"Sustainable Agronomic Management of Weeds: The Hidden Pest against Enhanced Food Productivity"

By

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2019

Inaugural Lecture Delivered under the Chairmanship of

Professor Gabriel Ayum Teye
Vice-Chancellor, UDS

Venue: Dr. Andani Andan Auditorium
Central Administration, Tamale Campus
University for Development Studies

Friday, May 31, 2019

PROFESSOR ISRAEL K. DZOMEKU

B.Sc. (Ghana), PGD. (Ås, Norway), M.Sc. (Ahmadu Bello, Nigeria), Ph.D. (Reading, UK)

Professor of Weed Science

CITATION

PROFESSOR ISRAEL KWAME DZOMEKU (Ph.D)

Professor Israel Kwame Dzomeku was born on 17th March, 1958 and is a native of Botoku in the North Dayi District of the Volta Region. He is a Weed Scientist and currently a Professor in Weed Science in the Department of Agronomy, Faculty of Agriculture at the University for Development Studies, Tamale.

Prof. Dzomeku undertook his Secondary School education in Kpando Secondary School, Kpando and Mawuli School, Ho where he respectively obtained his Ordinary ('O') and Advance ('A') Level Certificates. He holds Bachelor of Science (B.Sc.) Hons. degree in Agriculture (Soil Science option) from the University of Ghana, Legon and M.Sc. (Weed Science) and Ph.D. (Weed Science) respectively from the Ahmadu Bello University, Zaria, Nigeria and University of Reading, UK both with Commonwealth Scholarships.

Since March, 1996, Professor Dzomeku has been working in the Department of Agronomy, University for Development Studies (UDS), Tamale; first as a lecturer and later became a Senior Lecturer, Associate Professor and Professor in 2008, 2014 and 2018, respectively. Professor Dzomeku has held some administrative positions during his over 20 years of experience in teaching, research, dissemination of research knowledge and mentorship at UDS. These positions include:

i. Head of the Department of Agronomy (2003 - 2008),
ii. Vice Dean of the Faculty of Agriculture (2008 - 2009),
iii. Patron of the Ghana Association of Agricultural Students (2008 -2009),
iv. Chief-Editor of the Journal of Development Spectrum (2008 – 2011),

v. Dean of Graduate School (2010 – 2012),
vi. Dean of Student's Affairs (2013 – 2018),
vii. UDS representative on the Governing Board of the Golden Sunbeam International College of Science and Technology (2016 – 2017).

Professor Dzomeku during his term as the Dean of Graduate School organised the first International UDS Graduate School Conference and published the first Graduate School Handbook. UDS received, during his tenure, an enhanced number of Scholarships for needy but brilliant students notably the Standard Chartered, Barclays Bank, Cal-Bank and GNPC Scholarships.

Professor Dzomeku attended several local and international conferences and workshops including:

i. UDS 2017 Interdisciplinary Conference 6-7 September, 2017. Nyankpala Campus, Tamale,
ii. The 30th Biennial Conference of The Ghana Science Association 24-27 July, 2017. Koforidua Technical University, Koforidua,
iii. The 1st International Conference on Irrigation and Agricultural Development (IRAD) 2017, UDS ICC, Tamale,
iv. The 48th Annual Meeting of the American Peanut Research and Education Society, July 12-14, 2016, Clearwater Beach, Hilton, Florida, USA,
v. Tropentag 2016, September 18-21, 2016. University of Natural Resources and Life Sciences (BOKU Vienna), Austria,
vi. The 47th Annual Meeting of the American Peanut Research and Education Society, July 14-16, 2015, The Francis Marion Hotel In Charleston, Sc.,

vii. The 29th Biennial Conference of the Ghana Science Association, 3rd to 7th August, 2015 at the University for Development Studies, Tamale,

viii. The 2013 Harmattan School organized by CCEIR, University for Development Studies, Tamale. 13-14th February, 2013. East End Conference Room, Tamale Sports Stadium,

ix. the 28th Biennial Conference, Ghana Science Association. (Great Hall and Faculty of Science), 14th – 19th July 2013, University of Ghana, Legon,

x. Third (3rd) Africa Rice Congress Yaoundé, Cameroon, 21–24 October 2013;

xi. Xth Weed Science Conference of Nigeria at Kebbi State University, Kebbi State, Nigeria. November, 2013,

xii. Japan International Research Institute for Agricultural Sciences (JIRCAS) Conference in March 7-9, Tokyo. Japan,

xiii. Eleventh (11th) World Congress on Parasitic Plants. 7th-12 June 2011 – Martina Franca, Italy.

