CSIR - PLANT GENETIC RESOURCES RESEARCH INSTITUTE (CSIR-PGRRI)

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COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

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(CSIR-PGRRI)

2022

ANNUAL REPORT

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LIST OF ABBREVIATIONS AND ACRONYMS

ABS	-	Access Benefit Sharing
ACMV	-	African Cassava Mosaic Virus
BAP	-	Benzene Aminopurine
BGN	-	Bambara Groundnut
CBSV	-	Cassava Brown Streak Virus
CMD	-	Cassava Mosaic Disease
CTAB	-	Cetyl Trimethyl Ammonium Bromide
DNA	-	De-oxyribonucleic acid
EACMV	-	East African Cassava Mosaic Virus
FARA	-	Forum for Agriculture Research in Africa
GOAL	-	Genebank Operations and Advanced Learning
GGCE	-	Grin Global Community Edition
GUG	-	Germplasm User Group
IBPGR	-	International Board for Plant Genetic Resources
ICRAF	-	World Agroforestry Centre/International Centre for Research in Agroforestry
IGF	-	Internally Generated Funds
ILV	-	Indigenous Leafy Vegetable
KNUST	-	Kwame Nkrumah University of Science and Technology
MoFA	-	Ministry of Food and Agriculture
NAA	-	Naphthalene Acetic Acid
NGO	-	Non-Governmental Organisation
PCR	-	Polymerase Chain Reaction

PGR	-	Plant Genetic Resources
PGRFA	-	Plant Genetic Resources for Food and Agriculture
PVABM	-	Pro Vitamin A Biofortified Maize
QMS	-	Quality Management System
SDG	-	Sustainable Development Goal
SOP	-	Standard Operating Procedure
TVET	-	Technical and Vocational Education and Training
UCAES	-	University College of Agriculture and Environmental Studies

FOREWORD

Dr. Daniel Ashie Kotey, Acting
Director – CSIR – PGRRI

The National Genebank, CSIR-Plant Genetic Resources Research Institute (CSIR-PGRRI) is one of the thirteen research institutes of the CSIR, mandated to collect, characterise, evaluate, document, distribute, conserve and utilise Plant Genetic Resources (PGR) from Ghana and abroad. For the CSIR-PGRRI to achieve this mandate, the institute undertakes PGR conservation-based applied research on legumes, roots and tubers, cereals, leafy and fruit vegetables, crop wild relatives, tree crops and spices/medicinal plants. The institute also builds capacity and promotes the application of technologies for the sustainable utilisation of PGR for food and agriculture. This report, grouped under two (2) broad research themes namely: Food Security and Poverty Reduction and; Science and People, details the research outputs and outcomes for the year 2022. With the high dedication of its research staff, its culture of inter-disciplinary and multi-disciplinary collaboration and its strength in applied research, the CSIR-PGRRI strives to be one of the best research institutes of the CSIR as well as achieve excellence as one of the best national genebanks in Africa. On behalf of the Management of the CSIR-PGRRI, I applaud all staff for their hard work and selflessness in the discharge of their duties in the face of limited resources. As a genebank, our relevance to national development in terms of food and nutrition security could not be more critical than at this time of self-sufficiency, post the COVID-19 pandemic, coupled with the Russia-Ukraine war and the current economic challenges faced by the country.

1.0 EXECUTIVE SUMMARY

The Plant Genetic Resources Research Institute (PGRRI) is one of the thirteen research institutes under the Council for Scientific and Industrial Research (CSIR). The CSIR-PGRRI has the mandate to collect, characterise, evaluate, document, conserve, distribute and promote the utilisation of plant genetic resources (PGR) from Ghana and abroad. Plant genetic resources are fundamental to plant improvement but are threatened by the activities of man and natural hazards. The activities at the CSIR-PGRRI are administered by the Director assisted by six Divisional Heads. The Divisions are Plant Genetic Conservation, Plant Genetic Diversity, Plant Protection, Finance, Administration and Commercialisation. The research programmes involve surveys, collecting, characterisation, evaluation, documentation, conservation, regeneration, distribution and utilisation of legumes, cereals, vegetables, root and tuber crops, medicinal plants, fruit trees, spices and forest plant species. The commercialisation activities involve the production and sale of planting material (seedlings), farm produce, rendering of consultancy services and training. The institute has linkages with international organisations involved in PGR conservation, CSIR institutes, Universities and Non-Governmental Organisations.

1.1 Mandate

The mandate of the CSIR-PGRRI is to collect and conserve the PGR of Ghana as well as coordinate PGR activities in the country.

1.2 Vision

The vision of the CSIR-PGRRI is to become a Centre of Excellence in PGR conservation and sustainable utilisation for food security and wealth creation.

1.3 Mission

The CSIR-PGRRI has the mission to collect and conserve the PGR of Ghana and those from abroad to prevent their extinction.

1.4 Goal

The goal of the CSIR-PGRRI is to ensure the effective conservation and use of PGR for food security and sustainable agricultural development

1.5 Objectives

To develop technologies for the efficient conservation and utilisation of orthodox and recalcitrant PGR,

- To strengthen human resource capacity and capability,
- To identify, establish and strengthen inter-institutional collaboration and linkages,
- To identify and access external donor funding and commercialise research results and,
- To gather, process and disseminate information relevant to PGR management in Ghana.

1.6 Composition of Management Board

The Management Board of CSIR – PGRRI comprises of the following members

Mr. William A. Krofah – Ghana Chamber of Commerce – Chairman

Prof. Daniel A. Ofori – Cognate Director (CSIR-FORIG), Kumasi – Member

Dr. Daniel Ashie Kotey – Ag. Director (CSIR-PGRRI), Bunso – Member

Osabarima Adusei Peasah IV – Rep. Akyem Abuakwa Traditional Council – Member

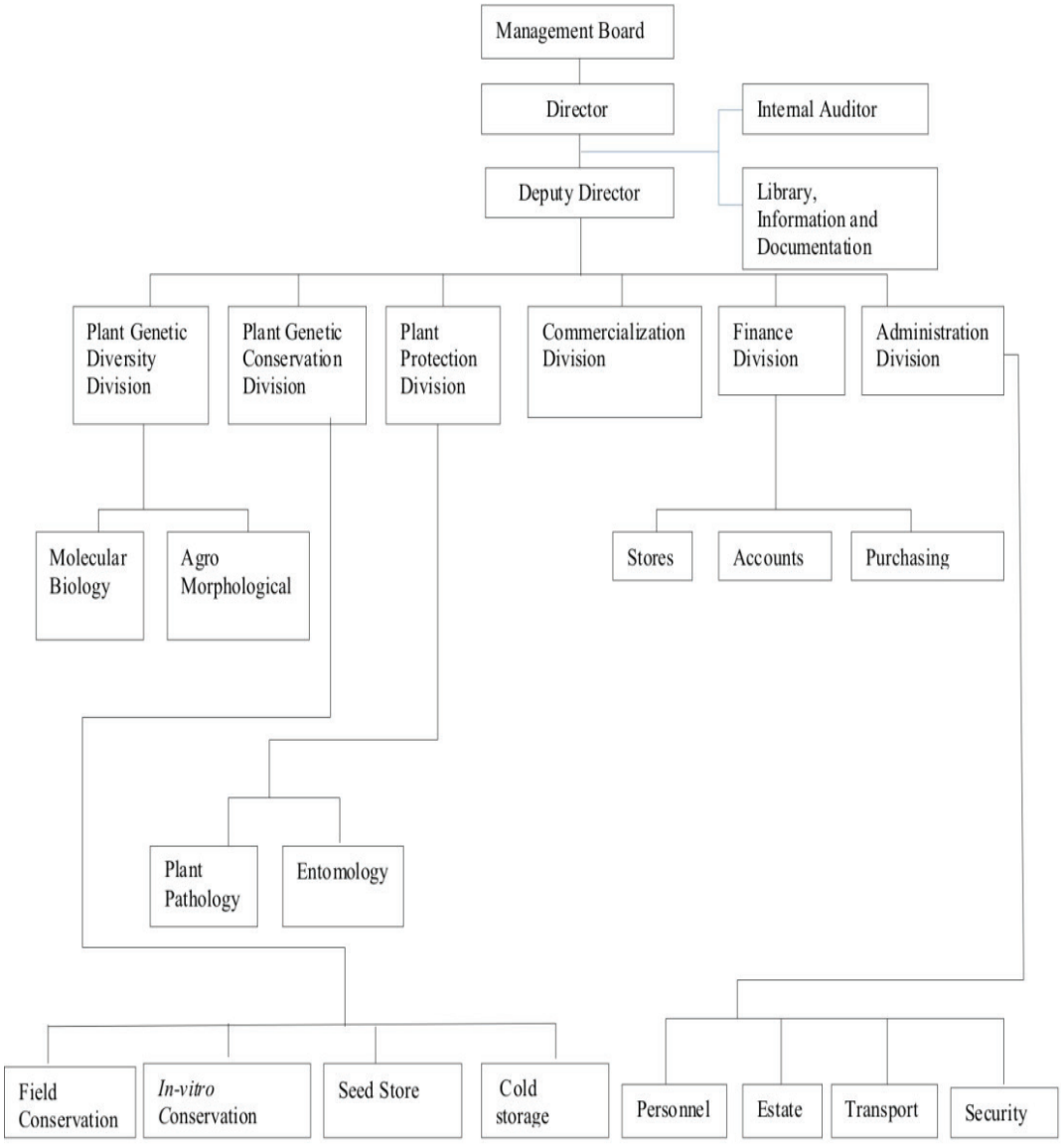
Mrs. Josephine Geraldo – Rep. Director-General, CSIR – Member

Mr. George Prah – Rep. Ministry of Food and Agriculture (MoFA) – Member

Mr. Kojo Ohene Kyei – MD ALLON Health and Pharmacy Ltd. – Member

Mr. Emmanuel Asiedu- Darko- Head of Administration (CSIR- Secretary PGRRI)

1.7 Organisational chart of the CSIR-PGRRI



THEMATIC AREA: FOOD SECURITY AND POVERTY REDUCTION (FSPR)

OUTPUT 1.1 EVALUATION OF THE EFFECT OF STORAGE CONDITIONS ON SEED LONGEVITY OF FIVE SOYBEAN ACCESSIONS

Research Team: Tetteh, R., Aboagye, L. M., Boateng, S. K. and Darko, R.

Donor: Government of Ghana

Background information and justification: Soybean (*Glycine max* L.) belongs to the Fabaceae family. It grows well in tropical, sub-tropical and temperate climates. Soybean is more protein-rich (40%) than any of the common vegetable or legume food sources in Africa (Dugje *et al.*, 2009). However, the major constraint to the production of soybean in the tropics is the rapid loss of seed viability and vigour during storage under ambient conditions. The objective of the study was to determine the effect of storage conditions on seed longevity of soybean accessions and to ascertain whether differences exist among the accessions.

Materials and methods: The experiment was conducted at the experimental site of the CSIR-Plant Genetic Resources Research Institute, Bunso, Eastern region. Seeds of five soybean accessions (GH9506, GH9507, GH9550, GH9552, and GH7379) were obtained from the Institute. The experiment was arranged in a Randomised Complete Block Design with three replicates. Agronomic practices undertaken were weeding, insect pest and disease control. Seeds of the five soybean accessions were harvested at the dry stage and processed for seed quality tests. Data collected before storage included the moisture content (%), 100 - seed weight (g), seed vigour and germination percentage. Germination and seed vigour tests were carried out using sterilised topsoil in seed trays. For each treatment, 50 seeds were used and replicated four times. A completely randomised design was used. The first count (seed vigour) and final count (germination percentage) were established on the 7th and 14th days, respectively. Storage of seeds at room temperature (28°C) and cold storage (-20°C in a deep freezer) began on 12th November 2021. Seeds of the five soybean accessions were sampled at two monthly intervals after storage for seed quality test for eight months. Statistical analyses were conducted using the SPSS Statistics 21 (IBM, Chicago, IL, USA). Data were subjected to two-way ANOVA, and when there was a significant interaction between accession and treatment, Tukey's HSD test was conducted to identify differences among treatments.

Results: The study showed significant ($p < 0.001$) differences in seed vigour and germination percentage at 4, 6 and 8 months after storage (MAS) with no difference at 2 MAS among soybean accessions when stored at room temperature and cold storage (Figures 1 and 2). Accession GH9507 stored at cold temperature had the highest vigour and germination percentage at 4, 6 and 8 MAS, but was not significantly different from accessions GH9506, GH9550, GH9552 and GH7379. The lowest seed vigour was observed in accession GH9550 at room temperature at 4, 6 and 8 MAS. Soybean seeds stored at room temperature showed a significant reduction in seed vigour and germination percentage at 8 MAS while seeds stored under cold temperature maintained their quality. It is therefore recommended that soybean seeds should be processed as soon as possible after harvest and stored under cold temperature for high seed quality over a longer period.

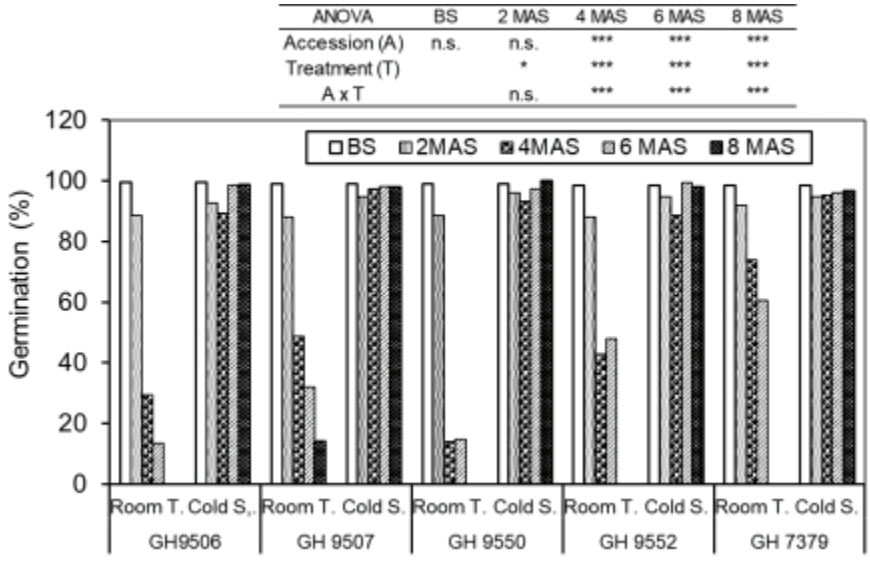


Figure 1: Effect of storage conditions on seed vigour of five soybean accessions at 2, 4, 6 and 8 months after storage. Two-way ANOVA: n.s.= not significant, *** $p < 0.001$. *Seed vigour was expressed as the number of seeds germinated at first count.

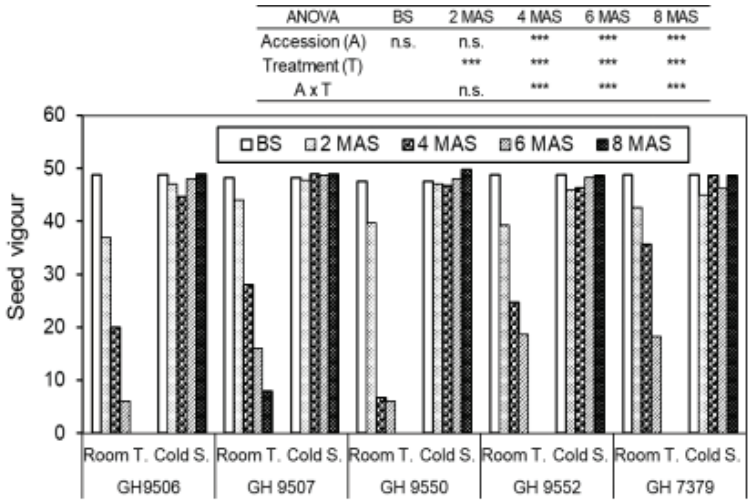


Figure 2: Effect of storage conditions on germination percentage of five soybean accessions at 2, 4, 6 and 8 months after storage. Two-way ANOVA: n.s.=not significant, *p < 0.05, *** p < 0.001.

OUTPUT 1.2 EVALUATION OF THE EFFECT OF DORMANCY-BREAKING TREATMENTS ON SIX *CORCHORUS OLITORIUS* ACCESSIONS

Research team: Tetteh, R., Yeboah, A., Boateng, S. K and Kotey, D.A.

Donor: Government of Ghana

Background information and justification: *Corchorus olitorius,* also known as jute mallow or bush okra is an annual erect herb that belongs to the Malvaceae family (Youssef *et al.*, 2019). Its' leaves and tender stems are rich in vitamin A and C, beta carotene, folic acid, iron, calcium, and several phenolic antioxidative compounds. However, it has been reported that poor and delayed seed germination, due to dormancy is one of the major challenge in its propagation. The objective of the study was to assess the effect of different dormancy breaking methods on seed germination, growth and yield of six accessions of *Corchorus olitorius.*

Materials and methods: The research was conducted at the experimental site of the CSIR-Plant Genetic Resources Research Institute, Bunso, Eastern Region. Seeds of six *Corchorus olitorius* accessions (GH10070, GH10080, GH10126, GH10308, GH10312, GH10441) obtained from the 2021 growing season from the institute were used. Seeds of six *Corchorus olitorius* accessions were subjected to four dormancy-breaking treatments which include no soaking, soaking in pure water (25°C) for 24 hours,

soaking in hot water (90°C) for 30 seconds and 60 seconds. The experiment was a 6 x 4 factorial arranged in a randomised complete block design with three replications. Fifty seeds were used for each treatment per replicate. Seed vigour and germination percentage were determined on the 11th and 14th day after sowing respectively. Transplanting of seedlings soaked in hot water (90°C) for 30 and 60 seconds was done on 26 July, 2022 to assess the effect of the treatment on the growth and yield of the six accessions. A spacing of 1 m x 0.6 m was used. Statistical analyses were conducted using the SPSS Statistics 21 (IBM, Chicago, IL, USA). Data were subjected to two-way ANOVA, and when there was a significant interaction between accession and treatment, Tukey's HSD test was conducted to identify differences among treatments.

Results: Significant differences ($p<0.001$) were observed in seed vigour and germination percentage among the six *Corchorus olitorius* accessions subjected to four dormancy breaking treatments. The highest seed vigour was observed in accession GH10126 soaked in hot water for 30 seconds. The no soaking treatment (control) of accessions GH10070, GH10126 and GH10441 had the least vigour. The highest germination percentage was observed in accession GH10308 soaked in hot water for 60 seconds. The no soaking treatment (control) of accessions GH10070, GH10126, GH10441 had the least germination. There were no significant differences in the number of branches per plant, plant height, pod length or number of seeds per pod among the six *Corchorus olitorius* accessions treated with hot water for 30 or 60 seconds. However, there was a significant difference between accessions in plant height, pod length and number of seeds per pod (Table 2). There was no significant interaction between accession and treatments.

Table 1: Effect of different dormancy breaking treatment on seed vigour and germination percentage of six *Corchorus olitorius* accessions

Accession	Treatment	Seed vigour	Germination (%)
GH10070	No soaking	0.0 (0.0)g	0.00 (0.00)f
	Soaking in pure water (25°C) for 24Hrs	1.3 (0.6)g	4.67 (1.15)ef
	Soakng in Hot water (90°C) for 30s	18.3 (0.6)cd	46.67 (3.06)c
	Soaking in Hot water (90°C) for 60s	17.7 (2.5)cd	52.67 (3.06)abc

GH10312	No soaking	4.7 (0.6)g	9.33 (1.15)ef
	Soaking in pure water (25°C) for 24Hrs	4.0 (1.7)g	12.67 (3.06)e
	Soakng in Hot water (90°C) for 30s	18.0 (1.0)cd	46.67 (6.43)c
	Soaking in Hot water (90°C) for 60s	21.7 (1.5)bc	47.33 (2.31)c
GH10080	No soaking	10.3 (0.6)f	21.33 (2.31)d
	Soaking in pure water (25°C) for 24Hrs	11.3 (1.15)ef	23.33 (3.06)d
	Soakng in Hot water (90°C) for 30s	15.0 (2.6)de	30.00 (5.29)d
	Soaking in Hot water (90°C) for 60s	13.3 (3.1)ef	26.67 (6.11)d
GH10441	No soaking	0.0 (0.0)g	0.00 (0.00)f
	Soaking in pure water (25°C) for 24Hrs	2.3 (0.6)g	6.67 (1.15)ef
	Soakng in Hot water (90°C) for 30s	23.0 (2.6)ab	49.33 (6.11)bc
	Soaking in Hot water (90°C) for 60s	23.7 (0.6)ab	54.00 (3.46)abc
GH10126	No soaking	0.0 (0.0)g	0.00 (0.00)f
	Soaking in pure water (25°C) for 24Hrs	1.0 (0.0)g	2.00 (0.00)f
	Soakng in Hot water (90°C) for 30s	26.3 (1.5)a	58.00 (2.00)ab
	Soaking in Hot water (90°C) for 60s	25.0 (2.0)ab	53.33 (4.16)abc
GH10308	No soaking	1.0 (0.0)g	2.67 (1.15)f
	Soaking in pure water (25°C) for 24Hrs	1.0 (0.0)g	4.00 (0.00)ef
	Soakng in Hot water (90°C) for 30s	25.3 (4.2)ab	58.00 (7.21)ab
	Soaking in Hot water (90°C) for 60s	24.7 (0.6)ab	60.00 (2.00)a
	Accession	n.s.	**
	Treatment	***	***
	A x T	***	***

Each value is the mean of three replicates and the standard deviation is shown in parentheses. Two-way ANOVA: n.s.= not significant, **p<0.01, *** p<0.001. When significant interaction between Accession (A) and Treatment (T) was detected, Tukey's HSD test was performed to identify significant differences among the 2 treatments. Values with different letters are significantly different at p<0.05. *Seed vigour was expressed as the number of seeds germinated at first count.

Table 2: Effect of hot water seed treatment on growth and yield parameters of six *Corchorus olitorius* accessions

Accession	Treatment	No. branches/ plant	Plant height (cm)	Pod length (cm)	No. of seeds per pod
GH10070	30sec	17.5 (1.0)	85.06 (8.77)	5.30 (0.78)	148.6 (0.8)
	60sec	18.9 (2.0)	92.66 (8.00)	5.20 (0.39)	154.5 (7.7)
GH10126	30sec	17.2 (1.4)	97.68 (8.15)	5.59 (1.05)	161.1 (14.1)
	60sec	16.1 (0.8)	90.91 (2.21)	5.35 (0.14)	151.5 (2.5)
GH10312	30sec	16.3 (2.4)	89.12 (2.13)	4.82 (0.08)	136.3 (9.4)
	60sec	17.6 (3.0)	87.69 (6.90)	4.76 (0.40)	136.1 (6.6)
GH10080	30sec	17.7 (0.9)	59.27 (7.61)	5.19 (0.26)	162.5 (11.2)
	60sec	17.6 (0.4)	56.64 (5.70)	5.11 (0.30)	155.9 (10.9)
GH10441	30sec	16.5 (0.9)	86.84 (3.25)	5.79 (0.59)	146.9 (6.1)
	60sec	17.4 (0.7)	93.07 (5.78)	5.83 (0.11)	148.5 (16.0)
GH10308	30sec	17.0 (0.7)	86.76 (3.79)	4.97 (0.30)	141.0 (4.3)
	60sec	18.0 (1.4)	89.13 (4.48)	4.45 (0.31)	133.1 (4.9)
ANOVA	Accession (A)	n.s.	***	**	**
	Treatment (T)	n.s.	n.s.	n.s.	n.s.
	A x T	n.s.	n.s.	n.s.	n.s.

Each value is the mean of three replicates and the standard deviation is shown in parentheses. Two-way ANOVA: n.s.= not significant, *** p<0.001.

OUTPUT 1.3 EFFECT OF EXTRACTION TIME ON SEED QUALITY AND GROWTH OF WATERLEAF *(TALINUM TRIANGULARE)* (JACQ) WILD

Research team: Yeboah, A., Tetteh, R., Amoah, R. A., Osei, C. Y., Amissah, A. A., Sackey, V. and Kotey, D. A.

Donor: Government of Ghana

Background information and justification: Waterleaf (*Talinum triangulare*) is classified among neglected and underutilised crop species (NUS) in Ghana because it is not incorporated into regular farming systems with dedicated research and extension activities despite its enormous benefits. Due to this seeming neglect as well as human

activities such as mining, infrastructure development and wildfires (Aboagye *et al*., 2007, Kasolo *et al*., 2018), the crop could go extinct. Presently, very scanty resources are available for seed extraction and handling of *T. triangulare* before germination. Seeds of waterleaf accessions received at the Seed genebank Section of the CSIR-PGRRI in the past did not germinate when they were tested, probably because of how they were collected or due to inappropriate seed handling, prompting the need for the current study. The study sought to identify a suitable means of extracting seeds of *T. triangulare* to achieve maximum germination performance for conservation, growth and yield of the crop.

