha was applied followed by the 160 kg and 120 kg N/ha. All the N rates above 40 kg N/ha, significantly out-yielded the unfertilised treatment. The highest nitrogen use efficiency (NUE) was recorded when 40 kg N ha^{-1} was applied followed by the 80 kg N/ha, whilst the lowest was recorded at 160 kg N/ha. Generally, nitrogen use efficiency decreased with an increase in N rate applied. Rainfall use efficiency (RUE) varied considerably among treatments with the highest N rate recording the highest RUE followed closely by 80 kg and 120 kg N/ha). The study would be repeated in 2013 to confirm or reject these preliminary findings with a view to recommending them to maize farmers.

On-farm evaluation of Extra-early maturity Drought Tolerant Maize for Africa (DTMA) varieties in a semi-arid agro-ecology in northern Ghana.

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Executive Summary
On-farm adaptive trials were conducted in the Garu-Tempane and Bawku Municipal districts of the Upper East Region of northern Ghana. The mother and baby methodology was adopted. The maize varieties and hybrids tested were: 2000 SYN EE-W; 2004 TZEE-W Pop STR C4; 2008 SYN EE-W; 2008 TZEE-W STR; 99 TZEE-Y STR; TZEEI 29 x TZEEI 49; TZEEI 29 x TZEEI 76; TZEE-W Pop STR C5 x TZEEI 21; TZEE-Y Pop STR C5 x TZEEI 82; the newly released DTMA variety CSIR-Abontem and the farmers' variety. For the baby trials 2000 SYN EE-W STR produced the highest grain yield followed by the newly released drought tolerant maize CSIR-Abontem, whilst TZEE-Y Pop STR C5 produced the lowest grain yield. All the improved varieties/hybrids with the exception of TZEE-Y Pop STR C5 produced considerably superior maize yields compared to the farmers' variety. 2004 TZEE-W Pop STR C4 produced the highest straw yield followed closely by TZEE-W Pop STR C5 x TZEEI 21, whilst 2000 SYN EE-W STR produced the lowest straw yield. For the mother trials in Garu 2008 SYN EE-W STR recorded the highest grain yield, whilst 99 TZEE-Y STR produced the lowest. All the varieties and hybrids with the exception of 2004 TZEE-Y Pop STR C4, 99TZEEI 29 and TZEE-Y Pop STR C5 x TZEEI 29 produced yields that were lower than the trial mean. Maize straw yield was also significantly affected by variety and hybrid with TZEE-W Pop SR C5 x TZEEI 29 recording the highest and 99 TZEE-Y STR producing the lowest. The rest of the varieties and hybrids with the exception of 2008 SYN EE-W STR; TZEE-W Pop STR CR x TZEEI 29; TZEEI 29 x TZZEI 79; CSIR-Abontem and the farmers' variety. Grain yields of maize for all varieties and hybrids recorded in the Bawku Municipal were generally lower than those reported for Garu-Tempane district. TZEEI 29 x TZEEI 49 produced the highest grain yield and followed closely by TZEE-W Pop STR C5 x TZEEI 29, whilst 99 TZEE-Y STR produced appreciably the lowest maize yield. All the improved drought tolerant maize varieties and hybrids gave yields that were higher than those recorded by the released CSIR-Abontem and the farmers' farmers' variety with the exception of 2008 SYN EE-W DT STR and 99 TZEE-Y STR. Straw yields of maize were generally high with TZEEI 29 x TZEEI 79 and TZEE-W Pop STR C5 x TZEEI 29 producing the highest straw yields and 99 TZEE-Y STR producing the lowest.

Introduction
Maize (*Zea mays* L.) is one of the most important food cereals in the developing world (CIMMYT, 1990). However, production is lower than demand and bridging the gap requires large increases in production mainly through yield improvement (Crosson & Anderson, 1992). In sub-Saharan Africa, maize is produced mainly under rainfed conditions which are characterized by highly variable rainfall, both in quantity and distribution. Consequently, the crop frequently suffers from moisture stress at some stage during its growth period (Johnston *et al*., 1986) with the ultimate result of reduced yields. In the three northern regions of Ghana, farmers participating in the Annual Planning Sessions under the auspices of the Research Extension Farmer Linkage Committee (RELC) have always identified low soil fertility and insufficient and erratic rainfall as the major constraints to maize production in the area. Although several water harvesting techniques, such as tied ridges, have been proposed to address the problem of water stress, their efficiency could be enhanced by cultivating drought-tolerant varieties that can use the harvested rainwater more efficiently. Participatory Variety Selection (PVS) is a more rapid and cost-effective way of identifying farmer-preferred cultivars if a suitable choice of cultivars exists (Witcomebe *et al*., 1996).

The objectives of the study were to:

- (i) evaluate drought-tolerant maize varieties and hybrids on farmers' fields;
- (ii) involve farmers in the selection of the best drought-tolerant maize varieties or hybrids;
- (iii) determine the economic benefits of planting drought-tolerant maize compared with farmers' varieties; and
- (iv) Introduce at least one drought-tolerant maize variety or hybrid to at least 50 farmers to enhance maize production in northern Ghana.

Materials and methods

In 2012, field trials were conducted at Garu-Tempane District and Bawku Municipal of the Upper East Region (in the Sudan Savanna agro-ecology). The trials evaluated drought-tolerant maize varieties and hybrids under the initiative of the Drought Tolerant Maize for Africa (DTMA)/International Institute of Tropical Agriculture (IITA) and the International Centre for Wheat and Maize Research (CIMMYT) Mexico. Farmers were selected based upon their previous experience in conducting on-farm adaptive trials with the Savanna Agricultural Research Institute Station at Manga and their willingness to collaborate in this particular study. The Mother and Baby concept of on-farm experimentation was adopted whereby all the maize entries were tested in a replicated trials in one farmer's field (Mother trial) while 2 or 3 entries were planted by 5 other farmers in each of the two districts (Baby trial). The maize varieties and hybrids tested were: 2000 SYN EE-W; 2004 TZEE-W Pop STR C4; 2008 SYN EE-W; 2008 TZEE-W STR; 99 TZEE-Y STR; TZEEI 29 x TZEEI 49; TZEEI 29 x TZEEI 76; TZEE-W Pop STR C5 x TZEEI 21; TZEE-Y Pop STR C5 x TZEEI 82; the newly released DTMA variety CSIR-Abontem and the farmers' variety. However, due to lack of seed the baby trials could not be implemented. The randomised complete block design was adopted, with 4 replications. Plot dimensions used were 4.5 m x 5m. This comprised of 6 ridges spaced at 0.75m apart and 5 m long with data recorded from the 4 central ridges with the outer rows serving as guard rows. Sowing was done on the 6th of July 2012 on ridges made with bullocks. Maize was sown at the rate of 3 to 4 seeds per hill at a spacing of 0.4 m between hills and later thinned to 2 plants per hill as practiced in the country. First weeding was done on the 16th of July 2012 and second weeding on 15th of August 2012. Compound fertilizer NPK (15-15-15) was applied on the 19th of July and topdressing was done on the 29th of July 2012. The compound fertilizer was applied in the form of 15:15:15 at the rate of 40 kg N; P_2O_5 and K_2O per ha; whilst in the topdressing sulphate of ammonia (S/A) was used at the rate of 40 kg N per ha. The ridges were reshaped two months after sowing to avoid root lodging and for weed control. Standard agronomic data on maize growth, development, yield and its components were taken. Other derived variables such as harvest index (H.I.) and rainfall use efficiency (RUE) were calculated. The incidence of insect pests and diseases was too low to have any economic effect on maize yields. The data was then subjected to statistical analysis using GenStat Release 13, and means were separated using standard errors.

Results

There were significant ($P<0.05$) differences among the varieties and hybrids with regards to the number of days taken to attain 50% flowering. 2000 SYN EE-W STR attained 50% flowering significantly earlier compared to the farmers' variety. There were significant (P<0.05) differences among treatments with regards to plant height. The tallest plants were produced by TZEE-Y Pop STR C5 x TZEEI 82, which were significantly (P<0.05) taller than those produced by 2008 TZEE-W STR. Maize plants were generally taller in the 2012 cropping season as compared to their counterparts in the 2011 cropping season. There were no significant (P<0.05) differences among treatments with regards to 100-kernel weight. However, 2008 SYN EE-W DT STR produced the boldest kernels whilst TZEEI 29 x TZEEI 49 produced the smallest maize kernels. Most of the improved maize varieties and hybrids produced bolder kernels than the newly released drought tolerant maize CSIR-Abontem and the farmers' variety. Maize harvest indices this year were generally lower compared to those recorded in 2011 cropping season. 2000 SYN EE-W STR recorded the highest harvest index whilst 2008 SYN EE-W produced the least. Maize grain yields this year were generally greater than those reported in the 2011 cropping season. 2000 SYN EE-W STR produced the highest grain yield followed by CSIR-Abontem, whilst TZEE-Y Pop STR C5 produced the lowest grain yield (Table 103). All the improved varieties/hybrids, with the exception of TZEE-Y Pop STR C5 produced considerably superior maize yields compared to the farmers' variety. 2004 TZEE-W Pop STR C4 produced the highest straw yield followed closely by TZEE-W Pop STR C5 x TZEEI 21, whilst 2000 SYN EE-W STR produced the lowest straw yield.

There were significant (P<0.07) location by variety/hybrid interaction for most of the traits studied. Garu-Tempane recorded a mean grain yield increment of 44% over that recorded for Bawku Municipal. In Bawku Municipal TZEEI 29 x TZEEI 49 recorded the highest grain yield followed closely by TZEEI 29 x TZEE 79, whilst 99 TZEE-Y STR and 2008 TZEE-W STR recorded the lowest yields. TZEEI 29 x TZEEI 49 produced significantly higher grain yield than that recorded by 99 TZEE-Y STR; 2008 TZEE-W STR; CSIR-Abontem and the farmers' variety. 2008 SYN EE-W DT STR produced the highest grain yield whilst TZEE-Y Pop STR C5 x TZEE 163 produced the least grain yield. 2008 SYN EE-W produced significantly higher grain yield than all the other treatments except the farmers' variety; 2000 SYN EE-W; CSIR-Abontem; 2008 TZEE-W STR and TZEEI 29 x TZEEI 49 (Table 104). Maize varieties and hybrids TZEE-W Pop STR QPM; TZEEI 29 x TZEEI 49 and TZEEI 29 x TZEEI 76 produced relatively stable grain yields across the locations.

Table 103. Yield and its components of baby trials of extra early drought tolerant maize varieties and hybrids evaluated on-farm in a semi-arid agro-ecology in northern Ghana in the 2012 cropping season

Maize variety/hybrid	Days to 50% flowering	Plant height (cm)	100-kernel weight(g)	Harvest index	Grain yield (kg/ha)	Straw yield (t/ha)
2000 SYN EE-W	51	174	29	0.64	4272	1942
2004 TZEE-W Pop STR C4	58	178	23	0.31	2852	5552
2008 SYN EE-W DT STR	57	161	30	0.48	3272	3612
2008 TZEE-W STR	56	185	24	0.28	2312	4852
99 TZEE-Y STR C1	55	187	30	0.38	2972	4792
TZEEI 29 x TZEEI 49	57	166	30	0.37	2512	4272
TZEEI 29 x TZEEI 76	56	167	17	0.50	2792	2432
TZEE-W Pop STR C5 x TZEEI 21	60	182	24	0.33	2712	5352
TZEE-Y Pop STR C5 x TZEEI 81	52	197	20	0.39	2092	4692

CSIR-Abontem	55	163	21	0.50	3712	3512
Farmers' variety	64	179	22	0.33	2192	4372
Mean					1736	
s.e.d.	5.15	24.61	6.90	0.142	841	2238
C.V. (%)	6.32	10.14	20.90	26.63	23.27	38.27

Table 104. Location by variety interaction of extra early maturing drought tolerant maize varieties and hybrids tested on-farm in a semi-arid agro-ecology in northern Ghana in the 2012 cropping season.

Maize variety	Bawku Municipal	Garu-Tempane District	Mean
2000 SYN EE-W	2117	3283	2700
2004 TZEE-W Pop STR C4	2217	2817	2517
2008 SYN EE-W DT STR	2050	3717	2884
2008 TZEE-W STR	1950	3233	2592
99 TZEE-Y STR	1850	2650	2250
TZEEI 29 x TZEI 49	2667	3133	2900
TZEEI 29 x TZEEI 76	2483	3250	2867
TZEE-W Pop STR C5 x TZEEI 21	2233	3017	2625
TZEE-Y Pop STR C5 x TZEEI 21	2333	2917	2625
CSIR-Abontem	2000	3267	2634
Farmers' variety	2050	3300	2675
Mean	2177	3144	
s.e.d.	279.8		
C.V. (%)	14.9		

Maize plant height was significantly (P<0.001) influenced by variety/hybrid with the CSIR-Abontem producing the tallest plants and followed closely by TZEE-W Pop STR C5 x TZEEI 21whilst 99 TZEE-Y STR produced the shortest plants (Table 105). Maize cobs per plant were not significantly influenced by maize variety. However, the farmers' variety produced the highest cob number per plant whilst TZEEI-W Pop STR C5 x TZEEI 21 produced the lowest. TZEEI 29 x TZEEI 49 and TZEEI 29 x TZEEI 76 also produced higher cobs per plant than the rest of the treatments. There were significantly (P<0.001) differences among varieties and hybrids with regards to number of cobs harvested, with CSIR-Abontem producing the highest cob number at harvest, followed closely by 2000 SYN EE-W and TZEEI 29 x TZEEI 49, whilst the farmers' variety recorded the least (Table 105). All the treatments with the exception of CSIR-Abontem, 2000 SYN EE-W, TZEEI 29 x TZEEI 49, TZEEI 29 x TZEEI 49 and TZEE-W Pop STR C5 x TZEEI 21 produced plants that were taller than the trial mean. Hundred kernel weight was not significantly (P<0.05) affected by maize variety/hybrid. However, 99 TZEE-Y STR produced the boldest kernels followed by 2004 TZEE-W Pop STR C4 and 2008 SYN EE-W DT STR whilst TZEE-W Pop STR C5 x TZEEI 29 produced the smallest kernels (Table 105).

Table 105. Yield and its components of extra early maize varieties and hybrids evaluated on-farm At Garu-Tempane District in a semi-arid agro-ecology in northern Ghana in the 2012 cropping season.

Maize variety/hybrid	Plant height (cm)	No. of cobs/plant	No. of cobs harvested	1000-kernel weight (g)	Harvest index	Grain yield (kg/ha)	Straw yield (t/ha)
2000 SYN EE-W	156	0.94	113	21.45	0.44	3283	4367
2004 TZEE-W Pop STR C4	180	0.90	94	26.25	0.37	2817	4856
2008 SYN EE-W DT STR	174	0.95	99	25.85	0.38	3717	6183
2008 TZEE-W STR	173	0.97	93	24.03	0.40	3233	4883
99 TZEE-Y STR	136	0.93	93	29.38	0.51	2650	2567
TZEEI 29 x TZEEI 49	160	0.98	112	23.60	0.39	3133	4883
TZEEI 29 x TZEEI 79	176	0.98	98	24.55	0.39	3250	5117
TZEE-W Pop STR C5 x TZEEI 29	188	0.91	100	19.30	0.32	3017	6633
TZEE-Y Pop STR C5 x TZEEI 29	181	0.98	104	23.95	0.42	2917	4267
CSIR-Abontem	191	0.85	116	21.30	0.35	3267	6083
Farmers' variety	180	1.1	84	21.90	0.36	3300	5983
Mean	172	0.94	101	23.78	0.39	3144	5074
s.e.d.	7.84	0.076	9.43	3.40	0.035	277.8	849.0
LSD	16.0	0.156	19.26	6.94	0.07	567.3	1733.9
C.V. (%)	6.4	11.5	13.3	20.2	12.80	12.5	23.10

There were significant ($P<0.001$) differences among treatments with regards to maize harvest index with 99 TZEE-Y STR recording the highest and TZEE-W Pop STR C5 x TZEEI 21 the lowest harvest indices. Maize grain yield this year were generally greater than those recorded in 2011. 2008 SYN EE-W STR recorded the highest grain yield, whilst 99 TZEE-Y STR produced the lowest. All the varieties and hybrids with the exception of 2004 TZEE-Y Pop STR C4, 99TZEEI 29 and TZEE-Y Pop STR C5 x TZEEI 29 produced yields that were lower than the trial mean. Maize straw yield was also significantly affected by variety and hybrid with TZEE-W Pop SR C5 x TZEEI 29 recording the highest and 99 TZEE-Y STR producing the lowest.

Maize plant height was not significantly influenced by variety and hybrid effect. However, 2004 TZEE-W Pop STR C4 produced the tallest plants followed closely by TZEE-W Pop STR C5 x TZEEI 29 whilst TZEEI 29 x TZEEI 79 produced the shortest plants. TZEEI 29 x TZEEI 49 produced the highest cob number per plant whilst TZEE-Y Pop STR C5 x TZEEI 29 produced least cobs per plant. TZEEI 29 x TEEI 49 recorded the highest cob number at harvest followed closely by TZEEI 29 x TZEEI 49 and 2000 SYN EE-W STR whilst TZEE-W Pop STR C5 x TZEEI 29 and 99 TZEE-Y STR produced the least cobs at harvest. 100-kernel weight was not significantly affected by maize variety or hybrid, however, TZEEI 29 x TZEEI 79; TZEE-W Pop STR C5 x TZEEI 29 and 2004 TZEE-W Pop STR C4 produced the boldest grains, whilst TZEEI 29 x TZEEI 49 produced the smallest. Maize harvest indices recorded in the Bawku Municipal were generally lower than those recorded in the Garu-Tempane District. TZEEI. 29 x TZEEI 49 and TZEE-Y Pop STRC5 x TZEEI 29 recorded the highest harvest indices compared to the rest of the varieties and hybrids. Grain yields of maize for all varieties and hybrids recorded in the Bawku Municipal were generally lower than those reported for Garu-Tempane District. TZEEI 29 x TZEEI 49 produced the highest grain yield and followed closely by TZEE-W Pop STR C5 x TZEEI 29, whilst 99 TZEE-Y STR produced the lowest maize yield (Table 106). All the improved drought tolerant maize varieties and hybrids gave yields that were higher than those recorded by CSIR-Abontem and the farmers' variety with the exception of 2008 SYN EE-W DT STR and 99 TZEE-Y STR. Straw yields of maize were generally high with TZEEI 29 x TZEEI 79 and TZEE-W Pop STR C5 x TZEEI 29 producing the highest straw yields and 99 TZEE-Y STR producing the lowest.

Table 106. Yield and its components of extra early maize varieties and hybrids evaluated on-farm at the Bawku Municipal in a semi-arid agro-ecology in northern Ghana in the 2012 cropping season.

Maize variety/hybrid	Plant height (cm)	No. of cobs/plant	No. of cobs at harvested	100-kernel weight (g)	Harvest index	Grain yield (kg/ha)	Straw yield (t/ha)
2000 SYN EE-W	183	1.1	94	22.93	0.34	2117	4167
2004 TZEE-W Pop STR C4	183	1.1	89	25.15	0.33	2217	4500
2008 SYN EE-W DT STR	173	1.0	80	23.62	0.34	2050	4167
2008 TZEE-W STR	173	1.1	81	24.88	0.35	1950	3500
99 TZEE-Y STR	172	0.84	79	23.05	0.36	1850	3167
TZEEI 29 x TZEEI 49	177	1.2	95	19.57	0.41	2667	3833
TZEEI 29 x TZEEI 82	165	0.98	82	25.68	0.35	2250	4667
TZEE-W Pop STR C5 x TZEEI 29	182	0.94	78	25.62	0.36	2467	9667
TZEE-Y Pop STR C5 x TZEEI 29	180	0.77	93	22.32	0.40	2333	3500
Abontem	179	0.93	81	22.43	0.34	2000	3833
Farmers' variety	175	0.89	75	22.00	0.27	2050	5500
Mean	176	0.99	84	23.39	0.35	2177	4136
s.e.d.	10.41	0.18	7.20	3.23	0.044	263.6	781.7
LSD	21.26	0.37	14.72	6.60	0.090	538.3	1596.5
C.V. (%)	8.3	26.1	12.1	19.5	17.7	17.1	26.7

Discussion

The performance of maize in 2012 was far better as compared to the yields that were obtained in 2011 because though the rain started late it was generally consistent in distribution for most of the time. TZEEI 29 x TZEEI 49; 2008 SYN EE-W DT STR; TZEEI 29 x TZEEI 76 and 2000 SYN EE-W in that order produced the highest maize yields across the two locations that the trials were conducted. These results have been corroborated by those reported in both the baby and mother trials. Thus these varieties and hybrid are stable across the locations in terms of their performance. At Garu-Tempane, all the variety/hybrids out-yielded their counterparts in the Bawku Municipal. This might be ascribed differences in rainfall pattern between the 2 locations and/or due to improved agronomic practices adopted by the farmers at Garu-Tempane or both. TZEE-Y Pop STR C5 x TZEEI 29 was taller than the other drought-tolerant maize varieties probably due to genetic differences. 2000 SYN EE-W was the earliest to attain 50% flowering, probably because it is an extra early maturing variety or due to weather differences or to the cultural practices adopted by the farmers or a combination of these factors. Maize, plant height, 1000-grain weight and grain yield reported in this study were far higher compared to those reported by (Girma Abebe, *et al*. 2005). Maize yields in the mother trials were 1.5 times greater than those obtained in the baby, which is contrary to what was obtained in the 2011 cropping season, probably due to differences in trial management between farmers in the mother trial and their counterparts who handled the baby trials. This was expected as the mother trials were farmer- researcher managed as against the baby trials, which were purely farmer managed. 2000 SYN EE-W was the highest yielder in the baby trials, out-yielding the highest yielder in the mother trial TZEEI 29 x TZEEI 49 by about 47%. This is quite intriguing considering that the yield attained by 2000 SYN EE-W was under farmers' management. 2000 SYN EE-W and 2008 SYN EE-W DT STR obtained greater maize yields in the baby trials than those recorded for the mother trials. These same varieties produced the second highest maize yields in the mother trials next only to the hybrid TZEEI 29 x TZEEI 49. Generally, maize yields in the current study are comparable to those reported for hybrid maize in on-farm trials by Sallah *et al*. (2007). The yields reported in the current study are higher than those reported by the Ministry of Food and Agriculture in the country, which hovers around 1500 kg per ha. The trials would be repeated in the 2013 cropping season and if the current varieties and hybrids that gave the best results should repeat then we would recommend them for release by the National Variety Release Committee.

Conclusion

These on-farm tests have demonstrated the potential of improved drought-tolerant maize varieties and hybrids for increasing and sustaining maize production and productivity in the Upper East Region, which until recently featured only millet and sorghum-based cropping systems. It is anticipated these varieties will help farmers to overcome the perennial initial, mid or terminal drought that is characteristic of the region, which often result in complete maize crop failure. These varieties can also increase the incomes of farmers in the area, given that their estimated rates of returns to investment are quite high. From these preliminary results TZEEI 29 x TZEEI 49; 2008 SYN EE-W DT STR and 2000 SYN EE-W were the most promising hybrids and variety in this year's evaluation and if they repeat this superior performance they would be selected for consideration by the National Variety Release Committee for release in 2016, should they repeat their superior performance in the 2013 cropping season.

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Compatibility of Millet and Legume under Relay Cropping Condition

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Executive Summary

Double-cropping millet and legumes is a popular cropping system in the Upper East region (UER) of Ghana. For improved production efficiency, suitable millet-legume combinations with short life cycles that permit extension of the growing season to facilitate double-cropping need to be explored. The objective of this study was therefore to use performance data to identify millet-legume combinations compatible for relay cropping within the UER. Three early millet cultivars (Bongo Shorthead, Arrow Millet and Bristled Millet) were factorially

relayed by three legumes namely cowpea, groundnut and soybean. Bongo Shorthead followed by cowpea in a relay cropping system has the greatest prospect of accounting for superiority in grain and stover/straw yield while Bongo Shorthead followed by groundnut in a relay will provide the least suitable combination for relay cropping within the Upper East Region of Ghana

Introduction

Double-cropping cereal and legume is a popular cropping system in the Upper East region (UER) of Ghana. Relay cropping or inter-seeding legume into standing maize is a concept that has been explored in the Midwest as a means of extending the growing season to facilitate double-cropping (Duncan et al., 1990; Moomaw & Powell, 1990 and Reinbott et al., 1987). Conventional double-cropping, a sequential planting of legume after cereal harvest, is often fraught with poor stands, weed infestations, and delayed legume planting due to adverse weather conditions. With relay planting, the legume is inter-seeded into the millet 1 to 3 weeks before maize harvest. Cereal-legume combinations with short life cycles provide excellent opportunity for double cropping in UER where diminishing soil moisture creates terminal drought stress and thus reduces profit potential, especially for the legumes. For improved production efficiency, suitable relay compatibility between cereal and legume with short life cycles that permit extension of the growing season to facilitate double-cropping need to be explored. There is little information regarding the compatibility of millet-legume combinations suitable for relay cropping system in the region. The objective of the current study was therefore to use performance data to identify millet-legume combinations compatible for relay cropping within the UER. Specifically, the study was to examine the grain yield and yield components of three millet cultivars and three legumes (soybean, groundnut and cowpea) under the relay cropping conditions.

Materials and methods

The experiment was conducted during the 2011 and 2012 cropping seasons (May/June to September/October) on Manga experimental station, near Bawku (11°01N, 0°16'W, 249m above sea level). Millet and legume components were planted in a randomized complete block design (RCBD) with three replications using the following millet-legume treatment combinations: AM/ G: Arrow millet followed by groundnut, AM/CO: Arrow millet followed by cowpea, AM/SOY: Arrow millet followed by soybean, BSH/G: Bongo Shorthead followed by g'nut, BSH/CO: Bongo Shorthead followed by cowpea, BSH/SOY:Bongo Shorthead followed by soybean, BM/G: Bristled Millet followed by groundnut, BM/CO: Bristled Millet followed by cowpea, BM/SOY: Bristled Millet followed by soybean. Factorial inter-seeding of the legumes in the standing millet was done one week to the harvest of each millet cultivar. The intra-row spacing of the legume lines was 20 cm with two plants per stand giving a spacing of 75 cm× 20 cm with 5 rows between the 6 rows of the millet per plot. Data was collected of millet on Stand count at establishment, Stand count at mid-season, Stand count at harvest, Days to 50% flowering (DFF), spike length, spike girth, Stover weight, incidence of Downy Mildew (DM) at establishment, and at maturity, 1000 grain weight (1000GW) and Grain yield. Data collected of legumes included Days to 50% flowering (DFF), stover weight and Grain yield. All statistical analyses were conducted using the GenStat Statistical program (GenStat Discovery Edition 3, version 7.2.0.220).