xiv. Inter-Faculty Lectures, organized by Center for Continuous Education and Interdisciplinary Research (CCEIR), University for Development Studies, held on 6-8th September, 2011, Wa,

xv. Twelfth (12th) Annual General Meeting of Ghana Institute of Horticulturalist (GhIH) held on the 14th-16th September, 2011, in Fumesua, Kumasi,

xvi. First (1st) AfroWeeds Workshop, organised by AfricaRice and CIRAD, 1-5th February, 2010 at Cotonou, Republic of Benin,

xvii. 2010 Annual Review meeting of the Ministry of Food and Agriculture, organised by Ministry of Food and Agriculture, and Centre for Science and Industrial Research 25-26th March, 2010 at Radach Memorial Hotel, Tamale. Ghana,

xviii. Tenth (10th) Annual General meeting of Ghana Institute of Horticulturists. Ghana Institute of Horticulturists, September, 2009, at Radach Memorial Hotel, Tamale. Ghana,

xix. Workshop on dissemination of 'good/best' land management practices under SLaM project in Northern Ghana, held on 21st June, 2008, Pastoral Centre, Nyankpala,

xx. SLaM Workshop On Database Development And Good/Best Land Mangement Practices 28-32 July, 2008, Akosombo Hotel, Atimpoku, Ghana,

xxi. Ninth (9th) Annual General meeting of Ghana Institute of Horticulturists. Ghana Institute of Horticulturists, 11-12th September, 2008. CSIR-STEPRI, Accra,

xxii. Seveth (7th) Annual General meeting of Ghana Horticulturists. Ghana Institute of Horticulturists, 6th-7th September, 2006. Fumesua. Kumasi,

xxiii. National SLaM Workshop. 14-16th Sept. 2006, Cocoa College, Bunso.E.R.UNDP/GoG Project,

xxiv. First (1st) African Rice Congress. 31st July – 5th August 2006. Movenpick Hotel. Dar es Salaam. Tanzania,

xxv. Twentieth (20th) Annual Seed Biology meeting of Horticulturists (2000). The Royal Horticultural Society Wisley Garden, Wisley, U.K.,

xxvi. First Biennial National Agricultural Research System (NARS) workshop. November, 16 – 20, 1998. Accra. Agricultural Engineering Programme of the National Agricultural Research System (NARP) of the Council for Scientific and Industrial Research (CSIR),

xxvii. Regional workshop on "Integrated weed management for the Humid and sub-Humid tropics of sub-Saharan Africa" Cameroon, Duola, 15 – 19th, September, 1997, xxviii. Fifteen (15th) Annual Conference of Nigerian Soybean Association at State House, Kawo, Kaduna, May12, 1994.

Professor Dzomeku belongs to the following Associations:

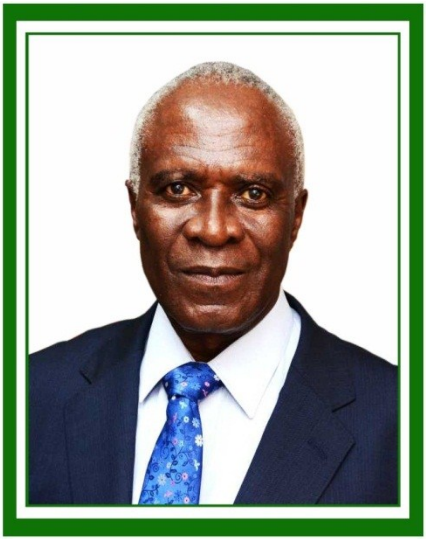
- Member of Ghana Science Association, 1996 to date.
- Member of Ghana National Agricultural System, 1996 to date,
- Member of Ghana Institute of Horticulturists, 2004 to date,
- Member of West African Rice Development Association, 2005 to date,
- Member of Northern Ghana-USA Peanut Research Team – 2008 to date,
- Member of African Weeds of Rice (AFROWeeds) Organisation, 2010 to date,
- Fellow of Ghana Institute of Horticulturists (FGhIH), 2013 to date,
- Member of Plant Protection Society of Ghana, 2019 to date,
- Member of Ghana Weed Science Society, 2019 to date,

Prof. Dzomeku has forty-six (46) peer-reviewed journal publications, and four (4) book chapters, one training manual and sixty (60) conference proceedings to his credit. He has also contributed and influenced publications of several handbook publications from research including: 'Good/best' land management practices identified under Sustainable Land Management (SLaM) project in the northern sector of Ghana, AFROweeds and Weedsbook: online and offline means of support for weed identification and management, Handouts for Farmers on Farm Water Management with Conflict Management Components prepared for 26 communities in three rice valleys of the Northern Region and Diagnostic Survey of Bunds in three rice valleys of the Northern Region and Required Technical Requirement for Rehabilitation.

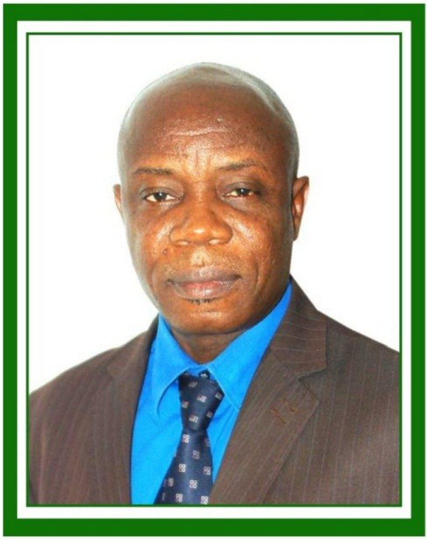
Prof. Dzomeku was the principal investigator for three donor funded projects which were successfully completed and these were: (1) Evaluation of effectiveness of maize-soybean integration in managing the devastating effects of *Striga hermonthica* (Del.) Benth in the Guinea savannah zone of Ghana (2) Effects of biochar, rice husk and rice straw on productivity of maize (*Zea mays* L.) and sustainable soil fertility restoration (Sponsor: IFDC USAID project, 2013-2015) and (3) Improvement of soil fertility with use of indigenous resources of organic materials and rock phosphate in Ghanaian lowland rice systems (Sponsor: Japan International Research Institute for Agricultural Sciences (JIRCAS), 2008-2012).

Prof. Dzomeku is an External examiner of graduate theses and promotion papers for the University of Ghana, Legon, University of Cape Coast (UCC) and the Evangelical Presbyterian University College, Ho.

Professor Dzomeku is involved in church activities being the Pastor of "House of Life" of the Spoken Word Ministry, Tamale. He is married to Mrs Mabel A. Dzomeku with four children: Masters Peter, Paul, Philip and Prince.



Nutifafa Kuenyehia, Esq., OOV
CHAIRMAN OF UDS
GOVERNING COUNCIL



Prof. Gabriel Ayum Teye
VICE-CHANCELLOR

Prof. Seidu Al-hassan
PRO-VICE-CHANCELLOR

Dr. A.B.T. Zakariah
REGISTRAR

Programme

Topic	:	**Sustainable Agronomic Management of Weeds: The Hidden Pest against Enhanced Food Productivity**
Venue	:	Dr. Andani Andan Auditorium, Central Administration, Tamale Campus
Chairman	:	Vice-Chancellor, **Professor Gabriel A. Teye**
2:00 pm	:	Guests Seated
2:15 pm	:	Vice-Chancellor's Procession (Audience stand) - Prayers (***Christian and Moslem***) - Introduction of Chairman by the Registrar, ***Dr. A. B. T. Zakariah*** - Welcome Address/Introduction of Lecturer by the Vice-Chancellor, ***Professor Gabriel A. Teye*** - Lecture on Sustainable Agronomic Management of Weeds: The Hidden Pest against Enhanced Food Productivity by ***Professor Israel Kwame Dzomeku*** - Chairman's Closing Remarks - Announcements - Recession (Audience stand)

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Dedication

This Inaugural Lecture is dedicated to the memory of my parents.