Materials and methods: Laboratory and field trials were carried out at the Seed genebank Section and research fields of the CSIR-PGRRI at Bunso. In the laboratory trial, seeds were extracted from mature capsules of *T. triangulare* collected from three different locations in the Eastern region and extracted at weekly intervals for up to four weeks. Fifty seeds were tested in sterilised topsoil in four replicates per extraction time. Data were taken on 1000-seed weight (g), germination percentage and seed vigour. The experiment was factorial and arranged in a completely randomised design with three accessions and five extraction times. A second experiment involving the transplanting of seedlings raised from the four weeks extraction time was done to evaluate the performance of the treated seeds under field conditions. This experiment was 3 x 3 factorial arranged in a randomised complete block design. Data collected included percentage field establishment of seedlings, days to 50% flowering, stem girth, plant height, seeds per capsule (wild and cultivated) and the number of branches. Data collected were subjected to analysis of variance (ANOVA) using SPSS version 21. Treatment means were separated when there was a significant interaction between accession and seed extraction method using Tukey's hsd test.

Results: Significant differences were observed for the treatments. The four weeks extraction time recorded the highest germination for accession AY/22/003, followed by accessions AY/22/002 and AY/22/001 in that order (Table 3). Results from the study indicated that the overall germination of *T. triangulare* seeds was low. Results presented in Table 2 however, shows that excessive production of capsules may compensate for low germination to enhance the perpetuation of the crop (Table 4).

Table 3: Seed vigour and final germination percentage of samples extracted at different times.

Accession	Extraction Time	Seed Vigour	FGP	1000 Seed Weight
AY/22/001	DOC	0.25(0.50)	0.50(1.00)	0.24(0.01)
	1 WAC	0.00(0.00)	0.00(0.00)	0.07(0.02)
	2 WAC	0.25(0.50)	1.00(1.15)	0.04(0.01)
	3 WAC	1.00(1.15)	2.00(2.31)	0.07(0.01)
	4 WAC	3.75(4.92)	8.00)9.38)	0.14(0.01)
AY/22/002	DOC	1.25(1.89)	2.50(3.78)	0.25(0.01)
	1 WAC	0.75(0.95)	1.50(1.91)	0.07(0.00)
	2 WAC	2.00(2.70)	4.00(5.41)	0.16(0.01)
	3 WAC	1.00(1.15)	2.00(2.31)	0.13(0.07)
	4 WAC	4.25(1.50)	8.50(3.00)	0.16(0.02)
AY/22/003	DOC	1.25(1.89)	3.00(3.83)	0.23(0.01)
	1 WAC	0.5(0.58)	1.00(1.15)	0.07(0.01)
	2 WAC	0.5(0.58)	1.00(1.15)	0.16(0.17)
	3 WAC	2.00(1.41)	4.00(2.83)	0.12(0.01)
	4 WAC	4.50(3.42)	11.00(6.83)	0.15(0.02)
ANOVA	Accession (A)	n.s.	n.s.	**
	Treatment ((T)	**	**	
	A x T	n.s.	**	**

Key: DOC- day of collection, WAC – week(s) after collection, FGP- final germination percentage. Each value is the mean of four replicates and the standard deviation is shown in parentheses. n.s. = not significant **$p < 0.05$

Table 4: Field performance of seedlings from seeds obtained from the four weeks extraction time.

Accession	Plant height (cm)	Seeds per capsule (wild)	Seeds per capsule (cultivated.)	No. of branches
AY/22/001	26.90(6.34)	59.00(2.31)	54.00(2.65)	10.00(1.53)
AY/22/002	29.93(7.39)	58.00(2.08)	67.00(8.14)	11.00(1.54)
AY/22/003	29.27(4.91)	62.00(1.00)	65.00(3.06)	12.00(1.73)
ANOVA	n.s.	n.s.	n.s.	n.s.

Each value is the mean of three replicates and the standard deviation is shown in parentheses. n.s. = not significant.

OUTPUT 1.4 *IN-VITRO* CONSERVATION OF SOME IMPROVED SWEET POTATO GENOTYPES AND EVALUATION OF THEIR PHENOLIC CONTENT AND ANTIOXIDANT ACTIVITY

Research team: Bruce, B. B., Quain, M. D., Amoah, R. A., Amoah-Andoh, F., Gyamfua, G., Bissah, M. N. and Kotey, D. A.

Donor: Government of Ghana

Background information and justification: Abiotic and biotic restrictions and a lack of effective methods for propagation, conservation and dissemination of high-quality planting material are all contributing factors to the low productivity of sweet potatoes in sub-Saharan Africa. Considering this, it is necessary to develop sweet potato propagation techniques that offer pathogen protection and improve access to planting material for preservation and direct use by farmers. One of the most promising methods for conservation is *in-vitro* slow growth. The study sought to assess the growth performance of ten sweet potato genotypes (DOS 021, Purple, 'Ogyefo', 'Okumkom', Savanna, Otoo, CRI Hi Starch, Fara, TT 03 015 and Patron) and evaluate their phenolic content and anti-oxidant activity under *in-vitro* conservation at the CSIR-Plant Genetic Resources Research Institute in Bunso, Ghana.

Materials and methods: The excised explants were cultured on complete plant growth hormone-free MS basal salt with vitamins supplemented with 30 g/l sucrose, 0.8 % purified (phytogel) agar as treatment (Figure 4). A completely randomised design (CRD) was used to set up the experiment, with three replicates.

Results: The purple genotype gave the highest number of shoots (2.01) after *in-vitro* conservation. The Fara genotype gave higher number of shoots (1.71) followed by CRI Hi starch (1.65), 'Ogyefo' (1.44), Savanna (1.42), Okumkum (1.39), TT 03 016 (1.38), DOS 022 (1.06) and the Patron (1.04) genotype. The Otoo genotype had as low as 1.00 shoot per culture as shown in Fig. 3. After twenty-four weeks of conservation, the Otoo genotype had the highest number of leaves (10.17). The purple genotype gave a higher number of leaves (8.92) followed by the Patron genotype (8.63), 'Ogyefo' (8.38), Savanna (7.93), CRI Hi Starch (7.47), Fara (7.29), 'Okumkom' (7.28) and TT 03 016 (6.19) genotypes. Dos 022 had as low as 5.75 leaves per shoot as shown in Fig. 3.

The Otoo genotype recorded the highest plant height (5.15 cm) on plant hormone-free MS medium after *in- vitro* conservation. The lower values of 4.96 cm, 4.76 cm, 3.97 cm, 3.80 cm, 3.77 cm, 3.74 cm, 3.52 cm, and 2.98 cm were obtained on Savanna, 'Ogyefo', CRI Hi Starch, 'Okumkom', Purple, Fara, Patron, and Dos 022 genotypes

respectively. The TT 03 016 genotype with 2.88 cm had the lowest plant height after twenty-four weeks of conservation compared with Otoo, Savanna, 'Ogyefo', CRI Hi Starch, 'Okumkom', Purple, Faara, Patron and Dos 022 as shown in Fig. 3. There was no significant difference between sweet potato genotype and weeks after culture as shown in Table 5. Although there were similar responses among all genotypes studied, slight variations were observed among these genotypes. These different responses during *in-vitro* conservation may be related to the genetic traits of each genotype. The highest total phenolic content was found to be 6.0394 mg/100 g (CRI Hi Starch), others were 4.0175 mg/100 g (Fara) 2.9057 mg/100 g (Savanna), 2.8057 mg/100 g ('Ogyefo'), 2.7916 mg/100 g (TT 03 015), 2.4055 mg/100 g (Patron) and 2.2223 mg/100g (Dos 021). The lowest phenolic content occurred on 1.7448 mg/100 g (Purple), 1.5953 mg/100 g ('Okumkom'), and 1.0538 mg/100 g (Otoo) as shown in Fig 5. *In-vitro* antioxidant activity was found to be maximum at 54% inhibition (Dos 021 and Patron) followed by 53% inhibition ('Okumkom'), 51% inhibition (TT 03 015 and CRI Hi Starch). The optimum antioxidant activity occurred at 49% inhibition (Fara), 48% inhibition (Otoo) and 48% inhibition (Savanna). 'Ogyefo' (46% inhibition) and Purple (45% inhibition) were found to have no minimum in antioxidant activity in *in-vitro* culture as shown in Fig. 5. The study found a weak correlation between the sweet potato genotypes and total phenolics (Fig. 5). There was also a weak correlation between genotype and antioxidant activity (Fig. 5).

In this study, it is evident that the extracts of the sweet potato plantlets possess effective and potent *in-vitro* antioxidant activity in diphenyl-2-picrylhydrazil (DPPH) radical scavenging assay. Results also demonstrated that the extent of antioxidant activity of the sweet potato genotypes were in accordance with the amount of phenolics present in this species.

Table 5: Analysis of variance (Variable number of shoots/cultures, leaves/shoot, Height)

Source	DF	Mean squares (Shoots per culture)	Mean squares (Leaves per shoot)	Mean squares (Height of shoot)
Weeks after Culture	5	2.31***	173.61***	43.32***
Rep	2	1.37^{NS}	11.60^{NS}	2.9^{NS}
Genotypes	9	1.89***	30.82***	11.04***
Weeks after culture*Genotypes	45	0.34^{NS}	4.04^{NS}	1.27***

***≤0.0001 **≤0.001 *≤0.05 NS=Non-Significant

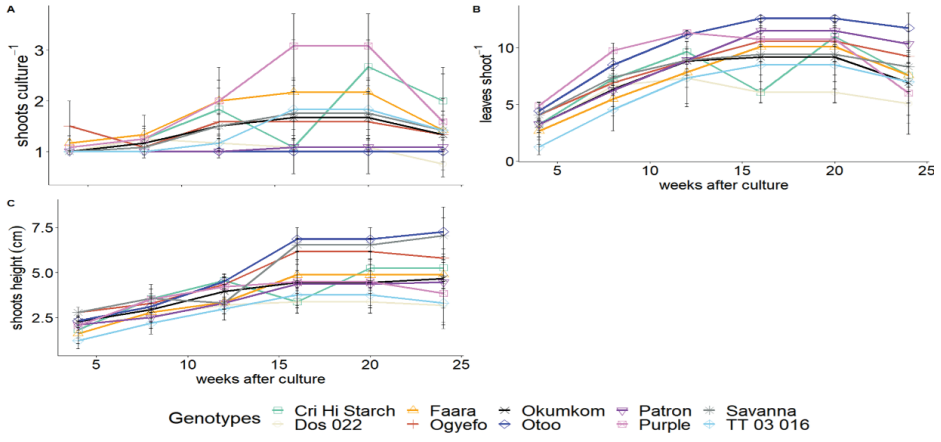


Figure 3: Performance of the ten sweet potato genotypes at 24 weeks under *in-vitro* conservation.

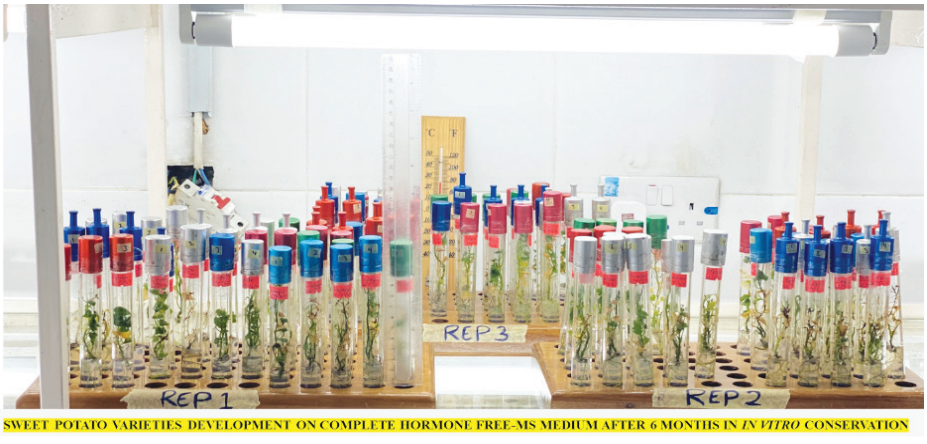


Figure 4: Growth performance of sweet potato genotypes on Plant growth hormone-free MS media

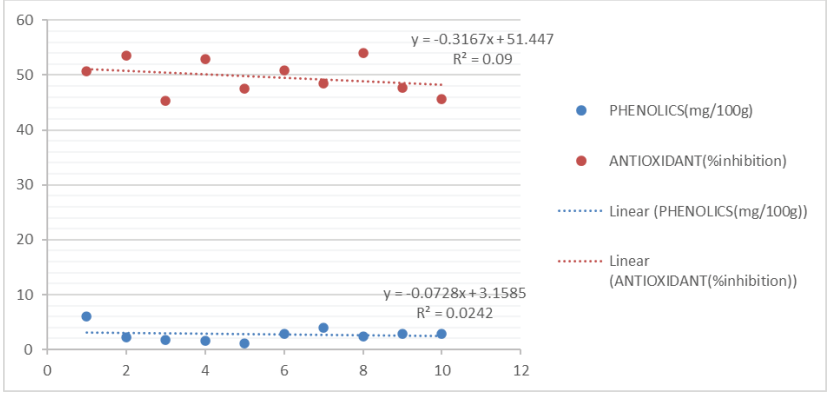


Figure 5: Graph showing the absorbance of total phenolics and activities of antioxidant by sweet potato genotypes after 24 weeks *in-vitro*.

OUTPUT 1.5 *IN-VITRO* MICRO PROPAGATION OF NUTMEG *(MYRISTICA FRAGRANS)*

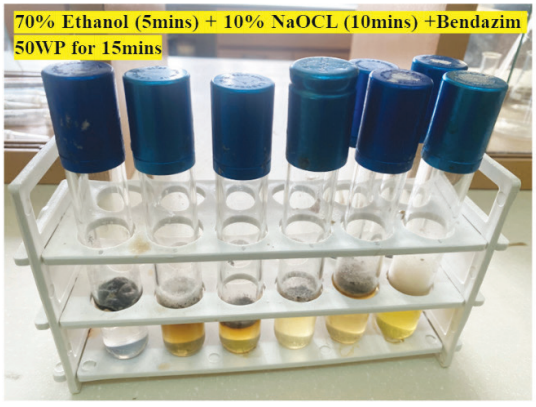
Research team: Bruce, B. B., Bissah, M. N., Amoah, R. A., Gyamfua, G., and Kotey, D. A.

Donor: Government of Ghana

Background information and justification: Nutmeg (*Myristica fragrans* H.) is a dioecious plant with male and female flowers found on different trees. Although hermaphrodite flowers and bisexual trees occur, they are very rare. The plant produces two separate spices, namely, the nut and the mace. These two products are of high commercial value both in the local and international markets. Efforts at expanding the production of nutmeg to meet local and export demand and to reap economic benefits, have been hampered by difficulties in propagation. In Ghana, the CSIR-PGRRI is the main source of seedlings for the establishment of nutmeg plantations. Nutmeg is generally propagated using either the seed or by vegetative means. Efficient propagation is however limited by the recalcitrant nature of the seeds, a long juvenile phase and scarcity of propagules. Given these challenges, the use of tissue culture techniques has been proposed as a viable alternative for propagating elite nutmeg clones. The development and application of *in-vitro* mass propagation protocols will ensure the production of quality planting materials of known sex which will promote nutmeg cultivation and income generation. The objective of the study was to develop an *in-vitro* micro-propagation protocol and study the effects of plant growth regulators on the establishment, proliferation and rooting of nutmeg.

Materials and methods: The study was carried out at the tissue culture laboratory section of CSIR-Plant Genetic Resources Research Institute in Bunso, Ghana. Nodal cuttings were collected from nutmeg plants of known sex growing in the field genebank. The sterilised explants were cultured on a woody plant medium and MS basal salt with vitamins supplemented with 30 g/l sucrose, 0.8% purified agar with different concentrations of BAP (0, 0.5, 1.0, 2.0 mgL^{-1}), NAA (0, 0.2, 0.5, 1.0 mgL^{-1}) and 80 mgL^{-1} $AdSO_4$ for nodal cultures (Fig. 6).

Results: Contamination occurred in all the cultures even though new shoots were coming out (Fig. 7).



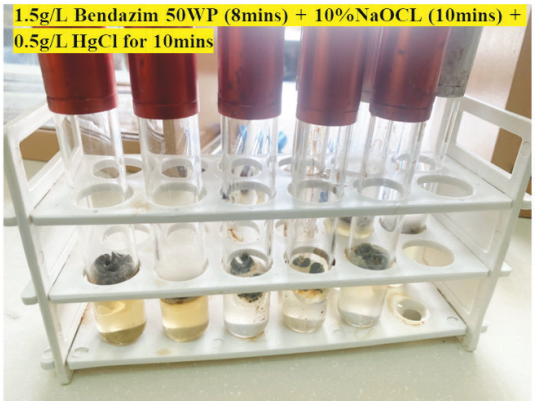
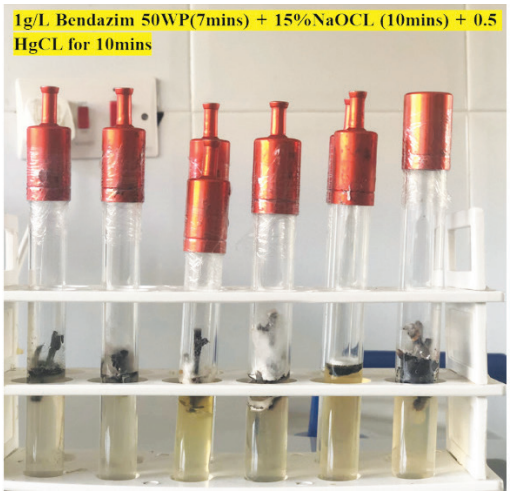


Figure 6: Growth of nutmeg explant on MS basal salt Growth of nutmeg explant on MS medium



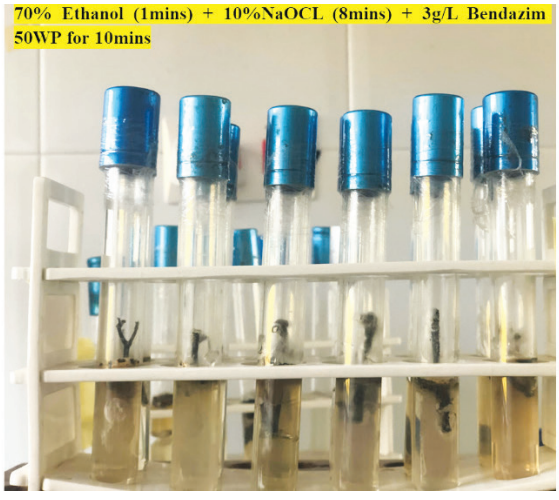


Figure 7: Growth of nutmeg explant on MS basal salt Growth of nutmeg explant on MS medium

OUTPUT 1.6 ASSESSING THE ENVIRONMENTAL AND SOCIO-ECONOMIC IMPORTANCE OF FOREST GENETIC RESOURCES: A CASE STUDY OF THE BUNSO ECO PARK IN THE EASTERN REGION OF GHANA

Research team: Asitoakor, B. K., Boateng, S. K., Kotey, D. A., Bandanaa, J., Nketiah, V. and Adu-Yeboah, E.

Donor: Government of Ghana

Background information and justification: Ecotourism sites are naturally protected areas that aid in the conservation of the environment, while sustaining the well-being of local people (TIES, 2015). They minimise negative environmental impacts, enhance interaction between tourists and local people and improve the social well-being of host communities (Sirakaya *et al*., 1999). They are important economic development strategies with the potential for prime economic growth and the minimisation of widespread poverty in developing countries such as Ghana (Ariya and Momanyi, 2015 and Obour *et al*., 2017).

The Bunso Eco park, which is an example of an ecotourism site is found in the Eastern region of Ghana. Like other ecotourism sites, the site has received little research attention particularly in the area of management practices on the ecological composition and diversity of the flora and fauna of the park. With worsening climate change scenarios, certain assessments (e.g. carbon sequestration potential and economic valuation) at the park are required to inform adaptation and mitigation, as it serves as a carbon reservoir and a biodiversity conservation site.

Materials and methods: In this research, we identified and generated a preliminary plant inventory list and the plant species diversity composition of the Bunso Eco Park (N 6º 16' 08.52, W 0º 27'47.39). Following a reconnaissance survey of the site to establish the land-use activities, we re-measured the size of the park and further enumerated the plant diversity by the spot identification approach. Species identification was mainly by local knowledge and use of photo guide information as a reference (Hawthorne, 1990).

Results: Currently, the Bunso Eco Park covers an area of about 16.3 ha with an undulating topography and with an elevation ranging between 220 – 270 m. Its fringes are characterised by cocoa farm expansion activities including the cutting of boundary flora species (Figures 8a, b, c and d) and the planting of cocoa trees. The expansion in the construction of recreational structures such as shelter, road networks, housing facilities and the introduction of sound equipment (Figure 8e) in portions of the conserved areas were also observed. Additionally, the creation of

a swimming pool facility (Figure 8f and g) about 30 – 40 m from the boundary of the Bunso Eco park towards Ettukrom was observed. Flora observed in the area included *Acacia sp. Ceiba pentandra, Elaeis sp., Terminalia sp., Lecythis Pisonis* and *Cedrela odorata*. The fauna observed included birds, butterflies among others.

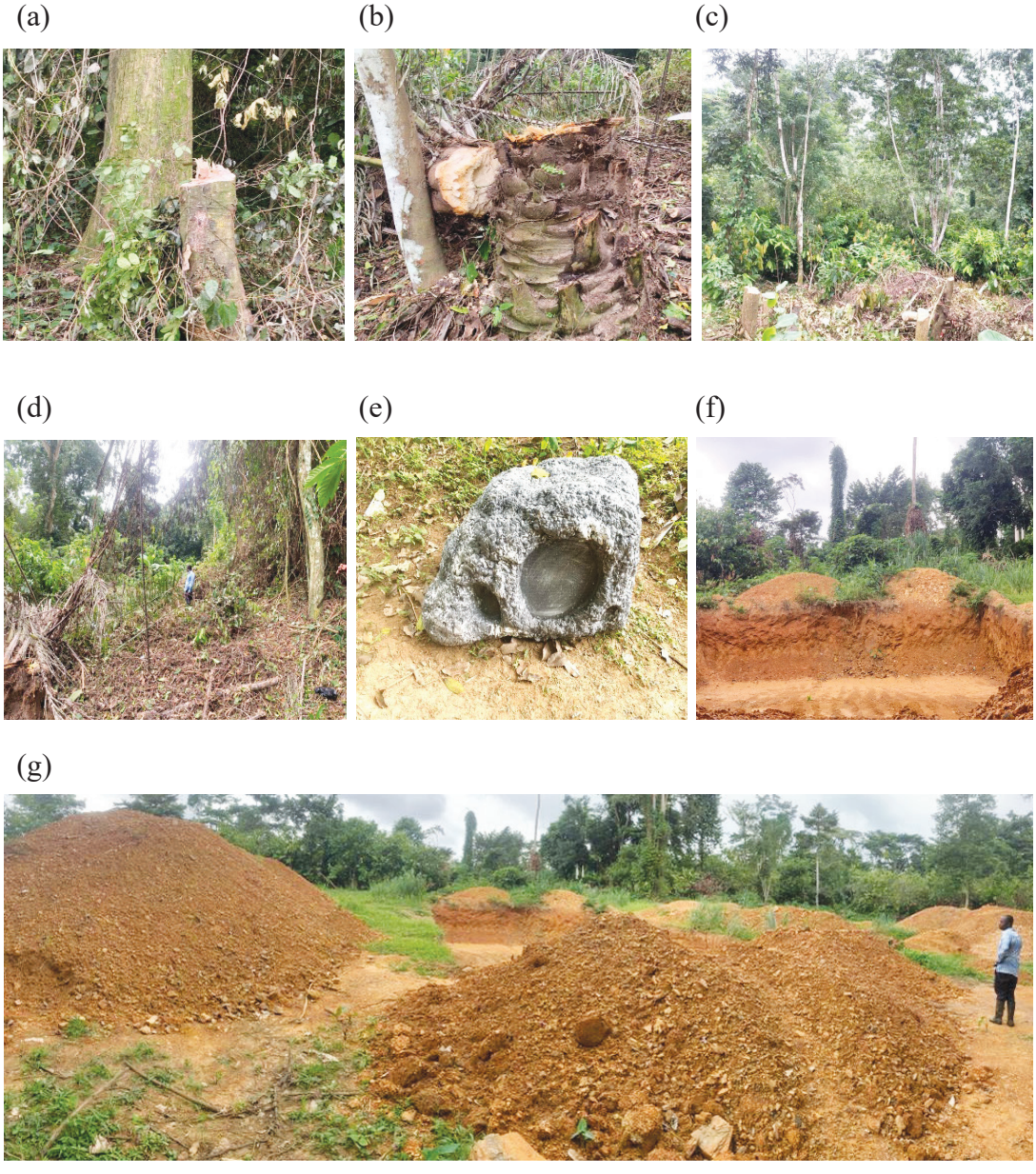


Figure 8: Observed boundary activities including felling of tree species (a, b, c and d), installed sound equipment (e), and swimming pool facility (f and g).