Results and discussion

Agronomic performance of millet showed that 1000-grain weight was generally low with Bristle millet recording the heaviest 1000-grain weight followed by Bongo Shorthead with Arrow millet producing the least. In terms of straw yield, Bongo Shorthead produced the highest straw yield in both cropping seasons followed by Bristled millet, whilst Arrow millet produced the lowest. Grain yield values were statistically different in both seasons with BSH maintaining consistently higher values above the mean yields of 2.333t/ha and 2.58 t/ha in 2011 and 2012 respectively. Grain yields of Arrow Millet were below these mean figures in both cropping seasons (Table 107).

Responses of legume grain yield and other agronomic traits to relay cropping systems

There were significant differences among the various legumes for days to flower initiation under the cropping systems. Consistently, and in both cropping seasons, cowpea flowered earlier than the mean DFF of 51.89 and 60.00 in 2011 and 2012 respectively. Soybean flowered significantly ($P<0.05$) later than the means in both seasons. Quantitative data such as grain yield and straw yield values of the legumes could not be compared statistically since they were not of the same genus. However, in terms of stover and grain yields, cowpea clearly maintained consistent yield superiority over the other legumes with cowpea stover yield values ranging from 14.5t/ha (in 2012 under AM/CO) to 17.2t/ha (in 2011 under BSH/CO), followed by soybean with stover yield ranging from 8.5t/ha (in 2012 under BM/SOY) to 12.9t/ha (in 2011 under BM/SOY).

Table 107: Thousand grain weight, Straw yield and Grain yield of millet under relay condition during 2011 and 2012 cropping seasons

Treatment	2011			2012		
	1000 GW (g)	Straw Yield (t/ha)	Grain Yields (t/ha)	1000 GW (g)	Straw Yield (t/ha)	Grain Yields (t/ha)
AM/ G	9.0	15.8	1.797	8.8	14.3	2.64
AM/CO	8.5	25.3	2.130	8.5	24.5	1.36
AM/SOY	9.5	24.5	2.080	8.0	25.8	2.12
BSH/G	9.5	28.9	2.567	9.5	29.1	4.27
BSH/CO	8.8	25.2	2.447	9.5	31.5	3.82
BSH/SOY	9.2	27.5	2.660	9.5	30.8	4.18
BM/G	11.5	21.7	2.373	10.0	22.1	1.49
BM/CO	10.0	25.3	2.590	11.5	26.1	1.51
BM/SO	12.5	21.9	2.350	11.9	23.5	1.81
Mean	9.8	24.0	2.333	9.7	25.3	2.58
Lsd (p<0.05)	0.46	0.85	0.5172	0.71	1.02	1.267
CV (%)	14.2	11.1	8.0	13	15.3	28.5

Table 108: DFF, Stover weight and Grain yield of legumes under relay condition during 2011 and 2012 cropping seasons

Treatment	2011	2012

	DFF	Stover Wt (t/ha)	Grain Yields (t/ha)	DFF	Stover Wt (t/ha)	Grain Yields (t/ha)
AM/ G	48.00	8.0	1.79	55.37	7.9	2.64
AM/CO	47.67	15.3	3.13	39.67	14.5	4.36
AM/SOY	53.67	10.5	1.80	55.33	9.9	3.12
BSH/G	47.33	8.9	1.56	54.67	7.7	1.27
BSH/CO	46.67	17.2	4.47	40.33	15.5	4.82
BSH/SOY	55.33	11.5	2.66	54.02	8.7	2.18
BM/G	46.67	9.7	2.37	54.31	8.1	1.49
BM/CO	46.00	15.8	3.95	40.00	16.1	4.51
BM/SO	54.67	12.9	2.350	54.11	8.5	1.81
Mean*	49.56			49.76		
Lsd (p<0.05)*	3.180			1.778		
CV (%)*	0.4			1.7		

** Mean, Lsd and CV could not be computed for quantitative data such as stover weight and Grain yield since the legumes are not of the same genus*

Cowpea attained maximum yield of 17.2t/ha stover and 4.82t/ha grain values both under BSH/CO relay cropping condition while groundnut produced the least stover of 7.7t/ha and accounted for the least grain yield of 1.27t/ha all under BSH/G relay cropping condition. These observations point to the fact that under normal rainfall pattern, Bongo Shorthead followed by cowpea in a relay cropping system has the greatest prospect of accounting for superiority in grain and stover/straw yield while Bongo Shorthead followed by groundnut in a relay will provide the least suitable combination for relay cropping within the Upper East Region of Ghana.

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Effect of spatial arrangement on the performance of Pearl millet-Cowpea intercrop

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Executive summary

Spatial arrangement of crops is critical in determining the growth and yield of intercrops. The productivity of four spatial arrangements of millet (*Pennisetum glaucum*, [L], Br) and cowpea (*Vigna unguiculata* [L.] Walp) in intercrop was studied from June to October 2010 in the Sudan savannah zone of Upper East Region of Ghana. The intercrop row arrangements were: one-row millet : one row cowpea (1M:1C), two-row millet : one row cowpea (2M:1C), two-row millet : two-row cowpea (2M:2C) and two-row millet : four-row cowpea (2M:4C). There were also the sole crop arrangements of millet and cowpea that formed the basis for comparison with the other arrangements. Even though yields of the intercrop components were lower than their sole crop counterparts, the intercrop components were more productive than the sole crop components as evidenced by the Land Equivalent Ratios (LERs) which ranged from 1.48 to 2.44. The results of the study showed that one row of millet to one row of cowpea (with millet planted 2 weeks before cowpea) proved superior to the other spatial arrangements.

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is cultivated in the Guinea and Sudan savannah zones of Ghana, where it is used in the preparation of various traditional foods. In all the agro-ecological zones of Ghana, cowpea is intercropped primarily with cereals (especially maize and sorghum), cassava and sometimes yam. It is generally grown as the minor crop in a system based on cereal or tuber crop (FCDP, 2005). The system is practically relevant to the development of a sustainable cropping system. In this system, the next non-leguminous crop utilizes the nitrogen fixed by the legume and thus reduces the need for added nutrients.

Cowpea is a major component of the traditional cropping systems within the Upper East Region of Ghana where it is widely grown in mixtures with other crops in various combinations. The dominant intercropping systems for cowpea in the semi-arid tropics is the additive series in which sorghum, millet or maize is planted at the typical population density for sole cropping, and the cowpea is planted between rows of the cereal after the cereal is well established. It is generally grown as the minor crop in a system based on cereal or tuber crop (FCDP, 2005). The major yield limiting factors of cowpea cropping systems are low population, low yield potential of local cultivars, insect pests and diseases, shading by the cereals and drought stress and low soil fertility. Opportunities for improved management practices that could be exploited to overcome some of these constraints include appropriate sowing date, row geometry, pest incidences, and variety improvement. To overcome the problems of insect pests and diseases as well as shading by the cereals, it is appropriate to develop improved cropping systems using improved cowpea varieties and different crop combinations. There is limited information on the effect of different cereals on the yield and yield components of cowpea in strip cropping system. The objective of this trial was to assess the productivity of cowpea-millet intercrop under different spatial arrangements

Methodology

The trial was conducted in SARI Research Station at Manga, Bawku (11°01N, 0°16'W) in the Sudan savannah zone of Ghana. Six spatial arrangements of millet/cowpea were used as treatments namely, one row of millet alternating with one row of cowpea (1M:1C); two rows of millet alternating with one row of cowpea (2M:1C); two rows of millet alternating with two rows of cowpea (2M:2C); two rows of millet alternating with four rows of cowpea (2M:4C); sole millet; sole cowpea. The randomized complete block design was used with three replications. Millet seeds were hand-sown in June 2010 in rows 0.75m apart and intra-row spacing of 0.30m at four seeds per hill. Each plot consisted of 6 rows. Cowpea seeds were planted between the millet rows two weeks after, at two seeds per hill with intra-row spacing of 0.20m. Data taken on cowpea from 2 central rows were: Grain yield, stover weight, pod weight per plot, bad (unmarketable shriveled or holed) pods and good (marketable) pods. For millet, Panicle length, grain yield, number of effective tillers per plant, percent incidence of downy mildew, percent incidence of chaffy heads and plant count were taken from 2 central rows.

Estimation of intercrop productivity and competitiveness

The biological productivity of the intercrops per unit of ground area was assessed as a ratio of intercrop to sole crop using the Land Equivalent Ratio (LER) as follows:

$$LER = \left(\frac{Yim}{Ysm}\right) + \left(\frac{Yic}{Ysc}\right)$$

Where *Yim* is the yield of millet under intercropping, *Ysm* is the yield of millet under sole cropping, *Yic* is the yield of cowpea under intercropping, and *Ysc* is the yield of the cowpea under sole cropping (Mead and Willey, 1980).

Results and Discussion

Crop Yields and Land Equivalent Ratios

The Grain yields and other agronomic traits of millet are presented in Table 109. Millet grain yield was highest under one-row millet : one-row cowpea (1M:1C) and lowest under two-row millet : two-row cowpea (2M:2C) as well as sole millet condition. Percent incidence of downy mildew (DM%) was significantly (P >0.05) high under 2M:4C, 2M:1C and 2M:2C but lowest under 1M:1C. There were no significant differences (P >0.05) among the arrangements in terms of initial plant count. One-row millet : one-row cowpea (1M:1C) was among the arrangements that recorded appreciable effective tillers with sole millet recording the least. Total number of effective tillers of millet might have affected millet yields. Even though sole millet recorded the highest number of total tillers, it had the least number of effective tillers as well as highest percentage of chaffy tillers. 2M:2C had the lowest total tillers.

Table 109:Agronomic Response of Pearl Millet as Affected by Spatial Arrangement

Treatment	DM%	P'cle L (cm)	Plt Ht (cm)	Effec-tive Tillers (%)	Chaffy Tillers (%)	Plt count	Grain yield (t/ha)	Total tillers
2M1C	71.3	26	144	34	28.7	32.3	1.97	47.7
2M2C	68.7	22.7	131	36	20	34.3	1.37	45
1M1C	58.4	25	142.7	33.3	46.3	34	2.40	62
2M4C	72.4	21.7	143	27	53.5	34	1.63	58
SM	68.7	24.3	141	26.4	73.6	34.3	1.36	66.7
Mean	67.9	23.94	140.34	31.34	44.42	33.73	1.746	55.88
LSD (p>0.05)	22.53	4.429	16.78	1.352	23.71	3.036	1.58	20.27
CV	17.4	3.9	2.7	8.8	19.3	1.2	6.8	4.1

Table 110: Productivity of Pearl Millet as Affected by Spatial Arrangement

Treatment	Plant count /ha	Plt Ht (cm)	Grain yield (t/ha)	LER	ATER	MEAN LERATER
2M1C	20,976	144	6.66	2.44	0.75	1.59
2M2C	21,3333	131	5.46	2.04	0.52	1.27
1M1C	21,509	142.7	6.51	1.48	0.91	1.19
2M4C	21,124	143	6.8	2.26	0.62	1.44
SM	20,091	141	7.0		0.75	1.59
Mean	21,006	140.3	6.49			
LSD(p>0.05)	ns	ns	ns			
CV(%)	2.8	2.2	20.7			

Land Equivalent Ratios (LERs) and the means of the LER and Area-Time Equivalent Ratios (LERATER) used to assess the productivity of the spatial arrangements in Table 110 showed that the intercrops were more productive than the sole crops. LER values showed that intercrop advantage (productivity) ranged from 48% under 1M1C to 144% under 2M1C. The differences in the reproductive yields of the different spatial arrangements are consistent with observation by Azam-Ali *et al.*,(1990). The differences in performance among the intercrop treatments could be accounted for by the differences in plant count. The system is therefore practically relevant to the development of a sustainable cropping system. The agronomic response of cowpea to the spatial arrangements is presented in Table 111. Cowpea grain yield was highest under 2M:4C and lowest under 2M:2C. Bad pods were most associated to 2M:4C and least associated to 2M:2C. Good pods were mostly recorded under the 2M:4C and sole cowpea arrangements. There were no significant differences among the arrangements in terms of stover weight. Two-row millet : four row cowpea (2M:4C) and sole cowpea were among the spatial arrangements that recorded appreciable pod weight per plot while 2M:2C recorded the least. Total number of good pods and pod weight per plot of cowpea might have affected the grain yields of cowpea. Sole cowpea which recorded the highest number of good pods also had the highest number of bad pods. Even though 2M:4C recorded significant numbers of bad pods, it accounted for the highest cowpea grain yield, and was also among the highest in terms of good pods and cowpea pod weight per plot.

Table 111:Agronomic Response of Cowpea as Affected by Spatial Arrangement

Treatment	Pod (t/ha)	Stover wt (t/ha)	Grain yield (t/ha)	Bad pods	Good pods
2M1C	5.3	35.0	4.11	24.3	202
2M2C	4.5	38.3	3.30	17.3	189
1M1C	6.5	38.3	4.66	27	235
2M4C	10.7	35.0	7.36	39.3	418
SC	16.2	36.7	6.86	39.7	423
Mean	8.64	36.6	5.258	29.52	293.4
Lsd(p>0.05)	2.283	ns	0.216	8.69	130.0
CV(%)	1.8	8.8	6.5	10.7	5.9

Increase in the productivity of the intercrop may be ascribed to both spatial and temporal advantage. By mixing such crops that have different resource requirements, i.e. light, water and space, it was likely that their demand for resources were at different times. Such complementarity for resource need by the crops is consistent with the findings of Willey (1979). Comparison of the different cropping patterns indicated that the two row millet alternating with one row cowpea (2M:1C) showed the best intercrop advantage. This may have resulted from the efficient use of the available resources. Since millet and cowpea were planted at different times in this cropping pattern, the two crops might have been subjected to less competition from each other. Therefore, to achieve higher intercrop advantage in two crop system such as described in this study, the best option will be an arrangement of one row millet alternating with one row cowpea.

Conclusion

Though farmers generally regard legume yield under cereal-legume cropping system as bonus harvest, the study shows that strip intercropping especially 2M:1C is more productive than the sole cropping. The higher intercrop advantage indicated that the system was more efficient in terms of resource use than the sole crops.

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Integrated management of rainwater and small reservoirs for multiple uses

Dr. Wilson Dogbe, Julius Yirzagla, Francis Kusi and Jonathan Agawini

Executive summary

A participatory constraint identification and analysis at the Binaba dam between the users of the dam and SARI research team showed that though several improved rice varieties have been developed and released by SARI, farmers still face basic challenges of access to quality rice seed. Farmers' access to quality seeds of improved varieties are constrained by a number of challenges including cost of improved rice seed and ignorance of availability of improved seeds. The urgent need to address the perennial pest and disease attack on onion was given the needed attention. Siltation of the dam resulting from improper soil tillage practices and farming activities too close to the dam revealed the urgent need for proper watershed management practices to be adopted by the dam users. Four intervention measures which were implemented

to address the challenges include a participatory varietal evaluation of improved rice, Integrated Pest Management (IPM) strategies on onion production, community seed production of rice and the establishment of vetiver grass within the watershed of the dam.

Introduction

The Challenge program on Water and Food is addressing a development challenge in the Volta basin on "*Integrated management of rainwater and small reservoirs for multiple uses".* The program is designed to explore the institutional, socio-economic and technical aspects of small reservoir development and maintenance embedded within a wider rainwater management system in the basin. The Project is being implemented in Ghana and Burkina Faso by 3 international Research and Development institutes in partnership with national. In Ghana the project is implemented at Binaba dam 2. The dam is fraught with a number of constraints; siltation of the dam, lack of high yielding varieties (HYV) of crops such as rice and onion as well as inadequate Integrated Pest Management (IPM) strategies on onion.

Measures to address the Prioritized Constraints

Participatory varietal evaluation of rice

Through a participatory varietal evaluation, 8 varieties consisting of seven newly improved varieties from SARI and a farmer variety were used in a demonstration field which was managed by the farmers under the leadership of a contact farmer and the Agriculture Extension Agent (AEA). The varieties included Gbewaa rice, Exbaika, L_2-4, Long grain ordinary, Perfume irrigated, WAS 122-13-WAS-10-WAR, WAB 163-B-5-3, Farmer (Local) variety.

Results

In an evaluation session, 20 farmers were asked to score the 8 rice varieties using stones. Table 112 represents the rice grain yield and farmer preference of the various varieties of rice. Most critical consumer preference traits were early maturing. Consumer preference scoring showed that 50% of farmers preferred Gbewaa rice, while 5% preferred the farmer variety. Majority of the farmers expressed their interest to adopt the improved varieties especially Gbewaa rice assigning high grain yield among others as reasons for their preference (Tables 1).

Table 112: Farmers' preference criteria for the various varieties of rice

Character/ Trait of rice	No. of farmers	Percentage	Cumulative
Early maturing	4	20	20
High yielding	7	35	55
Long rain	3	15	70
No lodging	3	15	85
Non-shattering	3	15	100

Conclusion

Based on high yield, the farmer preference scoring showed that Gbewah rice may be widely accepted by at least 35% of the farmers. For selection based on early maturing, 20% of the farmers preferred an improved variety. The Farmer variety appears less appealing to the farmers as only 5% of the farmers scored for it. Thus, from the farmers' preference criteria, the improved varieties can be considered for further evaluation and adoption.

Integrated pest management (IPM) strategies in onion production

Julius Yirzagla, Francis Kusi and Jonathan Agawini

Objectives

- To demonstrate to the farmers how IPM strategies can be used to manage pest and diseases in onion farming under irrigation.
- To demonstrate how onion bulb size can be increased with recommended spacing.
- To demonstrate how IPM strategies can be used to cultivate other new varieties of onion in Guinea Savannah zone of Ghana.

Methodology

Generally 50 farmers were directly trained on the demonstrations whereas about 150 other farmers, traders and transporters indirectly benefited from the demonstrations. Yield, pests and diseases data were collected on the communities. A demonstration field served as a learning centre for the FBOs where the Research Team and the AEA met them on forth night basis. Onion varieties used in the field include Bawku Red, Galmi and Red Cleole.

The earlier perception of the farmers that Galmi is a late variety as compared to Bawku Red was disproved. Both Bawku Red and Galmi were found to mature at 90 days after transplanting. However, the maturity period for Red Cleole was found to be 110 days. Early transplanting between late November and early December was found to respond positively to the treatments. This reflected in the bigger bulb sizes and higher yields. The AEAs should therefore prompt the farmers to start their farming activities in time.

Vetivar grass establishment in the catchment area

The establishment of the grass on contour bunds was undertaken at both banks of the dam. This exercise was heavily patronized by the farmers who also co-operated well with the Oversight Committee members to keep the catchment area free from any form of land tillage.

Results

The activity was to address effects of erosion and siltation of the dam. Apart from seeking to deter farmers from farming in the catchment area of the dam, the establishment was intended to reduce surface run-off thus minimising the problem of erosion and siltation. By the close of the season, it was obvious that no tillage practice was undertaken within at least 50 metre radius of the bank.

Community seed production scheme

The community seed component of the project sought to increase the availability of good quality rice seed to farmers. With the assistance of the Agriculture Extension Agent (AEA), ten beneficiary farmers were identified and selected under the scheme. The beneficiary farmers expressed satisfaction of the scheme and have successfully stored their seeds pending the next cropping season when they intend to use these seeds for cultivation and also sell some to buy inputs. Plans are underway to establish market linkage to these farmers to enable them sell their produce.

Conclusion/ way forward
All the four intervention measures were successfully executed during the 2012 cropping season. The measures will be repeated during the 2013 cropping season and if possible the number of participating farmers will be increased so as to scale up the benefit of the project activities within the Binaba community.

AGRICULTURAL ECONOMICS

Baseline Study; Onion farmer's livelihood and value chain improvement project

J. K. Bidzakin, Yahaya Iddrisu

Executive Summary
The onion farmers' livelihood and value chain improvement project is due to start at the beginning of the onion production season (August, 2011). A baseline study is required to establish data against which progress can be monitored. The data required are data on impact level, i.e. data on the livelihood of the onion farmers. Therefore the baseline study is a livelihood study, involving different data collection methods. These are both quantitative methods (questionnaires) and qualitative (participatory rural appraisal tools, focus group discussions, key informants interviews) methods. Besides that some secondary data was collected through research of literature and existing studies already done on the same topic. Average farm gross margin calculated was Gh₵1803.62, however the average onion enterprise gross margin per acre calculated was GHS526.20 which is very low as compared to the district estimate of GhS3,770.00 per acre. Farmer household were generally food secured in the month of August. Generally from the survey, onion production is a profitable business to undertake if the challenges of farmers are addressed especially in the area of sufficient water supply, efficient storage systems, good market conditions, improvement in road network, training on integrated pest management practices and good agronomic practices, availability of certified seed and other inputs and provision of credit facility.

Introduction
Project background:
Bawku West district is an up-coming onion producing district in Ghana's Upper East Region. An estimated 4,000 farmers are involved in onion production. Onion production is taking place in the dry season on irrigated farming land alongside rivers, dams and streams or on land irrigated by water pumps. Onions are a cash crop and the main source of livelihood for farmers in the dry-season. Through the sale of onion, farmers and their families are able to meet expenses, such as food, school fees, medical bills and expenses on funerals and weddings. Traditionally onion farming has been a male activity due to the high level of investments required. Nowadays, more and more women also take up onion farming as a source of income. The sale of onions at the local markets is completely in hands of women.

Onion farmers face numerous challenges in production, storage and marketing. Moreover their level of organization is low. Some farmers are organized in local producers groups consisting of an average of 25 farmers. There are no higher level farmer organizations (village and district level organizations). Consequently collective purchase of farming inputs, collective sales of onions to traders and access to credit are difficult to achieve. In addition, socio-economic concerns are not heard at district, regional and national policy levels.

Onion yield per hectare is low in the two districts compared to other onion producing areas in West African countries. In Ghana, the average yields per unit area is 7.7 ton per ha. This is on average five times lower than that of Niger (35 ton per ha), three times as low as Senegal, Mali and Burkina Faso (23 ton per ha) and 2.5 times as low as the average of all countries in West Africa (18 ton per ha). Several factors account for the low production of onion: low yielding variety (Bawku Red); inadequate access to farming inputs (such as seeds and fertilizers); high incidences of pests and diseases; poor production and poor genetic quality of the onion seeds; limited use of (organic) soil and water conservation techniques insufficient water for irrigation; and limited sui Table l and for onion production.

Poor traditional storage methods result in post-harvest losses of up to 70% in some cases. Most farmers therefore sell the bulk of their produce shortly after harvest because of problems with storage. The weather at the time of harvesting is extremely hot and dry and traditional storage facilities are inappropriate for the storage of the onions.

Profit margins of onions are very low as well. There is also very little information available to farmers about prices of the crop elsewhere in the country. Soon after the main harvesting season has ended, the price of onions falls drastically due to an excess of supply in local markets. Farmers are often in need of cash and are forced to sell their right after the harvest. Apart from low incomes resulting from poor market for the crop, farmers are faced with high cost of production arising from the high costs of tractor services for land preparation, high cost of seed, fertilizers and other chemicals; high labor costs required for the intensive cultural practices required to bring the bulbs to full maturity.

Objective of baseline Study:
A baseline study is required to identify, collect and analyse primary and secondary data on the livelihoods of onion farmers in the Bawku West District to establish data base (reference point/measuring scale) against which progress can be measured. The data required are data on impact level, i.e. data on the livelihoods of the onion farmers.

Methodology used:
The baseline study was a livelihood study, involving different data collection methods. These are both quantitative methods (questionnaires) and qualitative (participatory rural appraisal tools, focus group discussions, key informants interviews) methods.
Besides that secondary data was also collected through desktop research of literature on existing studies on similar subject.

Results

Key findings:

Generally, there was an even distribution of both adults and children in a household with an average age of male household head being 47 years and their wives was estimated as 38 years. Majority of the household heads and their wives had no education and their primary occupation was crop production. Household wealth was largely concentrated on Livestock inventory.

Farmers cultivate on more than one piece of land which is direct ownership and takes about 58 minutes to walk to the plot. Inputs of all kinds except labor use are very low. Major crops produced in the area include; maize, millet, peanuts, bambara beans, soybeans, rice, and cassava. Vegetables grown in the area are onion, okro, hot pepper, sweet pepper and tomatoes.
Household heads and their wives participate in clubs and groups to receive information on agricultural production. Knowledge on conservation practices in all categories was very high for households. However, knowledge on no-tillage (zero-tillage) varied. Average farm gross margin calculated was Gh₵1803.62, however the average onion enterprise gross margin per acre calculated was GH₵526.20 which is very low as compared to the district estimate of Gh₵3,770.00 per acre.

Farmer household were generally food secured in the month of August. Farmers are challenged with lack of onion storage facilities. The market situation is not favorable to them and they feel exploited by middle men. They are also faced with yearly water shortage in their dams. They identified the challenges of onion farming and even suggested possible remedies to them.
Generally from the survey, onion production is a profitable business to undertake if the challenges of farmers are addressed especially in the area of sufficient water supply, efficient storage systems, good market conditions, improvement in road network, training on integrated pest management practices and good agronomic practices, availability of certified seed and other inputs and provision of credit facility.

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ENTOMOLOGY

Executive Summary

The Entomology Section of Manga Station of CSIR-SARI based in Upper East Region conducted a series of research activities to contribute to the coordinated efforts to address the enormous insect pests' problem in agricultural production in the region. Research activities carried out in 2012 includes: Dissemination of strategies developed to manage pests and diseases of onion, tomato and pepper under irrigation and Integrated management of field and storage pests to extend shelf life of yam. The dissemination was carried out in collaboration with MoFA, NGOs and Farmer Based Organizations (FBOs). The dissemination activities formed part of the series of activities to end the phase 1 of the WAAPP and FABS projects in December 2012 and March 2013, respectively. Other activities carried out to end phase 1 and to prepare for the phase 2 of WAAPP project include; preparation of factsheets, production guide and multiplication of yam setts. This is to enhance up-scaling of the demonstrations across the major yam production areas in Northern and Upper West Regions. Other major research activity conduct by the Entomology Section is the deployment of aphid resistant gene to improve field resistance of some cowpea varieties to the cowpea aphid *Aphis craccivora*. Evaluation of planting date, cultivar and insecticide spraying regime for the control of insect pests of cowpea in northern Ghana was also carried out. The detailed research activities and the major achievements so far are as follows.

Integrated management of field and storage pests, and post-harvest handling to extend shelf life of yam.

Francis Kusi, Mukhtharu Zakaria and J. N. Azure

Introduction

The phase one of the West Africa Agricultural Productivity Programme (WAAPP) officially ended in December, 2012. A sub project, WAAPP 003: Integrated management of field, storage pests and post-harvest handling to extend shelf life of yam, ended with the following technologies: Pre-planting treatments of yam setts against early attack of the sprouts by pests and diseases; Post sprouting treatments against yam beetle infestation; improved yam storage structures, good agricultural practices (GAP) and good storage practices (GSP).