LECTURE BY
Professor Israel Kwame Dzomeku

1.0 Introduction

The Vice-Chancellor
Members of the UDS governing Council
Registrar
Pro. Vice-Chancellor
Director of Works and Physical Development
Director of Finance
UDS Campus Principals
University Librarian
Deans and Directors
Representatives of other Institutions
Members of Convocation
Nanima
Distinguish Invited Guests
Students and Alumini
Family and Friends
The Press
Ladies and Gentlemen

I am delighted to be given this opportunity by the Vice Chancellor of this progressive university to present the eighth (8^{th}) inaugural lecture. It is arguably the first inaugural lecture in the domain of Weed Science at UDS and interestingly opening the door of accomplished professorship to the esteemed Department of Agronomy. This feat will indeed pave the way and strengthen my colleagues from the Department to work assiduously to increase the number of Professors in the Department. I am greatly indebted to my research colleagues from the Council of Scientific and Industrial Research (CSIR-SARI) who in sundry times and in divers manners contributed to this feat we are celebrating today. I am humbled to have taken the right decision to join the *Adansonia digitata* family to contribute my service quota to the manpower development in the academic field of weed science for sustainable technological transformation of the Agricultural sector of Ghana.

Mr Chairman, an inaugural lecture is an event that usually signifies the immense contribution in the carrier of a University Academic. It is a baptismal event of the new Professor into the Association of Professors and obliges the Professor to showcase his contribution to advances and developments in his/her discipline. The message and philosophy behind my Inaugural Lecture are based on my research works for prudent and sustainable agronomic weed management in Ghana over the past twenty years in UDS. It is worth noting that, I have been very privileged to have worked with very hard-working supervisors, colleagues, international and local scientists and students, some of whose work feature in this presentation. Indeed, Ghana has the potential to increase food productivity and consequently generate sustainable and adequate revenue if investment is made in sustainable technological management of weed-pests in agricultural systems.

Mr Chairman with your permission, I proceed with the presentation of my inaugural lecture titled **"Sustainable Agronomic Management of Weeds: The Hidden Pest against Enhanced Food Productivity".**

1.1 Weeds as pests in Agriculture

The term 'weed' in the context of Agriculture is any plant species in close association with crops in a farming enterprise in a specific time and observed to be interfering with the growth and development and/or in some way intruding upon the welfare of the crops (Akobundu, 1987). Weeds therefore in this context constitute a hindrance to productive and sustainable food security. Weeds constitute about 30,000 plant species world-wide, which are prominent in agricultural and non-agricultural systems (Holm *et al.*, 1977).

Damage from weed-pests is relatively hidden (Figure 1a) in that it takes considerable time for the symptoms to be visible on the host plant in comparison with the rapid and noticeable injury caused by insect-pests (Figure 1b) and pathological organisms. Secondly some of weeds have ecstatic beauty that camouflages their harmful character. Thirdly, there is continuously a reservoir of germinable weed seeds and/or perennating propagules which are highly adapted to their habitat and "stored hidden" in the soil seed bank.

Figure. 1. (a) Weeds in a maize farm and (b) a fall army worm (*Spodoptera frugiperda*) on maize leaves.