In all, the Bunso Eco Park may be categorised as a flora and fauna diversity rich spot. However, current anthropogenic activities and the level of management of the conservation area poses high threats to the potential of the resources to support the biodiversity conservation objectives of the park. There is therefore the need for immediate actions to be taken to minimise the adverse impacts of the identified recreational related activities.

OUTPUT 1.7 GENOME WIDE ANALYSIS FOR SALT TOLERANCE AT SEEDLING STAGE OF RICE

Research Team: Bissah, M. N., Bandanaa, J., Ochar, K., Amissah, A.

Donor: Government of Ghana

Background information and justification: Crop plants differ in their ability to survive and yield satisfactorily when grown in saline soils and this tolerance often varies with the environmental conditions and growth stage of the plant (Quand *et al.*, 2017). Good seedling establishment contributes greatly to the productivity of crops and hence identifying relevant genotypes for successful seedling establishment under saline conditions has become an important breeding goal (Ganie *et al*., 2020). Characterisation and evaluation activities support the identification of potentially useful germplasm (Nguyen and Norton, 2020 ; Kumar *et al*., 2022; Tripathi *et al*., 2022;). Evaluation and characterisation for identification of salt-tolerant genotypes in Ghana's rice collection have not been reported. The increasing incidence of climate–linked salt stress in rice paddies in coastal Ghana requires that salt-tolerant rice genotypes are identified to facilitate crop improvement and increase productivity in salt-affected paddy fields.

Materials and methods: In this study, seedling vigour characteristics including shoot height (SH), leaf number (LN), root number (RN), and root length (RL) of 54 rice accessions collected from the Ghana National Genebank were studied.

Results: Generally, results indicted a reduction in the growth of rice accessions under salt stress conditions compared to the control (Table 6; Figure 9). The salt susceptibility indices of four traits: leaf number, plant height, root length and root number were, 40.62, 57.47, 52.81 and 66.82 respectively (Table 6). Analysis of variance showed highly significant variation among the accessions for all the four traits (Table 7).

Table 6: Variability in performance of rice genotypes under non-stress (control) and stress(6dSm^{-1}) conditions

Trait	Control			Stress			STI (%ROC)
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	
No of leaves	5.6	7.3	6.4	2.3	6.1	3.8	40.62
Plant height (cm)	34.7	73.0	58.1	23.1	38.3	36.2	57.47
Root length (cm)	12.3	34.5	17.8	2.3	17.0	8.4	52.81
Number of roots	17.3	29.3	22.3	3.8	17.0	7.4	66.82
SES Score				1.0	9.0	8.177	

STI - Salt tolerance index, ROC - Reduction over control, SES - Salinity score

Table 7: Mean square estimates for seedling growth parameters

S.O.V	df.	Number of leaves	Shoot height	Root Number	Root length
Gen.	53	2.854***	217.12***	55.12***	92.16***
Env.	1	754.147***	142885.06***	26735.97***	10386.01***
Gen. Env.	53	1.954***	141.12***	24.35**	50.24***
Residual	429	0.718	52.99	10.37	14.28
Total	536				

Note: S.O.V. – Sources of Variation, Gen – Genotype, Env. - Environment, df. – degree of freedom, ** - Significant at 0.05 level. *** - Significant at 0.01 level

Figure 9: Comparative growth of rice plants under control and salt stress (6dSm-^{1}) conditions

Among the 54 accessions tested for salinity tolerance, six, GH2153, GH9057, GH1574, GH1837, GH1571, and GH2091 showed moderate tolerance to salt stress at 6dSm^{-1} and were identified as the most promising,. Twenty-four accessions were susceptible while another 24 were highly susceptible to salt stress (Table 8). Accessions GH2153, GH9057 and GH1571 with high scores for salt tolerance also showed higher phenotypic values for leaf and root numbers in combination with either plant height or root length (Table 9). In contrast, accessions GH1837 and GH2091, which were among the top performing genotypes based on salinity scores, did not show high phenotypic value for the measured phenotypic traits (Table 9). This indicates that the genetic control of salt tolerance at the seedling stage is multi-genic and may require the stacking of these genes to ensure improved performance. The study provides a material basis for breeding superior salt-tolerant rice varieties.

Table 8: Salinity tolerance scores for 54 rice accessions tested at the CSIR-PGRRI, Bunso

Accessions	Source of germplasm	Salinity Score	Tolerance rate	Accessions	Source of germplasm	Salinity Score	Tolerance rate
GH2153	PGRRI	4.33	Mod. Tolerance	GH4005	PGRRI	8.67	Susceptible
GH9057	SARI	4.33	Mod. Tolerance	GH9047	PGRRI	8.83	Susceptible
GH1574	IRRI	6.33	Mod. Tolerance	GH1511	IRRI	9	Highly Susceptible
GH1837	PGRRI	6.33	Mod. Tolerance	GH1514	IRRI	9	Highly Susceptible

GH1571	IRRI	6.67	Mod. Tolerance	GH1535	IRRI	9	Highly Susceptible
GH2091	PGRRI	6.67	Mod. Tolerance	GH1541	IRRI	9	Highly Susceptible
GH1580	IRRI	7	Susceptible	GH1542	IRRI	9	Highly Susceptible
GH1801	PGRRI	7	Susceptible	GH1548	IRRI	9	Highly Susceptible
GH2085	PGRRI	7	Susceptible	GH1560A	IRRI	9	Highly Susceptible
GH2090	PGRRI	7	Susceptible	GH1578	IRRI	9	Highly Susceptible
AGRA	CRI	7.33	Susceptible	GH1581	IRRI	9	Highly Susceptible
GH1560B	IRRI	7.33	Susceptible	GH1583	IRRI	9	Highly Susceptible
GH1515	IRRI	7.67	Susceptible	GH1584	IRRI	9	Highly Susceptible
GH2233	PGRRI	7.67	Susceptible	GH1587	IRRI	9	Highly Susceptible
GH1579	IRRI	8	Susceptible	GH1589	IRRI	9	Highly Susceptible
GH2151	PGRRI	8	Susceptible	GH1560B	IRRI	9	Highly Susceptible
GH9051	SARI	8	Susceptible	GH1591	IRRI	9	Highly Susceptible
GH9055	SARI	8	Susceptible	GH1594	IRRI	9	Highly Susceptible
GH1585	IRRI	8.33	Susceptible	GH1598	IRRI	9	Highly Susceptible
GH2191	PGRRI	8.33	Susceptible	GH1599	IRRI	9	Highly Susceptible

GH1531	IRRI	8.67	Susceptible	GH1814	PGRRI	9	Highly Susceptible
GH1538	IRRI	8.67	Susceptible	GH2075	PGRRI	9	Highly Susceptible
GH1573	IRRI	8.67	Susceptible	GH2123	PGRRI	9	Highly Susceptible
GH1575	IRRI	8.67	Susceptible	GH8211	PGRRI	9	Highly Susceptible
GH1586	IRRI	8.67	Susceptible	GH9011	PGRRI	9	Highly Susceptible
GH1590A	PGRRI	8.67	Susceptible				
GH2143	PGRRI	8.67	Susceptible	Mean		8.2	
GH2148	PGRRI	8.67	Susceptible				

Table 9: Morphological characteristics of the top six salt-tolerant rice accessions

Accessions	**Traits**			
GH2153	Leaf number	Root number	x	Plant height
GH9057	Leaf number	Root number	x	x
GH1574	x	Root number	Root length	x
GH1837	x	x	x	x
GH1571	Leaf number	Root number	x	Plant height
GH2091	x	x	x	x

OUTPUT 1.8 GENOTYPIC VARIABILITY AND GENOTYPE BY ENVIRONMENT INTERACTION OF YIELD AND YIELD COMPONENTS OF COMMON BEAN.

Research Team: Amoah, R. A., Osei, C. Y., Ansah, E. O., Boampong, R., Awuah, S., Aboagye, L. M., Asibuo, J. Y. and Lamptey, M.

Donor: Government of Ghana

Background information and justification: Common bean has one of the highest levels of iron and zinc. Iron and zinc deficiencies affect over three billion people worldwide (Bouis and Welch, 2010; Blair, 2013). One of the main objectives of plant breeding is to direct the selection of cultivars in their most suitable cultivation environments and, to do this, performance evaluation of genotypes in different environments are carried out (Woyann *et al*., 2019). Data from multi-environment trials (MET) are necessary to assess the presence of genotype by environment (G x E) interaction and to verify the adaptability and stability of a genotype and its grain yield potential (Yan, 2015). Over the years, several methods to evaluate adaptability and stability have been described in the literature, differing according to the statistical methods used, such as the analysis of variance, parametric and non-parametric regression, mixed models and multivariate analysis (Bornhofen *et al*., 2017). Multivariate statistics facilitate the understanding of complex genotype by environment interaction (GxE) (Carvalho *et al*., 2016). Therefore, the objectives of the study were to evaluate the grain yield and stability of common bean genotypes, as well as the representativeness and discrimination ability of locations in multi-environment trials.

Materials and methods: Ten (10) common bean breeding lines (G1) BFS39, (G2) BFS55, (G4) SEF17, (G5) SEF29, (G6) SEF44, (G7) SEF47, (G8) SEF55, (G9) SEF60 and (G10) SEF64 and one check ('Nsroma' (G3)) were evaluated in an alpha lattice design with three replications at Bunso, Fumesua, Akomadan and Kwadaso during the 2022 minor season. Data collected included days to first flowering, days to 50% flowering, days to maturity, number of plants at harvest, five plant pod weight, five plant seed weight, 100 pod weight, seed weight per 100 pods, 100 seed weight, plot pod weight, plot seed weight, and grain yield.

Results: Large environmental effects were detected for most of the yield and yield component traits which indicate variability among the genotypes under different environments. Significant G x E interactions observed for yield suggest that the performance of the genotypes was not consistent in the same manner across the various environments (Table 10).

The early maturing genotypes took only 56 days to mature whiles the late maturing genotypes matured within 61 days (Table 10). With regards to the yield, the highest recorded was 834.66 kg/ha whereas the lowest was 554.12 kg/ha (Table 9). The GGE biplot for grain yield across the four environments revealed that G10 (SEF64) and G1 (BFS39) were the highest-yielding genotypes followed by G6 (SEF44), G2 (BFS55) (Figure 10). However, G4 (SEF17) was ranked the most stable genotype among the top five yielding genotypes (Figure 11). The genotypes that performed best in each environment based on the "which-won-where" polygon were G3 (Nsroma), G8 (SEF55), G10 (SEF64), and G1 (BFS39). The vertex genotype identified for Akomadan was G10, Kwadaso was G8 (SEF55), and G3 (Nsroma) whereas G1 (BFS 39) was the vertex genotype for Bunso and Fumesua (Figure 11). All other genotypes which were present in the other vertex but did not fall within any test environment were considered to be less responsive in the environments. Akomadan was identified as an ideal test environment with the longest vector of all the test environments (most discriminating) located on the average environment coordinate (very representative). Hence, Akomadan allowed the genotypes to express their genetic potential, minimising population development expenses by discriminating the worst genotypes at an early stage.

Table 10: Mean performances of 10 genotypes for grain yield, and other agronomic traits across four environments

Genotype	Days to 1st flower emergence	Days to 50% flowering	Days to maturity	Number of plants harvested	Hundred seed weight (g)	Net plot weight (g)	Net plot seed weight (g)	Yield kg/ha
G1 (BFS39)	28.63	31.56	59.75	91.94	27.69	732.95	533.83	834.12
G2 (BFS55)	29.25	32.81	61.00	93.50	26.13	640.42	462.56	722.74
G10 (SEF60)	27.81	30.88	57.63	83.75	23.65	751.21	534.18	834.66
G5 (SEF29)	29.00	32.38	61.44	66.44	26.45	553.72	397.75	621.48
G7 (SEF47)	27.69	31.25	57.63	75.38	27.54	577.53	415.33	648.95
G4 (SEF17)	28.31	31.25	57.06	74.25	26.59	599.66	425.12	664.25
G6 (SEF44)	27.31	30.63	56.81	71.00	26.50	655.60	477.03	745.36
G8 (SEF55)	27.88	30.69	57.88	80.94	24.52	545.16	393.01	614.08
G3 (NSROMA)	28.19	30.88	56.00	74.38	26.58	491.18	354.64	554.12
G9 (SEF60)	27.31	30.31	57.06	69.00	24.14	524.02	380.90	595.16
Source of variation			**Mean squares**					

Genotype	7.09***	10.08***	54.82***	1375.91***	31.22***	120933.00***	62386.00***	152310.00***
Environment	1.58*	20.63***	477.72***	9126.77***	136.98***	132454.00***	966170.00***	2358813.00***
Genotype x Environment	0.85*	1.27***	19.31***	877.51***	8.93***	123886.00***	64105.00***	156506.00***

**Significant at P < 0.001, ***Significant at P < 0.0001

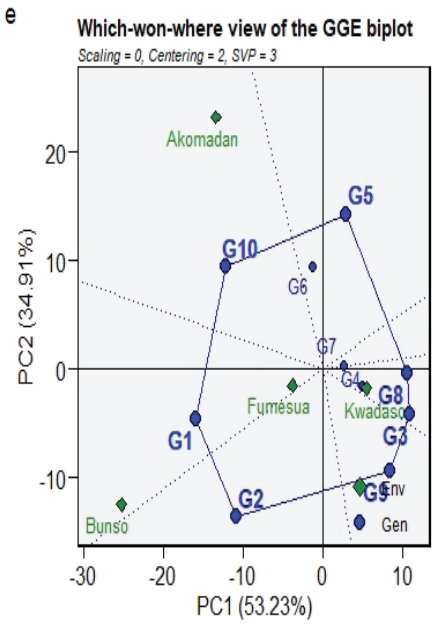


Figure 10: Mean yield and stability biplot of grain yield of of GGE biplot of common bean

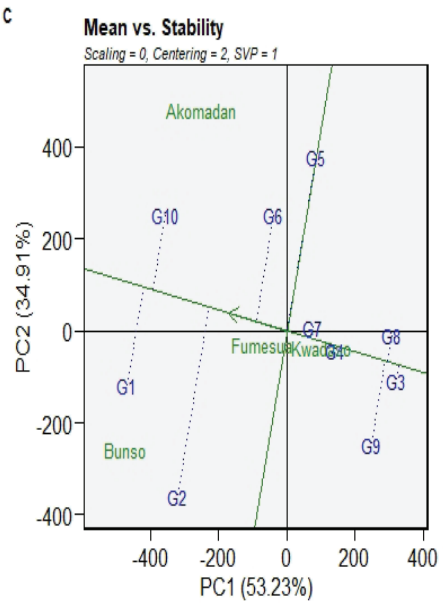


Figure 11: Polygon view of “which won grain yield of the common bean hybrids across environments

OUPUT 1.9 CHARACTERISATION OF OKRA ACCESSIONS IN THE SEMI-DECIDUOUS FOREST ZONE OF GHANA

Research Team: Mensah, E. O., Ansah, E. O., Bissah, M. N., Tetteh, R., Bosomtwe, A., Duku, E. B. Gyasi, E. and Kotey, D. A.

Donor: Government of Ghana

Background information and justification: Okra (*Abelmoschus esculentus* (L.) *Moench*) is an important vegetable, rich in nutrients and many essential compounds for socio-economic and industrial purposes. Different genotypes of okra with potentially unique genetic traits and environmental adaptation are available on farmers' fields. However, limited information exists on the traits carried by the available okra accessions, thus, restricting varietal development to address specific consumer needs. The objectives of this work were to assess the genetic diversity of 67 okra accessions available at the genebank and also to select okra accessions with promising traits for further work and recommendation to farmers.

Materials and methods: A study was conducted to characterise sixty-seven (67) okra accessions available at CSIR-Plant Genetic Resources Research Institute of Ghana. The study was laid in four blocks in an augmented design with three check entries ('Asontem', Hire, and OH102). Data taken covered, vegetative, flowering and post-flowering stages using International Board for Plant Genetic Resources (IBPGR, 1991) descriptors. During the experimental months, rainfall ranged from 11.70 mm to 320 mm with high values in June and in September. On average, temperatures were between 24 – 27 ˚C while the percentage relative humidity was between 77 to 96%.

Results: Thirty-three of the accessions showed branching all over the stem while 29 branched at the base. Ten accessions showed none of the two branching habits. The number of days to 50% flowering ranged from 39 to 160 days. Generally, 50% flower appearance was observed between 39 and 44 days for the early maturing accessions, 45 to 71 days (31 accessions) for the intermediate, and between 90 to 160 days (about 23 accessions) for the late maturing accessions.

Reproductive characteristics indicated differences and similarities of traits among the accessions. Three main petal colours were identified: cream, yellow and golden yellow. Positions of the pods on the main stem were either erect, semi-erect, horizontal, slightly falling or drooping with 31 accessions having erect pods and one showing the drooping phenotype. Twenty-seven accessions had light green immature pods, 28 were dark green, eight had green-with-red tinge and only two accessions were red.

Pod length was classified as long (> 15 cm), medium (8 to 15 cm), and short (< 7 cm). Forty-two accessions were medium, 19 short and 11 long. Pod width was either medium (1.5 – 2.0 cm) with 12 accessions or large (> 2.0 cm) with 60 accessions. The pod base of 27 accessions were strongly constricted, 30 were weakly constricted while 15 of the accessions did not show the trait. The pod surface pubescence was downy (8 accessions), slightly rough (47 accessions), or prickly (17 accessions). Forty-nine accessions showed concave surfaces between pod ridges, 10 were convex while 13 had plain surfaces. Cluster analysis of the morphological characteristics indicated three main cluster groups among the accessions (Figure 12).

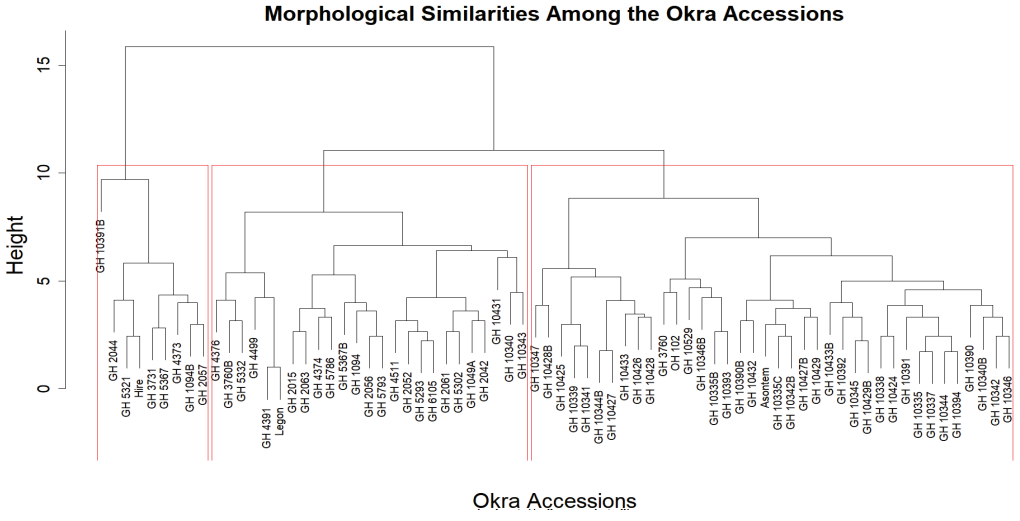


Figure 12: Cluster plot showing morphological similarities among the okra accessions.

The first group consisted of nine accessions, the second group had 25 accessions, while the last group had 38 accessions. Among the first group, all but one accession, GH10391B had similar traits like the check (Hire) entry. The last cluster had similar morphological characteristics as 'Asontem' and OH102. The results obtained provide information that can facilitate the selection of accessions with specific traits such as early maturity for crop improvement.

OUTPUT 1.10 CHARACTERISATION AND EVALUATION OF PEPPER GERMPLASM FROM THE CSIR-PGRRI

Research Team: Amissah, A. A., Bandanaa, J., Bissah M. N., Kotey, D. A.

Donor: Government of Ghana

Background information and justification: Pepper is a widely cultivated crop used in many Ghanaian dishes as a spice and a condiment. Pepper is rated as one of Ghana's most important vegetable crops in terms of hectarage and crop value with significant potential for generating income and exports thereby contributing to foreign exchange and creating jobs (Gonzalez *et al*., 2014).

Germplasm improvement is achieved by assessing genetic diversity and estimating the relationship among accessions (Dale and Schatz, 2002). Characterisation using morphological traits such as stem pubescence, flower colour, plant stature, fruit shape, fruit weight, plant height among others are used in grouping pepper genotypes (Fonseca *et al*., 2008, Weerakoon and Somaratne, 2010). The objective of the study was to characterise and evaluate nineteen (19) accessions of pepper at the CSIR-PGRRI, and document useful traits for utilisation in crop improvement.

Materials and methods: Nineteen pepper accessions from the genebank were assessed using 60 IPGRI (International Plant Genetic Resources Institute) descriptors, six seedling, 17 vegetative, 14 flowerings, 19 fruit, and four seed traits. Seeds were sown in seed trays with steam-sterilised topsoil and transplanted to the field at six weeks after sowing. Seedlings were planted at 1 m x 1 m in an augmented design with a single row (12 m long). The design was composed of three blocks and each block contained six genotypes including a check (Legon 18). Fertiliser application, insect and weed control and all agronomic practices were applied uniformly on the entire plot.

Results: The study revealed the existence of considerable variation among the 19 pepper accessions (Figure 13, Figure 14, and Table 11). Accessions GH10554 (55 days after transplanting) and GH7874 (54 days) had shorter days to fruiting while accessions NP3, GH7866, and GH3628 had longer maturity periods (Figure 13). Table 11 shows results for quantitative traits such as fruit length, fruit width, fruit weight, and fruit wall thickness. Fruit length of accessions ranged from 8.8 cm to 2.5 cm with accession GH10554 having the longest and accession GH3659B having the shortest fruit. Accession GH10556A had the widest fruit width of 25.10 mm while accession GH3627A had a width measuring 5.81 mm. Fruit weight from accessions ranged from 0.704 g to 6.314 g with accession GH10554 having the highest fruit weight. Accession GH3627A

had the lightest fruit weight. Accession GH10555 had the thickest fruit wall measuring 2.60 mm while accession GH3659 had the least value of 0.413 mm.

Accessions with promising morphological traits such as GH10554, GH3633, GH10556A, and GH10557 are recommended for further evaluation.

Table 11: Analysis of quantitative traits among pepper accessions

ACCESSION NUMBER	FRUIT LENGTH (cm)	FRUIT WIDTH (mm)	FRUIT WEIGHT (g)	FRUIT WALL THICKNESS (mm)
	MEAN	MEAN	MEAN	MEAN
GH10556	3.850	25.10	2.771	1.247
GH3627A	3.475	5.81	0.704	0.455
GH3659	5.233	7.803	1.343	0.413
GH3659B	2.525	10.600	1.159	1.133
GH10554	8.817	14.355	6.314	1.095
GH10555	3.250	18.533	2.470	2.600
LEGON 18	6.480	10.258	4.607	0.897
RANGE	2.525-8.817	5.81-25.1	0.704-6.314	0.413-2.6
ST. DEV.	0.607	1.582	0.706	0.218
MEAN	4.746	14.137	2.863	1.118
CV %	12.80	11.2	24.70	19.50

ST. DEV. = standard deviation

CV% = Coefficient of variation

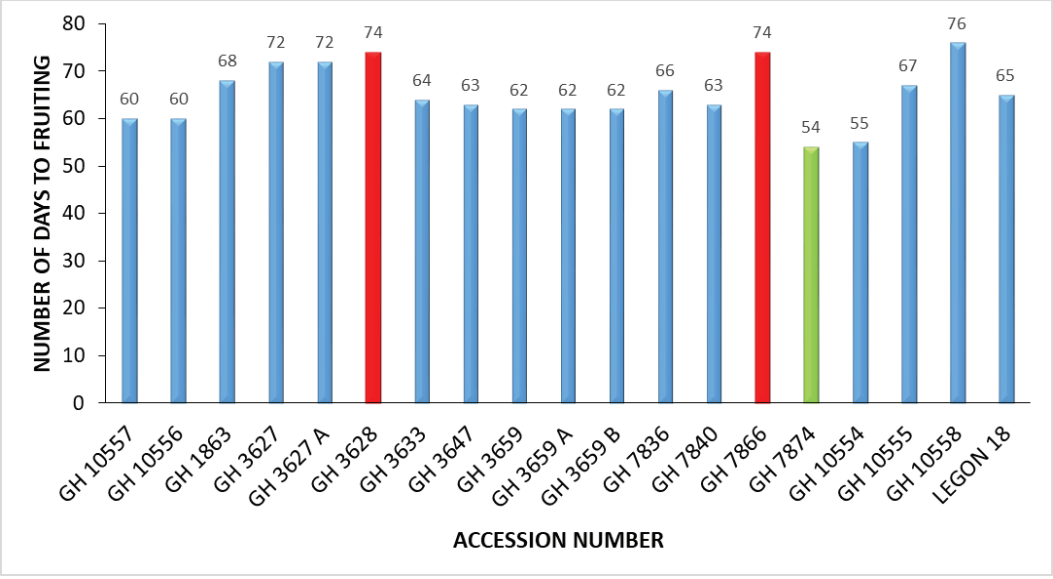


Figure 13: Number of days to fruiting of pepper accessions

Figure 14: Diversity in ripe fruit shape of pepper accessions fruit

OUTPUT 1.11 PRELIMINARY EVALUATION OF DIFFERENT ACCESSIONS OF PIGEON PEA (*CAJANUS CAJAN* L.) PLANTED IN SOILS UPPLEMENTED WITH POULTRY MANURE AND TRIPLE SUPERPHOSPHATE (TSS) FERTILISERS.