The activities carried out to conclude the activities of the project in 2012 cropping season are as follows:

- Field and storage demonstrations of the technologies in selected communities in yam growing areas in Upper West and Northern Regions.
- Yam sett production –this was part of the preparation to up-scale the demonstrations of the technologies in all the major yam growing areas under WAAPP phase two.
- Production of factsheets and yam production guide to enhance up-scale dissemination of the technologies generated under WAAPP phase two.

Methodology

Field and storage demonstrations of the technologies

Field and storage demonstrations were conducted in six communities in 2012 cropping season. These are Kpabia, Manjere, Tingoli and Akokayili in Northern Region and Kpongu and Loggu in Upper West Region. The Farmer Field School concept was used to train the farmers on the demonstrations. Field days and exchange visits were also used to enhance the dissemination of the technologies.

Yam sett production

Availability of yam setts was identified as one of the major constrains to yam production. This is mainly due to low multiplication rate of a yam tuber as compared to cereals like a cob or even a single seed of maize. As part of the preparation towards the up-scaling of the demonstrations in all the major yam growing areas in the two regions, the following methods were used together with farmers to generate yam setts.

Early milking of the tubers

At four months after planting, between mid August and early September, the mounds were carefully opened without much disturbance to the rooting system. The tubers were carefully detached at the crown with the tip of a sharp cutlass and removed. The crowns with the undisturbed roots were covered and the mound re-shaped. By early to mid December, between 4 – 6 setts of about 250 g each had been formed per mound. These were harvested, cured, treated and stored.

Curing of the milked tubers in pit

The milked tubers were kept in pits of about 70 cm deep. The bottoms of the pits were covered with grass before the tubers were carefully packed in the pits. The bigger tubers were cut into smaller sizes (about 300 g). After filling the pits, the tubers were covered with grass and finally covered it with soil, heaping it in a form of huge mounds. By early to mid December, the milked tubers had been well cured and these were removed and stored for planting with the early rains in the next cropping season.

Results and discussion

In all the communities a total of 900 farmers were trained on the demonstrations and this consisted of 150 farmers per community. The farmers were trained in the pre-planting treatments, post sprouting treatment, the improved storage structure and treatment of tubers against infestation and infection by pests and diseases after removing sprouts in storage. In addition to these the farmers were trained in Good Agronomic Practices (GAPs) and Good Storage practices (GSPs). The farmers were introduced to the following strategies to completely eliminate rodents from their thatch or mud structures storage structures:

Fencing with roofing sheets

Building a smoothly plastered round wall of about 70 cm high around the structure

Covering the base of the mud structure with roofing sheets. The farmers were also taught to create between 2 - 4 windows depending on the size of the mud structure to improve ventilation in order to control high mealy bug infestation

Production of Factsheets and yam production guide

To enhance the dissemination of the findings of the project under WAAPP phase 2, a total of four factsheets and yam production guide were prepared. The topics of the factsheets are as follows:

- Extending the shelf-life of yam from 3-7 months – improved storage structures
- Good storage practices to extend shelf-life of yam
- Double yam yield with recommended spacing and GAPs
- Good Agronomic practices in yam cultivation

Development of strategies to manage pests and diseases of onion, tomato and pepper under irrigation

Francis Kusi, Muktharu Zakaria and J. N. Azure

Introduction

The IPM strategies developed to manage pests and diseases of vegetables under irrigation through FABS Project (2011 Annual report) were disseminated. The dissemination was done in collaboration with Northfin Foundation, CPFW -3 and MoFA. Funds were provided by FABS, Northfin Foundation and CPFW -3 whiles the field staff of two NGOs (Northfin Foundation and ZOFA) and AEAs from MoFA collaborated in the project implementation.

The components of the IPM strategies

- Production within the favourable climatic condition for each of the crops
- Good nursery management practices
- Good land preparation
- Early transplanting within the favourable climatic condition
- Efficient water management
- Setting action thresholds for the key pests and diseases of the crops
- Monitoring and identification of pests and disease
- Managing the crop to prevent pests and diseases from becoming a threat using cultural practices
- Once monitoring, identification, and action thresholds indicate that pest and diseases control were required, control methods were evaluated both for effectiveness and risk. Timely, adequate and safe application of pesticides was used as the last resort.

The objective was to demonstrate to the farmers how the IPM strategies could be used to increase onion production. Specifically, to increase onion bulb size through spacing and good nutrition and to introduce three other onion varieties to the farmers.

Methodology

A total of seven demonstrations were established in the following irrigation sites in Bawku West and Binduri Districts:

1. Binaba 1
2. Binaba 2
3. Tanga

4. Tilli
5. Nagberi
6. Sapeliga
7. Manga

At each of the demonstration site, 150 onion farmers were trained on the demonstration. A master Farmer Field School (FFS) concept was used in order to reach out to many farmers with the same message within few days (1-2 days). The fortnight meetings were rotated among the 7 communities and at each of these meetings all the field staff and the AEAs from MoFA in-charge of the 7 communities met with the Research team together with the onion farmers in that particular community (Master FFS). Between 1-2 days after each master FFS, the field staff of the NGOs and the AEAs from MoFA moved to their respective communities to replicate the FFS with their farmers. With this approached all the 1050 farmers were reached with the same message within 2 days.

Results and Discussion

One thousand and fifty (1050) farmers were train on the demonstrations in all the communities. Three other onion varieties were introduced to the farmers in addition to their own variety, which was Bawku Red. The new varieties were Galmi, Red Cleole and Texas Grano. What informed the choice of the varieties is as follows:

Galmi – Has now gained popularity in the cities due to its large bulb size (≥ 100 g) mild pungency making it more preferred in salad preparation and for garnishing.

Red Cleole –Has large bulb size (≥ 100 g) mild pungency and it is also preferred in salad preparation and for garnishing. Beside the colour is just like the Bawku red which attracts those who will always go in for Bawku red.

Texas Grano - This is white coloured onion which has high export market value

Three spacing were demonstrated to the farmer and these are 10 x 10 cm, 10 x15 cm and farmers spacing. The average spacing used by most of the onion farmer is 6 x 6 cm and this usually results in small bulb sizes (≤ 40 g) due to competition for space and nutrients. Hence the need to introduce the farmers to appropriate spacing of onion to increase bulb size comparable to the size of Galmi and other exotic varieties.

Key findings

Although the number of bulbs per unit area was more as compared to the 10 x 10 cm, the weights were either the same or even higher in the 10 x 10 cm than the farmer practice. The farmers testified that in the market, the bigger bulbs of Bawku Red have higher premium over the smaller bulb size. In effect the farmer will gain more income from adopting 10 x 10 cm spacing for Bawku Red than their normal pacing of 6 x 6 cm. Field management such as weed control, stirring of the soil and fertilizer application were found to be easier with the row nursing and transplanting at the recommended spacing.

Comparing the Bawku Red and the other varieties, Bawku Red was found to be hardy against pest and disease when all were subjected to the IPM strategies. The new varieties were more susceptible to pests and diseases, most especially, the Red Cleole and the Texas Grano suffered significantly from the incidence of leaf miner (Fig. 32). In spite of this, the agro-ecological zone was found to be suitable for the production of the three varieties (Galmi, Texas Grano and Red Cleole). This is confirmed by the yields recorded in the three varieties and the bulb sizes (Fig. 33).

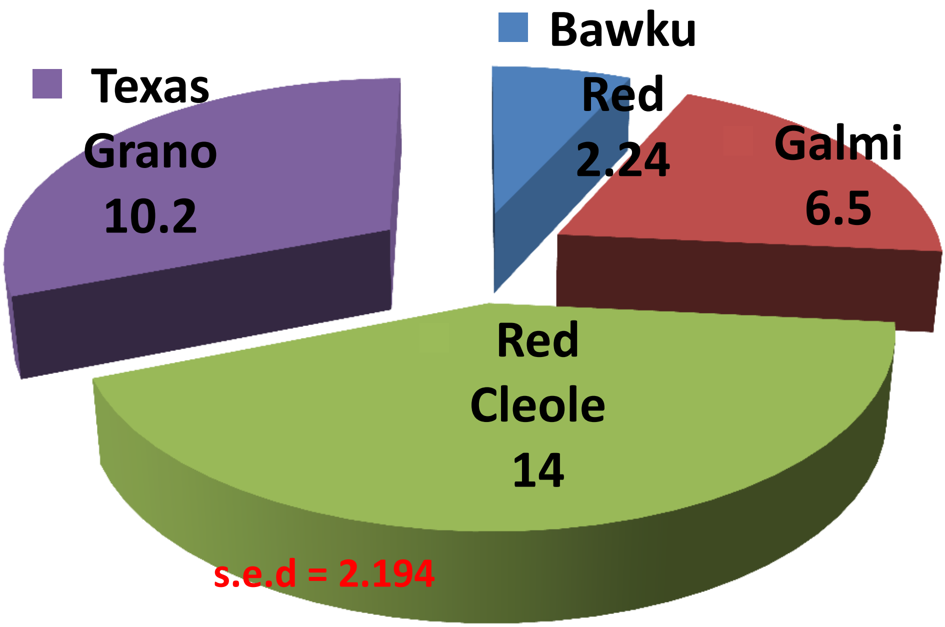

Fig. 32. Percent seedling infested by leaf miners

The potential bulb sizes of the new varieties were realised with 10 x 15 cm spacing when compared to 10 x 10 cm spacing. The earlier perception of the farmers that Galmi is a late variety as compared to Bawku Red was disproved. In both 2011/2012 and 2012/2013 results, both Bawku Red and Galmi were found to mature at 90 days after transplanting. However, the Maturity periods of Texas Grano and Red Cleole were found to be 110 days.

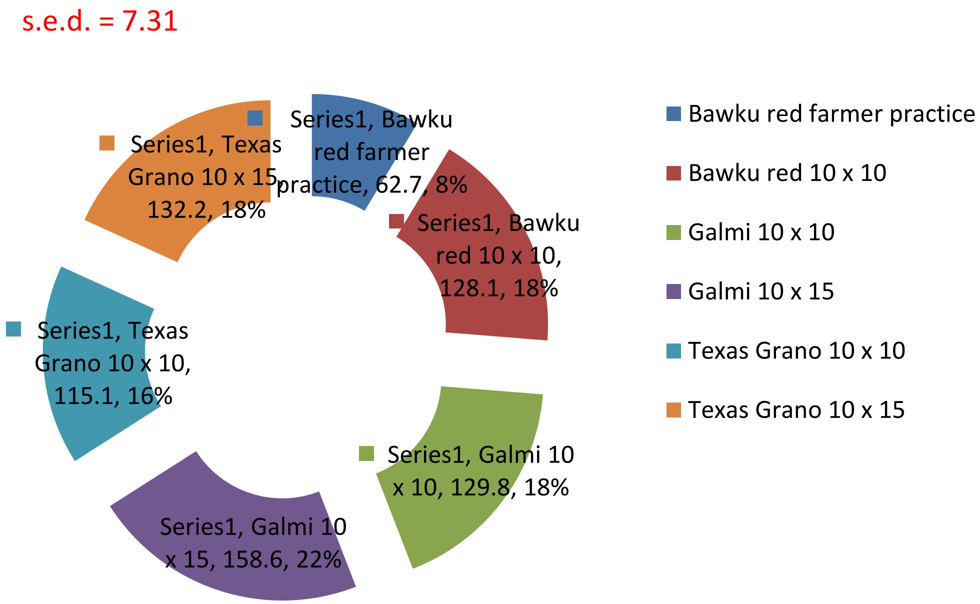

Fig. 33. Weight per bulb (g) per treatment at Tanga

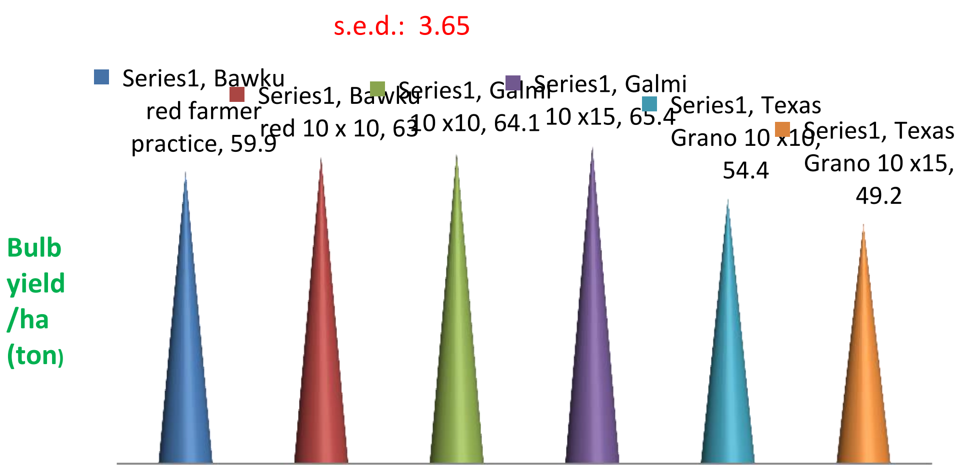

Fig 34. Bulb yield (t/ha) per treatment at Tanga

In general, early transplanting between late November and early December was found to respond positively to the treatments. This reflected in the bigger bulb sizes and yield recorded at Tanga (Fig, 2 and 3). Input supply to the farmers should therefore be timely and the AEAs should prompt the farmers to start their farming activities in time.

Deployment of cowpea aphid (Aphis craccivora) resistance gene to improve cowpea cultivars in Ghana

Introduction

SSR marker CP171/172 was identified out of 50 DNA markers supplied by Kirkhouse Trust and was further tested for its reliability to be used in marker assisted breeding of aphid resistant cultivars. CP171/172 was found to be about 90% effective in selecting aphid resistant progenies from large F2 segregating population. A 'marker directed' phenotyping approach was then designed to use CP171/172 in marker assisted backcrossing. When using this approach, the population is first genotyped with the marker in the laboratory to reduce the size of the population. This is followed by further screening of lines that are heterozygous for the region of the aphid resistance locus in the screen house using the seedling screening method. This approach helps to eliminate the crossovers that might have been selected among the heterozygote lines by the marker. This has successfully been used to develop a marker-assisted backcross population between Aphid resistant line and Zaayura which is currently in its BC_3 advanced stage.

A further search was carried out during the reporting period to identify other cowpea genotypes of commercial importance that can be improved with the aphid resistance gene using marker-assisted backcrossing.

Methodology

Screening for cowpea genotypes that are polymorphic with SARC1-57-2.

Between July and December 2012, screening of cowpea genotypes was carried out to identify genotypes with important traits. The screening was also to identify commercially important genotypes that are susceptible to aphid. Both phenotyping for target traits and genotyping with the marker CP 171/172 were conducted. The phenotyping was done by planting about one hundred cowpea lines in both *Striga gesnerioides* and aphid hot spots in the Upper East region of Ghana. The field results were further tested in Striga infested pots and subsequently tested for polymorphism with the aphid resistant line using the marker, CP171/172.

Results and Discussion

Careful monitoring and observation of these lines revealed two Striga resistant lines. These were IT99K-573-1-1 and IT99K-573-3-2-1 and further check on these lines among other lines in pot experiment found no Striga attachment on the two lines that were found to be resistant to striga in the field screening experiment (Fig. 35 and Table 113).

The polymorphic test also found the two IITA lines to be polymorphic with the aphid resistant line, SARC1-57-2, (Fig. 36). A proposal was consequently submitted to Kirkhouse Trust to improve IT99K-573-1-1 and IT99K-573-3-2-1 with the aphid resistance gene in a marker-assisted backcrossing scheme.

Fig 35. Pot screening for Striga resistant lines

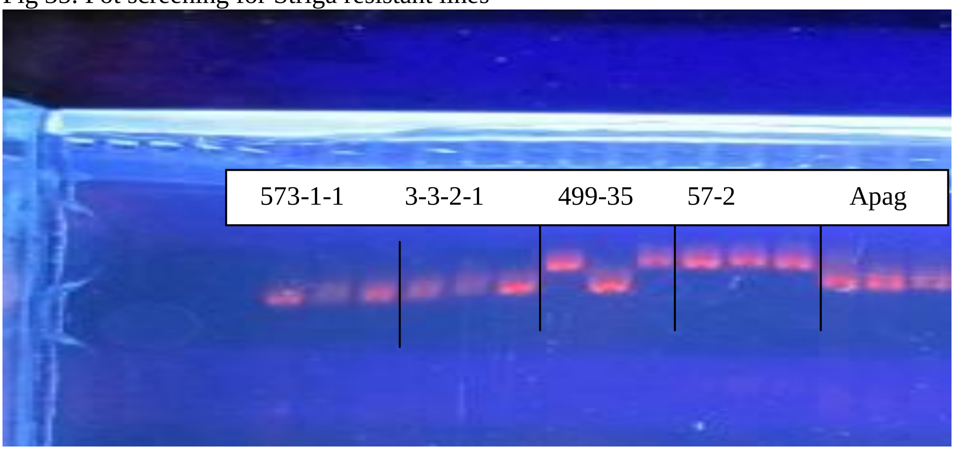

Fig. 36. SSR marker CP 171/172 profiles in triplicate, respectively for IT99K-573-1-1, IT99K-573-3-2-1, IT97k-499-35, SARC1-57-2 and Apagbaala. There seems to be a mixture in one of the 3 samples of IT97k-499-35.

Table 113. The scores of the pot screening for Striga resistance

Name	Rep	Striga Attached
Bawuta	1	Yes
	2	Yes
	3	Yes
	4	Yes
	5	Yes
	6	Yes
IT99K-573-1-1	1	No
	2	No
	3	No
	4	No
	5	No
	6	No
IT99K-573-3-2-1	1	No
	2	No
	3	No
	4	No
	5	No
	6	No
Songotra (IT97K-499-35)	1	No
	2	No
	3	No
	4	No
	5	No
	6	No
B 301	1	No
	2	No
	3	No
	4	No
	5	No
	6	No
Sanze	1	Yes

2	Yes
3	Yes
4	Yes
5	Yes
6	Yes

Evaluation of Planting Date, Cultivar and Insecticide Spraying Regime for Control of Insect Pests of Cowpea in Northern Ghana

Introduction

Cowpea, *Vigna unguiculata* (L) Walp, is one of the major staple crop in Ghana. The leaves, green pods, green peas and the dry grain are eaten as food and the haulms are fed to livestock. The grain contains 23-28% protein and constitutes the cheapest source of dietary protein for majority of people in Africa who lack the necessary financial resources to acquire animal protein (Tarawali et al., 1997). Sale of the grain also provides income to farmers and traders in Ghana. As a leguminous crop, cowpea also fixes atmospheric nitrogen into the soil which is of major benefit in African farming where most of the lands are exhausted and farmers lack adequate capital to purchase chemical fertilizers. Moreover, cowpea is shade-tolerant and therefore compatible as an intercrop in the mixed cropping systems widely practiced by small holder farmers (Singh and Sharma, 1996).

Despite its importance, cowpea yields on farmers' field are low averaging less than 500 kg ha^{-1}. The major cause of the low yields is due to problem of insect pests that attack the crop throughout its growth. Insecticide application is the recommended practice for control of insect pests on cowpea. However, most farmers in Ghana are resource-poor and require pest management strategies that are cost-effective and sustainable. The use of insecticides must be minimized because of high cost and harmful effects on the environment. The purpose of this study was to develop an integrated management system for cowpea insect pests using host plant resistance in elite cultivars, appropriate planting date and reduced insecticide spraying regimes.

Specific objectives

1. Evaluate cowpea cultivars for their resistance to major insect pests of cowpea
2. Determine appropriate planting dates as a cultural tool for pest management in cowpea
3. Determine the minimum insecticide protection required for increased cowpea yield

Methodology

Two experiments were established

Experiment 1

Treatment: 4 planting dates, 6 cultivars and 2 spray regimes

Design: Split-split-plot in RCBD

Main plot – Spray regime, Sub-plot- Planting date and sub-sub plot – cultivar
Replications: 3
Plot size: 4 rows of 4 m long spaced at 0.60 x 0.20 m
Spray regime: sprayed and unsprayed
Planting date: start from mid July in 2 weeks interval

Cultivar:
V1. IT99 K-573-1-1
V2. IT99 K-573-3-2-1
V3. Songotra
V4. Padi Tuya
V5. Bawutawuta
V6. Farmer variety (Marfo Tuya)

Experiment 2
Treatment: 6 cultivars and 4 insecticide spraying regimes
Design: Split-plot in RCBD
Main plot – Spray regime, Sub-plot- cultivar
Replications: 4
Plot size: 4 rows of 4 m long spaced at 0.60 x 0.20 m

Spray regime:
1. No spray
2. Spray once at 50% flowering
3. Two sprays, one at flower bud initiation and at early podding
4. Three sprays, one each at flower bud initiation, 50% flowering and 50% podding.

Cultivar:
V1. IT99 K-573-1-1
V2. IT99 K-573-3-2-1
V3. Songotra V4. Padi Tuya
V5. Bawutawuta
V6. Farmer variety

Data collected include:
Days to 50% flowering
Days to maturity,
Insect pests sampling (thrips, *Maruca vitrata* and pod sucking bugs)
Pods damage by PSBs and *Maruca* and
Yield parameters.

Key findings, year one
Timely planting of cowpea between mid July and early August is recommended for farmers in Upper East Region. Plots planted between mid July and early August showed all cultivars maturing before terminal drought. Also fewer shrivelled pods and pods with *Maruca* feeding holes recorded as compare to the late plantings and the grain yields were higher as well as the

grain quality.Planting between mid July and early August had good moisture conditions which also created conditions that had adverse natural effects on insect pests' development. Judicious and timely application of insecticide at flower bud initiation and at early podding in integration with good agronomic practices is also recommended. For a profitable cowpea production, unsprayed fields should not be encouraged

IT99K-573-1-1 and IT99K-573-3-2-1 were identified as new sources of *Striga gesnerioides* resistance in Northern Ghana (Fig 37). The *Striga* resistance of Songotra, IT99K-573-1-1 and IT99K-573-3-2-1 makes them the most preferred cultivars for the region due to the heavy infestation of Striga seeds in most of the soils in Upper East Region. The field resistance of Padi Tuya and Bawutawuta to *Striga* should be improved and Songotra, which is known to be resistant to *Striga* must be cleaned

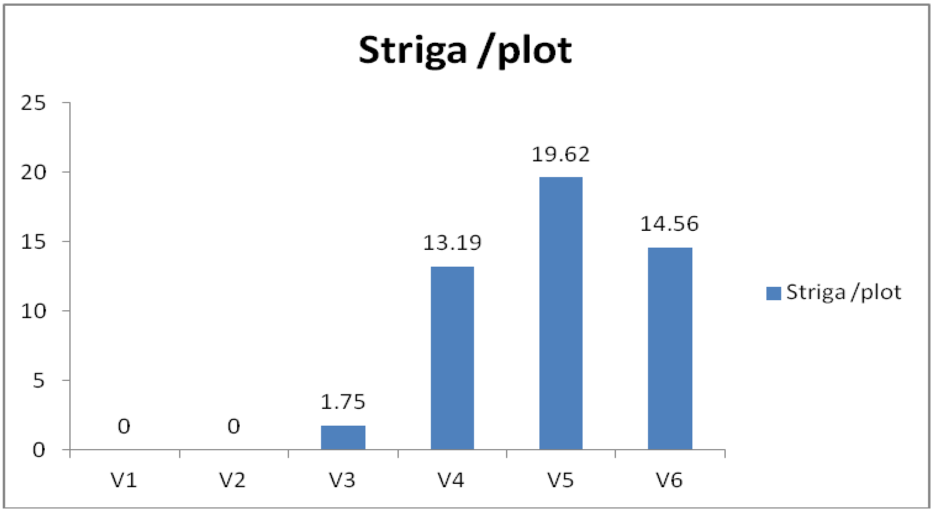

Fig 37. Number of Striga per plot

Seed programme of Maize: Influence on Seed Security and Farmer Livelihoods in the Upper East Region

Issah. Sugri, R.A.L Kanton, F. Kusi, M. Zakaria

Executive Summary

Though several maize (*Zea mays*) varieties and hybrids have been developed over the last three decades in Ghana, farmers still face basic challenges of access to quality seed. National seed programmes are still challenged by inefficient production, high cost, distribution and poor quality assurance systems. This study examined how research-policy-extension-private sector linkages can ameliorate these constraints. A structured questionnaire, farm visits and group discussions were employed to capture information from actors in the seed value chain. Seed samples (100-500g) were obtained from the respondents for seed quality test. From the study, farmers obtained maize seed from 11 recurrent sources; informal and formal. The informal sources include use of local varieties, recycled improved seed, seed sharing and non-packaged seed from open market. All sources of seed showed optimum germination (78.1-86.8%) range. Most preferred traits were early maturing (48%), high yielding (25%) and drought escape (23.2%). Access to seed was hindered by distance, price and lack of information about the improved varieties. Though each variety or hybrid possesses special traits, respondents could not ascertain which variety, or if their current variety possessed those traits. Over 90% of responds did not know the "release name" of the variety; seed colour (white or yellow) was the basis of identification. This poses great limitation if a farmer desires to change his variety.

Introduction

Despite the release of several crop varieties, hybrids and propagation technologies in Ghana, adoption rates by farmers are below optimum due to a combination of factors. A large proportion of farmers depend on informal sources of seeds for staple crops production. The quality of seed determines the success of crops in terms of yield and yield stability, product quality, and subsequent contribution to food security and market potential (Louwaars and de Boef, 2012). This has influence on food security of households in agricultural communities. Though, Africa has witnessed a 4-5 fold increase in the number of seed companies marketing various types of improved varieties in recent times, about 66-85% of seed used by resource-poor farmers in sub-Sahara Africa is derived from informal sources (Langyintuo *et al*. 2008). In some instances, Donor Agencies and Non-Governmental Organizations purchase seed from established seed companies and make it available at subsidized rate or as donation to farmers who do not have access to certified seed due to inaccessibility or poverty. Generally, the development of improve varieties should be supported by sustainable systems that provide quality seed at the right time and location. This study assessed the effect of current seed programme of maize using seed security component (availability, access and quality) approach.

Methodology

The study was carried out from June to September 2012, coinciding with the main cropping season of maize. A structured questionnaire and group discussions were used to capture information from 90 respondents which included farmers, agro-input dealers and seed growers from 6 districts: Bawku-East, Bawku-West, Talensi-Nabdam, Bongo, Kassena-East and Kassena-West, all in the Upper East Region. The questionnaire captured data on demographic information, name of variety, initial and/or current source of seed, reasons for selecting a variety, current constraints and modules to improve access to seed as well as areas requiring research and training. To improve the reliability of data, unannounced visits were made to farmers' field on days of planting. Seed samples of 100 to 500 g were obtained from respondents on the field for seed quality analysis.