1.2 Economic importance of weeds in Agriculture

The menace of weeds in agriculture is mainly in the form of the different harmful effects impacted directly or indirectly during and after production. Weeds, in general, precede crops on farming lands and are major yield reducing biotic factors. In ecological terms, most annual weeds are r-strategists, establishing populations with high relative growth rate (r). Thus, they produce numerous viable seeds; their populations quickly build up in an exponential pattern. Weed competition with crops or in allelopathic reaction reduces agricultural output (quantity and quality), and increases external costs by spreading them across farm boundaries. It is also a major constraint to increased farmers' productivity, particularly in developing countries where weed management takes about 20 to 50 % of farmers' time and keep smallholders in a vicious circle of poverty (Akobundu, 1987). The Weed Science Society of America reported that maize and soybean yields could be reduced by 50% if weeds in the cropping systems were left uncontrolled; resulting in potential economic loss of $43 billion a year (Soltani *et al*., 2016). Weeds have many other negative impacts on crops including serving as alternate hosts to many plant diseases, insect-pests, rodents, birds etc. that attack crops.

1.3 Present trends in weed management

Advances in weed ecology and weed management have shown that because of the numerous number of serious weed problems in all farming systems of the world, reliance on one method alone could not be effective. Weed Scientists have therefore adopted the approach of using the concept of integrated weed management based on the same philosophy as practiced for insect pests (Labrada and Fornasari, 2003). Nevertheless, new agricultural production methods continue to be developed with demand for specific and classified weed management methods. For example, organic agriculture does not permit the use of chemical herbicides, therefore cultural and biological approaches are the only feasible technologies left to manage weeds in such systems.

Several weed species are difficult to control and crops suffer serious weed infestation from a number of weeds. In Ghana 912 weed-pests have been identified and documented as occurring in field and plantation crops (PPRSD, 2002). The Directorate listed about sixteen (16) noxious weeds which must be assessed in production of certified seeds in Ghana, of which *Ageratum conyzoides* (billy goat weed), *Cyperus rotundus* (Purple nutsedge), *Ischaemum rugosum* (Saramolla grass), *Oryza longistaminata* (perennial wild rice), *Oryza barthii*

(African wild rice), *Rottboellia cochinchinensis* (Itchgras), *Imperata cylindrica* (speargrass, cogon grass), *Echinochloa crus-galli* (barnyard grass), *Striga hermonthica* and *S. gesnerioides* (witchweed) are of great concern in Northern Ghana Agricultural systems.

In the developed countries the continuous use of weedicides has given rise to the incidence of herbicide-resistant weeds. Although such chemical treatments have increased farmers' productivity, it has brought about a proliferation of some difficult-to-control species. The FAO Technical Committee Meeting in Beijing on management of such complex weeds (FAO, 2000) proposed: (a) Preventive measures such as enforcement of quarantine laws and regulations and field hygiene, (b) Education of farmers on the importance of keeping farm machines free from seeds and propagules, (c) Over-reliance on herbicides for weed control to avoid the incidence of herbicide-resistant biotypes, (d) Crop rotation as the key method for depleting seed banks of complex weeds, (e) Weed scientists and extension specialists should monitor complex weed populations and develop databases on such populations. Ultimately, therefore the solution for management of weed complexes, lies in integrated weed management, with the use of clean seeds, appropriate crop rotation and land preparation, as well as rational use of herbicides, thus avoiding problems of herbicide resistance (FAO, 2000).

1.4 The specific focus of this Inaugural lecture

Mr Chairman, this lecture will now highlight results of some of the pertinent research conducted within the jurisdiction of my academic and professional carrier in UDS with the goal of facilitating reduction of weed-pest populations and its economic interference in Agricultural systems.

2.0 MODELLING EFFECTS OF PROLONGED CONDITIONING ON DORMANCY AND GERMINATION OF *STRIGA HERMONTHICA* (DEL.) BENTH

The parasitic weed *Striga hermonthica* (Del.) Benth. (Figure 2a), commonly known as purple witchweed, is a hemi-parasitic plant (Parker and Riches, 1993), belonging to the family Orobanchaceae. It is the key biotic constraint to the production of major cereal crops such as maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L. Moench), pearl millet (*Pennisetum glaucum* L.), upland rice (*Oryza sativa* L.) and sugarcane (*Saccharum officinarum* L.). Over 120 million people living in Africa are affected by the parasitic weed resulting in food insecurity and rural poverty. Woomer *et al.*, 2008 reported that *Striga* has colonized about 2.4 million hectares of maize cropland resulting in the annual loss of 1.6 million tonnes of grain with an economic value of US $383 million.