Research Team: Ansah, E.O., Mensah, E. O., Bissah, M. N., Amoah, R. A., Tetteh, R., Duku, E. A., Bonsomtwe, A., Gyasi, E., and Kotey, D. A.

Donor: Government of Ghana

Background information and justification: Pigeon pea is a perennial leguminous plant with many nutritional attributes that makes it important to food security in the context of changing climatic conditions. The crop is high yielding and adapted to erratic climatic conditions. Although pigeon pea may fix nitrogen to the soil, due to its symbiotic association with Rhizobium under marginal soil conditions, the crop may need phosphorus boosters for establishment, growth and yield. The current experiment tested the hypothesis that different accessions of pigeon pea may respond differently to different soil amendments.

Materials and methods: The field trial was conducted at the CSIR-PGRRI using three different soil amendments: no-fertiliser, poultry manure (PM) and triple super phosphate (TSP) and four different accessions of pigeon pea: GH1706, GH1707, GH1708 and GH1710 collected from the genebank. The field design was split-plot with soil amendment as main plots and the accessions as sub-plots. Each sub-plot contained 18 plants of pigeon pea arranged in three rows of seven. Poultry manure was applied two weeks before planting at a rate of 4 t/ha, while triple super phosphate was applied two weeks after planting at a rate of 260 g/ha. Data were collected from the three plants in the middle of each sub-plot.

Results: During the experimental period, rainfall varied from 11.70 mm to 320 mm while temperatures were typically between 24 and 27 ^{0}C. Relative humidity was between 77% and 96%. The soil at the experimental field had a silty-loam texture with 1.21 gcm^{-3} bulk density and a slightly acidic pH of 5.5. Concentration of nitrogen, phosphorus and potassium were 0.11%, 10.02 mgkg^{-1}, and 0.014 cmol(+)kg^{-1} respectively. Generally, germination percentages of the accessions after seven days were between 59.6 – 65.2%. All the accessions comparatively responded well to growth in poultry manure-amended soils but in different patterns (Fig. 15). Accession GH1706 showed the highest growth performance with a plant height of 196.66 cm and 21.30 mm stem diameter three months after planting. Accession GH1707 showed more growth to stem expansion instead of plant height under all the soil amendments.

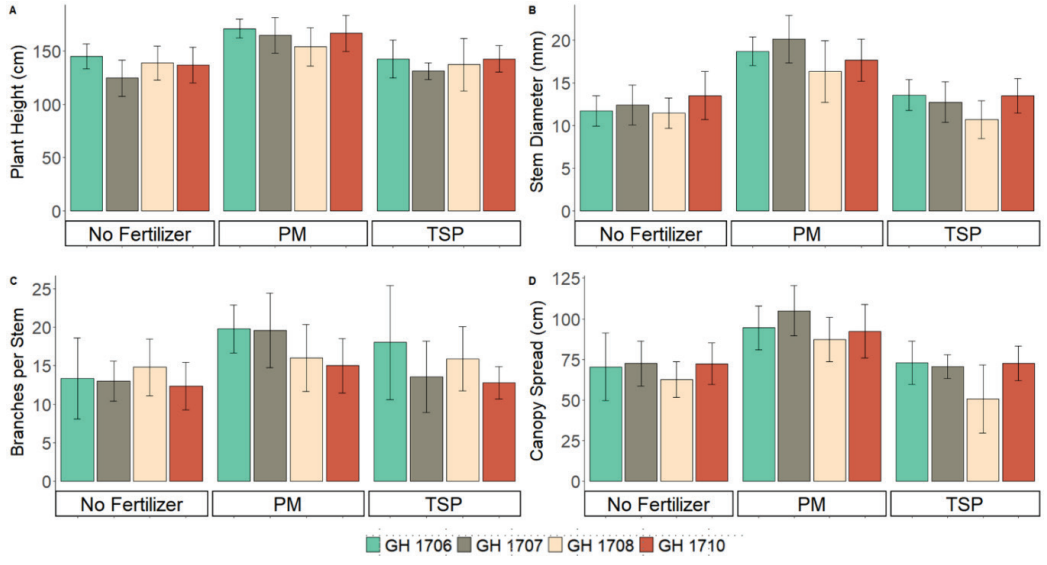


Figure 15: Plant growth parameters of pigeon pea under three different soil amendments three months after transplanting

Branching of all the accessions was generally low in triple super phosphate amended plots than in poultry manure and control plots. Accession GH1706 on the poultry manure amended plots produced more branches (28) than the other accessions while accession GH1708 produced more branches in control plots than the other accessions. Data on canopy spread also revealed that accession GH1706 produced the widest spread (104.88 cm) in poultry manure amended plots while accession GH1707 rather showed the widest spread in triple super phosphate amended plots. It was noted that whereas accession GH1707 flowered earlier (98 days) in poultry manure amended plots, accession GH1706 was earlier (99 days) in no fertiliser treatments (control). All the accessions in triple super phosphate amended plots flowered late.

In conclusion, the growth of pigeon pea accessions was differently affected by type of soil amendment. Generally, poultry manure enhanced the growth performance of pigeon pea than triple super phosphate and no-fertiliser amendments. Accession GH1706 gave the best performance in terms of growth, especially in poultry manure-amended soils.

OUTPUT 1.12 THE ECONOMIC COSTS OF *EX-SITU* CONSERVATION OF PLANT GENETIC RESOURCES AT CSIR-PGRRI – THE NATIONAL GENEBANK

Research Team: Bandanaa, J., Tetteh, R., Bissah, M. N, and Kotey, D. A

Donor: Government of Ghana

Background information and justification: The importance of plant genetic resources, especially seeds, to human life has been recognised since time immemorial. However, the natural habitats of cultivars are increasingly being destroyed through anthropogenic activities, thus *ex-situ* collections serve as a panacea for crop productivity improvement and production systems diversity. The *ex-situ* conservation of genetic resources comes at a high cost, which usually requires sustainable funding. This study aimed at determining the cost of seed crop germplasm conservation and distribution at the CSIR-PGRRI genebank as the foundation for answering many general operational issues and cost-effective storage methods.

Materials and methods: The study was conducted using the methodology developed by Koo *et al* (2002, 2003, 2004) on costing genebank operations. The Decision Support Tool (DST) which quantifies monetary costs based on historical data, without recourse to benefits of plant genetic resources conservation, which are dependent on an unpredictable future demand for genetic resources was used (Figure 16).

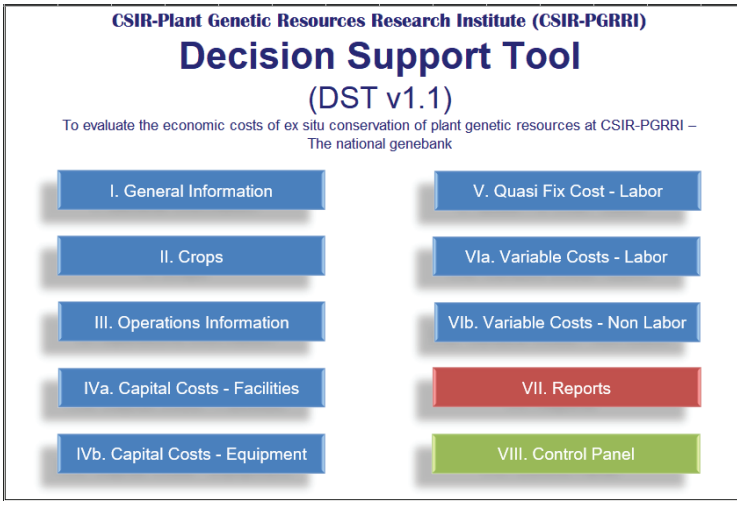


Figure 16: Main interface of the Decision Support Tool (DST)

The DST is based on a production economics framework in which a genebank is viewed as a production entity that converts inputs (facilities, labour, and variable inputs) into outputs (accessions conserved and distributed). For this study, 2021 calendar year operations at the CSIR-PGRRI genebank were used as the baseline for costing 11 seed crop germplasm [*Zea mays, Amaranthus* spp., *Corchorus* spp., *Hibiscus* spp., *Cucurbita sp., Cleome gynandra, Solanum* spp., *Vigna unguiculata, Phaseolus vulgaris, Glycine max, Arachis hypogaea, Oryza sativa, and Vigna subterranea*] conservation.

Results: Preliminary findings showed that a major cost centre for all the eleven seed germplasm were quasi-fixed costs. The quasi-fixed costs include senior scientists and technicians (including scientific staff and permanent staff working in the genebank) who were involved in operations related to the seed germplasm. For *Zea mays* and *Oryza sativa* majority of the costs emanated from quasi-fixed costs followed by capital costs (Figure 17).

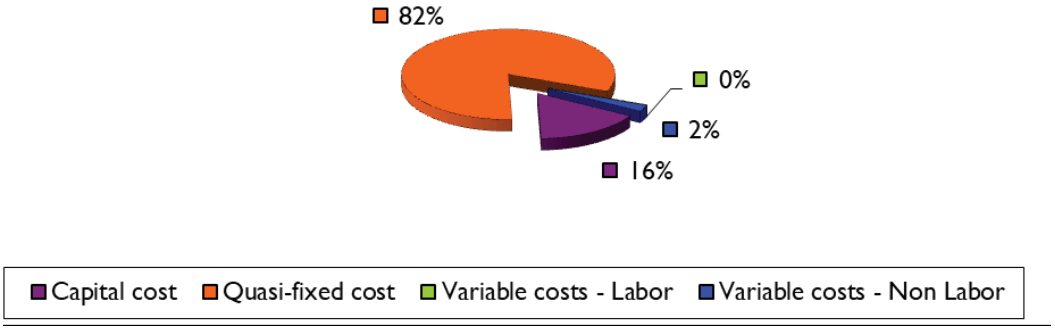


Figure 17: Cost distribution for *Zea mays*

In the case of capital costs which includes facilities, it is normal in managing genebanks. In average terms, the most expensive operations for *Zea mays* were regeneration (GH¢ 20.00), seed processing (GH¢ 17.5), and medium-term storage (GH¢ 10.00). *Oryza sativa* costs were like *Zea mays* albeit quasi-fixed costs contributed 71% and average prices varied slightly by GH¢ 0.65 for the various operations. Regeneration is a core operation that is related to procuring enough seed volumes for conservation but also for distribution. The cost centre for seed germplasm (e.g., *Cucurbita sp., Phaseolus vulgaris*, and *Glycine max*) with less than five accessions regenerated without distribution was largely capital (Figure 18) ranging from GH¢ 9 to 10.

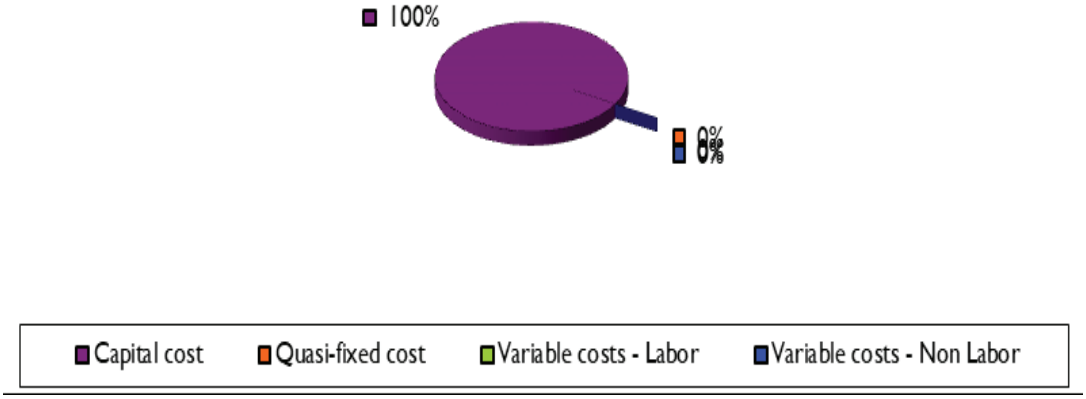


Figure 18: Cost centre for seed germplasm

Recommendations

The baseline study has pointed out several challenges in terms of data.

1. Asset management data for the genebank needs to be reconciled with the equipment available.

2. The 2021 costing performed made several assumptions because of incomplete data. For example, the space an accession covers in a freezer should be known. Freezers should be labeled based on their content. Given that area plays a key role in cost, this could influence the costs per accession estimated.

OUTPUT 1.13 EVALUATION OF METHODS FOR DISEASE RESISTANCE IN HORTICULTURAL CROPS

Research Team: Ochar, K., Hur, O., Ho-Cheol, K., Hee-Jong, W., Bum-Soo, H., Bissah, M. N. and Kotey, D. A.

Background and justification: The tomato gray leaf spot (GLS) disease, also known as Stemphylium leaf spot is one of the most important fungal diseases threatening the productivity of tomatoes in several growing regions of the world (Miranda *et al*., 2010; Yang *et al*., 2017a; Liu and Wang, 2020). The disease was reported some decades ago, but its re-emergence in recent times is more deleterious and requires early intervention (Liu and Wang 2020). The disease is caused by fungal species in the Stemphylium

genus including *S. solani, S. lycopersici (=S. floridanum)*, and *S. botryosum* of which *S. lycopersici* is the most frequently isolated in tomatoes (Miranda *et al*., 2010; Wang *et al*., 2020). In tomatoes, early-stage disease symptoms include brownish-black specks on leaf parts which subsequently develop into necrotic lesions with a gray portion in the centre of the affected leaf. The affected portion of the leaf is usually surrounded by dark-brown borders (Yang *et al*., 2017b; Su *et al.*, 2018). Infected leaves eventually dry and drop (Su *et al*., 2018; Park *et al*., 2020). The severe nature of the disease implies that most tomato varieties under cultivation are highly vulnerable to the pathogen. In particular, the humid conditions of tropical and subtropical environments are favourable for the increasing vulnerability of tomatoes to the disease (Park *et al.,* 2020). To date, Sm is the only *S. lycopersici*-resistant locus identified to harbour genes for breeding resistant cultivars (Park *et al*., 2020 Yang *et al*., 2021;). Screening germplasm resources of diverse geographical and genetic backgrounds is essential to identify new genetic and gene resources for conducting more effective and efficient disease-resilience breeding. To achieve this goal, a more efficient approach is required to have an accurate identification of desirable resistant accessions either under field or greenhouse conditions.

Materials and methods: The detached leaf assay technique has been frequently used in phyto-pathological experiments where sample leaves are inoculated with drops of inoculum on leaf surfaces (Foolad *et al*., 2015). As part of the experiment being reported, plants of 411 tomato accessions were produced under greenhouse conditions and the detached leaf assay method was used to evaluate them.

Results: Out of the 411 accessions evaluated (Figure 19), 18 (4%), 47 (12%; DSI: 10-30%) were resistant (DSI: < 10%) to the Stemphylium pathogen (Figure 20). Disease severity index of the resistant accessions ranged from 0 (accessions: Morioka No. 17 and Rodale to 8.9% (Pilluce 88-083 and Super Roma). With the exception of three accessions originating from Peru which were wild relatives (*Solanum peruvianum* and *Solanum pimpinellifolium)*, the rest of the resistant accessions were cultivated tomatoes (*Solanum lycopersicum var. lycopersicum*). Among the resistant accessions, Morioka No. 17 and Rodale originating from Japan showed superior resistance to the pathogen. Majority of the moderately resistant accessions only displayed brownish-black speck symptoms on their leaves (a score of 1). Comparatively, majority of the accessions were susceptible (DSI: > 30%) to *Stemphylium lycopersici*. Foliar symptoms of susceptible accessions were mainly observed as dark brown coloration on whole leaf (score of 4), and the presence of necrotic lesion with a gray centre and dark brown border (score of 3). The resistant accessions identified can be used for further breeding new resistant cultivars.

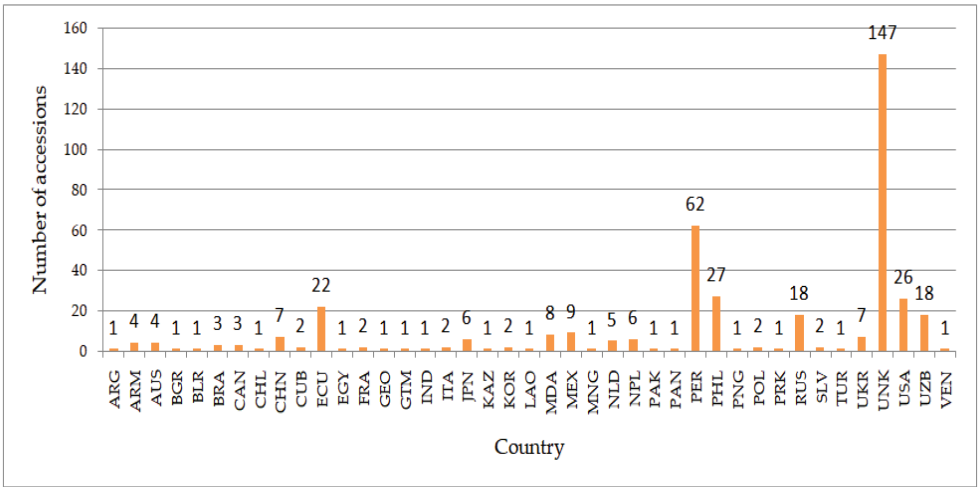


Figure 19: The number of tomato accessions from different countries used for the current experiment.

The short names ARG, ARM, AUS, BGR, BLR, BRA, CAN, CHL, CHN, CUB, ECU, EGY, FRA, GEO, GTM, IND, ITA, JPN, KAZ, KOR, LAO, MDA, MEX, MNG, NLD, NPL, PAK, PAN, PER, PHL, PNG, POL, PRK, RUS, SLV, TUR, UNK, USA, UZB, VEN represent Argentina, Republic of Armenia, Australia, Republic of Bulgaria, Republic of Belarus, Brazil, Canada, Chile, China, Cuba, Egypt, France, Georgia, Guatemala, India, Italy, Japan, Kazakhstan, Korea, Lao People's Democratic Republic, Republic of Moldova, Mexico, Mongolia, Netherlands, Nepal, Pakistan, Panama, Peru, Philippines, Papua New Guinea, Poland, Korea, Russia, Slovenia, Turkey, unknown origin, United States of America, Uzbekistan, and Venezuela respectively.

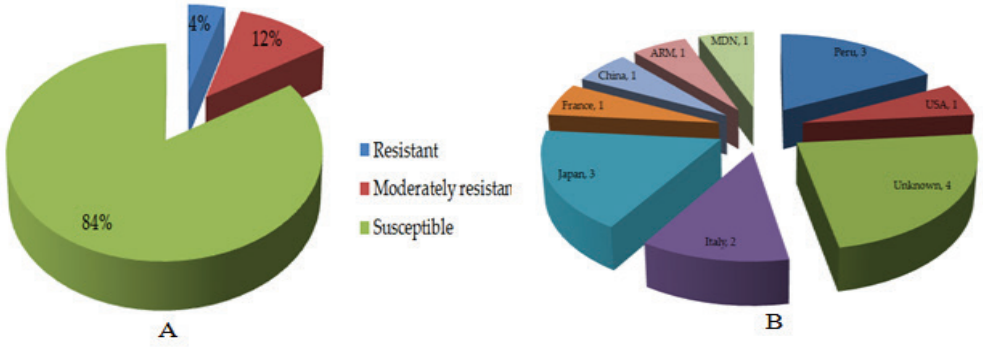


Figure 20: Estimate of disease severity index (DSI) of tomato accessions used for the experiment based on reaction to the *Stemphylium lycopersici* inoculation (A) and country-specific percentage contribution of *S. lycopersici*-resistant accessions (B). Numbers attached to each country represent the number of resistant accessions derived from the associated countries. ARM: Republic of Armenia MDN: Republic of Moldova

OUTPUT 1.14: EVALUATION OF SOME SWEET POTATO ACCESSIONS AGAINST *CYLAS* SPP. INFESTATION ON THE FIELD AT BUNSO.

Research team: Duku, E. B., Kotey, D. A., Bosomtwe, A., Mensah, E.O., Ansah, E. O., Kyei, E., Sordji, L. and Amofah, E.

Donor: Government of Ghana

Background information and justification: Sweet potato is the third most important root and tuber crop in Ghana. It is largely cultivated in the Sudan and Coastal Savannah zones of the country. It's production and utilisation are often considered as a means to generate income and improve food security among resources poor smallholder farmers in rural areas. Various constraints such as sweet potato virus disease (SPVD), insect and vertebrate pests, weed infestation, soil nutrient deficiencies, poor crop husbandry practices and socio-economic factors have contributed to low sweet potato root yields in sub-Saharan Africa. However, insect pest infestation is a major constraint. Among insect pests that infest sweet potato, the *Cylas* spp. complex, consisting of a widely distributed and destructive insect group is considered as the most limiting. Yield losses of between 60 – 90% have been reported. The cryptic nature of the *Cylas* spp. including its' nocturnal activity of the adults makes effective management of the species difficult and most often results in farmers applying insecticides three to five times during cropping seasons. The use of resistant cultivars and mulching in the context of a broad integrated pest management (IPM) strategy may thus be more economically and environmentally sustainable for resources poor sweet potato farmers.

The objectives of the study were:

i. To determine the level of susceptibility of 10 sweet potato genotypes to *Cylas* spp. infestation on the field.

ii. To identify the main *Cylas* spp. complex that infests sweet potato at Bunso.

iii. To determine the interaction between mulching and sweet potato genotypes on *Cylas* spp. infestation on the field at Bunso.

Materials and methods: The experiment was conducted at the research fields of the CSIR-PGRRI. Eight sweet potato genotypes from the CSIR-PGRRI were evaluated. Two released sweet potato varieties from the CSIR-CRI namely, CRI 'Apomuden' and CRI Otoo were included as check entries. The experimental design was 2 x 10 factorial laid

in a randomised complete block design with three replicates. Mulch and zero mulch (control) were used as factors. Each block consisted of 20 beds with a plot size of 2.4 m x 1.2 m with seven plants in a row of three on a bed with 0.3 m between and within rows. Data on insect count on the leaf canopy was done at three, four and five months after planting (MAP). At harvest, tuber stalk length as well as percentage tuber infestation per each genotype was recorded.

Results: The results showed that the main *Cylas* spp. infesting sweet potato on the field at Bunso was *Cylas puncticollis* (the African sweet potato weevil). The population of the weevil increased from three months through to four and five months after planting (MAP) on all the sweet potato genotypes evaluated. The use or non-use of mulch had no significant impact on weevil numbers (Figure 21).