Results

An analysis of sources of seed showed that only 25% of growers used local varieties as initial planting material. A large majority (75%) utilized certified seed from seed dealers (33%), CSIR-SARI (24%), MoFA (13%) and community seed growers (5%). Decisions on seed acquisition are influenced by price, perceived quality and overall availability. Access to quality seed was hindered by distance, price and information about the variety (Figure 1). Farmers obtained maize seed from 11 recurrent sources; informal, formal and semi-formal. The informal sources include use of local varieties, recycled improved seed, seed sharing from relations and non-packaged seed from open market. Seed age and recycling behavior of different actors indicated that farmers recycled the improve varieties for several years (2-25years) (Table 114). Overall, 60, 33.3, 2.2, 4.4 % of actors recycled seed for 1 to 2, 3 to 5, 6 to 10 and 11 to 25 years respectively (Table 114). First choice preference traits were early maturing (41.8%), high yielding (23%), drought escape (24.5%), *Striga* resistance (1.01%), less fertilizer requirement (2.04%), resistance to lodging (1.01%), sweet yellow maize (3.1%) and quality maize (QPM) (2.04%). The most utilized varieties were CSIR-Abontem, CSIR-Aburohemaa, Dorke, Obaatanpa, CSIR-Omankwa and Safita 2. Though these varieties possess specific traits, farmers could not ascertain which traits their current variety possessed. Over 90% of farmers respondence did not know the "release name" of the variety. Endosperm colour: white or yellow was the basis of identification. This poses great limitation if the farmer desires to change his variety due to poor performance.

Table 114: Seed age and recycling behaviour of different actors in the seed supply chain

Seed age (years)	Responses by category (% responding)						
	Farmer seed	Community seed growers	Certified seed growers	Research Institute (SARI)	MoFA	Total freq.	Overall response (%)
1-2	10.5	90	74.1	68.2	76.9	54	60
3-5	68.4	10	25.9	31.8	23.1	30	33.3
6-10	5.3	-	-	-	-	2	2.2
11-25	15.8	-	-	-	-	4	4.4
	100	100	100	100	100	90	100

Table 115: Most recurring reasons for selecting a particular variety

Quality traits	1st Choice Reason Freq.	% Responding	2nd Choice Reason Freq.	% Responding	Overall (% Responding)
Early maturing	27	48.2	14	33.3	41.8
High yielding	14	25	9	21.4	23.5
Drought escape	13	23.2	11	26.2	24.5
Striga resistance	1	1.8	-	-	1.01
Less fertilizer use	1	1.8	2	4.8	2.04
Resistance to Lodging	-	-	1	2.4	1.01
Yellow maize	-	-	3	7.1	3.1
Quality protein maize	-	-	2	4.8	2.04

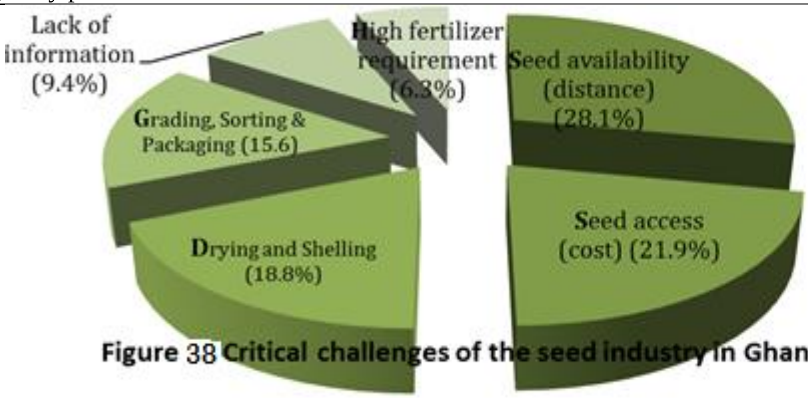

Figure 38 Critical challenges of the seed industry in Ghana

Recommendation

Overall, seed production, distribution and general information about improved varieties and hybrids require some improvement. Seed security is severely constrained in communities far away from urban and district markets. Strengthening the community seed concept, particularly in distant communities should be considered. Other marketing strategies such as seed fairs and seed vouchers can be considered. Finally, there is the need to strengthen institutional capacities of Ghana Seed Inspection Division and Grains and Legumes Development Board of MoFA with human, equipment and vehicles to conduct field seed inspection and offer seed processing and conditioning services at regional, district and zonal levels.

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Improving Agricultural Productivity through Storage and Handling Practices via Low Cost Technologies

Issah Sugri, John Kanburi Bidzakin, S.K. Nutsugah, Osei-Agyeman Yeboah, Cephas Naanwaab,

Executive Summary

Stored grains can be damaged by insect pests if they are not properly conditioned and protected. In Ghana, maize is harvested toward the cessation of the rainy season and stored during the drier months of the year. The produce is bulked from small-holder producers who practice different levels of farm hygiene. Integration of clean pre-harvest operations, responsive field chemical use, warehouse sanitation and timely pest management using monitoring and decision-making modules to minimize pest damage must be preferred to indiscriminate use of storage chemicals. This project has a technology development and delivery module; by demonstrating best storage practices to small-holder farmers in the Upper East Region of Ghana. The experiments demonstrate the appropriate use of jute sacs, polystyrene sac, PICS sacs and hermitic plastic tanks with/without grain protectants for prolong storage (1-3 years) of maize. Three experiments were established at 4 communities (Tansia, Azum-Sapielga, Tes-Natinga and Manga). Community animation and mobilization exercises were conducted in the target communities. Data was collected on grain physical characteristics such as moisture content, 100 grain weight, bulk density and dockage at 4 months intervals. Entomological data include number and weight of bored grains, number of live and dead insects present at sampling and insect species identification. Other technology dissemination programmes such as training was conducted in the intervention communities.

Introduction

Maize has become the major stable crop across regions and cultures of Ghana. Currently, maize base cropping systems have become dominant in drier northern savanna areas of Ghana where sorghum and millet were the traditional food security crops. According to SRID (2010), maize is the most cultivated crop in Ghana (991,669ha) on arable land compared to rice (181,228ha), millet (176,000ha), sorghum (252,555ha), cassava (875,013ha) and yam (384,942ha). Stored grains can be damaged by insect pests if they are not properly conditioned and protected. The conditions favourable for grain storage are as well suitable for insect pest reproduction. Pre-harvest pest infestation of notorious storage pests such as larger grain borer (*Prostephanus truncatus*), lesser grain borer (R*hyzopertha dominica*), maize weevil *(Sitophilus zeamais)*, granary weevil *(S. granaries)* as well as mycotoxins production by moulds, may occurre. Indiscriminate use of common grain protectants such as Actellic (Pyriphos methyl), bioresmethrin (pyrethroid) phostoxin, Gastox (Aluminium phosphate) and Wander77 powder is widespread in many communities. Most farmers acquire agro-chemicals from non-accredited informal sources without training on responsive use of chemicals. Integration of clean pre-harvest operations, responsive chemical use, warehouse sanitation and timely pest management using monitoring and decision-making modules to minimize pest damage must be preferred to chemicals. The objective of this study was to evaluate and demonstrate the appropriate use of jute sacs, polystyrene sac, PICS sacs and hermitic plastic tanks with/without grain protectants for prolong storage (1-3 years).

Methodology

A survey was conducted to assess current postharvest storage practices, trade volume, factors influencing adoption of bulk storage, and integrated storage and pest management strategies among others. Three experiments were established in 3 clusters of communities (Tansia, Azum-Sapielga and Tes-Natinga), the fourth replicate was cited on-station at Manga. Maize grains were bulked from arranged traders during the harvesting season for the study. For each treatment, 75kg of grain were stored in jute sacs, polystyrene sac, PICS sacs and hermitic plastic tanks with/without grain protectants for 1-3years. Two commonly used grain protectants, Betallic Super EC and phostoxin were applied at recommended rates of the manufacturers. Betallic Super EC is food-grade chemical containing 80g Pirimiphos-methyl and 15g Permithrin per litre as emulsifiable concentrate. Data collection included grain physical characteristics such as moisture content, 100 grain weight, bulk density and dockage at 4 months intervals. Initial proximate analysis for total carbohydrates, moisture content, crude fibre, crude ash and crude protein was carried out. Entomological data include number and weight of bored grains, number of live and dead insects present at sampling and insect species identification.

Results

Community animation and mobilization exercises was conducted in the target communities. Initial grain physical characteristics are shown in Table 116. Parameters such as 100 grain weight and bulk density will be monitored every 4 months to assess treatment effect on postharvest weight loss. Grain moisture content range was close to 8 % compared to recommended range of 11-13% for maize storage. This low moisture was influenced by dry north east trade wind which occurs from December to February each year. This shows additional advantage if farmers will observe clean pre-and-postharvest operations.

Table 116: Initial physical characteristics of grain at storage

Storage treatments	100 Grain Wt. (g)	Bulk density (kg/m^3)	Dockage (%)	Mouldy grain (%)	Moisture content (%db)	Moisture content (%wb)
FS only	25.6	72.2	3.7	0.83	6.2	6.6
FS+Actellic.	25.9	71.6	1.6	0.57	4.0	4.2
FS+phostoxin	26.7	73.4	1.7	1.08	5.2	5.5
JS only	26.9	71.6	1.7	0.86	4.7	5.0
JS+Actellic	26.4	71.2	1.8	0.61	5.4	5.8
JS+Phostoxin	27.2	72.3	1.6	0.80	8.4	5.9
PICS only	25.0	71.6	2.1	1.16	7.4	8.0
PICS+Actellic	24.1	71.4	2.3	0.63	7.2	7.9
PICS+Phostoxin	26.0	71.4	3.0	1.19	7.4	8.0
PT only	27.6	71.9	1.1	0.68	6.2	6.6
PT+Actellic	24.6	71.2	1.9	00.89	5.7	6.1
PT+Phostoxin	26.4	72.5	1.4	1.10	5.4	5.8
$P \leq 0.05$	0.001	0.001	0.001	0.082	0129	0.123
LSD(0.05)	0.97	0.08	0.61	0.48	2.9	3.3
CV (%)	0.3	0.3	20.2	42.3	15.8	16.8

FS=Fertilizer sac, JS=Jute sac, PICS=Perdue Improve Cowpea Storage sac, PT=Hermitic Polytank

Table 117 shows the initial insect data. The initial pest infestation was minimal, but the number of bored grains across treatments shows a latent pest infestation; high infestation could show when other favourable conditions exist.

Table 117: initial Insect pest prevalence at storage (per 100g of grain)

Storage treatments	Insect count			Insect species			Number of bored grain	Weight of bored grains
	Live	Dead	Larvae	*P. truncatus*	*R. dominica*	*S. zeamais*		
FS only	0.25	0.25	0			0.25	2.8	0.68
FC+Actellic.	0	0	0			0	2.1	0.55
FS+phostoxin	0	0	0			0	4.3	0.96
JS only	0	0	0			0	0.5	0.13
JS+Actellic	0	0	0			0	0.9	0.20
JS+Phostoxin	0	0	0			0	0.4	0.15
PICS only	0.25	0	0			0.25	1.4	0.34
PICS+Actellic	0	0	0			0	1.8	0.56
PICS+Phostoxin	0.5	0.25	0.25			0.5	1.8	0.33
PT only	0	0	0.25			0	0.5	0.10
PT+Actellic	0	0	0			0	0.5	0.10
PT+Phostoxin	0	0.25	0.25			0	1.2	0.54
$P \leq 0.05$	0.632	0.544	0.665			0.632	0.001	0.001
LSD(0.05)	0.26	0.10	0.18			0.26	1.46	0.42

FC=Fertilizer sac, JS=Jute sac, PICS=Perdue Improve Cowpea Storage sac, PT=Hermitic polytank

Conclusion

The study started in December 2012 and will end in November 2015. . Appropriate recommendations will be provided as the experiment is intended for 1-3 years. This study seeks to improve agricultural productivity and livelihoods through storage and handling practices using low cost strategies. This include evaluation, deployment and dissemination of medium to large scale storage methods to improve grain quality during prolong storage

UPPER WEST REGION FARMING SYSTEMS RESEARCH GROUP

The Upper West Region Farming Systems Research Group (UWR-FSRG) is based at the CSIR-SARI Wa Station in the Wa Municipality. Currently the team has a membership of four research scientists, two Soil Scientists, an Entomologist and an Agricultural Economist. The team's work focuses on characterizing and describing the farming systems of the region, identifying and prioritizing constraints to increase sustainable agricultural production and generating suitable interventions to address the prioritized problems of the farmers through adaptive on-farm as well as on-station research. Besides, the team also has oversight responsibility of coordinating the Research, Extension and Farmer Linkage Committee (RELC) activities in the UWR. This report highlights activities in the year under review.

AGRONOMY REPORT
ON-STATION TRIALS

Response of extra-early, early and medium maturing drought tolerant maize varieties to nitrogen fertilizer in the northern savanna zone

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Executive summary

Maize is an important staple food crop in Ghana, yet grain yields are low due partly to inherently poor soils, continuous cropping of cereals, high cost and unavailability of mineral fertilizers. Field trials were conducted during the 2012 cropping season in the Upper West region to assess agronomic and economic benefits of using five fertilizer N levels (0, 40, 80, 120 and 160 kg N/ha) on drought tolerant extra-early, early and medium maturity maize varieties. Preliminary results showed that the variation in N supply affected growth and yield of maize and low N stress reduced crop growth and grain yield significantly. Added N showed a better trend for higher grain yield and yield components than no fertilizer treatment. Grain yield reductions were noted under no fertilizer treatments. Lack of N probably enhanced kernel abortion and reduced final grain number. Across varieties, mean grain yield increases over zero N treatment as a result of fertilizer application of even 40 kg N/ha were more than 100%. Grain yield was more positively correlated with number of kernels than kernel weight. N use efficiency values among the varieties were consistent with the amount of grain produced at maturity with more efficient varieties having greater values. NUE decreased as a result of increased N supply. The results are preliminary and it would be imperative that the studies are repeated for another season so as to arrive at a firm fertilizer recommendation for maize production in the savanna zone.

Introduction

Maize is an important staple food crop in Ghana. In most of Ghana, low crop yields are common due to erratic rainfall, low soil nutrient levels (particularly N and P), use of unimproved varieties and poor management practices. Maize varieties and/or hybrids that are either tolerant to drought or mature earlier to escape drought have been developed for various agro-ecological systems through collaborative efforts between IITA and the NARS in West and Central Africa (WCA) within the framework of the Drought Tolerant Maize for Africa (DTMA) project. The breeding process is still on-going but some maize varieties have been jointly released from the programme by CSIR-SARI and CSIR-CRI. Prior to the release, the varieties were tested with farmers within the various ecological zones to validate the results obtained from the on-station trials for the past years. The assessment of these new varieties was done both on station and on-farm with the application of the outdated fertilizer recommendations for maize which is more than four decades old. However, with differences in the maturity periods and the additional attributes they possess to withstand both drought and *Striga*, it became necessary to assess the performance of these new varieties by subjecting them to different fertilizer N levels. The objective of the study was to assess agronomic and economic benefits of using different levels of fertilizer N on drought tolerant extra-early, early and medium maturity maize varieties in the northern savanna agro-ecology of Ghana.

Materials and methods

Three field studies involving three maturity groups of maize (i.e., extra-early, early and medium) were conducted during the 2012 cropping season at the CSIR-SARI experimental fields at Wa and Tumu in the Upper West region (UWR). The experiments were conducted in a split-plot arrangement of treatments in a randomized complete block design with four replications. In all trials, 60 kg P_2O_5/ha as triple superphosphate (TSP) and 60 kg K_2O as muriate of potash (MoP) were applied to each plot before sowing. For each trial the main plot treatments were five maize varieties. Five nitrogen levels of 0, 40, 80, 120 and 120 kg/ha as urea were applied to the subplots. The fertilizer N was applied in two equal doses to maximize N efficiency.

All the experiments were sown in July. Measurements included days to mid-silk and tassel emergence (days), plant height (m), grain yield (kg/ha) and 100-kernel weight (g). Leaf chlorophyll concentration of the second leaf from the top was assessed at 50% anthesis on 10 plants, using a portable Chlorophyll meter (SPAD-502 Minolta, Tokyo, Japan). Data collected were subjected to analysis of variance (ANOVA) to establish treatment and the interactions effects on grain yield and yield components. Regression analyses were conducted to determine yield response to N level for the genotypes and simple correlations were used to test association among traits. Nitrogen use efficiency (NUE) was calculated as yield of the N treatment minus yield of the zero kg N/ha (control treatment) divided by the quantity of fertilizer N applied in kg/ha (Cassman *et al*., 1996).

Results and discussion

Extra-early maturing maize

In Wa, days to anthesis ranged from 48 to 57 days. The variety 99 TZEE YSTR was the shortest and earliest to flower. It also produced the lowest grain yield of 1250 and 2772 kg/ha in Tumu and Wa, respectively (Table 118). Abontem and 99 TZEE YSTR produced similar but lowest grain yields. Mean grain yields were generally lower in Tumu compared with yields in Wa. The variety 2004 TZEE W POP STR C4 produced the highest grain yield (3671 kg/ha) in Wa. However, 2000 Syn EE W STR produced the highest grain yield (1724 kg/ha) in Tumu.

Three varieties (2000 Syn EE W STR, TZEE W POP STR QPM C0 and 2004 TZEE W POP STR C4) had more grain produced than Abontem in Tumu.

Nitrogen deprivation delayed silking at both sites. Chlorophyll concentration (SPAD values) as well as grain yield and its components increased with fertilizer N level. Grain yield increased with fertilizer N level with significant linear and quadratic responses in Wa ($Y=1244+34.89N-0.10N^2$; $R^2=0.67$) and Tumu ($Y=432.17+22.21N-0.08N^2$; $R^2=0.56$) Visually, the plants in the zero N treatments had yellowish leaves. Chlorophyll concentration reduction and leaf yellowing are good indicators of N remobilization. Generally, N deficiency accelerates senescence as revealed in the present study by the decrease in chlorophyll concentration under no fertilizer N treatment as compared with non-stressed conditions. Leaf N decrease in turn is expected to have a direct effect on canopy photosynthesis, resulting in greater kernel abortion (Pearson and Jacob, 1987) and lower grain number (Uhart and Andrade, 1995).

Fertilized plants produced more but heavier kernels and therefore had higher grain production in Wa (Table1). On average, grain yield increases as a result of the 40, 80, 120 and 160 kg N/ha applied over the zero N treatment were 153, 199, 248 and 301%, respectively in Wa. Similarly in Tumu, grain yield increases as a result of 40, 80, 120 and 160 kg N/ha applied over the zero N treatment were 168, 264, 301 and 343%, respectively. In Wa, Mean grain yield was more a function of number of kernels per square meter (r = 0.87) than kernel weight (r = 0.59). Grain yield was correlated with chlorophyll concentration (r = 0.73) suggesting that maintaining N and chlorophyll concentration of leaves during grain filling may lead to maintenance of leaf photosynthesis resulting in better grain filling.

Table 118a. Some agronomic traits of extra-early maturing maize varieties as affected by N levels in Wa and Tumu in 2012

	Wa					Tumu	
Variety	SPAD	100-seed wt	Kernel number/m^2	Grain yield	NUE	Grain yield	NUE
	No.	(g)	No.	kg/ha	kg/kg N	kg/ha	kg /kgN
99 TZEE Y STR	46.7	19.6	142	2772	25.9	1250	15.9
TZEE W POP STR QPM C0	42.0	23.0	130	3098	28.7	1496	14.4
2000 Syn EE W STR	42.6	22.0	139	3096	29.2	1724	12.2
2004 TZEE W POP STR C4	42.7	24.6	148	3671	34.4	1662	18.7
Abontem	44.4	21.6	131	2864	23.7	1170	13.7
Lsd (0.05) ‡	NS	NS	NS	507	7.7	306	NS

Table 118b. Some agronomic traits of extra-early maturing maize varieties as affected by N levels in Wa and Tumu in 2012

	Wa					Tumu	
N level	SPAD	100-seed weight	Kernel number/m^2	Grain yield	NUE	Grain yield	NUE
kg/ha	no	g	no	kg/ha	kg/kg N	kg/ha	kg /kg N
0	33.8	18.3	60	1106		397	
40	42.1	21.7	131	2796	42.3	1262	20.8
80	45.6	23.4	143	3312	27.6	1721	16.6
120	48.1	23.9	164	3851	22.9	1893	12.5
160	48.8	23.5	194	4438	20.8	2030	10.2
N linear	**	**	**	**	**	**	**
N quadratic	**	*	*	**	*	**	NS
CV%	13.5	17.4	20.7	22.1	32.4	28.3	34.0

NUE=N use efficiency., *, **, and NS = significant at 5 and 1% probability levels and not significant

Early maturing maize

At both sites, the two new varieties ((TZE W DT STR C4 and TZE Comp 3 DT C2F2) had similar grain yields as the two released varieties (Aburohemaa and Omankwa) (Table 119). All the drought tolerant maize varieties produced more grain than the farmer variety in Tumu. Over the years, TZE W DT STR C4 has consistently produced high and stable grain yields and was therefore released by CSIR-SARI in December 2012 and named CSIR-Wang-dataa.

Similar to results obtained from the extra-early maturing maize trial, N deprivation delayed silking at both sites. Fertilizer application generally, showed a better trend for higher grain yield and yield components than no fertilizer treatment. On average, grain yield increased with N level with significant linear and quadratic responses in Wa ($Y=831.90+27.51N-0.06N^2$; $R^2=0.79$) and Tumu ($Y=1098.56+24.31N-0.09N^2$; $R^2=0.67$). On average, increase in N levels beyond 80 kg/ha did not result in significant increases in grain yield. Application of the first 40 kg N/ha resulted in the highest mean grain yield increase when compared to the yield increases obtained from the application of 80 120 and 160 kg N/ha. In Wa, grain yield increase as a result of 40, 80, 120 and 160 kg N/ha applied over the Zero N treatment were 198, 269, 341 and 442%, respectively. Similar large increases were obtained in Tumu. Grain yield was more associated with kernel number (r = 0.89) than with kernel weight (r = 0.67) and also was positively correlated with chlorophyll concentration (r = 0.62). At both sites, grain yield was negatively correlated (r = -0.44 and -0.60) with days to 50% anthesis probably because the improved varieties which tended to produce higher grain yields matured earlier than the farmer's variety.

Medium maturing maize

Grain yield and yield components were not significantly different among the maize varieties (Table 120). However, two of the three new varieties, DT SYN 1W and IWD C3 Syn F2 which had comparable yields as the released variety, Obatanpa were subsequently released and named CSIR-Sanzal-sima and CSIR-Ewul-boyu, respectively in December 2012.

Table 119. Some agronomic traits of early maturing maize varieties as affected by N levels in Wa and Tumu in 2012

	Wa					Tumu	
Variety	SPAD no	100-seed weight g	Kernel number/m^2	Grain yield kg/ha	NUE kg/kg N	Grain yield kg/ha	NUE kg/kg N
TZE W DT STR C4	40.4	20.2	120	2487	21.5	2300	19.1
TZEComp3 DT C2F2	43.2	19.2	121	2307	22.6	2196	16.7
Aburohemaa	42.7	20.3	124	2587	25.7	2222	15.8
Omankwa	41.4	19.5	127	2572	28.8	2296	21.3
Farmer variety	40.4	19.0	120	2353	23.1	1716	11.2
Lsd (0.05) ‡	NS	NS	NS	NS	NS	209	3.8
N level (kg/ha)	SPAD no	100-seed weight g	Kernel number/m^2	Grain yield kg/ha	NUE kg/kg N	Grain yield kg/ha	NUE (kg/kg N
0	39.9	15.9	45	712		1017	
40	40.2	18.3	116	2096	34.6	2089	26.8
80	40.2	19.3	137	2593	23.5	2441	17.8
120	43.6	20.9	152	3095	19.9	2510	12.4
160	44.4	23.7	162	3810	19.4	2676	10.4
N linear	*	**	**	**	**	**	**
N quadratic	NS	NS	**	*	*	**	**
CV%	20.4	17.3	19.1	21.4	20.5	13.2	26.7

NUE=N use efficiency.*, **, and NS = significant at 5 and 1% probability levels and not significant

Table 120. Some agronomic traits of medium maturing maize varieties as affected by N levels in Wa, 2012

Variety	DFA	DFS	ASI	Plant height	SPAD	100-seed weight	Kernel number	Grain yield	NUE
	(day)	(day)	day	m	no	g		kg/ha	kg/kgN
DT ST W COF2	63	65	3	1.63	42.3	21.1	129	2851	30.0
DT SYN 1-W	69	71	3	1.66	43.4	19.3	120	2491	24.9
IWD C3SYN F2	66	69	3	1.47	43.9	17.1	132	2305	23.1
Obatanpa	63	66	3	1.81	42.1	19.0	149	2936	29.5
Farmer's variety	62	65	3	1.73	41.4	19.9	131	2698	25.0
Lsd (0.05) ‡	1	2	NS	0.12	NS	NS	NS	NS	2.9
N level (kg/ha)	DFA	DFS	ASI	Plant height	SPAD	100-seed weight	Kernel number	Grain yield	NUE
	day	day	day	m	no	(g)		kg/ha	kg/kgN
0	66	71	5	1.37	33.2	13.7	56	773	
40	65	68	3	1.59	38.4	17.2	134	2267	37.3
80	64	67	2	1.74	44.0	19.3	148	2811	25.5
120	64	66	2	1.80	49.3	22.4	165	3697	24.4
160	83	65	2	1.81	48.3	23.7	158	3732	18.5
N linear	**	**	**	**	**	**	**	**	**
N quadratic	NS	NS	**	**	*	NS	**	**	**
CV%	3.1	4.0	44.4	10.2	15.1	13.5	13.7	14.9	12.3

DFA=days to 50% anthesis; DFS=days to 50% silking; ASI=Anthesis-silking interval;
**, **, and NS = significant at 5 and 1% probability levels and not significant, respectively.*

Consistent with the results of the extra-early and early maturing varieties, variation in N supply affected both growth and development of the medium maturing maize plants. Averaged across varieties, grain yield increased with N level with significant linear and quadratic responses (($Y=818.61+36.76N-0.11N^2$; $R^2=0.78$). Significant grain yield reductions were noted under the no N fertilizer treatments. Chlorophyll concentration was significantly affected by N level with significant linear responses. On average, increase in N levels beyond 120 kg/ha did not result in significant increases in grain yield. Application of the first 40 kg N/ha resulted in the highest mean grain yield increase when compared to the yield increases obtained from the application of 80, 120 and 160 kg N/ha. Grain yield was more positively correlated with number of kernels per square meter (r = 0.85) than kernel weight (r = 0.57). Grain yield was all correlated with chlorophyll concentration (r = 0.64). A significant negative relationship was observed between ASI and grain yield (r = -0.66). This negative relationship may be due to the fact that no N treatment had the highest ASI but lowest grain yield.