The seeds are very tiny and range between 0.15 ~ 0.3 mm in diameter (Parker and Riches, 1993), Fig. 2b), and germinate only after being exposed to favorable moisture and temperature conditions for several days (preconditioning), in the presence of host exudates. For several decades, small-scale farmers sought to control the parasite by hand weeding, but the practice failed.

Figure 2 (a) *Striga hermonthica* (b) Seeds of *S. hermonthica* in comparison with maize and sorghum seeds.

The difficulty in *Striga* management needed more studies on the seed dormancy and germination characteristics, which are generally important phenological events that influence success or failure of its establishment as subject to precise regulation by external factors (Forcella *et al.*, 2000). When seeds do not germinate or germinate poorly under favourable growth conditions, they are considered dormant. Primary dormancy in parasitic weed seeds sets in during seed development on the mother plant; whilst secondary dormancy usually develops under conditions which do not permit germination of seeds (Baskin and Baskin, 1998). Conditions of imbibed storage environment are expected to influence the expression of dormancy and consequently the pattern of germination and subsequent emergence of weed seeds. Temperature has been identified as the main factor controlling changes in the degree of dormancy in temperate environments where water is not seasonally restricted (Benech-Amold *et al.,* 2000). The effect of temperature on dormancy release may however, be modified by other factors such as soil moisture (Benech-Amold *et al.,* 2000). Progressive loss of dormancy in seed populations may be related to a progressive decrease in mean water potential (Christensen *et al.,* 1996). Light, nitrate, smoke and other factors determine the dormancy status of a seed (Baskin and Baskin, 1998).

During imbibed storage of the parasite seeds, germination occurs in response to specific stimulatory action derived from root exudates of the hosts and sometimes non-hosts. However, when the transfer of seeds from the conditioning medium to a suitable stimulant is delayed beyond the optimum time, the final germination percentage may reduce progressively to zero due to induction of secondary dormancy (Vallance, 1950). It was suggested that empirical modelling focus on integration of important soil factors for enhanced prediction of the direct and interaction effects on dormancy release and induction and subsequent influence on seed germination (Forcella *et* *al*., 2000). However, information on the relationship between extended conditioning periods (as pertains in fields of *S. hermonthica*) and seed dormancy and germination, due to temperature was limited to 20° to 35°C and non-existent in the literature with respect to water potential and urea concentrations. Due to the ecological niche of the parasite, my study attempted to widen the temperature range from 17.5 to 37.5°C and also examine variation in water potentials and urea concentrations on expression of dormancy and germination of the parasite.

The objectives of this research were to examine the dormancy and germination response of *S. hermonthica* seed population over a wide range of conditioning environments including temperature, water potential and urea as variables and thereby provide a model for conditioning and secondary dormancy and validate this model in the field, so that planting date effects on *Striga* infestation in the field could be predicted. As such, the impact of environment on the germination biology of the parasite was studied in the laboratory with seeds conditioned at various water potentials, urea concentrations and at 17.5° to 37.5°C for up to 133 days.

Non-linear modelling was carried out using the fitnonlinear directive to analyse proportions of seed germination along the lines of probit analysis in Genstat (Anonymous, 2002) of seed conditioning data. Composite non-linear models were fitted. Final seed germination (G) of the parasite was modelled as the difference between number of seeds which have lost primary dormancy and the number that have induced secondary dormancy multiplied by the potential germinability of the seed population in a given environment. The effect on final percentage seed germination of the period of conditioning in forty out of the seventy-two environments have been described by the additive probability model. The model was based on data collected from 17.5 to 35°C, 0 to -1.5 MPa and 0 to 0.316 mM urea.