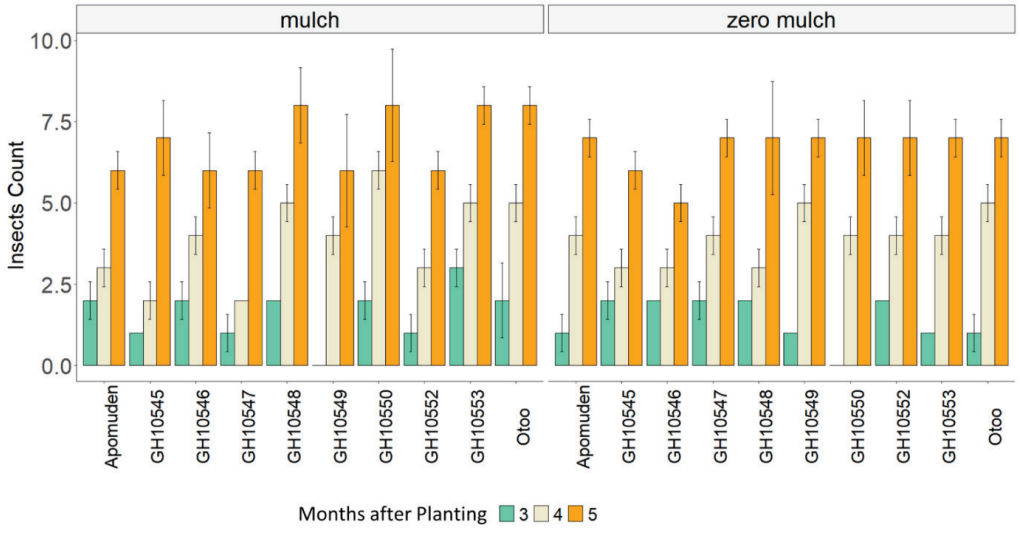


Figure 21: The mean number of *Cylas puncticollis* recorded on the sweet potato genotypes at 3, 4, and 5 MAP.

Significant differences ($P < 0.05$) were observed in tuber stalk length and tuber infestation among the sweet potato genotypes. The two treatments (mulch and zero mulch) superimposed on the sweet potato genotypes did not show any significant effect on tuber stalk length and tuber infestation. The interaction between treatment and sweet potato genotypes was not significant. Sweet potato genotypes such as GH10546, GH10550, and GH10547 which had the longest tuber stalk length had very low percent tuber infestation and vice versa (Figures 22 and 23).

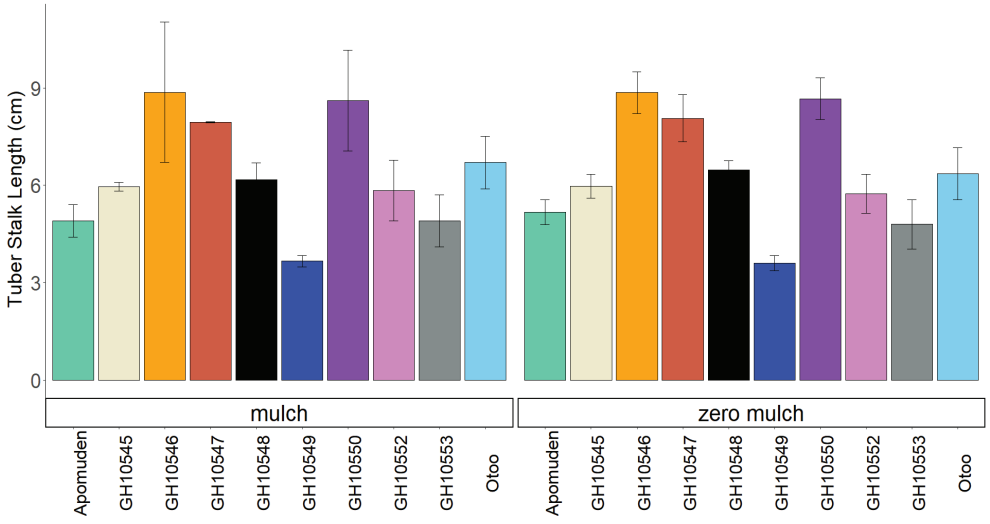


Figure 22: Mean tuber stalk length of sweet potato genotypes

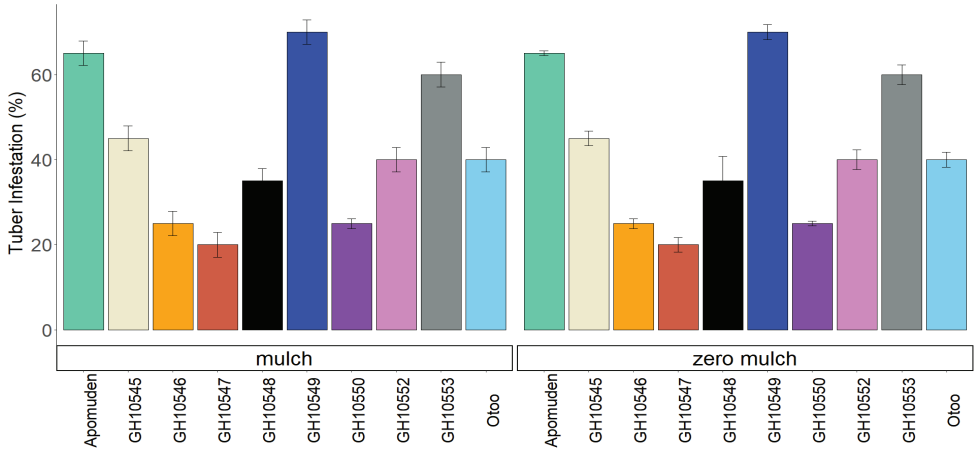


Figure 23: Mean percent tuber infestation of sweet potato genotypes

OUTPUT 1.15: EVALUATION OF PRO VITAMIN A BIO-FORTIFIED MAIZE ACCESSIONS AGAINST *SITOPHILUS ZEAMAIS* (MOTS) (COLEOPTERA: CURCULIONIDAE) AT STORAGE.

Research team: Duku, E. B., Kotey, D. A., Bosomtwe, A., Amoah, R. A., Kyei, E., Sordji, L and Amofah, S.

Donor: Government of Ghana

Background information and justification: Pro Vitamin A Biofortified maize is the main energy source for layer and egg production in the poultry industry, including forming about 60 – 70% of the total feed used. Aside from these, Pro Vitamin A biofortified maize has been identified as a cheaper, sustainable, convenient and an easy source of Vitamin A. In sub-Saharan Africa, large quantities of maize including Pro Vitamin A produced by small-holder farmers are lost between harvest and consumption. *Sitophilus zeamais* is one of the most serious insect pests that causes severe damage to maize in storage. Weight losses of as much as 30 – 40% can result from heavy weevil infestation in stores. The main strategy used for controlling the weevil is the use of conventional broad-spectrum synthetic insecticides, which poses risks to human and environmental health. Given the adverse impacts associated with this strategy, there is the need to look for resistant maize genotypes that can be integrated into the management of this serious stored product pest.

The objective of the trial was to determine the susceptibility of PVABM accessions to *Sitophilus zeamais*.

Materials and methods: A 60–day susceptibility experiment was conducted for 15 PVABM genotypes against *Sitophilus zeamais* at the Entomology laboratory of the Plant Protection Division of the CSIR-PGRRI. The experiment was laid out in a completely randomised design with three replications. Ten male and ten female *Sitophilus zeamais* adults were put on 50 g of grain each from 15 PVABM genotypes for eight (8) days and sieved out. The number of weevils that emerged 25 days from the commencement of the experiment was counted daily till no weevil emergence was observed. The number of weevils that emerged at the end of the experiment and the median development period (MDP) was used to calculate the index of susceptibility (SI). Percentage grain damage and weight loss were also calculated for each maize genotype.

Results: The results of the 60-day no-choice susceptibility experiment revealed that maize genotypes GH10469 and GH10467 had the highest number of *Sitophilus zeamais* that emerged whilst GH10470 and 'Ahoodzin' had the least number of weevils that emerged (Figure 24). Insect damage variables such as percentage grain damage

and weight loss were both high in accessions GH10469 and GH10467 and very low in accession GH10470 and 'Ahoodzin' (Figures 25 and 26). The SI values were observed to be very high in accessions GH10469 and GH10467 and very low in accession GH10470 and 'Ahoodzin' (Figure 27). The maize genotypes with a greatest number of weevil emergence had a high percentage of grain damage and weight loss and high SI values with a short median development period and vice versa.

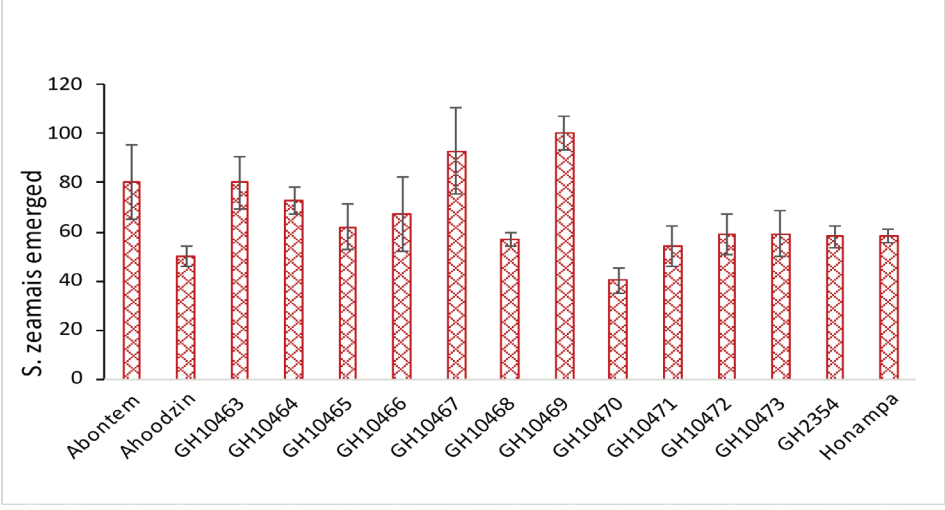


Figure 24: The mean number of *Sitophilus zeamais* emerged from the maize genotypes after 60 days.

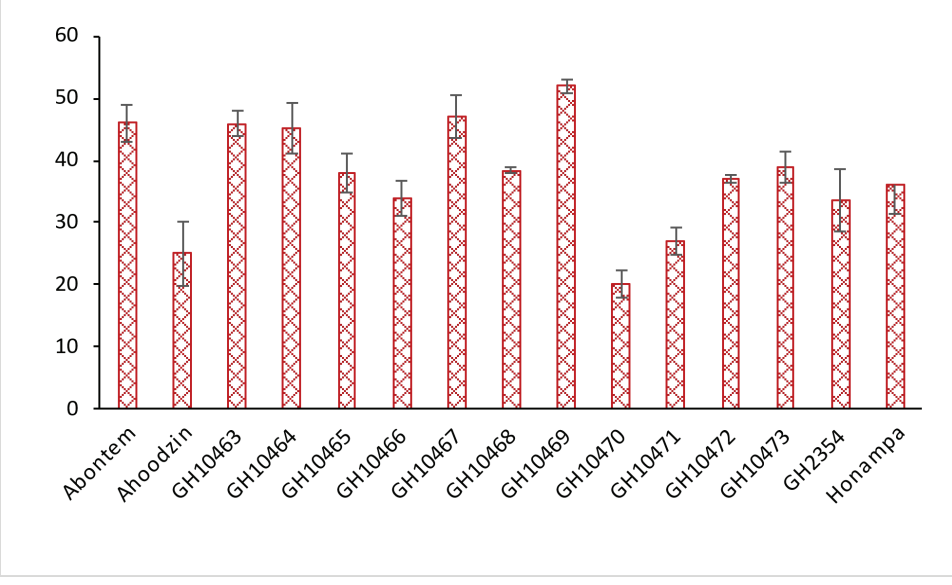


Figure 25: Percentage of grain damage caused by *S. zeamais* after 60 days

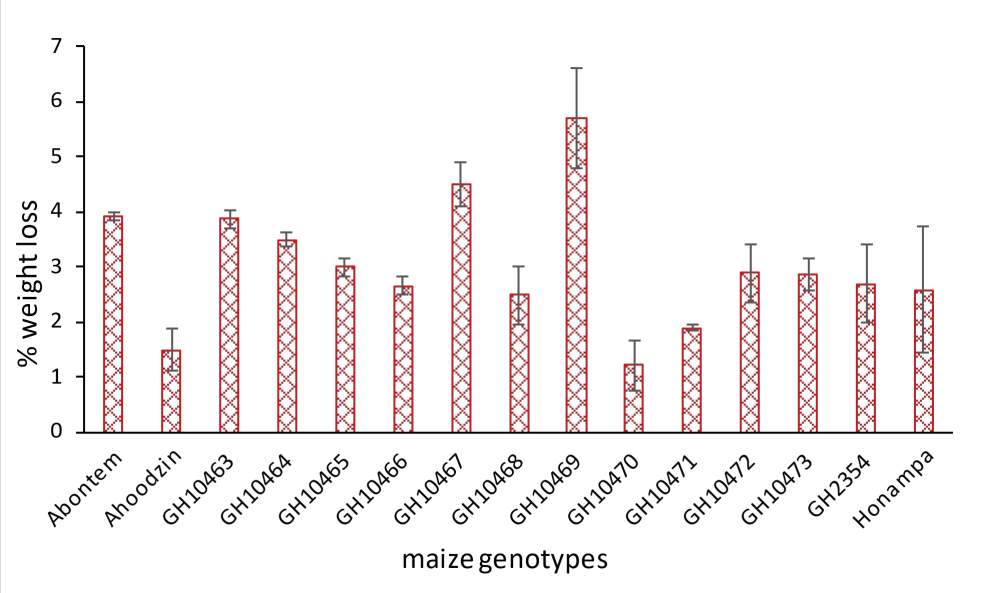


Figure 26: Percentage of weight loss caused by *S. zeamais* after 60 days

Figure 27: Susceptibility index of maize genotypes after 60 days.

OUTPUT 1.16: SCREENING OF EGGPLANT GERMPLASM FOR RESISTANCE TO FUSARIUM WILT DISEASE CAUSED BY *FUSARIUM SOLANI*

Project team: Owusu, E. O., Adongo, B. A., Gyasi, E. and Karim, F. A.

Donor: Government of Ghana

Background information and justification: Eggplant, *Solanum* spp. is globally considered an important food and nutrition security crop which yields good economic returns (FAOSTAT, 2018). Ghana has a rich genetic diversity and culinary use of eggplant. The crop is therefore a target for poverty alleviation in the country. Wilt of eggplant is an important disease that accounts for over 20% of eggplant yield loss globally (FAOSTAT, 2018). Several *Fusarium* and Verticillium species can cause wilt of eggplants (Kouassi *et al*., 2014 ; Mwaniki *et al.*, 2016). Management of the disease would therefore improve the income of smallholder farmers whose livelihood is dependent on the cultivation of eggplant. This study aimed to screen eggplant germplasm for resistance to Fusarium wilt disease caused by *Fusarium solani* using the root-dip inoculation method.

Materials and methods: Single spore cultures of *Fusarium solani* isolates were prepared and plated on potato dextrose agar using the procedure described by Leslie and Summerell (2006) and placed in an incubator at a temperature of 27 ± 2^0C. Sub-culture of the isolates was done regularly to keep them active (Figure 28). Seeds of forty eggplant accessions were sown and watered regularly until the seedlings were ready for inoculation.

Results: Sixty-five percent of the accessions germinated with an average germination of 40% (Table 12). Germinated accessions were planted out in a regeneration plot to multiply seeds. Seedling survival and seed extraction status are presented in Table (12).

Table 12: Seed germination, seedling survival, and seed extraction status of eggplant accessions

S/N	Accession no.	% germination	Seedling % survival	Seed extraction
1	GH4949	25	100	Y
2	GH3944	50	0	N
3	GH4946	75	67	Y

4	GH1090	5	33	Y
5	GH5168	85	50	Y
6	GH1877	55	100	Y
7	GH1859	15	100	Y
8	GH3870	35	17	Y
9	GH3911	25	83	Y
10	GH3947	5	67	N
11	GH4918	40	100	Y
12	GH4943	55	100	Y
13	GH4948	55	100	Y
14	GH1855	30	83	Y
15	GH3918	80	50	Y
16	GH4884	60	50	Y
17	GH3950	15	0	N
18	GH1875	15	100	Y
19	GH1856	55	100	Y
20	GH1874	40	100	Y
21	GH1854	45	100	Y
22	GH4939	30	100	Y
23	GH5887	35	0	N
24	GH3938	20	50	Y
	Average	40	68.75	

Y= seeds extracted

N- No seed extracted

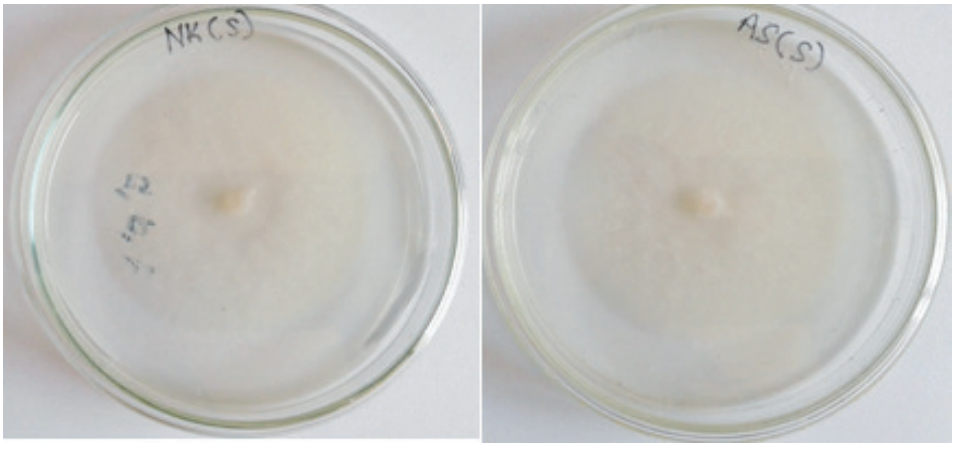


Figure 28: Culture of *Fusarium solani* isolate

OUTPUT 1.17: EVALUATION OF MAIZE AND RICE SEEDS FOR SEED-BORNE PATHOGENS

Project team: Owusu, E. O., Adongo, B. A., Gyasi, E., Karim, F. A. and Mohamed, A.

Background information and justification: Seeds of 60 maize and 52 rice accessions that were sent for regeneration and characterisation in the year 2022 were tested for seed-borne pathogens. The seeds were obtained from the stock conserved under cold storage (-20 °C) at the CSIR-PGRRI, Bunso, and examined for the presence of seed-borne fungi using the blotter method of the International Seed Testing Association.

Identified seed-borne fungal species on maize accessions: Six fungal species were identified on the maize accessions. These were *Fusarium verticillioides, Curvularia* sp., *Rhizopus* sp., *Aspergillus flavus, Aspergillus niger* and *Penicillium* sp. The most dominant fungus recovered from the seeds was *Fusarium verticillioides* (55%), with infection levels ranging from 2.5 - 72.5%. This was followed by *Aspergillus flavus* at 46.7%, with infection levels ranging from 2.5 - 82.5%. *Rhizopus sp.* recorded the least fungal incidence of 3.3% with infection levels ranging from 2.5 - 2.5% (Table 13).

Table 13: Incidence of infection (%) and infection level (%) by fungal species from maize seed samples

Fungal species	Total No. of accessions evaluated	Number of infected accessions	Incidence of fungi (%)	Infection level (%)
Aspergillus flavus	60	28	46.7	2.5-82.5
Aspergillus niger	60	4	6.7	2.5-30
Penicillium sp.	60	23	38.3	2.5-45
Rhizopus stolonifer	60	2	3.3	2.5-2.5
Curvularia sp.	60	6	10.0	2.5-10
Fusarium verticillioides	60	33	55.0	2.5-72.5

Identified seed-borne fungal species on rice accessions: Seven fungal species were identified on the rice accessions. These were *Fusarium verticillioides, Curvularia* sp., *Rhizopus* sp., *Sclerotium rolfsii, Aspergillus flavus, Aspergillus niger, and Penicillium* sp. The most dominant fungus recovered from the seeds was *Fusarium verticillioides* at 28.8%, with infection levels ranging from 2.0 – 36%. This was followed by *Rhizopus* sp. at 17.3%, with infection level ranged from 2.0 -19%. *Sclerotium rolfsii* recorded the least fungal incidence of 1.9% with infection levels ranging from 1.0-1.0% (Table 14).

Table 14: Incidence of infection (%) and infection level (%) by fungal species from rice seed samples

Fungal species	Total No. of accessions evaluated	Number of infected accessions	Incidence of fungi (%)	Infection level (%)
Aspergillus flavus	52	4	7.7	2.0-5
Aspergillus niger	52	2	3.8	2.0-2.0
Penicillium sp.	52	5	9.6	2.0-5
Rhizopus stolonifer	52	9	17.3	2.0-19
Curvularia sp.	52	3	5.8	1.0-3.0
Fusarium verticillioides	52	15	28.8	2.0-36
Sclerotium rolfsii	52	1	1.9	1.0-1.0

OUTPUT 1.18: POST-HARVEST ASSESSMENT OF THE INCIDENCE OF TARO CORM ROT IN THE EASTERN REGION OF GHANA

Project team: Gyasi, E., Owusu, E. O., Adongo, B. A., Karim, F. A., Boampong, R., Mohammed, A. and Kotey, D. A.

Background information and justification: Post-harvest rot accounts for losses of up to 85% of harvested taro corms within two weeks of storage in the tropics. In Ghana, there is scanty information on fungi and pre-disposing factors that cause post-harvest rot of taro corms. This study sought to document taro farmers' and traders knowledge of taro corm rot and post-harvest handling practices of taro corms and evaluated taro genotypes against five major identified rot-causing fungi *in-vitro*.

Materials and methods: A questionnaire-based survey of taro farmers' and traders' knowledge of rot and post-harvest handling practices of taro corms was undertaken in some communities in three districts of Eastern Region, Ghana. Twenty taro traders within the vicinity of the toll booth area at Akyem Sekyere, in the Atiwa East District, 18 farmers from Aboabo, Kwamoso, Nyawonsu, Akropong Akuapim, and Teiko in the Akuapim North District and 10 farmers each from Kwahu Atibie, Mpraeso, Kwahu Bepong, Pankase, Kwahu Adawso and Asakraka in the Kwahu South Municipality were interviewed. The data obtained from the survey were summarised using Microsoft Excel.

Three released taro varieties; CRI-'Yenanyawoa', CRI-'Agyenkwa' and CRI-'Asempa', and two accessions; KA019 and BL/SM/80 obtained from the institute's taro multiplication site at Apedwa were evaluated for their tolerance to *Lasiodiplodia theobromae, Aspergillus flavus, Aspergillus niger, Sclerotium rolfsii,* and *Rhizopus* sp. in the laboratory after harvest.

Results: From the survey, 75% of the taro traders obtained their corms directly from farmers, 10% from markets specifically, the Anyinam market. About 15% obtained their corms from both farmers and the Anyinam market. All the traders had challenges as far as the trading of taro corms was concerned. The rot of taro corms was ranked as the main challenge followed by the hardness of the corms when cooked, the unavailability of the corms at times, and conflict between the traders and the farmers. All the traders packed the corms in nylon sacks from the farm or market to their trading points. They only used a knife to remove the roots and mud on the corms designated for sale (Figure 29). The remaining corms were left intact with roots and mud on them. This, according to the taro traders delays the rotting of the corms. Of the 16 traders that stored their corms during the previous year, 93.8% kept the corms on the floor. Out of this, 75%

arranged the corms on the floor, 18.8% heaped the corms on the floor while 6.3% kept the corms on shelves. All the traders (100%) that stored their corms the previous year experienced rot of the corms during storage. The majority of the traders reported that 40-50% of the corms they stored deteriorated in storage.

Figure 29: Bunch of taro corms arranged in plastic bowls

About 89.3% of the interviewed farmers had challenges in the production of taro. The farmers ranked rot of the corms as their major challenge followed by the hardness of the corms when cooked, which affects marketability. From the evaluation of taro genotypes for their resistance to major rot fungi, CRI-'Asempa' and KA019 were found to be moderately resistant while the rest were moderately susceptible.

OUTPUT 1.19: GENERATING VIRUS-FREE CASSAVA ACCESSIONS FOR IN-VITRO CONSERVATION AT THE CSIR-PGRRI

Team: Adams, F. K, Kotey, D. A., Owusu, E. O., Bissah, M. N., Adongo, B. A., Gyasi, E., Mohammed, A., and Bruce, B. B.

Donor : Government of Ghana

Background information and justification: The country, through the national genebank, the CSIR-PGRRI, maintains a collection of 210 cassava accessions. These accessions serve as sources of diversity for the breeding of new varieties that are adapted to current and emerging constraints such as climate change, shifts in cropping systems, and changes in tastes and consumer preferences. The ability of the country to potentially benefit from the adaptation traits and genes inherent in the accessions

conserved at the CSIR-PGRRI is however being threatened by the incidence of Cassava Mosaic Diseases (CMDs). It is therefore highly advantageous to use virus-free cuttings in conservation, multiplication, and cultivation.