Nitrogen use efficiency

In Wa, NUE significantly differed among extra-early and medium maturing varieties but differences were not detected among early maturing varieties (Tables 1, 2 and 3). The variety

2004 TZEE W POP STR C4 produced the highest grain yield (3671 kg/ha) among the extra-early maturing varieties in Wa and also had the highest NUE (34.4 kg/kg N) (Table 120). Also, Obatanpa which tended to have high yields in Wa had the highest NUE among the medium maturing varieties (Table 120). However, in Tumu differences among early maturing varieties were significant with Omankwa having the highest NUE of 21.3 kg/kg N (Table 119). NUE values among the varieties were generally consistent with the amount of grain produced at maturity with more efficient varieties having greater values. Greater N use efficiency normally should allow a reduction of nutrient to be applied to efficient plants without reducing the crop yield. Generally, NUE decreased as a result of increased N supply, regardless of variety.

Conclusion and recommendations

Maize responses to fertilizer N application were measured only in one season. On this occasion variation in N supply affected both growth and development of maize plants and low N stress reduced crop growth and grain yield significantly. Consequently the application of fertilizer N would increase maize grain yield and sustain soil fertility in the Guinea savanna zone. The objectives of the experiment have not been fully met yet. Moreover, the soils collected from these sites are yet to be analyzed and the soil data will help further explain the responses observed in the study. It is therefore recommended that the studies should continue for another season probably with only one or two varieties since varietal differences were not very large. This will allow for collection of more data to document the following:

- Response of maize to N applications.
- N application effects on nutrient concentrations in plant and soil.
- Economic analysis (evaluation of net benefits).

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Response of soybean to fertilizer application and Rhizobium inoculation in the Upper West region

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Executive summary

Soybean is an important cash and oil seed crop yet its grain yields are low on farmers' fields. The low yields are due partly to low soil nutrient and management levels. Field trials were conducted to assess the agronomic and economic benefits of using fertilizer N, P and K as well as *Rhizobium* inoculants for soybean production in the Guinea savanna zone of Ghana. The responses of early and medium maturing soybean varieties to fertilizer and *Rhizobium*

inoculation were inconsistent. In Wa where the soil was slightly acidic, application of mineral fertilizer increased grain yield significantly relative to no fertilizer treatment or the treatment with *Rhizobium* inoculants only. Moreover, the Wa location had been planted to soybean in past years, and at this site, indigenous *Rhizobium* bacteria populations were probably adequate for soybean nodulation. In contrast, application of *Rhizobium* inoculants with or without P and K fertilizers increased grain yield significantly at Bamahu when compared with no fertilizer treatment. Thus the synergy between *Rhizobium* inoculants and PK fertilization was evident at Bamahu where soybean had not been grown for the last three years. In general, soybean grown without fertilizer or *Rhizobium* inoculants had the least grain yields. These results are preliminary and it would therefore be imperative that the experiments are repeated for one or more seasons to obtain more data to ascertain the conditions under which *Rhizobium* inoculants will increase soybean yields in the Guinea savanna zone.

Introduction

Soybean is becoming an important cash and oil crop. However, yields on farmers' fields are relatively low due to erratic rainfall, low soil nutrient levels (particularly nitrogen and phosphorus), use of poor quality seed and poor management practices. As a grain legume, soybean is able to fix atmospheric nitrogen thereby improving soil fertility and limiting the application of inorganic fertilizers. Additionally, soybean can be used as a trap crop against S*triga hermonthica*, an endemic parasitic weed in northern Ghana that causes severe yield losses of cereal crops.

Biological nitrogen fixation (BNF) is a renewable source of nitrogen to replace inorganic nitrogen fertilizer and it has great potential to compensate for the short falls in availability of fertilizers in African farming system. Soil-P availability during seedling development is an important determinant for plant growth, N_2 fixation, and grain formation of legumes. Phosphorus influences nodule development through its basic functions as an energy source. However, phosphorus is generally deficient and limits BNF in highly weathered tropical soils. Application of fertilizer N to soybean remains a complicated issue owing to conflicting results of previous research. Nevertheless, only 25 to 60% of N in soybean dry matter originates from symbiotic N_2 fixation, the remainder comes from soil-N. The use of biofertilizer as a nitrogen source and the amount of phosphorus needed during inoculation is still open to question. This study was therefore initiated to assess the agronomic and economic benefits of using fertilizer N, P and K as well as *Rhizobium* inoculants for soybean production in the Guinea savanna zone.

Materials and methods

Field studies were conducted at the CSIR-SARI experimental fields in Wa and Bamahu in the UWR. The experiments involving early and medium maturity groups of soybean were conducted in a split-plot arrangement of treatments in a randomized complete block design with four replications. For the medium maturing trial, the main plot treatments were five soybean varieties (TGX 1834-5E, TGX 1445-3E, TGX 1448-2E, TGX 1904-6F and Jenguma). Jenguma was released a couple of years ago and it is widely grown by farmers in the region. Five fertilizer treatments (no fertilizer, PK only, *Rhizobium* inoculants + PK fertilizer, *Rhizobium* inoculants only, NPK fertilizer) were applied to the subplots. The N, P and K rates were 25, 60 and 30 kg/ha as N, P_2O_5 and K_2O, respectively. Nitrogen was applied as urea (46% N). Phosphorus was applied as triple superphosphate (46% P_2O_5) and K as muriate of potash (60% K_2O). The no fertilizer treatment was the control representing the farmers' practice.

Sowing dates of the experiments at Wa and Bamahu were 13th and 19th July 2012, respectively. The medium-maturing varieties were sown in six rows spaced 0.75 m apart while the early-maturity varieties were sown in six rows spaced 0.60 m apart. Distance between plants was 5 cm in all experiments with one seedling per stand. Data collected included days to 50% flowering (days), plant height (m) and grain yield (kg/ha). Data collected were subjected to analysis of variance (ANOVA) to establish treatment and interaction effects on grain yield and yield components. Main effects and all interactions were considered significant when $P \leq 0.05$. Simple correlations were used to test association among traits.

Results and discussions

Wa location

The soil in Wa where the trial was conducted is slightly acidic (pH=5.4). The previous crop on this piece of land was maize which was fertilized with Urea. Differences among the medium-maturing varieties were only significant for days to 50% flowering (Table 121). TGX 1445-3E was the latest to flower while TGX 1834-5E was the earliest to flower. The released variety, Jenguma tended to have higher grain production (2789 kg/ha). In earlier studies, TGX 1834-5E and TGX 1445-3E which were released in December 2012 by CSIR-SARI and named Afayak and Songda, respectively were found to have enhanced capacity to stimulate suicidal germination of *Striga* seeds. Consequently, these two varieties could be used to partner *Striga*-tolerant maize to effectively minimize the harmful effects of *Striga* in maize production.

Fertilizer treatment significantly influenced flowering date and grain yield but not plant height, nodule number and weight when compared with the no fertilizer treatment (Table 121). On average, flowering was delayed by at most two days in the no fertilizer treatment. Nodule numbers were not significantly increased even when inoculation was employed. Recommended rate of fertilizer for soybean (25 kg N+60 kgP_2O_5+30 kg K_2O/ha) produced similar grain yields as the PK treatment and P and K fertilizers in combination with *Rhizobium* inoculants. In general, application of mineral fertilizers increased grain yield significantly relative to the no fertilizer treatment or the treatment with *Rhizobium* inoculants only, with the latter two having similar grain yields. Soybean did not respond to inoculation in this soil probably due to the acidic nature of the soil.

Table 121. Mean grain yield and some yield components of soybean as affected by fertilizer application and Rhizobium inoculation in Wa, Upper West region, 2012.

Treatment	Days to 50% flowering	Pods per plant (no)	Nodule number/10 plants	Nodule weight/10 plants (g)	Grain yield (kg/ha)
Variety					
TGX 1834-5E (Afayak)	48	84	342	1.47	2589
TGX 1445-3E (Songda)	54	87	312	1.25	2419
TGX 1448-2E	45	87	263	1.08	2704
TGX 1904-6F	47	92	274	1.16	2678
Jenguma	45	108	265	1.05	2789
Lsd (0.05)	1.0	NS	NS	NS	NS
Fertilizer treatment					
No fertilizer	49	79	204	0.84	2333
Rhizobium inoculation	48	98	304	1.28	2437
60 kgP_2O_5+30 kg K_2O/ha	48	93	349	1.24	2844
25 kg N+60 kgP_2O_5+30 kg K_2O/ha	48	94	311	1.34	2833
Rhizobium +60 kg P_2O_5+30 kg K_2O/ha	47	93	287	1.30	2720
Lsd (0.05)	1	NS	NS	NS	242
CV%	1.6	22.7	27.2	31.2	12.4

In addition, the experimental site had been planted to soybean in the last three years, and indigenous *Rhizobium* bacteria populations were probably adequate for soybean nodulation. The application of Rhizobium inoculants only tended to increase grain yield when compared with the no fertilizer treatment although the difference was not statistically significant.

Bamahu location

Drier areas in northern Ghana will benefit from early-maturing soybean varieties. Such early maturing varieties could be used as relay crops to early-maturing cereal crops. This will enable farmers benefit from both cereal and soybean cultivation in one season, particularly in *Striga*-endemic and drought- prone areas. Consequently, TGX 1799-8F and TGX 1805-8F will be particularly useful in these areas. At Bamahu, differences among three early-maturing varieties (TGX 1799-8F, TGX 1805-8E and Anidaso) were significant for days to flowering and grain yield (Table 122).

Table 122. Mean grain yield and some yield components of soybean as affected by fertilizer application and Rhizobium inoculation at Bamahu near Wa, Upper West region in 2012.

Treatment	Days to 50% flowering	Pods per plant (No.)	Grain yield (kg/ha)
Variety			
TGX 1799-8F (Suong-Pungun)	47	69	1752
TGX 1805-8F	50	74	1215
Anidaso	48	71	2011
Lsd (0.05)	1.0	NS	206
Fertilizer treatment			
No fertilizer	50	61	1500
Rhizobium inoculation	48	83	1778
60 kgP_2O_5+30 kg K_2O/ha	49	68	1617
25 kg N+60 kgP_2O_5+30 kg K_2O/ha	49	70	1574
Rhizobium +60 kg P_2O_5+30 kg K_2O/ha	49	74	1827
Lsd (0.05)	NS	NS	266
CV%	2.8	32.6	16.5

TGX 1799-8F flowered 3 days later than TGX 1805-8F and Anidaso. Nevertheless, Anidaso had the highest yield of 2011 kg/ha followed by TGX 1799-8F. The lowest grain yield of 1215 kg/ha was recorded for TGX 1805-8EF. TGX 1799-8F was recently released by CSIR-SARI and named Suong-Pungun. Fertilizer treatment did not significantly influence flowering date and number of pods. However, grain yield was highest for *Rhizobium* inoculants+ PK treatment and lowest for no fertilizer treatment. Application of *Rhizobium* inoculants with or without P and K fertilizers increased grain yield significantly at Bamahu when compared with the no fertilizer treatment. The synergy between *Rhizobium* inoculation and PK fertilizer application was evident at Bamahu. Results of this study confirm reports that on a land where soybean has not been grown for years, inoculation is recommended.

Conclusion and recommendations

Preliminary results suggest that symbiotic nitrogen fixation, a key component in biological nitrogen fixation, may not be as successful in substituting for mineral fertilizers on all soils as initially expected. However, the soils collected from these sites are yet to be analyzed and the data will help explain the inconsistent responses observed in the study. In any case, the Wa location had been planted to soybean in past years, and indigenous *Rhizobium* bacteria populations were probably adequate for soybean nodulation. More data will be required to confirm soybean response to *Rhizobium* inoculants in the Guinea Savanna zone.

ON-FARM TRIALS

On-farm Testing and Demonstration of Drought Tolerant Maize Varieties and/or hybrids

S.S.J. Buah, J.M. Kombiok and R.A.L. Kanton

Executive summary

Studies were initiated in 2008 and continued through 2012 in order to enhance maize productivity and improve livelihood opportunities through improved production technologies in drought-prone and *Striga*-endemic areas in the Savanna zone of Ghana. Promising high-yielding and drought-tolerant (DT) maize varieties and hybrids were evaluated in farmer participatory on-farm trials and demonstrations since 2008 in the UWR. In 2012, extra-early, early and intermediate maturing DT maize varieties were selected for on-farm validating after on-station trial. A total of 41 farmers (36 men and 5 women) were directly involved in the project. In each maturity group, the genotypes had similar grain yields in both the mother and baby trials. The IITA elite varieties are also known to show good performance when *Striga* infestation and drought conditions occur simultaneously. Over the years, the results from the on-farm trials in the UWR were used together with those from other on-farm and on-station trials in the savanna zone of Ghana to recommend the release of 4 varieties for commercial production. The early-maturing yellow maize TZE Y DT STR C4 and its white version, TZE W DT STR C4 as well as two medium varieties, DT SYN 1W and IWD C3SYN F2 were released for cultivation in December 2012. They were given names in different local languages that signified their drought and/or *Striga* tolerance. The genotype TZE Y DT STR C4 was named Bihilifa, TZE W DT STR C4 (Wang Dataa), IWD C3SYN F2 (Ewul-boyu) and DT SYN 1W (Sanzal-sima).

Introduction

The Maize Improvement Program of Ghana has been collaborating with the International Institute of Tropical Agriculture (IITA) over the years to develop and evaluate improved maize varieties and hybrids suitable for various agro-ecological systems in Ghana. Since 2008, promising high-yielding and DT maize varieties and hybrids selected based on results of on-station trials were evaluated in farmer participatory on-farm trials and demonstrations. These trials served as important vehicles to showcase the effectiveness of new technology to farmers. Additionally, the participatory on-farm testing of the varieties could also facilitate the rapid transfer and adoption or acceptance of these DT maize varieties by farmers. Through the on-farm trials, 12 DT varieties have so far been released in Ghana. During the 2012 cropping season, several extra-early, early- and medium-maturing DT maize varieties and hybrids which combine *Striga* and drought tolerance were evaluated in on-farm trials in three districts in UWR using the mother and baby methodology. CSIR-SARI in partnerships with MoFA and farmers conducted on-farm trials at Kpongu in the Wa Municipality, Bulenga in the Wa East District, Goriyiri in the Nadowli District as well as Silbelle and Sorbelle in the Sissala West District with funding from the DTMA project. The objectives of the on-farm testing were:

1. To expose farmers to available DT varieties and/or hybrids with stable and high yields in order to facilitate the adoption of the varieties
2. To demonstrate and promote the application of modern technologies for the production of DT maize varieties and/or hybrids

Methodology

Mother Trials

The mother-baby on-farm testing approach has been widely adopted by the DTMA Project as a strategy for testing and promoting the release and adoption of maize varieties and hybrids. It is a new approach consisting of a central researcher-managed “mother" trial comprising all tested varieties, and satellites or “baby" trials which are farmer-managed and testing of a subset of varieties from the mother trial. Sets of mother trials comprising of extra-early maturing (80-85 days to maturity), early-maturing (90-95 days to maturity) and intermediate/medium-maturing (110 days to maturity) varieties were planted in farmers’ fields at Bulenga, Kpongu, Goriyiri, Sorbelle and Silbelle, The extra-early mother trial consisted of nine (9) elite varieties involving yellow and white source populations obtained from IITA (2004 TZEE W POP STR C4, 99 TZEE Y STR C1, TZEE W POP STR QPM C0, 2000 SYN EE W, 2008 TZEE W POP STR F2, TZEE W POP STR C5 x TZEE1 21, TZEE W POP STR C5 x TZEE1 82, TZEE1 49 x TZEE1 29 and 2008 SYN EE W) which were compared with a local check (the best available variety in the location) and a reference entry, Abontem which was released in 2010. The extra-early-maturing mother trials were planted at Silbelle and Sorbelle in July while the early-maturing mother trial consisting of 6 varieties (TZE Y DT STR C4, TZE Y POP STR C4 x TZE1 17, TZE W POP DT STR C4, Omankwa, Aburohemaa and Farmer variety) was planted at Goriyiri. The intermediate-maturing mother trials consisting of 6 varieties from IITA (M1026-10, L0904-27, M0226-8, DT SYN 1W, DT ST W C2 and DT SR W C0F2) one QPM hybrid (Etubi from CSIR-CRI), PAN 53 from Wienco Company and a local check were planted at Bulenga. The local checks for all maturity groups were the best available varieties in the location, which differed among locations. A randomized complete block design (RBCD) with three replications per site was used for each maturity group. Data recorded in the mother trials included days to 50% silking and anthesis, plant height, ear number and grain yield. Grain yield was calculated based on 80% (800 g grain/kg ear weight) shelling percentage. Recommended cultural practices were followed. The total fertilizer rate was 64-38-38 kg/ha as N, P_2O_5 and K_2O, respectively. Field days were organized at planting and when the maize plants reached physiological maturity. Farmers evaluated the varieties at physiological maturity and their preference criteria were based on earliness, cob size, grain colour, disease and drought tolerance and productivity of the variety. The research team also independently evaluated all mother trials for yield and other agronomic traits. Analysis of variance was done for each location.

Satellite or baby trials

Baby trials were also conducted on farmers' fields at the various sites using extra-early, early as well as intermediate maturing varieties and/or hybrids. Each baby trial was located at site close to the mother trial Farmers’ fields near to mother sites were selected for each baby trial.

Farmers evaluated a subset of three DT maize varieties from the mother trials alongside their local varieties. Planting was done between 14th and 24th July 2012. In all, the varieties tested were the same as those grown in the mother trial and each variety was tested by four farmers. Each plot for a particular variety measured 20 x 20 m.

Results and discussion

Mother and baby trials for extra-early maturing varieties

In the extra-early-maturing mother trials at both Sorbelle and Silbelle, the varieties flowered in 42-55 days after planting, producing dry grains in about 85 days. At both sites 2008 SYN EE W was the earliest to flower while 2004 TZEE W POP STR C4 was the latest to flower. Differences among the varieties for plant height and grain yield were not statistically significant at either site although grain yield tended to be highest for the hybrid TZEE1 49 x TZEE1 29 at both sites (5.7 and 6.1 t/ha), respectively.

In the extra-early maturing baby trials, the varieties flowered in 42- 56 days after planting. The improved DT maize varieties and the farmers’ variety had similar yields. This was not surprising because the farmers’ varieties that were included in these experiments were mostly not extra-early-maturing varieties. Moreover the farmers` varieties were probably improved varieties previously bought from seed dealers or supplied by other development organizations over the past years. Hence, the word “farmer variety” should be used with caution as the use and/or recycling of improved seed is a common practice in Ghana.

Mother and baby trials for early maturing varieties

In both the mother and baby trials at Goriyiri in the Nadowli district, the varieties flowered in 50-54 days after planting. TZE Y POP STR C4 x TZE1 17 flowered earliest while the farmers` variety flowered latest. Genotypic differences among the early DT maize for plant height and grain yield were not statistically significant. Grain yield tended to be highest (5.7 t/ha) for TZE Y POP STR C4 x TZE1 17

Mother and baby trials for intermediate maturing varieties

Two intermediate maturing mother trials were planted at Bulenga. In these trials, the varieties flowered in 52-57 days after planting. Etubi flowered earliest while L0904-27 took the longest time to flower. In addition, Etubi, PAN 53 and the farmer’s variety grew taller and were visually prone to lodging while the shortest variety was DT ST W C0F2. Nevertheless, differences among the varieties for grain yield were not statistically significant at each site although M1026-10 and M0226-8 tended to produce higher grain yields (3.2 and 3.9 t/ha).

In the baby trials for intermediate maturing varieties, the varieties had similar days to 50% anthesis and grain production. Again, M1026-10 tended to have the highest grain production (2.8 t/ha) while the yield of PAN 53 was low (1.5 t/ha). All genotypes produced lower yields in the baby trials that were managed by farmers when compared with their yields in the mother trials.

Farmer assessment of the varieties

Out of the two hundred and thirty-two (232) participants at three field days organized at Silbelle, Goriyiri and Bulenga at physiological maturity, 42 were women. Farmers valued many characteristics in maize varieties, especially traits related to consumption. Yellow maize was mostly preferred by women The assessment exercise suggested that TZEE1 49 x TZEE1 29 and Abontem were the most preferred extra-early maturing varieties. The most preferred early maturing hybrid was TZE Y POP STR C4 x TZE1 17. Farmers also preferred the extra-early yellow maize variety, Abontem because it could be planted with the early rains and sold or eaten fresh. Among the intermediate varieties, M1026-10 and DT ST W C2 were the most preferred varieties. It seems farmers like a range of varieties (i.e., a range of diversity). The IITA varieties were considered to be better than the farmers' varieties and PAN 53.

In decreasing order of importance, the criteria that were most frequently cited by farmers for preference of a variety were heavier ears (bigger cobs), earliness, drought tolerance and endosperm colour. However, poor access to hybrid seed and a lack of specialized knowledge in hybrid seed production coupled with the necessity to purchase hybrid seeds every year are the most binding constraints to adopting hybrid maize in the region. The early-maturing yellow maize TZE Y DT STR C4 and its white version, TZE W DT STR C4 as well as a medium-maturing variety DT SYN 1 W were among five new maize genotypes that were released by CSIR-SARI for cultivation in December 2012. They were given names in different local languages that signified their drought or *Striga* tolerance. The genotype DT SYN 1W was named Sanzal-sima, TZE Y DT STR C4 (Bihilifa) and TZE W DT STR C4 (Wang Dataa)

Conclusion

In this study, mean grain yields from researcher-managed trials were higher than the national average yield of 1.7 t/ha as a result of the use of good cultural practices. Moreover, farmers recognized that improved varieties and/or hybrids perform better if accompanied by recommended cultural practices. The results of both the mother and baby trials for all maturity groups suggested that some IITA varieties and/or hybrids had relatively stable grain yields. Extra-early or early maturing yellow maize is preferred for its earliness and yellow endosperm. Most of the IITA elite varieties are also known to show good performance when *Striga* infestation and drought conditions occur simultaneously. Through the project, farmers gained access to the diversity of DT maize varieties. Thus, the DT maize varieties should be vigorously promoted for adoption by farmers in drought prone and *Striga* endemic areas in the Guinea savanna zone.

Boosting maize cropping system productivity in northern Ghana through widespread adoption of integrated soil fertility management

M. Fosu and S.S.J. Buah

Source of funding: Alliance for a Green Revolution in Africa (AGRA)

Executive Summary

Five demonstrations were installed in 27 communities in eight districts in the Upper West region in 2012. Demonstration 1 (Demo 1) showed the effect of different rates of fertilizer and groundnut rotation on yield of maize. Demo 2 showed the response of a hybrid and an OPV maize varieties to different levels of fertilizer application. Demo 3 compared the performance of farmer variety and two drought tolerant maize varieties. Demo 4 showed the effect of

organic and inorganic fertilizers and their mixtures on maize yield and Demo 5 showed the effect of *Rhizobium* inoculation as well as P and K application on soybean yield. The demonstrations were installed with MoFA and managed by 33 Farmer-based Organizations (FBOs). The FBOs were trained in governance, managing farming as a business, and credit management. About 28 AEAs were trained in farmer school facilitation and extension communication. Radio and TV programs were used to reach farmers with extension messages.

On average, one-year rotation of groundnut with maize and recommended fertilizer rate (250 kg NPK/ha + 125 kg/ha sulphate of ammonia) produced similar maize yield of 3.1 t/ha. With recommended rate of fertilizer, the yield of Obatanpa (3.1 t/ha) was similar to that of hybrid maize Etubi (2.8 t/ha). The drought tolerant maize varieties Aburohema and Omankwa produced similar yields as the farmer varieties. A combination of organic fertilizer (fertisoil) and sulphate of ammonia increased maize yield similar to 250 kg NPK/ha + 250 kg SA/ha (2.9 t/ha) and recommended rate of mineral fertilizer (2.7 t/ha). When soybean was inoculated with *Rhizobium* inoculants and fertilized with P and K, the yield (1.8 t/ha) was greater than of the control (1.5 t/ha) at Bamahu. Maize yield without any soil amendment was below 1.0 t/ha. Technology dissemination pathways used to up-scale ISFM in the region included demonstrations on ISFM, training of trainers, Farmer Field Schools, exchange visits, field days, posters, community outreach programs (radio broadcast) and feed back (review and planning meetings with farmers). About 600 farmers were reached directly through demonstrations, FFS and field days. At least 1,000 more farmers got information on ISFM through radio broadcast in the region.

Introduction

Maize is either grown alone, in mixtures or rotation with legumes such as soybean, cowpea and groundnuts. In the Guinea Savanna zone of Ghana, on-farm grain yields of cereals and legumes, even of the improved varieties, are far below the on-station yields. The low yields could be attributed to management problems such as low plant populations, inappropriate plating time, inadequate control of weeds, pest and diseases and control of *Striga* as well as untimely application of adequate quantities of fertilizers. Other constraints on crop production include access to land and water resources, low and erratic rainfall, lack of inputs (especially fertilizer and seeds), lack of labour, credit, adequate drying and storage facilities leading to high post-harvest losses, and poor market access. Soybean is becoming an important cash and oil seed crop which is relatively drought-tolerant and requires less production inputs. The goal of this project is to contribute to agricultural production and reduce poverty through up-scaling of integrated soil fertility management (ISFM), practices strengthening of the capacity of extension agents and farmers, developing fertilizer recommendations and monitoring the impact of ISFM adoption on livelihoods of farmers.

Materials and Methodology

Five demonstrations involving various ISFM technologies were installed in 27 communities in the Upper West region. Demonstration (Demo) 1 showed the effect of different rates of fertilizer and groundnut rotation on yield of maize. Demo 2 showed the response of a hybrid and an OPV maize varieties to different levels of fertilizer. Demo 3 compared the performance of farmer variety and two drought-tolerant maize varieties. Demo 4 showed the effect of organic and inorganic fertilizers and their mixtures on maize yield and Demo 5 showed the effect of *Rhizobium* inoculation and PK application on soybean yield. The demonstrations were installed with MoFA and managed by 33 FBOs. The FBOs and agro-dealers were profiled and trained. The FBOs were trained in governance, managing farming as a business, and credit management. AEAs were trained in Farmer Field School facilitation and extension communication. Radio and TV programs were used to reach farmers with extension messages.