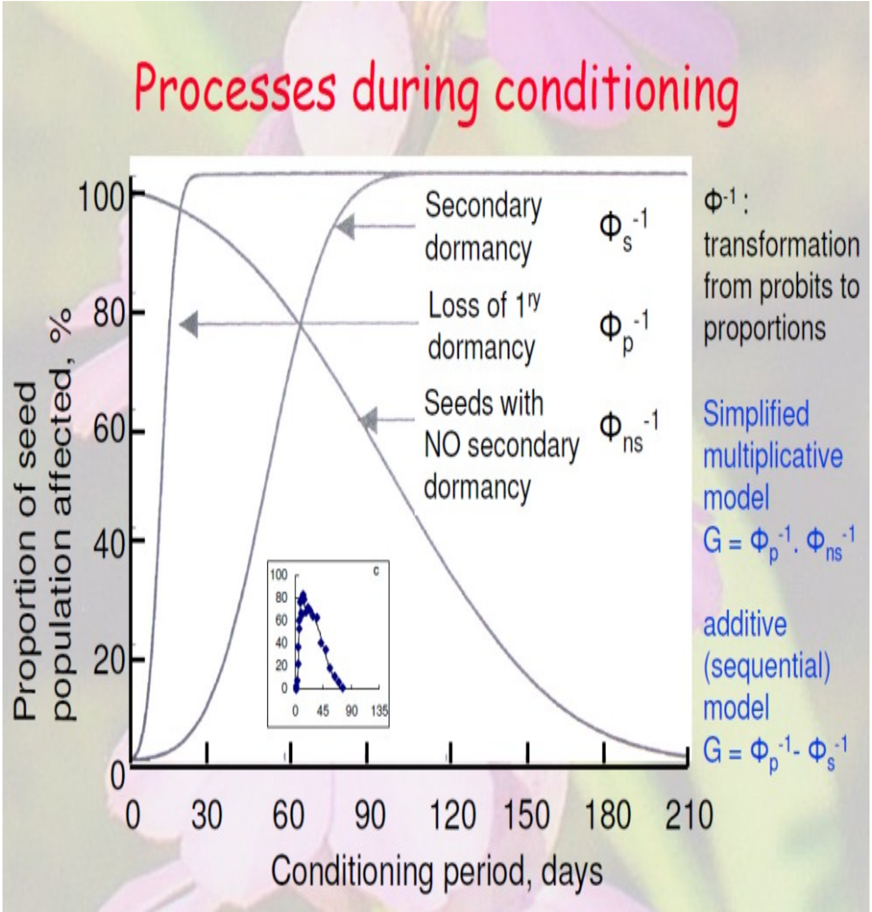

Figure 3. Underlying theoretical cumulative normal distributions of processes of loss of primary dormancy and induction of secondary dormancy in *Striga hermonthica* seeds during conditioning in –0.25MPa at 25°C leading to the predicted net germination with 3ppm GR24 at 35°C.

Results showed that maximum seed germination occurred at 20 to 25°C, whilst water stress and urea suppressed this parameter. The final percentage germination response to period of conditioning showed a non-linear relationship and suggests the release of seeds from dormancy during the initial period and later on dormancy induction (Dzomeku and Murdoch, 2007a). Germination percentage increased with increase in conditioning period to a threshold and remained stable for variable periods followed by a decline with further extension of conditioning time. The decline in germination finally terminated in zero germination in most treatments before the end of experimentation. Temperature, water potential and urea showed clear effects on the expression of dormancy pattern of the parasite. The effects of water potential and urea were viewed as modifying a primary response of seeds to temperature during conditioning. The changes in germinability potential during conditioning were consistent with the hypothesis that dormancy periods are normally distributed within seed populations and that loss of primary dormancy precedes induction of secondary dormancy. Hence an additive non-linear mathematical model (G) of loss of primary dormancy and induction of secondary as affected by forty environments were developed to support integrated management of the *S. hermonthica* in sub-Saharan Africa as:

$G=\{[\Phi^{-1}(K_p+(p_o+p_nN+p_wW)(T-T_b)t)]-[\Phi^{-1}(K_s+((s_wW+s_a)+s_or^T)t)]\}[\Phi^{-1}(aT^2+bT+c+c_wW)]$. (Source: Dzomeku and Murdoch, 2007b).