Materials and methods: Ten stem cuttings each of 50 cassava accessions maintained in the field genebank were randomly selected and treated with a systemic insecticide with the active ingredient imidacloprid for 30 minutes to kill scales, mealybugs, mites and any other pests before planting in a mixture of soil and compost in small plastic pots. Each plant was labeled with its unique accession number and maintained in an insect-proof screen house (Fig. 30). For a period of six months, the plants were observed in the screen house for the appearance of any viral disease symptom on a weekly basis.

Results: Currently, observation of the plants is still ongoing and watering and hand weeding are done as and when needed. So far, none of the accessions have shown any viral disease symptoms.

Figure 30: Cassava accessions planted and currently being observed at the screen house

Further work for 2023

Observation of the cassava accessions in the screen house will continue. Any viral disease symptom observed will be recorded within this period after which leaf samples will be tested for ACMV, EACMV, and EACMV-Cameroon by Polymerase Chain Reaction (PCR) and CBSVs by Reverse transcriptase PCR. Micro-propagation of the 50 accessions will be done at the tissue culture laboratory of the CSIR-PGRRI. Materials will be subjected to thermo- and chemotherapies and virus-free plants will be conserved in the tissue culture laboratory whereas unclean (virus-infected) plants will be re-established in the screen house to begin the entire cleaning process again.

OUTPUT 1.20: COLLECTING, CHARACTERISING AND CONSERVATION OF VEGETABLE (EGGPLANT, TOMATO, PEPPER) AND CEREAL (MAIZE, RICE) GERMPLASM FROM GHANA

Team: Kotey, D. A., Aboagye, L. M., Boateng, S. K., Bissah, M. N., Tetteh, R., Adu-Amoah, R., Kwateng, Y., Adongo, B. and Abednego, O. M.

Donor: LIMAGRAIN

Background and justification: Crops, including cereals and vegetables are an integral part of diets and livelihoods of people in many parts of the world. In Ghana, while there is the need to increase the yield of these crops to make up for reduced availability of agricultural lands, declining soil fertility, increased incidence of biotic and abiotic stresses as well as rapid population growth, the average yields of cereal and vegetable crops remain low. Addressing the low yields requires the breeding of varieties with good adaptation to the different farming conditions and environments in the country. All breeding efforts are however underpinned by genetic diversity which is largely provided for by the management of *ex-situ* conserved genetic resources in genebanks. The collecting, characterisation, conservation and distribution of crop germplasm is thus essential for enhanced food and nutrition security and livelihoods. In view of this, the CSIR-PGRRI, embarked on germplasm collecting missions from October to December 2022 to collect, conserve and assess landraces, obsolete and modern varieties of eggplant, pepper, tomato, maize and rice for useful traits for direct use, research and crop improvement.

Materials and methods: The collecting of tomato, eggplant, pepper, maize and rice germplasm was undertaken in all the six agro-ecological zones covering the sixteen administrative regions of Ghana. Collecting teams consisted of staff from the CSIR-PGRRI, extension personnel from District Directorates of the Department of Agriculture and researchers with knowledge of the agricultural practices and patterns in specific collecting localities. The expedition to each region was timed to coincide with the harvesting period of the crops of interest. Aside collecting from localities identified through information from various stakeholders (extension staff, farmers, and researchers) as potential hotspots for the occurrence of the targeted species, regular stops were made by team members about every 10 or 20 km. Farmers in these areas were visited in their homes and fields and information on the types of crops and their uniqueness (visual estimation) sought (Figures 32-36). Adequate quantities of healthy fruit or seed

samples were collected, labelled and packaged as necessary following the granting of consent by farmers to collect samples of the crops of interest. A prescribed passport data sheet (Figure 31) was used to collect relevant information from the donors of the germplasm.

COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

PLANT GENETIC RESOURCES CENTER

P. O. BOX 7. BUNSO, GHANA.

COLLECTION DATA

1. Collection Number.....2.Accession No.....

3. Crop Species.....

4.Collector(s).....5. Date.....20.....

6. Country..... 7.Region.....8.District.....

9.Village.....

10.Precise Locality.....

11. Altitude..... 12.Latitude..... 13.Longitude.....

14. Soil & topography.....

15. Precipitation less than 450mm, 451-650mm. 851-900. More than 900mm.

16. Samples source: Field - Garden - Farm-store - Market - Institution - Others

17. Local name.....18.Type/Race etc. .....

19. Ethic group..... 20.Donor's name.....

Donor's source: Own - Local - Market - Other

21. Cultural practices: Rainfed - Irrigated - Flooded - Transplanted

22. Planting period.....23. Harvesting period.....

24. Associated crop: Sole - Mixed - With.....

25. Population variability: Uniform - Low - Medium - High.....

26. Disease.....

27. Insects.....

28. Agronomic score: Very poor - Average - Good - Very good

29. Remarks: (Materials. Uses etc.) ....

.28. Agronomic score: Very poor - Average - Good - Very good

29. Remarks: (Materials. Uses etc.) .....

Figure 31: A data sheet used for recording passport data during germplasm collecting

The germplasm collected was transported to the genebank for processing (i.e. seed extraction, drying, sorting, seed morphology documentation and viability testing). Accessions with viable seed samples were registered and further processed before being stored at -20°C.

Results: A total of 1010 accessions were collected from the 16 administrative regions of Ghana (Figure 32). Compared to collections from other regions, more accessions of eggplant (14% of total), pepper (18% of total) and rice (26% of total) were collected in the Volta region. The highest proportion of tomato (18% of total) and maize accessions were respectively collected in the Western and Bono regions.

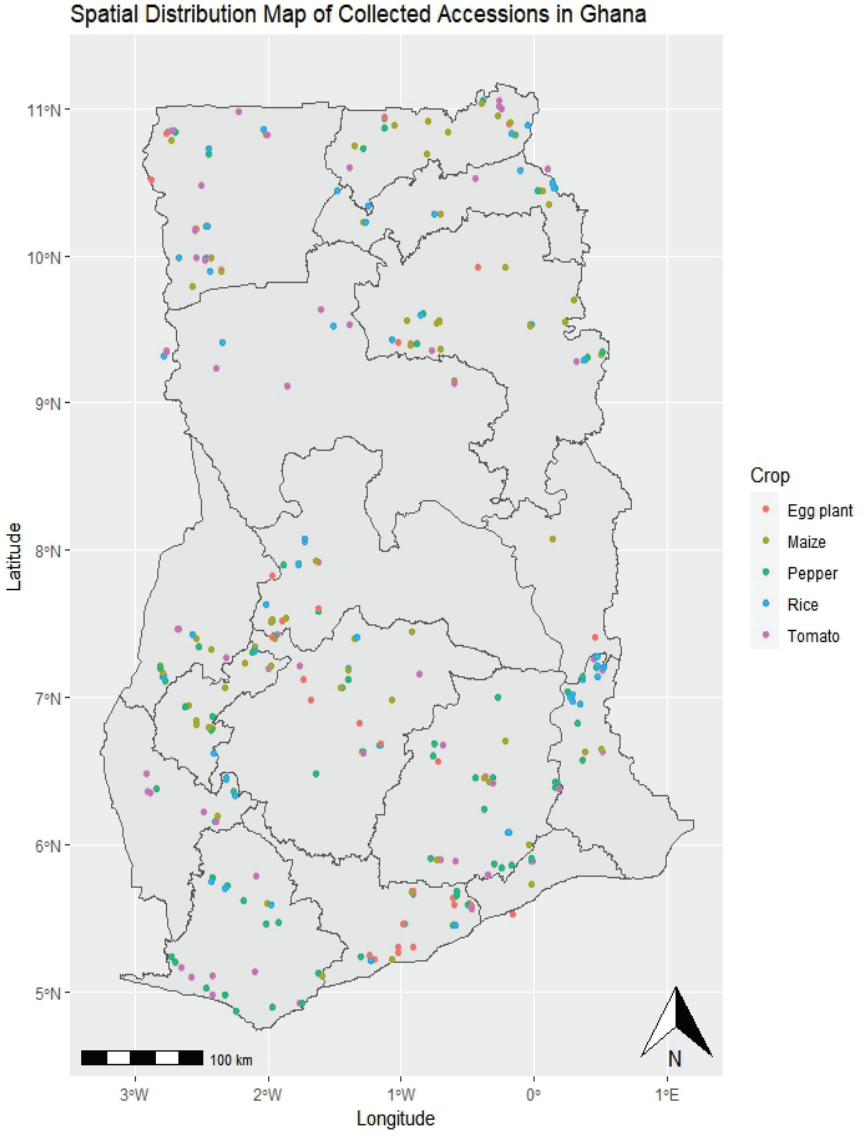


Figure 32: Map of Ghana indicating locations from which crop germplasm were collected

The number per crop species and the initial viability of accessions of each species are presented in Figure 33. In line with the results of the viability tests, a total of 972 collected accessions were registered at the Seed genebank. These include 140 accessions of rice, 212 accessions of maize, 188 accessions of tomato, 300 accessions of pepper and 151 accessions of eggplant.

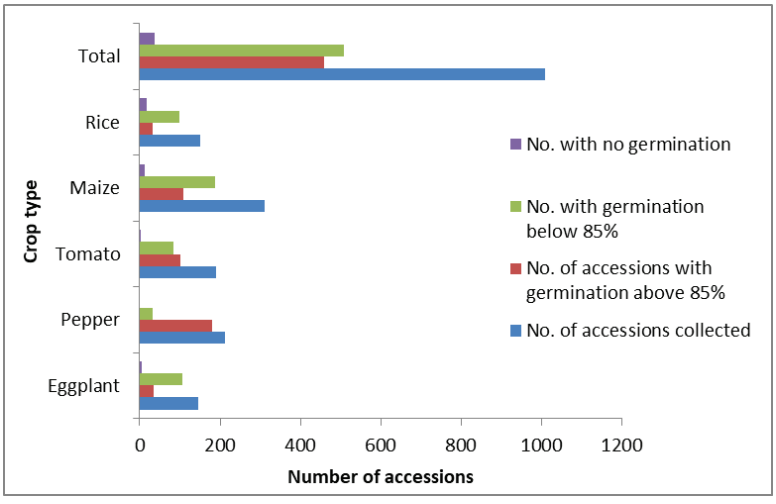


Figure 33: A summary of the total number of accessions collected and their initial viability

(The diversity of the various crops selected are shown in figure 34-37.)

Figure 34: Diversity of tomato germplasm collected

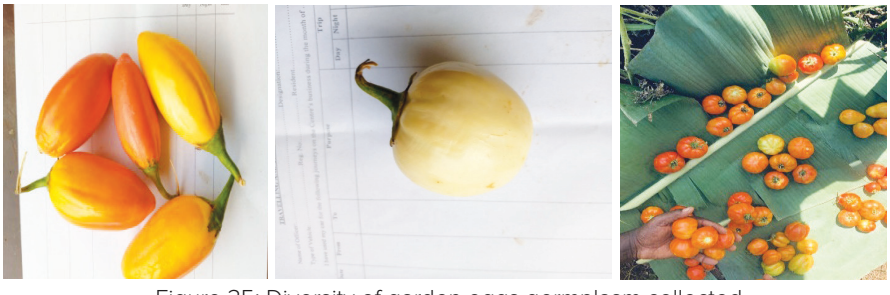


Figure 35: Diversity of garden eggs germplasm collected

Figure 36: Diversity of pepper germplasm collected

Figure 37: Diversity of maize germplasm collected

Figure 38: Germplasm collecting by members of the team to the Bono East region

Figure 39: Rice and maize germplasm collecting in the Northern region

Way forward

Seeds of all viable accessions have been processed for characterisation. As part of this, data on vegetative and reproductive traits will be collected using Bioversity International descriptors for tomato, pepper and eggplant. The passport and morphological data sets will be used to estimate variation and genetic relationship among the collections.

OUTPUT 1.21 GERMPLASM REGISTRATION, VIABILITY, TESTING/MONITORING, REGENERATION, CONSERVATION AND DISTRIBUTION

Research Team: Tetteh, R., Yeboah, A., Bennett-Lartey, R, Sackey, V., Ankomah, M., Huadey, G. and Opoku, M.

Donor: Government of Ghana

Germplasm regeneration: A total of seven hundred and ninety-seven (797) accessions of different crop species were regenerated. Accessions of *Oryza* spp. (130), *Zea mays* (92), ***Capsicum*** spp. (36), *Abelmoschus esculentus* (99), *Vigna unguiculata* (47), *Glycine max* (36), *Arachis hypogaea* (4), *Vigna subterranea* (4) and *Citrullus* sp.(1), *Amaranthus* spp. (108), *Corchorus* spp. (53), *Hibiscus* spp. (145), *Curcubita* sp. (1), *Cleome gyandra* (8) and *Solanum* spp. (33).

Germplasm distribution: A total of seven hundred and ninety-nine (799) accessions of different crop species were distributed during the year. These include *Solanum spp.* (55), *Abelmoschus esculentus* (68), *Vigna subterranea* (27), *Mung bean* (5), *Solanum lycopersicum* (20), *Arachis hypogaea* (13), *Canavalia* spp. (1), *Glycine max* (27), *Ipomoea batatas* (10), *Oryza* spp. (222), *Hibiscus* spp. (112), *Capsicum* spp. (14), *Zea mays* (185), *Cajanus cajan* (13), *Sphenostylis sternocarpa* (20) and *Dioscorea* spp. (7).

Germplasm registration: A total of ninety accessions of different crop species were registered during the quarter. These comprised *Zea mays* (12), *Vigna unguiculata* (6), *Arachis hypogaea* (4), *Sorghum bicolor* (3), *Pennisetum glaucum* (8), *Oryza sativa* (13), *Solenostemon rotundifolius* (5), *Glycine max* (4), *Vigna subterranea* (12), *Abelmoschus esculentus* (3), *Sesanum indicum* (3), *Hibiscus cannabinus* (6), *Amaranthus* spp.(2), *Curcubita maxima* (3) and *Ipomoea batatas* (6).

Germplasm testing: Viability monitoring and testing were conducted on one thousand four hundred and sixty-two (1,462) accessions of different crop species throughout the year. These comprised accessions of *Sphenostylis stenocarpa* (22), *Zea mays* (234),

Vigna unguiculata (234), *Arachis hypogaea* (17), *Sorghum bicolor* (28), *Pennisetum glaucum* (19), *Oryza sativa* (270), *Glycine max* (19), *Vigna subterranea* (16), *Abelmoschus esculentus* (146), *Sesanum indicum (6), Hibiscus cannabinus* (6), *Amaranthus* spp. (27), *Solanum macrocarpon* (2), *Glycine max* (14), *Solanum spp.* (89), *Curcubita* spp.(26), *Corchorus olitorius* (15), *Hibiscus* spp. (35), *Lagenaria* (5), *Solanum lycopersicum* (78), *Capsicum* spp (145), *Phaseolus* spp (2), *Luffa (*2), *Citrullus* spp. (6) and unknown seed (1).

Seed processing: A total of one thousand eight hundred and forty-six (1,846) accessions of different crop species were processed during the year. These include accessions of *Cleome gynandra* (15), *Zea mays* (224), *Vigna unguiculata* (112), *Arachis hypogaea* (17), *Sorghum bicolor* (*30), Pennisetum glaucum* (20), *Oryza sativa* (159), *Glycine max* (20), *Vigna subterranea* (12), *Abelmoschus esculentus* (313), *Sesanum indicum* (7), *curcubita maxima* (3), *Hibiscus cannabinus* (66), *Hibiscus sabdariffa* (58), *Amaranthus spp.* (74), *Solanum* spp. (152), *Curcubita* spp.(17), *Corchorus olitorius* (1), *Lagenaria* spp. (2), *Capsicum* spp. (12), *Sphenostylis stenocarpa* (2), *Citrullus* spp. (7), *Corchorus* spp. (10), *Luffa* spp. (2), *Allium cepa* (1), *Capsicum* spp. (313), *Phaseolus* spp. (2), *Spinacia oleracea* (1), *Solanum lycopersicum* (188), *Curcuma longa* (1), *unidentified* (5) and *Cucumis melo* (1).

Spice processing: Nutmeg seeds and nutmeg mace were processed during the year.

Germplasm conservation: A total of Four Hundred and Forty-seven (447) accessions of different crop species were bagged in aluminium foil packets and conserved in deep freezers at -20°C during the year. These include accessions of *Amaranthus* spp. (125), *Corchorus* spp. (50), *Cleome gynandra* (26), *Zea mays* (12), *Vigna unguiculata* (6), *Arachis hypogaea* (13), *Sorghum bicolor* (6), *Pennisetum glaucum* (12), *Oryza sativa* (65), *Glycine max* (31), *Vigna subterranea* (24), *Abelmoschus esculentus* (21), *Sesanum indicum* (5), *Hibiscus cannabinus* (6), *Curcubita maxima* (3), *Hibiscus cannabinus* (6), *Curcubita maxima* (3), *Capsicum* spp. (15) and *Solanum lycopersicum* (18).

Visit: A total of three hundred and eleven (311) students came for industrial attachment and a familiarisation tour at the seed store section during the year.

SCIENCE AND PEOPLE (S & P)

2.0 Background and highlights of research achievements under the S & P thematic area

Activities under this thematic area were aimed at promoting science and the relevance of plant genetic resources conservation and use to socio-economic and sustainable agricultural development, particularly at the local level to communities, PGR user groups and development partners. This was achieved through training, sensitisation, participatory community projects with a focus on culture, indigenous knowledge, community improvement and education stakeholder engagements and distribution of germplasm to PGR users.

OUTPUT 2.1 STAKEHOLDER ENGAGEMENTS: ENHANCING THE VISIBILITY OF THE INSTITUTE THROUGH EXHIBITIONS, MEDIA INTERACTIONS AND GENEBANK TOURS

By Yaw Kwateng

Team: Kwateng, Y., Nketiah, V., Sakyi, B., Teiko, R. L., Tetteh, R., Nkrumah, S. E., Bosomtwe, A., Boamah, E. D., Mensah, E. O., Effah, Z., Danquah, E. A., Gyasi, E. and Adongo, B.

Donor: GoG/ CSIR-PGRRI

Activity 1: ACHIEVING GHANA BEYOND AID- GSA 18TH BIENNIAL WORKSHOP

The Ghana genebank participated in an exhibition at the Koforidua Technical University, Koforidua as part of the 18th Biennial workshop of the Ghana Science Association on the theme, 'Achieving Ghana Beyond Aid: Positioning TVET to Drive Ghana's Industrialisation in a Post COVID Era'.

The exhibition provided the opportunity to engage and promote the Institute to different stakeholders. Products of the genebank such as flyers for distribution, bagged seeds of legumes and spices, potted planting material (seedlings) and packaged nutmeg were showcased. Visitors to the stand were briefed on the role of the genebank in the conservation and use of forgotten crops such as Pigeon pea (*Cajanus cajan*), Jack bean (*Canavalia ensiformis)* and velvet bean (*Mucuna pruriens var utilis*) for food and nutrition security in the post COVID-19 era. Some of the notable personalities who visited the stand included the Education Minister, Dr. Yaw Osei Adutwum and

the Eastern Regional Minister, Mr. Seth Acheampong. Others included members of the Ghana Science Association, the media, students, farmers, individuals, policy makers, people from the private sector and traditional authorities (Figures 40 – 41).

Figure 40: Education Minister, Dr. Yaw Adutwum visits the genebank stand

Figure 41: Mr. Seth Acheampong (Eastern Regional minister) visits the genebank stand

Activity 2: Commemorating the CSIR-World Food Day celebrations 2022

The National genebank joined other organisations across the length and breadth of Ghana and the world to celebrate the World Food Day, 2022 at the CSIR-Food Research Institute (FRI). The theme for the celebration was 'Safe Food Today for a Better Life Tomorrow".

Figure 42: Banner of the CSIR-World Food Day Celebration 2022

The fair and exhibition organised by the CSIR was aimed at bringing together agro-food processors, food vendors, nutrition and health institutions and other food industry stakeholders to showcase and market their products to the public. The celebration also witnessed a series of presentations related to food and nutrition. Dr. Kwaku Afriyie, the Minster for Environment, Science, Technology and Innovation and Professor Paul Pinnock Bosu, the Director-General of CSIR in their introductory remarks urged scientists to let the world know their contribution to the development of the nation. Ghanaians were also advised to patronise made in Ghana foods to help reduce food imports and thus, food inflation to help boost the Ghanaian economy. Several people visited the stand of the CSIR-PGRRI either to know more about the Institute or to buy products (Figure 43).

Figure 43: Professor Charles Tortoe (Director, CSIR-FRI) visit to the genebank's stand

Activity 3: A call to duty to serve the surrounding local communities

The national genebank plays a crucial role in the development of the nation through the conservation and promotion of the utilisation of plant genetic resources. Also, it contributes to education and awareness creation about PGRs, while ensuring that there is availability of PGRs to facilitate research and breeding programmes, for food security, biodiversity conservation and sustainable development. It is on this premise that the national genebank in collaboration with a local community radio station known as Radio 1, as part of their 'Ghana Akuafo-Green leaf' programme, held a series of interactive radio discussion programmes on issues of importance to sustainable agricultural development (Figure 44). Some of the topics discussed included the management and control of stored product pests, climate-smart agriculture, quality and healthy seeds for planting, pests and diseases of crops and their control. It is estimated that at least 3000 homes within the catchment area of the radio station were reached and sensitised during these broadcasts.

Figure 44: CSIR-PGRRI staff educuating the public and its cherished germplasm users

Activity 4: Educational visits to the National Genebank

Every year, the national genebank, hosts hundreds of visitors, largely from tertiary and second cycle institutions. It also attracts organised farmer groups, private enterprises, individuals and NGO's. Additionally, international scientists and students on research or academic missions including PhD and Master's degree students are also frequent visitors to the genebank.

Some of the reasons for these visits include;

- To learn and know more about the day to day operations of the genebank;
- To learn about the crop diversity and germplasm under conservation; seed genebank, *in-vitro* genebank and field genebank;
- To know more about the research activities and collaborations undertaken by the genebank;
- To have first hand information on the cultivation techniques of some of the crop collections that can be cultivated for commercial purposes;
- To request for germplasm for academic research or collaboration with scientists at the genebank and;
- To acquire practical experience about specific aspects of scientific research.

In total, 311 students were documented to have been hosted by the genebank. They were introduced to the various aspects of the genebank's operations including seed cleaning and drying, seed bagging, seed health testing, seed conservation *in-vitro* and cold storage, tree crops conservation, seed viability testing and documentation. In addition, three PhD students, two from Ghana and one from abroad (Ghanaian student based in the Czech Republic) were attached to the institute.

Figure 45: Students on tour at the national genebank

OUTPUT 2.2 PROMOTING THE CONSERVATION AND UTILISATION OF BAMBARA GROUNDNUT (BGN) AND INDIGENOUS LEAFY VEGETABLES THROUGH GERMPLASM USER GROUPS

By Yaw Kwateng

Team: Kwateng, Y., Kotey, D. A. Bandanaa, J., Etwire, P. M, Adogoba, D. S., Tetteh,R., Aboagye, L. M., Acheampong, P., Agyare, R., Bissah, M. N., Adu- Amoah, R., Attamah, P., Boateng, S. K., Asomani, N. A., Kusi, F., Acheampong, P., and Newton, I.

Donor: The Global Crop Trust (Seeds for Resilience (SfR) Project)

The national genebank seeks, by means of the ILV and BGN germplasm user groups (GUG), to develop a sustainable mechanism for identifying, producing and disseminating seeds of farmer-preferred crop accessions that will diversify varietal options and contribute to resilience to climate change. As part of this, a communication plan to engage germplasm users and promote the conservation and utilisation of Bambara groundnut (BGN) and Indigenous leafy vegetable (ILVs) germplasm was developed and implemented. The overarching goal of the communication plan was to enhance the visibility of the Ghana genebank and highlight its importance in ensuring food and nutrition security, as well as contributing to national development at both local and international levels.

Project activities for BGN are located at Manga, Bugri Bulpieli and Naransaag in the Upper East region (Figure 46). The sites for ILVs are located in the Northern region (Nyankpala, Golinga and Libga) and the Ashanti region (Kwadwo, Boadi and Barekese). As part of communicating germplasm user group activites, farmers were engaged to ascertain their perception, experiences and preliminary observations on the crops being evaluated in their fields and on the whole project concept; which is to allow farmers to plant and evaluate genebank accessions in their own fields and select those that possess traits that address needs that are specific to their farming contexts. Additionally, participatory varietal selection or open days were used to obtain, document and publicise feedback from farmers and other BGN and ILV value chain actors (Figure 47 & 49).

Figure 46: Farmers' BGN varietal selection in Bulpielis in the Upper East region

Figure 47: Focus group discussion with ILV GUG

Figure 48: Radio talk show in radio Tamale

Through these, short documentaries of field activities, focus group discussions, as well as interviews with farmers and researchers were disseminated using electronic, print and social media (Facebook, Twitter and YouTube channels) .