Results and Discussions

On average, one-year rotation of groundnut with maize and full fertilizer rate (250 kg NPK/ha + 125 kg/ha sulphate of ammonia) produced similar maize yields of 3.1 t/ha each with a recommended rate of fertilizer, the yield of Obatanpa (3.1 t/ha) was similar to that of the hybrid maize Etubi (2.8 t/ha). The drought tolerant maize varieties Aburohema and Omankwa produced similar yields as the farmer varieties. A combination of organic fertilizer (fertisoil) and sulphate of ammonia increased maize yield similar to 250 kg NPK/ha + 250 kg SA/ha (2.9 t/ha) and recommended rate of mineral fertilizer (2.7 t/ha). When soybean was inoculated with *Rhizobium* inoculants and fertilized with P and K, the yield (1.8 t/ha) was greater than of the control (1.5 t/ha) at Bamahu. Maize yield without any soil amendment was below 1.0 t/ha. About 28 AEAs in the UWR were trained. Technology dissemination pathways used to up-scale ISFM technologies in the region included demonstrations on ISFM, training of trainers, Farmer Field Schools, exchange visits, field days, posters, community outreach programs (radio broadcast) and feed back (reporting to farmers). Integrated soil fertility management technologies were transferred in 27 communities in 8 districts in the region. About 600 farmers were reached directly through demonstrations, FFS and field days. At least 1,000 more farmers got information on ISFM through radio broadcast in the region. *Rhizobium* inoculation technology was also transferred to farmers. In 2012, a good number of soybean farmers inoculated their soybean seeds before planting as the *Rhizobium* inoculants were available in agro-input shops where farmers could purchase them for use.

Conclusions/Recommendations

Maize productivity can be increased substantially by use of ISFM. Without fertilizer application, maize production is economically not viable in the UWR. Use of organic and inorganic fertilizers as well as cereal-legume integration through crop rotation to improve system productivity is important for increased maize yield. Drought-tolerant maize has high potential in northern Ghana. Farmers may get increased soybean yield with the use of *Rhizobium* inoculants on some soils. The above activities will be continued in 2013.

Participatory variety selection of new rice in the Upper West Region

W. Dogbe and S.S.J. Buah

Source of funding: Rice Sector Support Project (RSSP)/AFD/MoFA

Executive summary

The Rice Sector Support Project (RSSP) aims to increase rice productivity and generate income for the rural household farmers in northern Ghana through the adoption of appropriate technologies in rice production. In 2012, Participatory Variety Selection (PVS) exercise was carried out using the Mother and Baby trial approach in the Polee community in the Wa West

district, UWR. MoFA staff and FBO representatives were trained in the PVS methodology as well as Participatory Learning Action Research (PLAR) procedure before the start of the season. Farmers evaluated 6 new improved varieties which were validated on-station (Exbaika, WAS 163-B-5-3, Perfume irrigated, L2-4, Long grain ordinary 2, WAS 122-13-WAS-10-WAR) alongside their own local varieties. At the vegetative stage, farmers evaluated the varieties based on tillering ability and plant height. Plant vigour and rapid plant growth were also important. At maturity, the characteristics criteria that were most frequently cited by farmers for preference of a variety were plant height, panicle size, grain yield and grain shape. Majority of the farmers selected Exbaika as the best performing variety because of its vigour, good tillering ability, pest resistance and large and healthy panicles. In Polee, farmers cultivated about 30 ha of rice in the 2011 cropping season and 34 ha in the 2012 season with improved varieties from CSIR-SARI. About 15 t of certified seed was produced from foundation seed given to farmers in Polee in 2012. The farmers were happy and enthusiastic to adopt the new rice varieties to improve their rice production and income generation.

Introduction

Low rice yields in northern Ghana could be attributed to management problems such as the use of low yielding varieties, low plant populations, inappropriate planting time, inadequate control of weeds, pest and diseases as well as untimely application of adequate quantities of fertilizers. Research has shown that adoption of improved varieties by small holder farmers is low. Reasons attributed to these, among others, are that iimproved varieties poorly adapted to farmers` conditions or do not meet their needs and farmers have limited access to seeds and information about new varieties. There is therefore the need to improve farmers` access and adoption of improved rice varieties. One way of doing this is through participatory varietal selection (PVS) using the mother and baby trial approach. PVS is a method used to increase the speed of adoption of new varieties by involving farmers in variety needs assessment, selection and testing of a wide range of novel cultivars. CSIR-SARI in collaboration with MOFA implemented mother and baby trials under the Rice Sector Support Project (RSSP) at Polee Kpanyaluu valley in 2012. The goal of the RSSP is to increase rice productivity and generate income for the rural house hold farmers in northern Ghana through the adoption of appropriate rice production technologies. The project is being implemented in four districts (Sissala East, Wa East, Wa West and Wa municipality) in the UWR. Polee is one of the beneficiary communities in Wa West district. The objective of the PVS trials was to evaluate promising lowland rice varieties in collaboration with farmers and other stakeholders in the rice industry in the variety selection processes taking into account their preferences. This is to enhance the acceptability of the varieties by farmers and consumers.

Materials and methods

In 2012, PVS used the Mother and Baby trials approach in the Polee community in the Wa West district, UWR. MoFA staff (AEAs and DAO) and FBO representatives were trained in the PVS methodology as well as PLAR procedure before the trials were planted. Farmers evaluated 6 new improved varieties which were validated on-station (Exbaika, WAS 163-B-5-3, Perfume irrigated, L2-4, Long grain ordinary 2, WAS 122-13-WAS-10-WAR) alongside their own local varieties. The mother and baby trials were installed by MoFA staff and managed by farmers. Seeds of the improved varieties were provided by CSIR-SARI but the farmers took care of land preparation, planting, weed control and harvesting. They also provided fertilizers for the trials. The farmers were trained and advised to follow recommended agronomic practices. Agronomic data and farmer preferences of varieties were collected using qualitative (participatory) and quantitative methods. At vegetative and maturity stapes, farmers ranked each trait of interest as better, same or worse than their own variety. Grain yield was measured for each variety at physiological maturity. A field day was organized for farmers on 26th November, 2012 at physiological maturity. The objectives of the field day were to:

- Gain an overall understanding of rice production in the area.
- Identify desirable and acceptable rice varieties with farmers
- Identify farmers' considerations in selecting rice varieties for planting.

Results and discussion

Farmers in Polee cultivated about 30 ha and 34 ha of rice in the 2011 and 2012 cropping seasons, respectively using improved varieties from CSIR-SARI. At the vegetative stage, farmers evaluated the rice varieties based on tillering ability and plant height. Plant vigour and rapid plant growth were also important. At maturity, the traits that were most frequently cited by farmers for preference of a variety were plant height, panicle size, grain yield and grain shape. A total number of 71 people (53 males + 18 females) attended a field day organized at Polee. The categories of participants were host farmers, visiting farmers, press men, opinion leaders and MoFA staff. At the field day, participants were asked to select the best varieties among the various varieties planted. Majority of the farmers (68%) selected Exbaika as the best performing variety because of its vigour, good tillering ability, pest resistance and large and healthy panicles. Those farmers who chose Long Grain Ordinary 2 as their first choice said they did so because of the following reasons:

- The variety was high yielding and looks nice
- The variety was medium in height and therefore easier to harvest while standing
- Although the variety was tall, it did not lodge
- The variety had bigger panicles and long grain size.

Generally, farmers were happy with the field day as they were now aware that planting quality seed of improved varieties at optimum plant stand and at the appropriate planting time with adequate control of weeds, pest and diseases as well as timely application of adequate quantities of fertilizers would maximize rice yield while the contrary would lead to yield reductions. They also noted that it is much easier to apply fertilizer, weed and execute other agronomic practices if rice is planted in rows as was observed in the mother trial.

Conclusion

All participants were happy and expressed willingness to adopt or adapt the new technologies to improve their rice productivity and income generation. Exbaika was the most preferred variety. This variety seems to meet farmers' expectations in the field. Further assessment for palatability and consumers' acceptance should be conducted. Exbaika is known to be aromatic and this should be a strong factor for farmers to choose to crop this variety. There is the need to investigate milling and parboiling qualities of the new varieties.The technologies demonstrated in the beneficiary community have proven to be successful hence the need to disseminate such proven technologies to many more farmers. In 2013, Mother and Baby trials will be repeated to increase the reliability of results and to confirm previous results. More communities in the other three project districts in the region will be involved in the process.

Commissioned Project on Strengthening Seed System Research and Development in West and Central Africa

I.D.K. Atokple and S.S.J. Buah

Source of funding: AusAID/CSIRO-CORAF/WECARD

Executive summary

In the northern Guinea savanna of Ghana, low crop yields are common due to erratic rainfall, low soil nutrient levels, use of unimproved varieties and poor management practices. On-farm experiments were conducted in three districts (Lawra, Sissala West and Wa East) to evaluate the performance of high yielding varieties of maize, sorghum, groundnut and cowpea under two fertility regimes with farmers in their own environment with the aim of finding adoptable varieties and fertility regimes which are appropriate to their needs. Increasing fertilizer levels beyond the recommended rate for maize did not result in any significant increases in grain production in both researcher- and farmer-managed trials. On average, sorghum grain yield was increased by about 23 % (207 kg/ha more grain) when the fertilizer rate was increased beyond the recommended rate. Despite higher yields of Dorado and Kapaala, farmers were not interested in these two varieties because of heavy bird damage due to the sugary nature of the grains coupled with grain quality problems associated with the two varieties. At Silbelle, all the groundnut varieties produced similar grain yields in the mother trial, but in the baby trials, Nkatiesari had the highest grain yield followed closely by Manipintar. Application of fertilizer P did not result in any significant increase in groundnut grain production for any variety in the mother trials. Nevertheless, in the baby trials, addition of fertilizer P resulted in increases in groundnut pod weight, dry matter production as well as a 37% increase in grain production. At Silbelle, there were no significant differences in terms of grain yield among the cowpea varieties but added P resulted in a 26% increase in grain yield in the baby trials only. At Loggu, Apagbaala recorded the highest yield of 270 kg/ha while the local check had the lowest yield of 188 kg/ha. On average, fertilizer P addition resulted in a 31 % yield increase in the mother trial at this location. These results are preliminary and it would therefore be imperative that the experiments are repeated so as to confirm or reject these current results.

Introduction

Maize and sorghum are either grown alone, in mixtures or in rotation with legumes such as soybean, cowpea and groundnut. In the Guinea savanna zone of Ghana, grain yields of cereals and legumes, even of the improved varieties are far below the on-station yields. The low yields could be attributed to management problems such as low plant populations, inappropriate planting time, inadequate control of weeds such as strigger, pests and diseases as well as untimely applications of adequate quantities of fertilizers. Other constraints to crop production, include access to land and water resources, low and erratic rainfall, lack of inputs (especially fertilizer and seeds); lack of labour, credit, adequate drying and storage facilities leading to high post-harvest losses, and poor market access. As low soil N is a major factor limiting cereal production, rotations with legumes such as soybean, cowpea and groundnuts could supply a part of the nitrogen required for cereal growth and yield may minimize the depletion of soil of organic matter and the build-up of weeds, diseases, and insects. Integration of grain legumes such as soybeans, groundnut and cowpeas with maize or sorghum can provide additional protein in the diet which contributes to improved human nutrition.

As part of the Australian Government's Food Security and Rural Development Initiative to improve food security and agricultural production in West and Central Africa, the Australian Agency for International Development (AusAID) is supporting a multi-stakeholder agricultural research project through the AusAID/CSIRO-CORAF/WECARD partnership to improve agricultural research, technology dissemination and adoption to significantly increase productivity in the sub-region. CSIR-SARI in collaboration with MoFA initiated some sub-projects in northern Ghana starting in 2013 as part of the CORAF project initiative. The objective of the sub-project was to evaluate the performance of high-yielding varieties of maize, sorghum, groundnut and cowpea under two fertility levels with farmers in their own environment with the aim of finding adoptable varieties which are appropriate to their needs. This report covers experiments implemented in the Upper West region in 2012.

Methodology

The mother-baby on-farm testing approach was adopted for testing of high yielding varieties of maize, sorghum, cowpea and groundnut in communities in three districts (Silbelle in the Sissala West district, Loggu in the Wa East district and Lawra in the Lawra district) in the Upper West Region. Mother trials comprising three improved varieties each of maize, sorghum, cowpea and groundnut and managed by researchers were planted in farmers' fields under two fertility regimes during the 2012 growing seasons at Silbelle, Loggu and Lawra. The three improved varieties for each crop were planted alongside a local check. A randomized complete block design (RCBD) with three replications per site was used for each crop in the mother trials. Recommended cultural practices were followed. The treatment design was a 2 x 4 factorial involving four varieties of each crop grown under two fertility levels. The fertility levels for maize and sorghum were recommended fertilizer rate (250 kg NPK + 125 kg Sulphate of ammonia) and a higher fertilizer rate (250 kg NPK + 250 kg Sulphate of ammonia). Each of the cowpea and groundnut varieties was grown with or without 30 kg P_2O_5 /ha. Satellite or baby trials were also conducted on farmers' fields near to mother sites in each location. For each crop, farmers evaluated one variety under the two fertility levels alongside their local varieties. The sowing dates of all experiments were between 13th to19th July, 2012. For each crop, the grain was harvested at physiological maturity. Other measurements included days to flowering (days), and plant height (m). Data collected were subjected to analysis of variance (ANOVA) to establish treatment and interactions effects on grain yield and yield components.

Results and discussions

Maize trials

Despite the prevalence of bad weather in 2012, mean grain yields from the maize mother trials were higher than the average grain yield of maize (1.7 t/ha) reported for the northern Guinea savanna of Ghana. The higher maize yields may be due to the use of improved maize seed and recommended quantities of fertilizer. Moreover, the agricultural extension staff ensured that the farmers carried out timely crop management practices on the mother trials as these were researcher-managed.

Meaningful data were obtained from one mother trial each at Silbelle near Tumu and Loggu only. No data were obtained from Lawra because it was too late to plant maize in this drier area at the time the fields were ready for planting. In the mother trial at Silbelle, the three DT maize varieties flowered earlier but they also produced lower biomass compared with the farmer variety (Table 123). The farmer variety was late-maturing and also accumulated more dry matter but this did not translate into higher grain production as expected probably because less biomass was partitioned to the grains as evident by the low harvest index value. Differences among the varieties in terms of grain production were not statistically significant. Increasing fertilizer level beyond the recommended rate for maize did not result in any significant increase in grain production for any variety (Table 123).

At Loggu, average grain yields for the varieties were relatively greater than those obtained at Silbelle probably due to better growth conditions. The farmer variety was taller and late maturing. Similar to results obtained at Silbelle, all the varieties had similar grain yields at Loggu. Furthermore, increasing fertilizer level beyond the recommended rate did not result in any significant increase in grain production but it reduced the days to anthesis for all the varieties.

Table 123. Some agronomic traits of some maize varieties as affected by fertilizer levels in a mother trial at Silbelle near Tumu, Sissala West District in 2012

Variety	DFA (day)	DFS (day)	Plant height (m)	Biomass yield (kg/ha)	Grain yield (kg/ha)	Harvest index (no)
Aburohemaa	51	54	1.81	4400	3867	0.47
Omankwa	50	53	2.03	3422	3467	0.48
Abontem	53	56	2.16	4422	3178	0.42
Farmer variety	55	58	1.76	6756	2578	0.27
Lsd (0.05)	1	1	0.25	786	NS	0.07
Fertilizer rate (kg/ha)						
250 kg NPK + 125 SA	53	56	1.90	4489	3033	0.41
250 kg NPK + 250 SA	52	54	1.90	5011	3511	0.41
Lsd (0.05)	NS	1	NS	NS	NS	NS
CV%	0.7	0.9	10.2	13.4	33.9	14.9

DFA=days to 50% anthesis; DFS=days to 50% silking; Harvest index = (Grain dry weight/total plant dry weight).

Only three baby trials involving Aburohemaa were planted in Loggu but 12 were planted in Silbelle. In the baby trials at both Silbelle and Loggu, genotypic differences in terms of grain yields were not statistically significant. The farmer varieties were taller and late maturing and also accumulated more dry matter but they did not produce greater grain yields. Also increasing the fertilizer rate beyond the recommended rate did not significantly influence grain yield at either site.

Sorghum trials

Meaningful data were obtained from only one mother trial at Silbelle. No data were obtained from Loggu and Lawra because farmers failed to plant the experiments. It seems the collaborating farmers were not interested in Kapaala and Dorado, the improved sorghum varieties being introduced because of heavy bird damage due to the sugary nature of the grains coupled with grain quality problems associated with these varieties. It was difficult getting farmers to plant the baby trials of sorghum in the project districts, Farmers need to be sensitized further as Kapaala and Dorado are suitable for brewing lager beer and therefore have an assured market because the brewery is interested in buying the grain of these varieties. The farmer variety and Kadaga were the tallest (about 2.7 m tall) and took a longer time to flower (Table 124). Kapaala and Dorado had similar yields that were significantly higher than those of the former variety and Kadaga. The farmer variety tended to have more panicles which were however, lighter in weight. Panicle weight had a greater influenced on grain yield than panicle number. On average, grain yield was increased by about 23 % (207 kg/ha more grain) when the fertilizer rate was increased beyond the recommended rate.

Table 124. Some agronomic traits of some sorghum varieties as affected by fertilizer levels in a mother trial at Silbelle near Tumu, Sissala West district, 2012.

Variety	DFF (day)	Plant height (m)	Panicle No/ha (no)	Panicle weight (kg/ha)	Grain yield (kg/ha)
Dorado	69	1.22	26370	1896	1109
Kapaala	66	1.81	27481	1911	1111
Kadaga	72	2.73	26519	1711	919
Farmer variety	74	2.71	30296	1548	844
Lsd (0.05)	1	0.14	2180	NS	228
Fertilizer rate (kg/ha)					
250 kg NPK + 125 SA	70	2.11	27963	1656	893
250 kg NPK + 250 SA	70	2.13	27370	1878	1100
Lsd (0.05)	NS	NS	NS	215	161
CV%	1.6	5.3	6.4	13.9	18.5

DFF=days to 50% flowering;

Groundnut trials

Meaningful data were obtained from one mother trial and nine baby trials in Silbelle only. The experiments were not planted in Loggu and Lawra due to inadequate seed. In the mother trial, Manipintar was the latest to flower, followed by Nkatiesari. The farmer variety and Chinese flowered earliest. Nkatiesari tended to produce numerically more pods which were nonetheless heavier than and also higher grain yields than the farmer variety and Chinese. The performance of the farmer variety and Chinese were similar. Application of fertilizer P did not cause any significant increase in grain production for any variety.

In the baby trial at Silbelle, Manipintar and Nkatiesari produced more biomass and numerically more pods than the farmer variety and Chinese (Table 125). Nkatiesari had the highest grain yield (467 kg/ha) followed closely by Manipintar. The farmer variety had the highest yield of 509 kg/ha while Chinese had the lowest grain yield of 307 kg/ha. The farmer variety and Chinese produced similar pod numbers which had similar weights. The similarity in the performance of Chinese and the farmer varieties was not surprising as the varieties provided by the farmers were either second-generation Chinese variety previously bought from seed companies or supplied by other development organizations over the past years. Addition of fertilizer P resulted in increases in pod weight and biomass yield as well as a 37% increase in grain production.

Table 125. Some agronomic traits of some groundnut varieties as affected by fertilizer P in baby trials at Silbelle near Tumu, Sissala West district in 2012.

Variety	Plant height (m)	Pods number/ha	Pod weight (kg/ha)	Biomass Yield (kg/ha)	Grain yield (kg/ha)
Chinese	39.2	2710	1047	2260	307
Manipintar	45.0	4056	1187	2480	380
Nkatiesari	40.6	3422	1333	2500	467
Farmer variety	40.1	2704	1020	1878	509
Lsd (0.05) ‡	2.3	600	NS	330	68
Fertilizer P rate (kg P_2O_5/ha)					
0	41	2370	1921	1031	308
30	41	4076	2637	1202	423
Lsd (0.05)	NS	379	209	200	43
CV%	5.1	18.2	14.2	26.3	18.0

Cowpea trials

Meaningful data were obtained from one mother trial and twelve baby trials in Silbelle. Only one mother trial each was planted in Loggu and Lawra and baby trials were not planted in these two locations due to inadequate seed. Average grain yields at all the locations were generally lower than expected. At Silbelle, there were no significant differences in terms of grain yield among the varieties but the addition of fertilizer P tended to increase grain yield although the difference was not statistically significant. At Loggu, Apagbaala recorded the highest yield of 270 kg/ha while the local check had the lowest yield of 188 kg/ha. Fertilizer P addition resulted in significant yield increases (31%) at Loggu. The variability at Lawra was too high (the coefficient of variation; CV = 86%)and there were no significant differences among the varieties for grain yield. In the baby trial at Silbelle, the farmer variety and Songotra produced the highest dry matter but this did not result in higher grain production as all the varieties produced similar amount of grain at physiological maturity. However, the application of fertilizer P resulted in a 26% increase in grain yield.

Field day

A field day was held on 4th October 2012 at Silbelle in collaboration with MoFA in order to facilitate the dissemination of the various technologies to farmers. The field day also allowed non-participating farmers to assess the new varieties and other technologies using their own criteria. In attendance were 61 farmers (42 males + 19 females) from three communities (Silbelle, Sorbelle and Tumu) who evaluated the various crop varieties. This event was covered by the community radio station in Tumu (RADFORD Radio). Farmers evaluated many characteristics in the new crop varieties, especially traits related to consumption. All the improved varieties were considered to be better than the local checks (farmers' varieties). The field day drew much attention and participation from farmers who were happy with the response of cowpea and groundnut to fertilizer P. Farmers who participated in the baby trials of cowpea and groundnut testified that cowpea and groundnut plants that received fertilizer P had the tendency to perform better than those that did not receive the fertilizer even under their circumstances. They therefore expressed interest in applying fertilizer P to their legumes and wondered where they could purchase P fertilizers, more especially when the two most popular P fertilizers in Ghana (triple superphosphate, TSP and single superphosphate, SSP) are not covered by the current Government subsidy on fertilizers

Conclusion and recommendation

Crop responses to fertilizer application were measured only in one season. The results of both the mother and baby trials suggested that many of the improved varieties evaluated in this study performed similarly as or better than the best available local varieties in the various locations. This was not surprising as there are no true "farmers' local varieties" in all the control plots. Maize was the major cereal crop in the selected communities because its production is largely motivated by market considerations to generate income to farmers. The project allowed farmers to gain access to a diversity of crop varieties. The variation in P supply affected both growth and development of cowpea and groundnut plants and low P stress tended to reduce crop growth and grain yield. The objectives of the experiment have not been fully met yet. Moreover, the soils collected from these sites are yet to be analyzed and the soil data will help further explain the inconsistent responses observed in the study. It is therefore recommended that the studies should continue for one or more seasons. This will allow for collection of more crop and soil data to reliably document the following:

- Response of the various crops to fertilizer applications.
- Fertilizer application effects on nutrient concentrations in plant and soil.
- Economic analysis (evaluation of net benefits).

Evaluation of maize hybrids in the Upper West Region

S.S.J. Buah and H. Asumadu, CSIR-CRI
Source of funding: AGRISERVE/Pioneer Hi-bred Seed Co. Ltd

Executive summary
Maize (*Zea mays*) is a major source of calories and cash income in Ghana, yet grain yield levels are low as a result of the use of low yielding varieties, low soil nutrient levels, use of varieties with low yield potential and low management levels. In 2012, four single cross maize hybrids (30B74, 30K73, 30F32 and 30Y87) which were introduced by Pioneer Hi-bred Company were evaluated in on-station and on-farm trials at eight (8) locations spread across five districts in the Upper West Region of Ghana alongside another single cross hybrid from Wienco (PAN 53), and a three-way cross hybrid (Etubi) from CSIR-CRI. The major objective was to determine which best performing hybrids could be recommended for further on-farm testing, and for eventual release for commercial production. Mean grain yields were high with Wa being the most productive site and Kpongu the least. Pioneer 30 B 74 was the highest yielding hybrid, significantly out-yielding Etubi, PAN 53 and farmer variety. The other Pioneer hybrids (30K73, 30F32 and 30Y87) followed in that order but grain differences among these hybrids were not statistically significant. As expected, the Pioneer hybrids, all of which were single crosses produced consistently high yields across locations. In the on-station trials, the Pioneer hybrids, on average, out-yielded Etubi by 14-25% and the farmer variety by 39-52%. However, in the on-farm trials, the Pioneer hybrids out-yielded Etubi by 23-50% and the farmer variety by 24-52%. Although the results are for one season only, the four Pioneer hybrids have shown consistency in performance across the locations and are therefore recommended for further on-farm evaluation and possible release.

Introduction
Maize (*Zea mays*) is an important cereal in terms of production and utilization in Ghana. It is also an important component of poultry and livestock feed and to a lesser extent, a substitute in the brewing industry, yet on-farm grain yield levels even of the improved varieties are far below the on-station yields. The low yields could be attributed to poor management practices as well as the use of varieties with low yield potentials. Hybrid maize is superior to OPVs in terms of grain production under good management. However, most farmers in Ghana often plant OPVs instead of hybrid maize. Unfortunately, adoption of hybrid maize has remained at a fairly low level despite the potential of hybrid seed to revolutionize maize production in Ghana. Farmers are often of the opinion that they would derive economic returns from hybrid maize production only when fertilizers can be applied at relatively high rates. Furthermore, small-scale farmers are frequently unaware of the benefits they could obtain by regularly planting fresh seed of hybrid maize. Hence the present demand for seed is very low. Most maize farmers still retain a part of their crop for seed and therefore have no need to purchase commercial seed. As most of the maize varieties grown in Ghana are open-pollinated, this practice does not result in significant yield decline, as would be the case with hybrids. It was therefore proposed to evaluate promising high-yielding maize hybrids for grain yield and other important agronomic characteristics in on-station and farmer-participatory on-farm trials with the aim of finding adoptable hybrids which are best suited to farmers' needs. Specific objectives were:

1. To familiarize farmers with high-yielding maize hybrids in order to facilitate the adoption of the hybrids
2. To demonstrate and promote the application of modern technologies for the production of maize hybrids in the northern savanna zone of Ghana.

Materials and methods

On-station trials

Researcher-managed field trials were conducted during the 2012 cropping season at eight locations spread across five districts (Wa municipal, Wa West, Wa East, Sissala East and Nadowli) in the Upper West Region Seven genotypes comprising four single cross hybrids (30 B 74, 30 K 73, 30 F 32 and 30 Y 87) from Pioneer Hi-bred Seed Co. Ltd., a three-way-cross hybrid (Etubi) developed by Crops Research Institute, Kumasi, a single-cross hybrid (PAN 83) from Wienco Seed Company were evaluated alongside a local check (farmer variety). The farmer variety was the best available local variety at each location.

Each hybrid was evaluated using four replications per site in a randomized complete block design. The trials were planted between 4 and 26th July 2012. Fertilizer N was applied in two equal doses to maximize N efficiency. Thus, the compound fertilizer with micronutrients, Actyva (23-10-5-3-2-0.3 as N, P, K S, Mg and Zn) was applied at the rate of 250 kg/ha at 10 days after sowing and Sulphate of ammonia (21% N) was applied at the rate of 250 kg/ha at 35 days after sowing, when the plants started to grow rapidly and N demand was high. Weeds were controlled with pre-emergence application of atrazine followed by one hand weeding.