.

Figure 49: ILV varietal selection in Boadi, Kumasi

Figure 50: BGN GUG in action in Bulpielis

It is estimated that at least 150,000 people were reached around the world via the online network promotions and more are being reached by the day. At least 800,000 homes were reached via radio (Figure 48) and TV news broadcasts while at least 10,000 people were reached through the print media. Key indicators of the successs of the project's communications have been evident in the number of contacts of germplasm users, policy makers, the general public and other collaborators to the genebank as well as feedback from farmers on the project.

OUTPUT 2.3: SEEDS FOR RESILIENCE PROJECT (SfR)

By Yaw Kwateng and D. A. Kotey

Team: Kotey, D. A., Aboagye, L. M., Tetteh, R., Kwateng, Y., Antwi, N. A., Bissah, M., Boateng, S. K., Bandanaa, J., and Amoah, R. A.

Donor: The Global Crop Trust

The SfR is a three- year project (2021-2024) which aims to upgrade the equipment, improve the internal processes and staff technical capacity of the CSIR – PGRRI to ensure that it achieves international operational standards and by so doing, enhance the long term conservation and availability of the CSIR-PGRRI's germplasm collection for addressing current and future national agricultural adaptation and industrial utilisation needs. It also seeks to build synergies between the genebank, scientists/ researchers

and farmers to sustain the utilisation of the germplasm conserved to enhance food security and build climate resilience.

As part of the project, some genebank staff participated in capacity building workshops at the IITA, Ibadan, Nigeria and in Nairobi, Kenya (Figures 51 & 52). The workshops covered essential topics in genebank operation including genebank information management systems (e.g. the Grin-Global Community Edition implementation), access and benefits-sharing (ABS), and policies, treaties and conventions regulating the use, collecting, acquisition and transfer of germplasm. Some presentation on farmers' rights, conflict management, standard operating procedures for safety duplication and information management were also made.

Best practices on bio-cultural community protocols and community seed bank models in some African countries such as Madagascar and Benin were also highlighted.

Figure 51 : Participants at the GOAL workshop pay a visit to the World Agroforestry Center (ICRAF) in Nairobi, Kenya

Figure 52: Participants at the ICRAF, Kenya seed genebank

The workshops also captured practical and interactive sessions on ways to advance germplasm user engagements;- sharing experiences of engaging with stakeholders and collaborators in exploring germplasm use; clarifying roles and responsibilities in the evaluation of germplasm with farmers; and dealing with farmers perception in arriving at decisions on trait selection. In addition to the workshops, there were a number of webinars on very important quality management systems topics including safety and health as it relates to genebanks, occupational health and safety for genebanks, safety duplication, regeneration strategies, seed, *in-vitro*; field and cryopreservation: an overview of key steps, facilities, capacities and costs, as well as sessions on Grin Global Community Edition (GGCE) data uploading, labelling and barcoding, and GGCE germplasm distribution.

During the year under review, some international genebank experts visited the institute as part of the SfR Project to support and buid the capacity of staff of the Ghana genebank. Most notably, there was a hands-on quality management system (QMS) session on seed viability testing, regeneration, safety duplication, seed health testing, documentation, seed, *in-vitro,* field and cryopreservation, germplasm distribution and acquisition (Figure 53). Consultative sessions (farmers, extensionists, genebank staff, breeders from other research and academic institutions and other stakeholders) facilitated by a consultant engaged by the Crop Trust were also held in the two districts each in the Ashanti, Northern and Upper East Regions to lay the foundation for germplasm user engagement activities in these areas.

Figure 53: Scenes from the QMS intensive sessions with Janny van Beem

Figure 54: Group photo of QMS workshop participants

In conclusion, the capacity building component of the SfR Project is gradually beginning to transform the way procedures are undertaken at the national genebank. Specifically, there has been a tremendous shift in the documentation and sharing of germplasm information, clearing of seed viability testing and regeneration of backlogs.

OUTPUT 2.4 FARM MANAGEMENT

Team: Mensah, A. O. T, Owusu, O., Osae, E., Obeng, K. and Yeboah, E.

Donor: CSIR-PGRRI

The Farm Management section undertakes the maintenance of field genebanks, research fields, plantations and the office compounds as well as the regular harvesting of oil palm, dry coconut and *Garcinia cola* fruits (Table 15) at the Institute's plantations and field genebanks. The main activities undertaken during the year included the maintenance of research fields and plantations, demarcation of farmlands which included all the citrus fields and some oil palm fields, allocation of plots for research purposes, allocation of labour for all field activities and the establishment of new rambutan fields at the old nursery.

Table 15: Fruits harvested from the plantations and fields of the CSIR-PGRRI in 2022

Crop	Quantity
Oil Palm	81,926 kg
Dry Coconut	5633 fruits/nuts
Garcina cola	191 fruits

3.0 COMMERCIALISATION DIVISION

The Division is responsible for the generation of funds through the marketing of research by products to the public. The activities undertaken in line with this includes;

- The production and sale of planting material and farm produce
- The provision of consultancy and other services.
- Research and development activities.

OUTPUT 3.1 CONSULTANCY SERVICES, TRAINING AND AWARENESS CREATION

By Yaw Kwateng

Team: Kotey, D. A., Aboagye, L. M., Tetteh, R., Bissah, M. N., Boamah, E. D., Nketiah, V., Bandanaa, J., Kwateng, Y., Owusu, E.O. and Nkrumah, S. E.

Activity 1: COLLECTING OF CROP GERMPLASM: MOP UP EXERCISE

The mandate of the national genebank primarily is to collect and conserve plant genetic resources and prevent their extinction. This is very vital in ensuring sustainable agricultural development and food security for the nation. Collecting of germplasm from around the country and abroad is a major activity which needs to be carried out on a regular basis. However, this has not been the case due to lack of sustainable funding leading to periodic collecting gaps or extended breaks. On the other hand, with new staff being employed as the old and experienced staff exit, knowledge gap in this critical area is created. Between 2015 and 2021, it was noted that only one major collecting mission focused on Crop Wild Relatives had taken place with a small fraction (17 percent) of the staff currently at post having any practical experience or being part of germplasm collecting teams in the past. Therefore, as part of the LIMAGRAIN project which sought to collect five major crops namely eggplant, tomato, pepper, maize and rice from all the 16 regions of Ghana, a two-day training workshop was organised for staff on crop germplasm collecting. The training was aimed at enhancing the knowledge base, skills and understanding of staff in germplasm collecting through a hands-on experience. It also paved the way for some experienced staff of the institute as well as two international experts from the Crop Trust to impart their knowledge and experiences through online webinars (Figures 55 and 56).

Figure 55: Presentations on germplasm collecting and community entry approaches

Key highlights of the presentations included preparation and processes involved in germplasm collecting; community entry approaches and protocols; risk assessment in germplasm collecting; diseases and pests associated with germplasm collecting and how to handle them; and appropriate techniques for handling seeds, seed filing, documentation, registration and conservation of germplasm.

Figure 56: An international expert sharing his experiences on germplasm collecting via zoom

As part of the practical session of the training, genebank staff embarked on a mock germplam collecting exercise at Begoro in the Fanteakwa North District of the Eastern Region. A farmer's field measuring about 2 ha and cultivated to multiple crops was

randomly selected and used. Prior consent from the farmer was obtained through the Fanteakwa North District Department of Agriculture. The staff were put into groups of five, provided with collecting logistics including apron bags, passport data sheets, masking tapes, permanent markers, labels and GPS devices and tasked to collect unique samples of crop germplasm within specific areas of the farm (Figure 57 & 58).

Figure 57: Pepper germplasm collecting mission on a farmer's field in Begoro.

A session on protocols for preparing germplasm for registration and conservation at the seed genebank was carried out upon return from the field.

Feedback at the end of the training indicated that the expectations of staff were met and their level of confidence was raised.

Figure 58: CSIR-PGRRI pepper germplasm collecting mission team 2022.

Activity 2: WEBSITE MANAGEMENT TRAINING AND USER AGREEMENT TESTING

The website of the national genebank has been re-designed and its content is constantly being improved. To acertain if the website meets the required specifications given to the developer, a two-day staff training workshop was organised at Bunso. Aside conducting a user agreement test, the training sought to equip staff with the skills to be able to update the website content as well as resolve remotely, minor issues relating to the proper functioning of the website (Figure 59).

Figure 59: Website management training session with staff of the genebank

At the end of the two-day training, the website was accepted as meeting the required specifications as demanded from the developers (CSIR-INSTI). Staff participants were also equipped with the skills to update content and maintain the website.

Activity 3: 'KOBO'-COLLECT TRAINING

A one day training workshop was organised to sensitise research and technical staff on the use of the 'Kobo' Collect data collection application (App) for field data collection particularly, agro-morphological data. Staff were taken through the various steps involved in the use of the application including registration, data entry, storage and retrieval (Figure 60).

Figure 60: Kobo–collect training

At the end of the training, a 'Kobo'-Collect training manual was developed for staff to serve as a guide. At least five scientists and their technical officers were equipped with the skills to use the application for data collection.

Activity 4: TRAINING ON INTEGRATED MANAGEMENT OF MANGO FRUIT FLIES AND MANGO STONE WEEVILS

A two- day training workshop on integrated management of mango fruit flies was organised for about 27 commercial farmers in the Upper East and Savannah Regions of Ghana by the Agriculture and Finance Consultants (AFC) which included an entomologist from the Ghana Genebank (Figure 61).

Figure 61: Workshop on integrated management of mango fruit flies and mango stone weevils

The workshop was aimed at building the capacity of farmers on ways to manage mango stone weevil and fruit fly infestation in their orchards. Farmers were taken through the various stages of the life cycle of the two insect pests as well as some cultural practices that mitigate infestation, early detection, effective control mechanisms and management of the pests. On-farm demonstrations were also undertaken as part of the training.

Activity 5: PESTICIDE APPLICATION AND HANDLING TRAINING

A one-day training on pesticide application and handling was organised by the Plant Protection Division of the CSIR-PGRRI for staff especially research scientists, principal technologists and technical officers. The training sought to educate staff on pesticide use and application as well as health and safety issues related to pesticide use and handling, biological impacts and effects to the environment and micro-organisms, product label information among others (Figure 62).

Figure 62: Staff analysing pesticide information on the bottle label

OUTPUT 3.2: INTERNALLY GENERATED FUNDS

Research team: Nketiah, V. and Sakyi, B.

The sale of tree crop seedlings (mango, avocado, oil plam, nutmeg, rambutan) and farm produce from oil palm, coconut, rambutan and nutmeg contributed significantly to Internally Generated Funds (IGF) (Table 16).

Table 16: IGF from seedlings, farm produce and other services

ITEM	INCOME (GH¢)
Seedlings	214,699.00
Farm produce	112,474.10
Consultancy and Other services	40,545
Total	**367,718.10**

Table 17: Cumulative performance of internally generated funds for year 2022

Details	Quarter one	Quarter two	Quarter Three	Quarter four
Inflow (GH¢)	55,704.80	142,150.90	82,904.00	86,958.40
Outflow (GH¢)	12,451.36	59,531.56	33,264.24	28,049.00
Net income (GH¢)	43,253.44	82,619.34	49,639.76	58,909.40

4.0 ADMINISTRATION DIVISION

By Mrs Awurama Andoh

4.1 Introduction: The Administration Division is responsible for the control and implementation of corporate policies, planning, monitoring of institutional programmes and activities in support of office operations. This report gives an overview of administrative activities for the period under review.

4.2 Staff Strength: The total staff strength as of 31st December 2022 was 131

The breakdown is as follows:

Senior Members - 36

Senior Staff - 39

Junior Staff - 56

4.3 Recruitment: Eleven staff members comprising six (6) Senior staff and four (4) Junior Staff were recruited during the period as follows;

No.	Name	Grade	Effective Date
1.	Ruby Bennett - Lartey	Technical Officer	15th July 2022
2.	Richmond Agyekum Agyei	Technical Officer	15th July 2022
3.	Jerry Richmond Ansah	Technical Officer	1st August 2022
4.	Larweh Sordji	Technical Officer	1st August 2022
5.	Solomon Edwin Nkrumah	Administrative Assistant	15th July 2022
6.	Christina Afua Appiah	Administrative Assistant	1st August 2022
7.	Emmanuel Asare Danquah	Snr. Technical Assistant	1st September 2022
8.	Isaac Boadu	Snr. Marketing Clerk	1st September 2022
9.	Philemon Majesty Abah	Technical Assist. Gd. I	1st August 2022.
10.	Edmond Boateng Sarpong	Overseer	1st August 2022
11.	Nicolas Donkor	Labourer	1st September 2022

Staff Training

No.	Name of Staff	Progrmme	Duration
1.	Barko Labantey	BSc. Sustainable Agriculture	4 years
2.	Collins Owusu	MBA (HRM)	2 years
3.	Esther Ofori Armah	MBA (logistics Chain and Supply Management)	2 years
4.	Sule Alhassan	BSc. Agriculture	4 years
5.	Abdul Mohammed	MPhil. Agronomy	2 years
6.	Emma Biriwa	MBA Accounting and Finance	2 years
7.	Shine Anku	MBA (HRM)	2 years
8.	Augustine Bosomtwe	PhD Entomology	4 years

4.5 Completion of Study leave and Resumption of Duty

No.	Name of Staff	Progrmme pursued	Institution	Date of Resumption
1.	Dr. Zechariah Effah	PhD. Agronomy	GANSU Agric. Univ	15th June 2022
2.	Benjamin Sakyi	B'Tech (Marketing)	Koforidua Techn. Univ.	15th Oct. 2022

4.6 Meetings: Meetings that took place during the period under review are:

Type of Meeting	No. of meetings
Management Board	2
IMC	4
Heads of Division	4
General meeting	4

4.7 Industrial Attachment and National Service

There were one hundred and one (101) students from various Universities and Polytechnics who undertook Industrial attachment and National Service at the Institute.

4.8 Retirement

Five (5) staff members proceeded on compulsory retirement from the service of the Council as indicated below:

No.	Name of Staff	Grade	Date of Retirement	Length of Service
1.	Dr. Lawrence M. Aboagye	Chief Res. Scientist	24th Jan. 2022	35 years
2.	Dr. Samuel K. Boateng	Prin. Res. Scientist	6th August 2022	25 years
3.	Sangmor Edward Adams	Snr. Security Officer	10th March 2022	30 years
4.	Stephen Boakye	Snr. Technical Assist.	24th June 2022	16 years
5.	Kingsley Konadu	Overseer	14th Jan. 2022	37 years

4.9 Staff Transfer: Mrs Awurama Nti Andoh was transferred from the CSIR-Forestry Research Institute of Ghana to the CSIR-Plant Genetic Resources Research Institute on Ist November, 2022

4.10 Estate Section: The Section renovated three (3) bungalows and nine (9) offices of the Institute under the reporting period.

4.11 Security Section: Effective controls of our duty posts and patrols of the Institute's plantations were ensured and commendably managed.

5.0 FINANCE DIVISION

By Peterson Dacosta Opoku

5.1 The role of the Finance division include;

- Collection of accounting data, analysis, classification, presentation and interpretation for decision making.
- Provide suitable financial information to management for the daily management of the Institute.
- Assist in short and long-term planning
- Help establish internal control measures to safeguard assets of the institute and ensure the completeness, accuracy and reliability of financial reports.
- Liaising with both Internal and External Auditors in the annual auditing process
- Forecasting of annual and quarterly internally generated funds by the institute
- Management of accountable imprest granted to staff; (staff debtors)
- Prepare an annual budget for the institute.
- Prepare quarterly and annual financial reports (GoG, IGF and donor)
- Respond to audit findings and implementation of audit recommendations for both internal and external audit reports.
- Prepare CAGD inputs forms etc.

5.3: Summary of financial report 2022 GoG budgeted and actual

	Budgeted GH¢	Approved GH¢ A	Funds released GH¢ B	Variance GH¢ c
Compensation of Employee	7,254,200.00	6,605,075.00	5,938,257.66	666,817.34
Goods and Services	235,000.00	39,784.00	3,676.80	36,107.20
CAPEX	-	-	-	-
TOTAL	**7,489,200.00**	**6,644,859.00**	**5,941,934.46**	**702,924.54**

5.4 IGF 2022

Quarter	Budget revenue GH¢	Actual revenue GH¢ A	Actual Expenditure GH¢ B	Variance GH¢ A-B
1ST	90,000	76,746.80	85,707.65	-8,960.85
2nd	280,000	233,148.90	106,987.20	126,161.70
3rd	260,000	216,644.26	257,618.57	-40,974.31
4th	90,000	121,256.18	153,043.98	-31,787.80
TOTAL	**560,000**	**647,796.14**	**603,357.40**	**44,438.74**

5.5 Donor Projects 2022

S/N	Name of Donor / Project	OPENING BALANCE 2021 GH¢	GRANT RECEIVED GH¢	EXPENSES GH¢	BALANCE AS AT 31/12/22 GH¢
1	MAG/CRI	1,200.00	34,945.50	24,477.59	10,467.91
2	SFR PROJECT	316,877.32	-	329,377.32	-12,500
3	VILMORIN & CIE	-	375,500.00	351,388.57	24,111.43
	Total	**318,077.32**	**410,445.50**	**705,243.48**	**22,079.34**

6.0 DOCUMENTATION, COMMUNICATION AND INFORMATION MANAGEMENT

By Yaw Kwateng

Grin-Global Community Edition(GGCE): Training on the use of the GGCE intensified with a focus on uploading data onto the GGCE platform. At least, one training session each month was carried out online, predimoninantly, on how to upload data onto the GGCE including inventory and viability data. Other practical sessions also covered topics such as the GGCE inventory maintenance policy (IMP) and barcode labels. The GGCE curator tool (Old version) was paired with the Ghana Instance (Live in the cloud) and the Ghana Instance (Demo used at the GOAL workshop in Nairobi) to allow for easy data transfer from the old version to the Ghana Instance (which is due to expire in June, 2023). Passport information on about 1,857 accessions were transferred to the GGCE Ghana Instance. The IMP was set for legume and cereal crop germplasm and about 10 accessions comprising pigeon pea (*Cajanus cajan*) and rice (*Oryza sativa*) inventory data were added.

Genesys: In total, Multi-Crop Passport Data (MCPD) of 1,857 accessions including legumes, cereals, vegetables, roots and tubers and crop wild relatives was published on Genesys and assigned digital object identifiers (DOIs). The Passport Data Completeness Index (PDCI) score for the published information was 6.49 with 7.25 being the maximum score and 0.95, the minimum.

In addition, two webinars for data managers were carried out on topics including, the introduction to Genesys and MCPD, and SfR Genesys PDCI reporting. The staff of the genebank also contributed to a blog,

What does it take for a genebank to go online? (genesys-pgr.org), on the Genesys website.

Data management Community of Practice (CoP): It is a platform for data managers, I.T. experts and researchers across the globe to discuss cross sectoral issues related to data management through the use of genebank information systems for crop diversity data collection, documentation and dissemination. The genebank was invited to join the group and about four meetings were attended online throughout the year. The Data Management CoP has served as a useful platform to build a network for genebank experts to share experiences and to build each other's capacity.

Website: The CSIR-PGRRI re-launched its re-designed website after a user agreement testing (UAT) was undertaken. The website domain name is www.csir-pgrri.org.gh and it is hosted by the parent organisation, the CSIR-corporate- www.csir.org.gh. The website was re-designed to include more features, and enable the updating of germplasm information as well as allow the uploading of audio-visual content relevant to effectively communicating the activities of the genebank. New features include the CSIR-PGRRI social media platforms such as twitter (https://twitter.com/CsirPlant), Facebook(https://web.facebook.com/CSIR-Plant-Genetic-Resources-Research-Institute-33861824720696), Instagram (www.instagram.com/csir_pgrri) and YouTube (www.youtube.com/channel/UCbaRPw-3C-JlqUXQgrGITLA). Other features such as Flickr (https://www.flickr.com/photos/195655059@N08/) and links to the CSIR-PGRRI's germplasm information on Genesys (https://www.genesys-pgr.org/wiews/GHA091) and the Global Biodiversity Information Facility (https://www.gbif.org/search?q=pgrri) have also been introduced.

Communication: Some of the key communication activities for the year under review are summarised below;

Video documentary involving field interviews of farmers and scientists on Bambara groundnut was produced. The documentary covered the on-station trials in Manga, Mother and Baby trials at the community level (Bugri Bulpieli- Tempane district; Naransaag in the Binduri district of the Upper East region). Production was aired on Joy news and an article published online.https://www.youtube.com/watch?v=QXGe2ujdCA,https://www.myjoyonline.com/csir-pgrri-introduces-farmer-varieties-of-bambara-groundnuts-for-trials-by-farmers-in-upper-east/

Live radio broadcast was carried out on Radio Tamale to create awareness on the SfR Project which was aimed at reaching and engaging the people of Tamale and its immediate environs. fb.watch/fpn1tnTqHe

Media coverage on user group engagement of Farmers' varietal selection trials in Kumasi was captured by the Ghana News Agency and published online. http://newsghana.com.gh/csir-pgrri-promoting-cultivation-of-indigenous-leafy-vegetables/

Flickr: - Photos of on-station and mother trials of Bambara groundnut in Manga in the upper East region and Indigenous Leafy Vegetables in Boadi in the Oforikrom Municipality of the Ashanti region were uploaded on CSIR-PGRRI Flickr page.

Social media: Dr. Janny van Beem of the Crop Trust's visit to the institute garnered the highest impressions on twitter while the Limagrain project mop up germplasm collecting exercise at Begoro received the highest engagement, reaching a lot more

people on Facebook with majority of them being students. Followers of the genebank social media handles increased by more than 30 percent of the following year which suggest that more people were reached and sensitised on the genebank's activities and key messages.

APPENDIX I: Workshops, conferences, meetings, exhibitions and seminars attended

Workshops:

1. **Kotey, D. A., Tetteh, R., Kwateng, Y., Bissah, M. N., Amoah, R. A.,** Acheampong, P. and Etwire, P. M. participated in a Genebank Operations and Advanced Learning (GOAL) workshop organised by Crop Trust as part of the Seeds for Resilience (SfR) Project from 6th- 10th May, 2022 in Nairobi, Kenya.

2. Tetteh, R. and Amoah, R. A . participated in a Data workshop organised by Crop Trust as part of the Seeds for Resilience Project at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, from 25th to 28th April, 2022.

3. Kwateng, Y., Osei-Kofi, P.S., Kotey, D. A Nkrumah, S. E. participated in a workshop on Biodiversity Data Mobilisation organised by A Rocha Ghana on 28th July, 2022 at he CSIR-PGRRI conference room. In addition, a follow-up virtual workshop was organised by A Rocha Ghana on 28th September, 2022 on the same subject as part of the Global Biodiversity Information Facility data capture training.

4. Bruce, B. B. participated in a training workshop on molecular techniques for crop improvement of mutant populations at the Ghana Atomic Energy- Biotechnology and Nuclear Agriculture Research Institute, Accra from 3rd to 7th October, 2022.

5. Bissah, M.N. participated in a workshop on molecular techniques for crop improvement of seed crops at the Ghana Atomic Energy Commission- Biotechnology and Nuclear Agriculture Research Institute, Accra from 7th to 11th November, 2022

6. All senior members of the CSIR-PGRRI participated in an online training on proposal writing for European Union Horizon projects on 13th July, 2022.

7. All staff participated in the training on pesticide application and handling which was organised by the Plant Protection Division of the National genebank (CSIR- PGRRI) on 27th April, 2022 at the CSIR-PGRRI conference room.

8. Boamah, E. D. participated in a training workshop from 5th to 6th October, 2022 as a resource person to train farmers on integrated management of mango fruit flies and mango stone weevils in the Upper East and Savannah regions of Ghana.

9. Adams, F. K. and Bonsu B. B. attended a training workshop on molecular detection of Cassava Mosaic Viruses by the West Africa Virus Epidemiology (WAVE) at the CSIR-Crops Research Institute, Kumasi.

10. Kwateng, Y. participated in the virtual training of the Right to Information (RTI) as the CSIR-PGRRI's focal person.

11. Kwateng, Y., Nkrumah, S. E., Danquah, E., Bissah, M. N., Adu, R. A., Bandanaa, J., Asitoakor, B. K., Bosomtwe, A., Anku, S., Sackey, V and Bruce, B. B. participated in a website management training organised on 28th August, 2022 at the CSIR-PGRRI conference room as part of the implementation of the Seeds for Resilience (SfR) communication plan.

Conferences:

Mensah, E. O., Rabild, A., Asare, R., Amoatey, C. A., Markussen, B., Owusu, K., **Asitoakor, B. K.,** Vaast, P. (2022). Eco-physiological responses of adult cocoa plants to shade and water suppression. Quebec City, Canada: 5th World Congress on Agroforestry (July 17 – 20, 2022).