Data were taken on several traits including yield and yield components but for the sake of the assessment, only those of ultimate importance are discussed. Usable data could not be obtained from the on-station trial at Naahaa in the Wa East district because the farmer harvested and bulked the cobs from all plots hence results from this location were not included in the combined analyses. Combined analyses for seven locations (Wa, Kpongu, Goriyiri, Wechiau, Loggu, Silbelle and Sorbelle) are presented in this report. Data collected were subjected to analysis of variance (ANOVA) to establish treatment effect on grain yield and yield components.

On-farm trials

Farmer-managed trials were also conducted on farmers' fields in the five districts. In all, five hybrids were evaluated alongside the farmers’ varieties as local checks. Farmers’ fields near to the on-station trial sites were selected for each on-farm trial. Farmers evaluated a subset of three varieties from the on-station trials alongside their local varieties which were the best available variety at each evaluated site.

Field days were organized at planting and when the maize plants reached physiological maturity so farmers could view the experiments. Farmers met to discuss what they thought were the important criteria for selecting a given hybrid. The criteria were ranked and the top-ranking criteria were used. Farmers were also asked to give an overall score to each hybrid. The research team also independently evaluated both mother trials for yield and other agronomic traits.

Results and discussion

On-station trials

There was minimal variation among the genotypes in terms of maturity. Averaging over all locations, plant height of the genotypes ranged from 1.97 m for 30 K 73 to 2.21 m for 30 B 74. Significant differences among locations and among varieties within locations were noted for grain yield (Table 126). Mean grain yields were generally high with Wa being the most productive site (Mean yield: 7.87 t/ha) followed by Silbelle (Mean yield: 5.20 t/ha). Kpongu was the least productive site (Mean yield: 3.37 t/ha) and this may be attributed to poor management of the trial by the field staff.

Table 126. Grain Yield (t/ha) of maize genotypes evaluated across six locations in the Guinea Savanna zone of Ghana in 2012.

	Location						
Genotype	Wa	Kpongu	Wechiau	Goriyiri	Silbelle	Sorbelle	Mean
30B74	9.08	4.37	4.56	4.10	6.93	4.70	5.62
30F32	8.59	2.85	4.00	3.87	5.43	6.40	5.19
30K73	8.88	3.99	4.67	4.23	5.43	5.07	5.38
30Y87	8.99	4.03	3.44	3.72	5.80	4.80	5.13
PAN53	6,81	1.97	2.89	4.58	4.48	3.53	4.00
Etubi	6.57	3.76	3.56	4.48	4.53	3.77	4.49
Farmer variety	6.19	2.62	2.78	3.45	3.83	3.33	3.70
Lsd (0.05)	2.21	2.62	1.41	0.56	1.11	NS	0.63
CV%	15.8	21.5	21.5	7.7	12.0	35.6	20.5
Grand Mean	7.87	3.37	3.70	4.06	5.20	4.51	4.79

NS= not significant at the 0.05 and 0.01% level of significant.

On-farm trials: Averaging over locations, mean grain yields among the varieties ranged from 3.70 t/ha to 5.62 t/ha with a grand mean of 4.79 t/ha across the six locations (Table 126). The Pioneer hybrid 30 B 74 produced consistently high yields (5.6 t/ha) across locations followed by 30 K 73 which recorded a grain yield of 5.4 t/ha. The farmer variety recorded the lowest mean yield of 3.7 t/ha across all locations. On average, the single-cross hybrids from Pioneer Hi-bred Seed Co. Ltd (30 B 74, 30 K 73, 30 F 32 and 30 Y 87) produced similar yield while were significantly higher than those of PAN 53, Etubi and the farmer variety. Pioneer hybrids, on average, out-yielded Etubi by 14-25% and the farmer variety by 39-52%. In general, hybrid maize is superior to OPVs in terms of performance where the cultural conditions are optimal. The farmer varieties which were included in the evaluation were OPVs, which are known to be lower yielding when compared to hybrids of similar maturity period, particularly single cross hybrids which, on the contrary, are known to have very high yield potentials.

All the Pioneer hybrids tested in these trials had good stalk quality and very good husk cover. However, due to the low incidence of the major diseases in the Guinea Savanna zone during the cropping season, a detailed assessment of the hybrids for their tolerance or otherwise to the major diseases in the Guinea Savanna zone could not be made. The Wienco single-cross hybrid PAN 53 similarly exhibited good potential for high yields but generally had poor stalk quality.

Significant differences among locations were noted for grain yield. Mean grain yields ranged from 3.3 to 5.5 t/ha with a mean of 4.0 t/ha across the six locations. Grain yields were highest at the SARI research farm in Wa and lowest at Loggu. The hybrid 30 Y 87 produced the highest grain yields at three locations (Wa, Kpongu and Wechiau). Etubi and farmer variety had the lowest yields at the three locations. However, three hybrids (30 F 32, 30 K 73 and 30 B 74) produced similar grain yields at all locations. Differences in grain yield among the hybrids were not statistically significant at Loggu, Goriyiri and Silbelle. However, the Pioneer hybrids, on average, out-yielded Etubi 23-50% and the farmer variety by 24-52%.

Farmer assessment of the genotypes

Out of the three hundred and fifty (350) participants at four field days organized at Naahaa, Silbelle, Kpongu and Jirapa at physiological maturity, 60 were women. The field days allowed non-colaborating farmers to assess the new hybrids. Women preferred the yellow maize variety because it could be planted and sold or eaten fresh. The hybrids 30 B 74, 30 Y 87, 30 K 73 and 30 F 32 were the most preferred maize genotypes in that order. Higher yields of the hybrids have excited farmers. In most cases, all the hybrids were considered to be better than the farmers' varieties. Farmers who participated in on-farm trials testified that the hybrids performed better than their local varieties even under their own circumstances. In decreasing order of importance, the traits that were most frequently cited by farmers for preference of a hybrid at all locations were heavier ears (bigger cobs), earliness, drought tolerance and endosperm colour. However, farmers perceived that poor access to hybrid seed and a lack of specialized knowledge in hybrid seed production coupled with the necessity to purchase hybrid seeds every year are the most binding constraints to adopting hybrid maize.

Summary and conclusion

The results of both the on-station and on-farm trials suggested that 30B74, 30Y87, 30K73 and 30F32 produced consistently higher grain yields across a number of locations than Etubi and the farmer varieties. However, it is not clear how these hybrids will perform under *Striga*, disease and pest infestation as well as drought conditions in northern Ghana. It seems a fundamental step towards promoting adoption of a technology would be to develop mechanisms for providing knowledge and inputs especially fertilizer and quality seed. Combining improved agronomic practices with improved hybrid seed could make an overall maize production package economically viable.

The results of this study bring into focus the general perception held by many stakeholders that hybrid maize has the potential to revolutionize maize production in Ghana and that serious efforts must be made to promote the adoption and use of hybrid maize as means of increasing maize productivity and production in the country. Despite this potential, adoption of hybrids has remained at a fairly low level. Therefore, to convince farmers to switch over to hybrid seeds, there is the need to develop and make available to them superior hybrids (preferably single cross hybrids) with visible and obvious yield advantages rather than abstract statistical differences which may be less obvious to farmers. Furthermore, farmers are often of the opinion that they could derive maximum economic returns from hybrid maize seed only when fertilizers can be applied at relatively high rates. Nevertheless, it is anticipated that the demand for hybrid seed will increase with the re-organization of the national seed industry and with the continued improvement in crop management and extension. Tentatively, it is recommended that the four Pioneer hybrids 30 B 74 (white), 30 K 73 (yellow), 30 F 32 (white) and 30 Y 87 (yellow), which have shown consistency in performance across most locations in both on-station and on-farm trials be advanced on-farm for further evaluation and possible release.

Evaluation of improved sorghum varieties and hybrids in the Upper West Region

(S.S.J. Buah)
Source of funding: Wienco Ghana Ltd.,

Executive summary

Sorghum (*Sorghum bicolor*) is an important staple crop in northern Ghana and it also has tremendous potential in the brewing industry. However, average yields from farmers' fields are below 1.0 t/ha as a result of low soil nutrient levels, use of varieties with low yield potential and low management levels. In 2012, sorghum varieties and hybrids with stable and high yields were evaluated in selected locations in the Upper West Region with the aim of finding adoptable genotypes which are appropriate to the needs of farmers. Two hybrids (Pan 606 and Pan 8816) were evaluated alongside OPVs (Kapaala, Dorado and IRAT 204) and farmers' varieties. The farmer's local varieties were taller and also flowered late while the hybrids were shorter and took relatively fewer days to flower. Because the farmer's local varieties flowered late, they were affected by midge resulting in lower grain production. Also, terminal drought prevented the late planted sorghum from reaching their yield potential. Averaging across all locations, mean grain yields ranged from 1,879 to 2,192 kg/ha. Mean grain yields of Kapaala and Dorado were comparable to those of the hybrids. Moreover, PAN 606 and PAN 8816 had similar grain yields. Farmers' preference criteria for sorghum genotypes were based on food quality, stable grain yield, earliness, brewing qualities, drought tolerance and grain quality. Food quality was the most frequently indicated prefered trait by farmers followed by productivity and earliness. White-grained sorghum is preferred for food but they are mostly prone to bird damage in the field because they lack the bitter taste of pigmented sorghum. The bitter taste of brown or red-grained sorghum acts to repel birds. The preferred attributes of brown sorghum genotypes were suitability for brewing and resistance to bird damage. The two hybrids PAN8816 and PAN606 which have red seedes generally have similar growth requirements as Dorado and Kapaala and can therefore be grown successfully in the savanna zone of Ghana.

Introduction

Grain sorghum (*Sorghum bicolor*) is an important staple crop in the northern savanna zone of Ghana where it is largely grown as a rainfed crop by subsistence farmers. It also has tremendous potential in the brewing industry. Average yields from farmers' fields are below

1.0 t/ha as a result of low soil nutrient levels, use of varieties with low yield potential and low management levels. Sorghum producers in the northern savanna zone mostly grow local sorghum landraces with loose open panicles, which are chosen for their grain and stalk qualities, adaptation to low soil fertility and, most importantly, to match the length of the growing season. White-grained sorghum generally is preferred for food because they give the desired colour while red and brown grains are preferred for brewing a local beer called *pito*. Thus sorghum is an important cash and food security crop in northern Ghana where it is also used in most traditional festivities. Recently the brewing industries in Ghana, especially Guinness Ghana Ltd., have expressed interest in using sorghum as a local substitute for barley malt in the brewery industry. This has therefore stimulated widespread interest in scaling up sorghum production in the country.

The initial sources of sorghum seed for planting include on-farm seed selection, use of seed saved from previous crop harvest and to a less extent through loans and exchanges among farmers. Most farmers therefore have no need to purchase commercial seed. However, timely availability of quality seed in sufficient quantities at a reasonable price is essential to fully harness the benefits of the improved varieties and/or hybrids. Sorghum production can be substantially increased simply by ensuring the availability of improved seed of OPVs and hybrids that are capable of giving greater yields with improved crop management than the local landraces. The objective of the study was to assess the performance and yield of improved varieties and hybrids of sorghum with the aim of finding adoptable varieties which are appropriate to the needs of farmers. Specific objectives were:

- To introduce farmers to available sorghum hybrids with stable and high yields in order to facilitate the adoption of the varieties
- To demonstrate and promote the application of modern technologies for the production of sorghum.

Materials and methods

Two (2) sorghum hybrids (PAN 606 and PAN 8816) were evaluated alongside three OPVs (Kapaala, Dorado and IRAT 204) and a local check (farmer variety) on farmers' fields at eight locations spread across five districts (Wa municipal, Wa West, Wa East, Sissala East and Nadowli) in the Upper West Region. The local check was the best available variety at each location. The trials were not replicated at either site due to insufficient seed. The trials were planted between 4 and 26th July 2012. Rock phosphate fertilizer was applied at the rate of 125 kg/ha at harrowing as starter fertilizer. The compound fertilizer, Actyva with micronutrients (23-10-5-3-2-0.3 as N, P, K S, Mg and Zn) was applied at the rate of 380 kg/ha at 10 days after sowing. Urea (46% N) was applied at the rate of 65 kg/ha at 5 weeks after sowing at 5 cm from the hills. Weeds were controlled with pre-emergence herbicide followed by one hand weeding. Data recorded for sorghum included date to 50% flowering, plant height, number of seed/m^2, 100-seed weight and number of heads/m^2 and grain yield at harvest.

Results and discussions

Wa Municipal

The trials were planted on farmers' fields at two sites (SARI, Wa Station research farms in Wa and Kpongu) both in the Wa municipality. At the research farm in Wa, days to 50% flowering ranged from 60 to 69 days. Plant height ranged from 1.2 to above 3.0 m. The farmer's local variety was tallest (>3 m) and also flowered late (69 days) while PAN606 and PAN8816 were shorter and PAN8816 and IRAT 204 flowered earliest. PAN 8816 flowered 4 and 6 days earlier than Kapaala and Dorado, respectively. However, PAN606 flowered 7 days later than PAN 8816. The shorter genotypes, PAN606, PAN8816, Dorado and IRAT204 were less than 2.0 m tall. Kapaala was also taller than Dorado, IRAT204 and the two hybrids. The shortest genotype was PAN606.

Hundred seed weight (seed size) ranged from 1.65 to 2.79 g with a mean of 2.24 g. Kapaala and IRAT204 had larger seeds. Seed number (seeds/m^2) ranged from 9907 to 13564 with a mean of 11661. Seed number was rather higher for Dorado and PAN8616. Although seed weight was highest for Kapaala, seed number was numerically lower. It appears larger seed size compensated for the fewer seeds produced by Kapaala, Grain yields ranged from 2900 to 3390 kg/ha. Grain yield of Dorado was comparable to the yield of PAN8816. Grain yield of IRAT 204 was the least due to bird damage as it was among the earliest to mature. PAN606 produced a grain yield of 2950 kg/ha and this was similar to the yield of IRAT204. PAN8816 produced more grains than PAN606 at Wa. The two hybrids PAN 606 and PAN 8816, had the longest panicles while IRAT204 had the shortest panicles. Gain yields were relatively lower (712 to 1288 kg/ha) at Kpongu when compared with yields obtained at the Wa site and this may be due to poor management of the trials at Kpongu. .

Wa East District

The on-farm trials were planted at two sites (Loggu and Bulenga) in the Wa East district. At Loggu, days to 50% flowering ranged from 62 to 80 days among the sorghum genotypes. Plant height ranged from less than 1.0 m to above 3.0 m. The farmer's local variety was tallest (>3 m) and also flowered late (80 days) while PAN8816 was among the shortest genotypes but flowered earlier than Dorado and the farmer's variety. PAN606 flowered later than PAN 8816 at Loggu. PAN606, PAN8816 and IRAT204 were about 1.0 m tall. Kapaala was taller than Dorado, IRAT 204 and the two hybrids. Grain yields were relatively low at Loggu with a range of 400 to 2040 kg/ha and the grain yield of the farmer's variety was the least due to midge damage. IRAT204 also had low yields due to bird damage. Kapaala recorded the highest grain yields followed by PAN606 and PAN8816. At Bulenga, grain yields ranged from 2100 to 2500 kg/ha. Grain yields of PAN606 and Dorado were the least whereas PAN8816 recorded the highest grain yields followed by IRAT204 and Kapaala.

Wa West District

Only one trial was planted in the Wa West district at Wechiau. The farmer's local variety was tallest (2.38 m) while PAN606 and PAN8816 were among the shortest genotypes and were about 1.0 m tall. Kapaala was generally taller than Dorado, IRAT 204 and the two hybrids. Grain yields ranged from 800 to 2200 kg/ha with the farmer's variety recording the highest grain yields followed by PAN606 and PAN8816. Dorado had the least grain yield of 800 kg/ha.

Nadowli District

Only one trial was planted in the Nadowli district at Goriyiri. At Goriyiri, the farmer's local variety was tallest (>3 m) and also flowered late (80 days) while PAN8816 was among the shortest genotypes but flowered earlier than Dorado, PAN606 and the farmer's variety. Like at other sites, PAN606 flowered later than PAN 8816 at Goriyiri. Grain yields ranged from 1770 to 3930 kg/ha With the grain yield of the farmer's variety being the least due to midge damage. Dorado recorded the highest grain yields followed by PAN606 and IRAT204 while Kapaala and PAN8816 had comparable grain yields.

Sissala West District

The on-farm trials were planted at two sites (Silbelle and Sorbelle) in the Sissala West District. Plant height ranged from 0.83 m to 2.20 m. The farmer's local variety was tallest (2.20 m) while PAN606 and PAN8816 were shortest. PAN606 flowered 6 days later than PAN 8816. The two hybrids (PAN606 and PAN8816), Dorado and IRAT 204 were less than 2.0 m tall And shorter than Kapaala. Grain yields of all the genotypes evaluated ranged from 2440 to 3120 kg/ha and the yield of the farmer variety was comparable to that of PAN8816. Kapaala produced the highest yield and this was greater than the yields obtained by PAN606 and PAN8816. At Sorbelle in the Sissala West district, grain yields ranged from 2400 to 2800 kg/ha. Kapaala obtained grain yield of 2560 kg/ha and this was comparable to the yield obtained by PAN606. The farmer variety had the highest grain yield of 2800 kg/ha at Sorbelle. Grain yield of IRAT 204 was the least at both sites due to bird damage.

Combined Analysis

The combined analysis over all the 8 sites revealed that only locations were statistically significant. Mean grain yields ranged from 956 to 3103 kg/ha across sites. Evidently, the highest grain yields were obtained at the SARI research farm while the lowest yields were obtained at Kpongu. The lower yields at Kpongu were probably due to the poor management of the trials at this site. Across locations, mean grain yields among the genotypes ranged from 1879 to 2192 kg/ha and yield differences among the sorghum genotypes were not statistically significant. However, PAN8816 tended to produce the highest grain yield while IRAT204 had the least grain yield due to severe bird damage. The farmer's local varieties were generally taller and because they flowered late, they were consequently affected by midge resulting in lower grain yields. In general, a series of flowerings (as a result of sowing sorghum of different growth cycles close to each other) results in midge build-up and this was observed in this experiment. Timing the sowing of sorghum so that flowering occurs simultaneously is important to minimize midge damage.

Field days

During field days organized in each district to showcase the new sorghum varieties and the hybrids and several visits by seed producers and farmers to the experimental plot at Wa, most farmers generally were satisfied with the performance of the genotypes. Majority of the farmers were impressed with the high grain yields of PAN606 and PAN8816 hybrids with short stature although these hybrids are red sorghums.

Development of control strategy for termite infestation in the field

S.S. Seini, J.B. Naab, Saaka Buah, Yahaya Iddrisu

Executive Summary

Many farmers in the Upper West Region of Ghana have reported termite damage to their field crops. The importance and seriousness of the attack came to the fore when termite attack ranked highly as a priority problem to farmers in the region during recent RELC planning sessions. Many laboratory bioassays have demonstrated the efficacy of plant extracts on termites. Extracts such as those of neem have been found to be effective against termites on cassava-maize intercrops (Umeh *et al*., 2001). Since plant extracts are less hazardous, it is appropriate to harness the insecticidal activity for the control of termites in field crops. The current study therefore seeks to conduct survey to assess damage and estimate crop losses due to termites in the Upper West Region of Ghana and develop effective termite control measures in the region.

Introduction

Project Rationale/Background

Termites are very destructive to all manner of field crops including cereals such as maize, millet and sorghum. Other field crops attacked include cowpea, groundnuts, bambara groundnuts, soya bean as well as all kinds of vegetables. Termites in the genera *Microtermes* and *Odontotermese* are important pests of groundnuts in the semi-arid regions of India and Africa. Their attack may cause up to 50% reduction in groundnut yield, and affect quality and market price (Johnson *et al*., 1981). Damage and yield losses result from cutting of stems, removal of foliage and invasion of tap root (Johnson *et al*., 1981). Termites also remove manure and other organic matter from fields (Wood, 1976) which may reduce soil fertility and crop yield. They also cause widespread destruction to grains in stores as well as general building infrastructure.

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Many laboratory bioassays have demonstrated the efficacy of plant extracts on termites Extracts such as those of neem have been found to be effective against termites on cassava-maize intercrops (Umeh *et al*., 2001). Since plant extracts are less hazardous, it is appropriate to harness the insecticidal activity for the control of termites in field crops.

Materials and Methodology

Survey of farmers' fields

Farm surveys were conducted in each of the nine districts of the Upper West Region at a time crops were well-established in the field. Special emphasis was placed on termite hot-spots, reports of which were obtained in collaboration with Agricultural Extension Agents (AEAs) of

Ministry of Food and Agriculture in the region. The incidence of termites was assessed by noting the presence or absence of termites in any farm visited. Information was recorded about the range of crops mostly attacked. Crop losses were evaluated by counting the number of plant stands destroyed by termites and calculated as a percentage of total plant stands. Samples of termite were collected from all farms in which they were present, for subsequent identification.

On-station termite control trials

The study was conducted on-station at SARI research fields at Boli, Yibile, Dinansu and Kpongu in the Upper West Region of Ghana, where termites have been regularly reported to destroy crops. The trials involved two crops, maize and groundnuts. For the groundnut trial, experimental layout was randomized complete block design and treatments replicated six times. Each plot consisted of six rows 5m long with spacing of 0.4m between rows and 0.1m between plants in a row. The groundnut variety Chinese was used. Treatments consisted of neem seed extract applied at 10% (w/v) concentration at pegging stage of the crop. Untreated control and plots treated with lambda cyhalothrin were included as checks. Crop losses were evaluated by counting the number of plant stands destroyed by termites and calculated as a percentage of total plant stands.

For the maize trial, experimental layout was randomized complete block design and treatments replicated six times. Each plot consisted of six rows 5m long with spacing of 0.75m between rows and 0.4m between plants in a row with 2 plants /hill. The maize variety Obatampa was used. Treatments consisted of neem seed extract applied at 10% (w/v) concentration at planting. Untreated control and plots treated with lambda cyhalothrin included as checks. Crop losses were evaluated by counting the number of plant stands destroyed by termites and calculated as a percentage of total plant stands.

Results and Discussions

Scientific findings

A survey of crop fields during the season indicated that termites were present in all districts of the Upper West Region. The major crop affected was maize in which damage levels range between 5 and 65%. Other crops affected to a lesser degree were millet, sorghum, groundnuts, yam and cassava with damage levels of up to 13%. Across the survey area two genera of termites were encountered viz: *Macrotermes bellicocus* which build large spectacular mounds and whose presence is generally obvious, and *Odontotermes badius* which occur in the ground and build smaller mounds.

In the on-station trials, maize stalk damage due to termites was generally between 20% and 47% in the untreated control plots. Treatments with neem seed powder reduced maize stalk damage significantly to between 2% and 24%, a reduction of about 50% ($P < 0.05$). Comparing the maize yield in all treated plots there was no significant difference between the neem and lambda cyhalothrin treated plots ($P>0.05$). The control plots in general recorded between 620 and 766 kg/ha of maize grain yield. This was lower than that of the treated plots which recorded between 900 and 1,450 kg/ha maize grain yield ($P>0.05$). From these results, yield loss due to termites in maize is estimated to be about 34%.

Conclusions/Recommendations

Jatropha and neem seed powders therefore have the potential to protect maize against termite damage in the field. This compares favourably with reports of similar protection offered by neem.

Future activities

Development of technology transfer modules for training MoFA AEAs on use of Jatropha for termite control

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Development of control strategies for pests and diseases of harvested groundnuts left on the field and in storage barns

S.S. Seini, J. B. Naab, Saaka Buah, Yahaya Iddrisu

Executive Summary

Groundnut is a major food and cash crop in Ghana, especially in northern Ghana which accounts for 92% of national groundnut production (SRID, 2004). However, average yields of 840 kg/ha obtained on farmers' fields in Ghana are low compared to 2500 kg/ha reported in developed countries such as the United States (FAO, 2002). Relatively low groundnut yield in Ghana and other parts of West Africa is attributed largely to the deleterious effects of soil arthropod pests, soil and foliar disease, nematodes and weed interference (Kishore, 2005; Umeh, 2001). Yield loss from termites ranges from 21 to 50% in West Africa (Johnson *et al*., 1981; Umeh *et al*., 1999). Infestation by these pests predisposes pods to attack by disease causing organisms such as the carcinogenic fungus *Aspergillus flavus* (Link) (Lynch *et al*., 1990; Waliyar *et al*., 1994). Many laboratory bioassays have demonstrated the efficacy of plant extracts on termites and other arthropod pests of groundnut in the field and in storage. Extracts such as those of neem have been found to be effective against termites on cassava-maize intercrops (Umeh *et al*., 2001). Since plant extracts are less hazardous, it is appropriate to harness the insecticidal activity for the control of storage and field pests.

Introduction

Project Rationale/Background:

Many farmers in the Upper West Region of Ghana have reported sighting unfamiliar field insect pests which infest harvested pods. These reports were made more serious when during recent RELC district planning sessions, all districts reported that apart from these field pests, some other pests also attack groundnuts in storage. The pests suck out valuable oil from kennel leading to shriveling of grain. The kennels are rendered bitter making them unsuitable for consumption.

Many laboratory bioassays have demonstrated the efficacy of plant extracts on termites and other arthropod pests of groundnut in the field and in storage. Extracts such as those of neem have been found to be effective against termites on cassava-maize intercrops (Umeh *et al.*, 2001). Since plant extracts are less hazardous, it is appropriate to harness the insecticidal activity for the control of storage and field pests. This study therefore seeks to survey field and farm stores to estimate losses in groundnut yield and storage due to field and storage pests in the Upper West Region of Ghana and develop effective control measures for them. The main objective of this proposal is to develop effective and sustainable control for groundnut field and storage pests.

Materials and Methodology:

Survey of farmers' fields

A survey of groundnut storage structures were conducted in each of nine districts of the Upper West Region. Special emphasis was placed on groundnut storage pest hot-spots, reports of which were obtained in collaboration with Agricultural Extension Agents (AEAs) of Ministry of Food and Agriculture in the region. Three farm stores were visited in each district of the region. The incidence of groundnut storage pests were assessed by noting the presence or absence of storage pests in any store visited. Losses in groundnut weight and quality were assessed. Insect samples were collected for identification.

On-station groundnut pest control trials

The study was conducted on-station at SARI research fields at Boli, Yibile, Dinansu and Kpongu in the Upper West Region of Ghana, where groundnut field pests have been regularly reported to destroy crops. Experimental lay out was randomized complete block design and treatments replicated six times. Each plot consisted of six rows 5m long with spacing of 0.4m between rows and 0.1m between plants in a row. The groundnut variety Chinese was used. Treatments consisted of neem and Jatropha seed extracts applied at 10% (w/v) concentration at planting or pegging stage of the crop. Untreated control and plots treated with lambda cyhalothrin were included as checks. Crop losses were evaluated by counting the number of groundnut pods damaged by field pests and calculated as a percentage of total pod yields.

Groundnut storage studies

Storage studies were conducted to investigate the ability of neem and Jatropha seed extracts to protect stored groundnut from insect pest attack. Groundnut variety Chinese was used. Treatments consisted of neem and Jatropha seed extracts applied at 10% (w/v) concentration. Untreated control and groundnut samples treated with lambda cyhalothrin were included as checks. Grain weight losses were evaluated after six months of storage. Each sample initially weighed 1.0kg.

Results and Discussions

Scientific Findings

During survey of groundnut farm stores the groundnut pod borer, *Caryedon serratus* was found to attack unshelled groundnuts causing an estimated 22% loss in grain weight in the most seriously infested stores. *Caryedon serratus* was present in 58% of farm stores inspected. In the on-station trials, groundnut pod damage due to soil arthropods was generally between 7 – 11 % in the untreated control plots. Treatments with Jatropha and Neem seed powder reduced groundnut pod damage significantly to between 1.0 – 3.0%, a reduction of about 63% ($P < 0.05$).

Comparing the fresh pod yield in all treated plots there was no significant difference between the neem and Jatropha treated plots ($P>0.05$). The control plots in general recorded between 650 and 800 kg/ha of fresh pod yield. This was lower than that of the treated plots which recorded between 920 and 1,250 kg/ha fresh pod yield ($P>0.05$) From these results yield loss due to soil arthropods in groundnuts is estimated to be about 24%.

Jatropha seed powder therefore has the potential to protect groundnuts against damage from soil arthropods. This compares favourably with reports of neem being able to protect groundnut pods from soil arthropod damage.

In the storage trials Jatropha and Neem seed extracts were able to protect stored groundnut pods from insect damage for about 3 months which is half of the storage period. The check protectant, lambda cyhalothrin offered good protection for about 3 months. At the end of the experimental period of six months, the control lots suffered more damage to groundnut pods than the treated lots ($P>0.05$). The estimated weight loss in groundnuts in the control was 14%; that in the chlorpyrifos lot was 5% and that in the seed extract lots was 8.1. Jatropha seed extract has the ability, just as in neem to protect stored groundnuts against storage pests. It can be postulated that two treatments with Jatropha seed extract at 2 to 3 month intervals can offer enough protection for a storage period of six months.

Technology under development

The use of Jatropha seed products for groundnut pest control

Conclusions/Recommendations

Jatropha seed powder has the potential to protect groundnuts against soil pest damage in the field. This compares favourably with similar protection offered by neem.

Future activities

Development of technology transfer modules for training MoFA AEAs on use of Jatropha for groundnut pest control

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Evaluation of planting date and cultivar for insect pest management in cowpea

S.S. Seini, Mumuni Abudulai, Francis Kusi, Asamoah Larbi, Mohammed Haruna

Executive Summary

Despite its importance, cowpea yields on farmers' field are low averaging less than 500 kg/ha. The major cause of the low yields is due to problem of insect pests that attack the crop throughout its growth, although the most important insect pests are those that attack the crop from flowering (Jackai *et al*. 1985). Insecticide application is the recommended practice for control of insect pests on cowpea. However, most farmers in Ghana are resource-poor and require pest management strategies that are cost-effective and sustainable. The use of insecticides must be minimized because of high cost and harmful effects on the environment. Therefore, the objectives of this study were: 1) To evaluate cowpea cultivars for their resistance to major insect pests, 2). To determine appropriate planting dates as a cultural tool for pest management in cowpea

Introduction

Cowpea, *Vigna unguiculata* (L) Walp, is a major staple crop in Ghana. The leaves, green pods, green peas and the dry grain are eaten as food and the haulms are fed to livestock. The grain contains 23-28% protein and constitutes the cheapest source of dietary protein for majority of people in Africa who lack the necessary financial resources to acquire animal protein (Tarawali *et al*., 1997). Sale of the grain also provides income to farmers and traders in Ghana. As a leguminous crop, cowpea also fixes atmospheric nitrogen into the soil which is of major benefit in African farming where most of the lands are exhausted and farmers lack adequate capital to purchase chemical fertilizers. Moreover, cowpea is shade-tolerant and therefore compatible as an intercrop in the mixed cropping systems widely practiced by small holder farmers (Singh and Sharma, 1996).

Despite its importance, cowpea yields on farmers' field are low averaging less than 500 kg/ha. The major cause of the low yields is due to problem of insect pests that attack the crop throughout its growth, although the most important insect pests are those that attack the crop from flowering (Jackai *et al*. 1985). Insecticide application is the recommended practice for control of insect pests on cowpea. However, most farmers in Ghana are resource-poor and require pest management strategies that are cost-effective and sustainable. The use of insecticides must be minimized because of high cost and harmful effects on the environment.

Materials and Methodology

The experiment was conducted at Bulenga in the Wa East District and Kaleo in the Nadowli District of the Upper West Region. The treatments consisted of four planting dates and 3 cowpea cultivars of maturity periods ranging from early to late, which were sprayed with insecticide or unsprayed. The experiment was a split-split-plot in a randomized complete block design with four treatment replications. Insecticide spraying regime was used as main plots, planting date as sub-plots and cowpea cultivars as sub-sub-plots. The three cowpea cultivars used were Bawutawuta, Padituya and Songotra obtained from the breeding program at CSIR-SARI. Planting was done in mid-July, late-July, mid-August and late-August. Sub-sub-plots consisted of 4 rows 5 m long spaced at 0.60 between rows and 0.20 m between plants in a row. The replicates and main plots were separated by 2 m alleys while the sub and sub-sub plots were spaced 1 m apart. In Experiment 2, the treatments comprised three cowpea cultivars as in Experiment 1 and four insecticide spraying regimes. The insecticide spraying regime treatments were: 1) no spray (untreated control), 2) spraying once at 50% flowering, 3) two sprays, one at flower bud initiation and a second at early podding and 4) three sprays, one each at flower bud initiation, 50% flowering and 50% podding. The experiment was a split-plot in a randomized complete block design with insecticide spraying regime as the main plots and cowpea cultivars as sub-plots. The treatments were replicated four times. Sub-plots consisted of 4 rows 5 m long spaced at 0.60 between rows and 0.20 m between plants in a row. The replicates and main plots were separated by 2 m alleys while the sub-plots were spaced 1 m apart.

Data collection

Data were collected on agronomic parameters such as percent germination and days to 50% flowering and maturity. Insect pests were sampled from the two middle rows of each plot. Populations of thrips and *Maruca vitrata* were estimated beginning at flower bud formation until 50% podding by picking 20 flowers from the two middle rows to the laboratory to count the insects. Populations of pod-sucking bugs (PSBs) were estimated by counting nymphs and adults in the two middle rows of each plot. Pod damage by PSBs and *Maruca* were estimated from a sub-sample of 100 pods after harvest. Data also were taken on yield parameters such as number of pods per plant, number of seeds per pod and seed yield.

Results and Discussion

Scientific findings

As shown in the Tables 127 and 128, results indicate planting date had significant effect on populations of *Maruca vitrata* in flowers and thrips in flower buds. There were more thrips and maruca at the last planting dates than the earlier planting dates. There was also a significant effect of planting date on the number of seeds per pod, pod-sucking bugs and cowpea haulm weight. The third and last planting dates recorded a lower number of seeds per pod compared with the first two planting dates. The number of thrips in flowers and yield were significantly affected by the interaction of spraying by planting date. Yield was similar and more at the earlier planting dates especially when treated with insecticide compared with latter plantings.

Table 127. Effect of date of planting on populations of Maruca and Thripds

Planting date	No. of Maruca/20 flowers	No. of Thrips/20 flower buds
Mid-July	0.7 b	15.8b
Late July	0.7 b	16.8 b
Mid August	1.2 a	19.0 a
Late August	1.4 a	19.5 a

Table 128 . Effect of date of planting on seed per pod, percentage pod damage and haulm weight

Planting date	No. of seeds/pod	% pod damage	Haulm weigh
Mid-July	6.9 a	29.4b	2123.2 b
Late July	7.1 a	26.7 b	2446.1 b
Mid August	3.9 b	25.9 b	3255.8 a
Late August	0.8 c	90.2a	1764.6 c

Technology under development: Use of varietal resistance and planting dates as cultural tools for pest management in cowpea.

Conclusion: The best planting dates for cowpea irrespective of the variety is mid- to late July.

Future activities: Repeating the trial for the second year

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Evaluation of cultivar and spraying regime for insect pest management in cowpea

S.S. Seini, Mumuni Abudulai, Francis Kusi, Asamoah Larbi, Mohammed Haruna

Executive Summary

Despite its importance, cowpea yields on farmers' field are low averaging less than 500 kg/ha. The major cause of the low yields is due to problem of insect pests that attack the crop

throughout its growth, although the most important insect pests are those that attack the crop from flowering (Jackai *et al*. 1985). Insecticide application is the recommended practice for control of insect pests on cowpea. However, most farmers in Ghana are resource-poor and require pest management strategies that are cost-effective and sustainable. The use of insecticides must be minimized because of high cost and harmful effects on the environment. Therefore, the objectives of this study were: 1) To evaluate cowpea cultivars for their resistance to major insect pests of cowpea, 2). To determine the minimum insecticide protection required for increased cowpea yield.

Introduction

Cowpea, *Vigna unguiculata* (L) Walp, is a major staple crop in Ghana. The leaves, green pods, green peas and the dry grain are eaten as food and the haulms are fed to livestock. The grain contains 23-28% protein and constitutes the cheapest source of dietary protein for majority of people in Africa who lack the necessary financial resources to acquire animal protein (Tarawali *et al*., 1997). Sale of the grain also provides income to farmers and traders in Ghana. As a leguminous crop, cowpea also fixes atmospheric nitrogen into the soil which is of major benefit in African farming where most of the lands are exhausted and farmers lack adequate capital to purchase chemical fertilizers. Moreover, cowpea is shade-tolerant and therefore compatible as an intercrop in the mixed cropping systems widely practiced by small holder farmers (Singh and Sharma, 1996).

Despite its importance, cowpea yields on farmers' field are low averaging less than 500 kg ha^{-1}. The major cause of the low yields is due to problem of insect pests that attack the crop throughout its growth, although the most important insect pests are those that attack the crop from flowering (Jackai et al. 1985). Insecticide application is the recommended practice for control of insect pests on cowpea. However, most farmers in Ghana are resource-poor and require pest management strategies that are cost-effective and sustainable. The use of insecticides must be minimized because of high cost and harmful effects on the environment.

Materials and Methodology

The experiment was conducted at Bulenga in the Wa East District and Kaleo in the Nadowli District of the Upper West Region.The treatments comprised three cowpea cultivars as in Experiment 1 and four insecticide spraying regimes. The insecticide spraying regime treatments were: 1) no spray (untreated control), 2) spraying once at 50% flowering, 4) two sprays, one at flower bud initiation and a second at early podding and 4) three sprays, one each at flower bud initiation, 50% flowering and 50% podding. The experiment was a split-plot in a randomized complete block design with insecticide spraying regime as the main plots and cowpea cultivars as sub-plots. The treatments were replicated four times. Sub-plots consisted of 4 rows 5 m long spaced at 0.60 between rows and 0.20 m between plants in a row. The replicates and main plots were separated by 2 m alleys while the sub-plots were spaced 1 m apart.

Data collection

Data were collected on agronomic parameters such as percent germination and days to 50% flowering and maturity. Insect pests were sampled from the two middle rows of each plot. Populations of thrips and *Maruca vitrata* were estimated beginning at flower bud formation until 50% podding by picking 20 flowers from the two middle rows to the laboratory to count the insects. Populations of pod-sucking bugs (PSBs) were estimated by counting nymphs and adults in the two middle rows of each plot. Pod damage by PSBs and *Maruca* were estimated from a sub-sample of 100 pods after harvest. Data also were taken on yield parameters such as number of pods per plant, number of seeds per pod and seed yield.

Results and Discussion

Scientific findings

Main effects of variety and spraying regime were significant on numbers of thrips in flowers, number of pods per plant, damage and grain yield. Generally, there were more pest infestations at the No spray (S0) and Single (S1) treatments compared with the other treatments. These infestations resulted in significantly lower yield as shown in the Table 129.

Table 129. Effect of spraying regime on pest populations and yield

Spraying regime	No. of thrips/20 flowers	No. of pods/plant	Yield
S0	18.5a	25.4b	52.9 c
S1	17.1 a	30.2 b	154.2b
S2	7.9 b	60.4a	471.3 a
S3	7.4 b	61.6 a	472.6 a

Technology under development: Use of varietal resistance and insecticide spray regime as tools for pest management in cowpea.

Conclusion

Spraying twice (S2) at flowering and podding stage or spraying thrice at budding, flowering and podding showed similar effects in lowering pest populations and increasing grain yield. The indication is that a third spray can be discounted with.

Future activities: Repeating the trial for the second year

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SORHGUM IMPROVEMENT

Evaluation Of Sorghum Hybrids In Northern Ghana – 2012

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Abstract

Ten sorghum genetic materials including 8 hybrids and 2 commercial varieties were evaluated at four locations across Northern Ghana with the aim of identifying or selecting well adapted and high yielding hybrids for increased sorghum production and productivity. The results of the studies indicated that locations significantly ($p<0.01$) affected days to 50% flowering, plant height and, grain weight per ha. Though the results revealed and ranked the materials across locations, the general performance of the materials were generally low. This might be due the late planting during the third week of July 2012 and the resultant terminal drought. Pooling the results, the highest yielders were Fada and Pablo which were significantly different from the rest of the test materials. Preliminary brewing tests on the eleven (11) sorghum samples have shown that three varieties, Dorado, Kapaala and Sewa fully meet the specifications. It is noteworthy that Dorado and Kapaala are currently the commercial sorghum varieties that are being used by Guinness Ghana Breweries Limited (GGBL). The additional hybrid, Sewa looks promising. However GGBL needs 4.0T grain of this hybrid (Sewa) to do a full scale trials for the confirmation of its suitability. According to GGBL, the other hybrids, Soumalemba, Fodda, 82W21, Boboji, Lata 3, Doua G and Pabilo which were off-white could also be used after further trials. Conversely, the red-coloured hybrid, 82G55 is found unsuitable by GGBL but it is been tried for "pito" brewing. It is recommended that the trials are repeated in 2013 completing all plantings by the end of June to observe the potentials of these materials.

Introduction

In most West African countries, sorghum alone accounts for 50% of the total cereal crop land area (FAO, 2005). In northern Ghana it is cultivated throughout the savannah agro-ecological zones, covering about 41% of the total land area of the country (Atokple, 1999). The crop is consumed in the form of stiff porridge (tuo zaafi); thin porridge (koko) or fried dumpling (maasa). Sorghum utilization in brewing local opaque beer (pito) is an important cottage industry in Northern Ghana and has existed in the country for over five centuries (Atokple, 2004). Its industrial use in brewing lager beer has also increased over the past decade. Depending on the year, sorghum yields range between 500 and 800 kg/ha in the Northern Region and slightly higher (between 700 and 900 kg/ha) in the Upper Regions. These low yields are due to the cultivation of indigenous land-race varieties with inherent low yield potential, lack of a wide diversity of new improved varieties and hybrids, little or no use of fertilizer and low planting densities characteristic of traditional mixed cropping systems (Schipprack and Mercer-Quarshie, 1984; Atokple et. al. 1998).

Although there have been significant increases in yields with some improved varieties, in most places traditional cultivars are used in the same ways as in the past. Limited availability of improved seeds, processing and markets have also been a disincentive for the farmers to invest more in sorghum production (Atokple et. al. 1998). High-yielding, improved cultivars/hybrids of sorghum are available and obtainable. This implies that with the increasing cereal demand for human consumption, sorghum production must be increased by enhancing yield potential per unit area as land holdings continue to diminish due to the increasing human population and urbanization of the agricultural land. To meet the industrial demand of sorghum, there is a need for technological options for increasing grain yield potential of sorghum genotypes. The use of sorghum hybrids is one of such technologies which will provide opportunities for both increased productivity through the exploitation of heterosis and access to markets that demand a more standardized product quality through sales of surplus production. The increase in human population of the country, the development of agro industries using sorghum as raw material, and the emergence of private seeds growers and companies are incentives for development and release of high yielding hybrids for the benefit of Ghanaians. To this end, SCIR-SARI as short term strategy has introduced hybrids from Pioneer, and other West African countries for adaptability test. The present study was therefore designed to evaluate sorghum hybrids for their adaptation and yield performance on farmers' fields across Northern Ghana for appropriate package of hybrid technologies.

Materials and Methods

Ten (10) genetic materials (Table 130) including 8 hybrids and 2 commercial varieties were evaluated at four locations (Fig. 39) across Northern Ghana. All the trials which were planted between 21st -24th July 2012, were laid out in Randomized Complete Block Design (RCBD) with four replications. There were six-row plots of length 5m and spacing of 75cm and 30cm inter- and intra-row respectively. Four to five seeds were planted per hole but thinned out to two seedlings per stand two weeks after planting. Data collected included grain yield, days to 50% flowering panicle weight, biomass yield and plant height at physiological maturity were subjected to statistical analysis using the GENSTAT Package. Participatory farmer selections were conducted in the communities where the trials were conducted.

Table 130. Sorghum hybrid and varieties evaluated in 2012

No	HYBRID/LINE	Type	Origin
1	NSH -27	Hybrid	
2	NSH - 36	Hybrid	
3	FADDA	Hybrid	ICRISAT
4	SEWA	Hybrid	ICRISAT
5	PABILO	Hybrid	ICRISAT
6	82 G 55	Hybrid	PIONEER, USA
7.	82 W 21	Hybrid	PIONEER, USA
8.	NSH - 54	Hybrid	
9.	KAPAALA (local check)	Pure line	SARI
10.	DORADO (local check)	Pure line	SARI

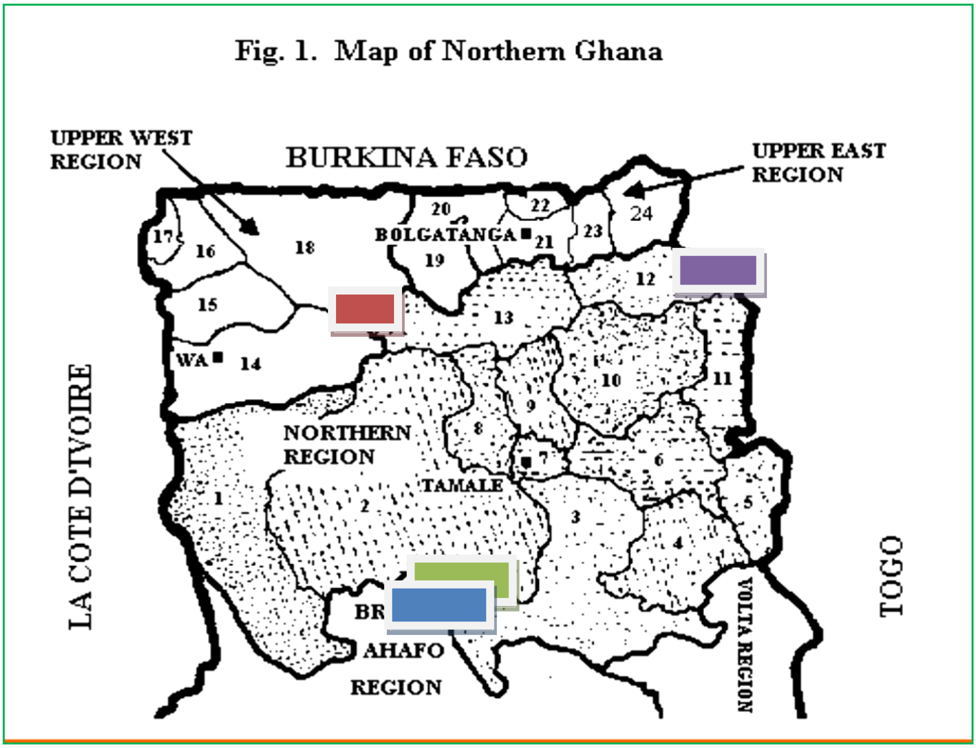

Fig. 39: Geographical locations of the trials in Northern Ghana

Results and Discussions

Ten sorghum genetic materials including 8 hybrids and 2 commercial varieties were evaluated at four locations across Northern Ghana with the aim of identifying or selecting well adapted and high yielding hybrids for increased sorghum production and productivity. The trial at Tumu was severely affected by drought that no meaningful data could be obtained from there. The results of the studies indicated that locations significantly ($p<0.01$) affected days to 50% flowering, plant height and, grain weight per ha. Though the results revealed and ranked the materials across locations, the general performance of the materials were generally low. This might be due the late planting during the third week of July 2012 and the resultant terminal drought. Pooling the results, the highest yielders were Fada and Pablo which were significantly different from the rest of the test materials. There were no significant differences between the local commercial checks, (Kapaala and Dorado) and the rest of the test hybrids.

Table 131. Days to fifty per cent flowering (DFF) and Plant height of Sorghum Hybrids at two locations in N. Ghana

	DFF		**Plant height (cm)**	
Variety	**Limo**	**Nyankpala**	**Limo**	**Nyankpala**
SEWA	71	97	184.2	155.5
DORADO	79	96.25	135.8	132
N.S.H-54	78.5	95.75	175.5	167
N.S.H-36	84.25	91.25	185.5	172
82G55	72.5	90.5	140.5	121.2
FADDA	76.5	88.75	233.8	215
PABLO	72.5	88.5	283.8	235
82W21	72.25	84.75	154.8	132.5
KAPAALA	74	81.5	193.2	184.2
N.S.H-27	73	73.75	180.8	175.2
Lsd $_{(\alpha = 0.05)}$	**3.9**	**5.911**	**20.46**	**21.58**
%CV	**3.6**	**4.6**	**7.6**	**8.8**

Table 132. Grain Yields of Sorghum Hybrids across three Locations in Northern Ghana

VARIETY	**GRAIN YIELD (Kg/ ha)**		
	LIMO	**YENDI**	**NYANKPALA**
SEWA	382b	334.9bc	194.4
DORADO	178.4bc	263.5bc	254.4
N.S.H-54	480c	150c	304.6
N.S.H-36	114.0bc	197.1bc	424.5
82G55	645bc	334.9bc	147.5
FADDA	891a	423.5b	403.4
PABLO	1075.8a	1002.4a	350.9
82W21	139.4bc	372.6bc	69.9
KAPAALA	228.5bc	261bc	232.1
N.S.H-27	213.8bc	160.2c	283.6
Fprob.	**<.001**	**<.001**	**0.298**
%CV	**69.8**	**46**	**74.3**

Table 133a. Brewing qualities Tests of Sorghum Hybrids by Guiness Ghana Brewery Limited (GGBL) .

Parameters	Unit	Target	Desired Range	Operational Limits	Soumalemba	Dorado	Fadda	82w21	Boboji
Colour			White to off white		Off white with brown patches	White	Off white with brown patches	Off white with brown patches	Off white with brown patches
Oil	% dry	<3.5	<3.5	<4.0	2.16	1.07	1.25	1.72	1.67
Moisture	%	10.0	9.0 – 11.0	9.0 – 12.5	9.4	12.05	7.83	10.19	8.46
1000 Kernel Weight	g dry wt	30	>28	>27	-	-	-	-	-
Extract	EBC - %		>72.0	>68.0	70.70	70.63	68.73	71.80	70.35
Grains Attached To Glumes	%	< 0.5	< 0.8	< 1.0	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
Broken Kernels	%	NIL	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Weevil Damaged	%	NIL	< 0.5	< 1.0	NIL	NIL	NIL	NIL	NIL
Insect Infestation	%	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Mould Infection	%	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Total Nitrogen	% dry wt.	1.9	1.7 – 2.0	1.5 – 2.2	-	-	-	-	-
Protein (Tn X 6.25)	% dry wt.	11.9	10.6 – 12.5	9.4 – 13.8	6.03	6.89	7.41	4.27	7.83
Aflatoxin	Ppb	< 2.0	< 5	< 10					
Purity	%	100	> 95	> 95	-	-	-	-	-
Foreign Matter	%	NIL	NIL	< 0.03	NIL	NIL	NIL	NIL	NIL
Odour									
Dust Level	-						NIL	NIL	
Overall Score	**%**						≤ 2	≤ 3	

Table 133b. Brewing qualities Tests of Sorghum Hybrids by Guiness Ghana Brewery Limited (GGBL) .

Parameters	Unit	Target	Desired Range	Operational Limits	82g55	Lata 3	Kapa ala	Doua G	Pabilo	Sewa
Colour			White to off white		Brown	Off white with brown patches	Whit e	Off white with brown patches	Off white with brown patche	White
Oil	% dry	<3.5	<3.5	<4.0	3.08	1.25	2.02	0.25	2.85	1.75
Moisture	%	10.0	9.0 – 11.0	9.0 – 12.5	8.05	9.76	12.5	9.08	8.05	8.21
1000Kernel Weight	g dry wt	30	>28	>27	-	-	-	-	-	-
Extract	EBC %		>72.0	>68.0	71.01	69.51	69.86	70.94	65.47	69.95
Grains Attached To Glumes	%	< 0.5	< 0.8	< 1.0	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8	< 0.8
Broken Kernels	%	NIL	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Weevil Damaged	%	NIL	< 0.5	< 1.0	NIL	NIL	NIL	NIL	NIL	NIL
Insect Infestation	%	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Mould Infection	%	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
Total Nitrogen	% dry wt.	1.9	1.7 – 2.0	1.5 – 2.2	-	-	-	-	-	-
Protein (Tn X 6.25)	% dry wt.	11.9	10.6 – 12.5	9.4 – 13.8	5.61	7.48	6.43	8.00	7.91	7.44
Aflatoxin	Ppb	< 2.0	< 5	< 10						
Purity	%	100	> 95	> 95	-	-	-	-	-	-
Foreign Matter	%	NIL	NIL	< 0.03	NIL	NIL	NIL	NIL	NIL	NIL

Conclusion

Preliminary brewing tests on the eleven (11) sorghum samples have shown that three varieties, Dorado, Kapaala and Sewa fully meet the specifications. It is noteworthy that Dorado and Kapaala are currently the commercial sorghum varieties that are being used by Guinness Ghana Breweries Limited (GGBL). The additional hybrid, Sewa looks promising. However GGBL needs 4.0T grain of this hybrid (Sewa) to do a full scale trials for the confirmation of its suitability. According to GGBL, the other hybrids, Soumalemba, Fadda, 82W21, Boboji, Lata 3, Doua G and Pabilo which were off-white could also be used after further trials. Conversely, the red-coloured hybrid, 82G55 is found unsuitable by GGBL but it is been tried for “pito” brewing. It is recommended that the trials are repeated in 2013 completing all plantings by the end of June to observe the potentials of these materials.