Mensah, E. O., Rabild, A., Asare, R., Amoatey, C. A., Markussen, B., Owusu, K., **Asitoakor, B. K.,** Vaast, P. (2022). Effect of shade on eco-physiology of cocoa under stress conditions. Accra, Ghana: CocoaSoils workshop on reconciling different objectives in cocoa landscapes from national to local levels: identifying research needs (April 26 – 27, 2022).

Meeting:

Owusu, E. O and Bissah, M. N. participated in Research Extension and Farmer linkage Committee (RELC) in Kyebi at the Abuakwa South Municipality on 13th July, 2022.

Exhibitions:

The CSIR-PGRRI participated and exhibited at the 18th Biennial workshop of the Ghana Science Association at the Koforidua Technical University in Koforidua on 12th October, 2022.

The CSIR-PGRRI participated and exhibited at the World Food Day celebration at the CSIR-Food Research Institute, Accra between 13th and 14th October, 2022.

APPENDIX II: Staff publications

Staff publications for 2022

Book Chapter

1. **Ochar, K.,** Lili, Y., Bo-hong, S., Ming-ming, Z., Zhang-Xiong, L., Hua-wei, G., Lamlom, S, F. & Li-juan, Q. (2022). Genetic improvement of minor crop legumes: Prospects of De Novo domestication. IntechOpen Legumes Research- Volume 1.

Refereed Journals

2. Adjei, E. A., Banful, B. K., Asiedu, E. A., **Amoah, R. A.**, Arthur, M., Yeboah, S. and Asibuo, J. Y (2022). Interactive Effects of Moisture Content and Packaging Material on Common Bean Seed Yield and Yield Components. *Journal of Experimental Agriculture,* DOI: 10.9734/JEAI/2022/v44i630830

3. **Asitoakor, B. K.**, Asare, R., Ræbild, A., Ravn, H.P., Eziah, Y.V., Owusu, K., **Mensah, . E.O.** and Vaast, P. (2022). Influences of climate variability on cocoa health and productivity in agroforestry systems in Ghana. *Agricultural and Forest Meteorology*, 327 (109199). 1 – 13. https://doi.org/10.1016/j.agrformet.2022.109199

4. **Asitoakor, B.K.,** Ræbild, A., Ravn, H.P., Vaast, P, Eziah, Y.V., Owusu, K., Mensah, E.O. and Asare, R. (2022). Selected shade tree species improved cocoa yields in low input agroforestry systems in Ghana. *Agricultural Systems.* 202 (103476). 1 – 9. https://doi.org/10.1016/j.agsy.2022.103476

5. **Bissah, M. N., Kotey, D. A.**, Egbadzor, K. F., Tongoona, P., Gracen, V., and Danquah, E. Y., (2022). Factors influencing rice production in coastal ecology of Ghana. *Heliyon*, 8 (12) e12404. Obtainable from https://doi.org/10.1016/j.heliyon.2022.e12404.

6. Egbadzor, K. F., Ansah, S., **Siamey, J**. and **Kotey, D. A**. (2022). Assessment of citrus diversity in Ghana. African *Crop Science Journal*, 30 (4): 429-440.

7. Filho, W. L., Lange S. A., Vasconcelos, C. R. P., Anholon, R., Rampasso, I. S., Paulino, J. H., Eustachio, P., Liakh, O., Alzira, M., Dinis, P., Olpoc, R. C., **Bandanaa, J.,** Aina, Y. A, Regine Lolekola Lukina, R. L., and Sharif, A. (2022) Barriers to institutional social sustainability https://doi.org/10.1007/s11625-022-01204-0 *Sustainability Science* (2022) 17:2615–2630. IR3S IGES

8. Gyasi, E., Akrofi, S., Adongo, B. A., Osafo, E. A., Kotey, D. A. and Mohammed, A. (2022). ''Fungi associated with sweet potato tuber rot at CSIR-PGRRI, Bunso-Eastern Region, Ghana''. *Ghana Journal of Agricultural Science*, 57(1): 106-112.

9. Gyasi, E., Kotey, D. A., Adongo, B. A., Adams, F. K., Owusu, E. O. and Mohammed, A. (2022). Management of major seed-borne fungi of cowpea (*Vigna unguiculata L. Walp*) with four selected botanical extracts. *Advances in Agriculture*. Obtainable from doi.org\\10.1155\2022\3125240.

10. Heidenreich, A., Grovermann, C., Kadzere, I., Egyir, I. S., Muriuki, A., **Bandanaa, J.** and Schader, C. (2022). Sustainable intensification pathways in Sub-Saharan Africa: Assessing eco-efficiency of smallholder perennial cash crop production. *Agricultural Systems*, 195, 103304.

11. Mensah, E. O., Asare, R., Vaast, P., Amoatey, C. A., Markussen, B., Owusu, K., **Asitoakor, B. K.** and Ræbild, A. (2022). Limited effects of shade on physiological performances of cocoa (*Theobroma cacao L.*) under elevated temperature. *Environmental* and *Experimental Botany*, 201: 104983.

12. Ochar, K., Su, B., YU, L., Zhou, M, Liu, Z., Gao, H., Sobhi F. L., and Qiu, L. (2022). Genetic improvement of minor crop legumes: Prospects of de novo domestication: In J. C. Jimenez-Lopez, and A. Clemente (Eds.), *Legumes Research*, 1, IntechOpen Access publishers. Retrievable from https://www.intechopen.com/chapters/80717.

13. Tetteh, R., Aboagye, L.M., Boateng, S.K., Darko, R., Obirih-Opareh, J. and Ibrahim, A.A. (2022) . Variation in physiological seed quality of eggplant cultivars in relation to seed extraction time. *Vegetos*. https://doi.org/10.1007/s42535-022-00504-1

14. Tetteh, R., Aboagye, L.M., Osafo, E.A., Darko, R., Dassah, A. and **Obirih-Opareh, J.,** (2022). Effect of tree age on fruit characteristics, seed emergence and seedling growth in Rambutan (*Nephelium lappaceum L.*). *Journal of Horticultural Sciences* 17:245-248.

15. Vernet, A., Meynard, D., Lian, Q., Mieulet, D., Gibert, O., **Bissah, M. N.,** Rivallan, R., Meunier, A. C., Frouin, J., Taillebois, J., Shankle, K., Khanday, I., Mercier, R., Sundaresan, V., and Guiderdoni, E. (2022). High-frequency synthetic apomixis in hybrid rice. *Nature Communications,* 13:7963. Obtainable from https://doi.org/10.1038/s41467-022-35679-3

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Technical reports

1. Acheampong, P., Etwire, P. M., Adogoba, D. S., Boakye Boateng, Agyare, R. Y, A., **Tetteh, R., Aboagye, L. M., Kwateng, Y., Bissah, M. N., Bandanaa, J.,** Attamah, P., **Boateng, S. K., Asomani N.A.**, Kusi, F. and **Kotey, D.A.** (2022). Stakeholder analysis of indigenous leafy vegetables in Ghana. A Report Submitted to the Global Crop Diversity Trust by the CSIR-Crops Research Institute (CRI), the CSIR-Savannah Agriculture Research Institute (SARI) & the CSIR-Plant Genetic Resources Research Institute (PGRRI) as Part of the Seeds for Resilience (SfR) Project. CSIR-PGRRI/CR/PA/2022/3

2. Acheampong, P., Boakye Boateng, A., **Tetteh, R., Aboagye, L. M.**, **Kwateng, Y.**, **Bissah, M. N., Bandanaa, J., Amoah, R.A., Boateng, S. K., Asomani, N.A. and Kotey, D. A.** (2022) Indigenous Leafy Vegetables User Group Engagement in the Ashanti Region. A Report Submitted to the Global Crop Diversity Trust by the CSIR-Crops Research Institute (CRI) & the CSIR-Plant Genetic Resources Research Institute (PGRRI) as Part of the Seeds for Resilience (SfR) Project. CSIR-PGRRI/CR/PA/2022/4

3. Amissah, A. A., Sackey, V., Osei, Y. C., Yeboah, A., and Amoah, R. (2022). Effect of scarification on germination of Bambara groundnut and seedling development. CSIRPGRRI/TR/AAA/2022/112. CSIR-PGRRI.

4. Bissah, M. N., Dzokoto, C., Ansah, J. R., Amissah, A. A., Gyasi, E., Ochar, K., and Kotey, D. A. (2022). Phenotypic diversity of *Corchorus spp*. in Ghana. CSIR-PGRRI/TR/BMN/2022/114.

5. Etwire, P. M., Adogoba, D. S., **Tetteh, R., Aboagye, L. M., Kwateng, Y., Bissah, M. N., Bandanaa, J.,** Attamah, P., **Boateng, S. K., Asomani, N. A**., Kusi, F., and **Kotey, D. A.** (March, 2022). Stakeholder analysis and participatory rural appraisal: The case of Bambara groundnut in the Upper East Region. A Seed for Resilience Project. Report Submitted to the Crop Trust. CSIR-PGRRI/CR/PEM/2022/5

6. Etwire, P. M., Adogoba, D. S., **Tetteh, R., Aboagye, L. M., Kwateng, Y., Bissah, M. N., Bandanaa, J., Amoah,R.A., Kotey, D. A.** and Attamah, P. (2022). Facilitation of Indigenous Leafy Vegetables (ILVs) and Bambara Groundnut User Groups in Northern Ghana. CSIR-PGRRI/CR/PEM/2022/6

7. Sackey, V., Adongo, B. A., Owusu, E. O., Amissah, A. A., Yeboah, A., Osei, Y. C. and Kotey, D. A. (2022). Effect of different organic substrates on seed germination and seedling performance of nutmeg (*Myristica Fragrans*). CSIRPGRRI/TR/SV/ABA/OEO/AAA/YA/OYC/KDA/2022/115

8. Sackey, V., Adongo, B. A., Owusu, E.O., Amissah, A. A., Yeboah, A., Osei, Y. C., and Kotey, D. A. (2022). Effect of different organic substrates on seed germination and seedling performance of nutmeg. PGRRI/TR/SV/2022/115.

9. Tetteh, R., Aboagye, L. M., Darko, R. and Obirih-Opareh, J. (2022). Effect of seed coat colour on seed quality of four cowpea accessions CSIR-PGRRI/TR/RT/2022/108.

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11. Yeboah, A., Tetteh, R., Amissah, A. A., Osei, C. Y., Sackey, V. and Kotey, D. A. (2022). Preliminary evaluation of hydropriming on seed germination enhancement and seedling growth of four *Corchorus olitorious* L. accessions. CSIR-PGRRI/TR/YA/2022/110.

Handbooks

1. Bissah, M. N., Essilfi, I., Bandanaa, J., Amissah, A.A., Gyasi, E. & Kotey, D. A. (2022). Photo album of rice genetic resources in the seed genebank.

2. Tetteh, R., Kotey, D. A. & Aboagye, L. M. (2022). Notes on some indigenous leafy vegetables at the national genebank, Ghana. CSIR-PGRRI/HB/TR/2022/13, 19pp

Manuals

3. Bissah, M. N., Kotey, D. A., Adu-Amoah, R., Aboagye, L. M. & Tetteh, R. (2022). Standard operating procedures for characterisation. CSIR-PGRRI/HB/BMN/2022/14, 10pp.

4. Tetteh, R., Kotey, D. A., Aboagye, L. M., Antwi, N. A. & Bissah, M. N. (2022). Standard operating procedures for seed conservation. CSIR-PGRRI/HB/TR/2022/15, 24pp.

5. Tetteh, R., Kotey, D. A. & Aboagye, L. M. (2022). Notes on some indigenous leafy vegetables at the national genebank, Ghana. CSIR-PGRRI/HB/TR/2022/13, 19pp.

6. Tetteh, R., Bissah, M. N., Amoah, A. R., Kwateng, Y. & Kotey, D. A., (2022). Standard Operating Procedures for Germplasm Acquisition. CSIR-PGRRI/HB/TR/2022/118.

7. Tetteh, R., Kotey, D. A., Aboagye, L. M. & Bissah, M. N. and Kwateng, Y. (2022). Standard operating procedures for germplasm distribution, CSIR-PGRRI/HB/TR/2022/17, 13pp.

8. Tetteh, R., Kotey, D. A., Aboagye, L. M., Bissah, M. N. and Kwateng, Y. (2022). Standard operating procedures for regeneration. CSIR-PGRRI/HB/TR/2022/16, 13pp.

9. Tetteh, R., Kotey, D. A., Aboagye, L. M. and Bissah, M. N. (2022). Standard operating procedures for seed Conservation. CSIR-PGRRI/HB/TR/2022/15, 24pp.

Conference Papers

1. Bissah, M. N., Amissah, A. A., Gyasi, E., Dzokoto, C., Bandanaa, J. and Kotey, D. A. (2022). Agronomic characterisation of rice (*Oryza sativa* L.) at the National Genebank of Ghana. Paper presented at CSIR Research Staff Association (RSA) 4th Scientific Conference at Soil Research Institute, Kumasi on 20th October, 2022.

2. Boamah, E. D., Osekre, E. A., Oppong, A., **Effah, Z.,** Yeboah, A. and Borigu, M. (2022). Prevalence of insect pests and mycotoxins in maize stored for feed and its implication for poultry production in Ghana. Paper presented at CSIR Research Staff Association (RSA) 4th Scientific Conference at Soil Research Institute, Kumasi on 19th October, 2022.

3. Elusiyan, C. A., **Owusu, E. O.,** Kemigisha, E., and Bosu, P. P. (2022). Biological studies of some T*etrapleura tetraptera* provenances from Ghana, Nigeria and Uganda. Paper presented at CSIR Research Staff Association (RSA) 4th Scientific Conference at Soil Research Institute, Kumasi on 19th October, 2022.

4. Elusiyan, C. A., **Owusu, E. O.,** Kemigisha, E., Bosu P. P., and McDonald, A. G. (2022). Chemical profiling of some *Tetrapleura tetraptera* genotypes from Ghana, Nigeria and Uganda, Paper presented at CSIR Research Staff Association (RSA) 4th Scientific Conference at Soil Research Institute, Kumasi on 19th October, 2022.

5. Gyasi, E., Adongo, B. A., Kotey, D. A., Adofo, K.**, Osafo, E.A., Owusu, E. O., and Mohammed, A.** (2022). Assessment of different genotypes of sweet potato (*Ipomoea batatas* (L.) Lam.) tubers for their tolerance to three storage rot fungi. Paper presented at CSIR Research Staff Association (RSA) 4th Scientific Conference at Soil Research Institute, Kumasi on 19th October, 2022.

6. Gyasi, E., Kotey, D. A., Adongo, B. A., Owusu, E. O., Adams, F. K., Boampong, R. and Mohammed, A. (2022). Differential susceptibility of taro (*Colocasia esculenta* (L.) Schott) genotypes to various corm rot fungi. Paper presented at CSIR Research Staff Association (RSA) 4th Scientific Conference at Soil Research Institute, Kumasi on 19th October, 2022.

7. Gyasi, E., Kotey, D. A., Adongo, B. A., Owusu, E. O., Adams, F. K., Boampong, R. and Mohammed, A. (2022). Differential susceptibility of taro (*Colocasia esculenta (L.*) Schott) genotypes to various corm rot fungi. Paper presented at CSIR Research Staff Association (RSA) 4th Scientific Conference at Soil Research Institute, Kumasi on 19th October, 2022.

8. **Ochar, K**., Ho-Cheol, K, Hee-Jong, W., Hae-Ryun, K. and On-Sook, H. (2022) Evaluation to resistance to Pepper Mild Mottle Virus (PMMoV) in pepper germplasm.

9. **Owusu, E. O.**, Kwoseh, C., Osekre, E., and Akromah, R. (2022). Incidence, diversity, and distribution of Fusarium wilt pathogens of eggplant. Paper presented at CSIR Research Staff Association (RSA) 4th Scientific Conference at Soil Research Institute, Kumasi on 19th October, 2022.

Edited Conference Paper

1. Adhikari, K., Azevedo, V., Bebeli, P. J., Chatzigeorgiou, A., Gálvez, A., Guarino, L., **Kotey, D. A.,** Ortega-Paczka, R., Ranieri, R., Spyrou, S., Thanopoulos, R. and Maria-Valamoti, S. (2022). The Thessaloniki Declaration: We Save Landraces – We Use Landraces. Paper presented at the 6th Scientific Meeting of Landraces and Indigenous Varieties, 31 May-1 June 2022, Thessaloniki, Greece. http://www.minagric.gr/images/6h%20epistimoniki%20sinantisi%20poikilion/Thessaloniki-Declaration090822.pdf

Posters, leaflets, brochures and other promotional materials

Posters

1. Ochar, K., Ko, H., Woo, J. H., Hae-Ryun, K. & On-Sook, H. (2022). Phenotypic Evaluation of Pepper Germplasm for Natural Variation of Resistance to Pepper Mild Mottle Virus (PMMoV).

Leaflets

1. Kwateng, Y., Boateng, S. K., Owusu, E. O., Bissah, M. N., Nketiah, V., Tetteh, R. Asiedu-Darko, E. & Kotey, D. A. (2022). An overview of CSIR- PGRRI- Mandate, Structure, Research Programmes, Flagship Projects, Key Partners, Consultancy services & Available Planting Materials for sale. 2nd Edition

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12. Foolad, M. R., Sullenberger, M. T., and Ashrafi, H. (2015). Detached-Leaflet Evaluation of Tomato Germplasm for Late Blight Resistance and Its Correspondence to Field and Greenhouse Screenings. *Plant Disease,* 99(5), 718–722. https://doi.org/10.1094/pdis-08-14-0794re

13. Ganie, S. A., Wani, Shabir, H. W., Goetz, h. et al., (2020). Improving rice salt tolerance by precision breeding in a new era. *Biology,* 60 https://doi.org/10.1016/j.pbi.2020.101996

14. Gonzalez, Y.S., Dijkxhoorn Y., Obeng P., and Schotel P. (2014). Export vegetable sector in Ghana: Identifying opportunities for development. The GhanaVeg Program and Wageningen UR Report CDI-14-021. Wageningen, The Netherlands: Wageningen UR.

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39. Yan, W. (2015). Mega-environment analysis and test location evaluation based on unbalanced multi-year data. *Crop Science*, 55(1), 113-122.

APPENDIX III: List of Senior Members

DIRECTORATE	
Daniel Ashie Kotey	BSc. (Hons) Biology, MPhil. PhD- (Entomology) -Senior Research Scientist Ag. **Director, CSIR-PGRRI**
Yaw Kwateng	BSc. Natural Resources Management, MSc. Nature Conservation and Biodiversity Management - Scientific Secretary
Paul Smart Osei-Kofi	BA. Information Studies and Sociology, MA Publishing Studies, Librarian
ADMINISTRATION DIVISION	
Emmanuel Asiedu- Darko	BA (Hons) Social Science, M.Phil. Adult Education – Senior Administrative Officer, **Head of Division**
Mavis Anneh	BSc. Botany, MBA Human Resources -Administrative Officer
Mrs. Awurama Nti Andoh	Bachelor of Business Administration, MA. Sociology, Administrative Ofiicer
PLANT GENETIC CONSERVATION DIVISION	
Samuel Kwasi Boateng	BSc. (Hons) Biology, M.Phil. Botany, PhD. (Plant Physiology) – Principal Research Scientist, **Head of Division** (January - August, 2022)
Rashied Tetteh	BSc. (Hons) Agriculture, MPhil in Crop Science, PhD in Environmental Science - Research Scientist and Acting Head of Division from August, 2022.

Richard Boampong	B.Ed. Agriculture, M.Phil. Agronomy, Principal Technologist
Victoria Sackey	BSc. Agriculture, M.Phil. Seed Science, Principal Technologist
Abraham Yeboah	BSc. Agriculture, M.Phil. Seed Science- Principal Technologist
Benjamin Bonsu Bruce	BSc. Agriculture, M.Phil. Agronomy- Principal Technologist
Bismark Kwesi Asitoakor	BSc. Botany, M.Phil. Agronomy, PhD. Crop Science/ PhD in Forest Science- Research Scientist
Collins Yeboah Osei	BSc. Agriculture M.Phil. Seed Science- Principal Technologist
PLANT GENETIC DIVERSITY	
Matilda Ntowaa Bissah	BSc. (Hons) Botany, MPhil Botany, PhD, Plant Breeding- Senior Research Scientist - **Head of Division**
Richard Adu-Amoah	BSc. (Hons) Agriculture, MPhil. Plant Breeding, PhD, Plant Breeding- Research Scientist
Kinsley Ochar	Ed. Agriculture, M.Phil. Crop Science, Principal Technologist
Joseph Bandanaa	BSc. Agriculture, M.Phil. Environmental Science, PhD, Environmental Science- Research Scientist
Zechariah Effah	B. Ed Agriculture,M.Phil. Plant Breeding, Principal Technologist
Eric Ansah Osafo	B.Ed Agriculture, MSc. (Postharvest Tech.)-Principal Technologist

Eric Opoku Mensah	BSc. Agriculture, MSc. Agriculture Biotechnology, M.Phil. Agronomy- Principal Technologist
Amanda Ama Amissah	BSc. Agriculture, M.Phil. Seed Science
PLANT PROTECTION DIVISION	
Edmund Osei Owusu	BSc. Agriculture, MSc. Plant Pathology- Senior Research Scientist - **Head of Division**
Emmanuel Duku Boamah	BSc. Agriculture, MSc. Entomology- Research Scientist
Barnabas Ayinedeneba Adongo	BSc. Agriculture, MSc. (Plant Pathology)- Principal Technologist
Eric Geoffrey Gyasi	BSc. Agriculture, MSc. Crop Protection – Principal Technologist
Fuleratu Karim Adams	BSc. (Hons) Agriculture, M.Phil. (Plant Virology PrincipalTechnologist
Augustine Bosomtwe	BSc. (Hons) Agriculture, M.Phil. Entomology Principal Technologist
COMMERCIALISATION DIVISION	
Victor Nketiah	BSc. Agriculture. M.Phil. Crop Science- Principal Technologist - Ag. **Head of Division**
ACCOUNTS AND FINANCE DIVISION	
Peterson Dacosta Opoku	BSc. Accounting, MBA Finance, Diploma in Public relations and Accounting, Diploma in Public finance- Accountant, Ag. Head of Division

Rita Abigail Teiko Leigh	B. Tech Accounting, MSc. Accounting and Finance- Finance & Accounts officer
Okyere Boateng	BA Management studies, MSc. Accounting and Finance- Auditor

POST RETIREMENT CONTRACT STAFF	
Dr. Lawrence Misa Aboagye	BSc. Agriculture (Crop Science), MSc. Plant Physiology, PhD (Plant Breeding and Physiology), Chief Research Scientist
Dr. Stephen Nutsugah	BSc. Agriculture (Crop Science), MSc. Plant Pathology, PhD Plant Pathology, Chief Research Scientist

APPENDIX IV- List of Senior staff

	Name of staff	Grade
1	Miss. Catherine Elikem Dzokoto	Chief Technical Officer
2	Mr. Abednego Opoku Mensah	Chief Technical Officer
3	Mr. Emmaneul Ofori	Principal Administrative Asst.
4	Miss Emma Biriwaa Osei	Principal Accounting Assistant
5	Mr. Ebenezer Adu Yeboah	Principal Technical Officer
6	Mr. Sule Alhansan	Assistant Farm manager
7	Mrs. Afua Abayie Owusu-Korankye	Senior Accounting Assistant
8	Mr. John Ohene Ampofo	Senior Administrative Assistant
9	Miss Esther Adu	Principal Stores Superintendent
10	Mr. Benjamin Sakyi	Senior Technical Officer
12	Mr. Peter Kwaku Nintang	Senior Security Officer
13	Mr. Hayford Horsu	Senior Security Officer
14	Mr. William Amoako Antwi	Senior Accounting Assistant
15	Mr. Jonathan Siamey	Senior Technical Officer
16	Mr. Prince Asare	Accounting Assistant
17	Mr. Jonas Azillah	Security Officer
18	Mr. Samuel Awuah	Principal Technical Officer
19	Mr. Abdul Mohammed	Senior Technical Officer
20	Miss. Gifty Batsa	Technical Officer (Catering)
21	Mr. George Annan	Assistant Farm Manager
22	Mr. Eric Osae	Assistant Farm Manager

23	Mr. Malik Ali Baba	Technical Officer
24	Miss Grace Gyamfua	Technical Officer
25	Mr. Sampson Akakpo	Security Officer
26	Mr. Richard Amanor	Security Officer
27	Mr. Joseph Arhin	Accounting Assistant
28	Mr. Prince Yaw Donkor	Administrative Assistant
29	Mr. Collins Owusu	Administrative Assiatant
30	Miss Mary Opoku	Technical Officer (Catering)

For more information, please contact

The Director

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