2.1 Validation of the Additive model (G)

The additive model was validated by a field study at three sites in the Zebila District of Bawku West in 1999, in planting date experiment. *S. hermonthica* seeds were buried in nylon bags and the seeds retrieved periodically to test seed germination with 3ppm of GR24.

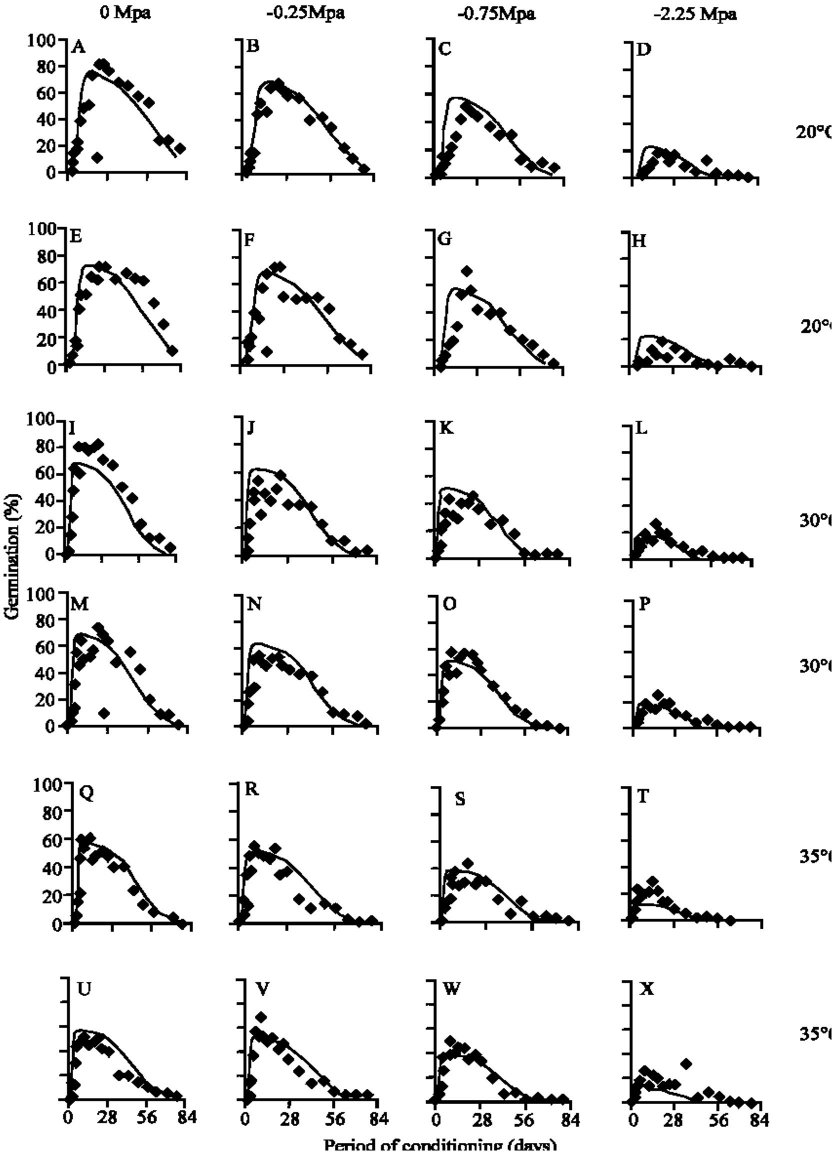

Figure 4. Validation of additive model (G). Observed percentage germination (�) of *Striga hermonthica* seeds compared with predicted lines (---) in twenty four out of forty environments modeled. *Source*: **Dzomeku, I. K.** and Murdoch, A. J. (2007b).

3.0 RESEARCH ON WEED MANAGEMENT IN RICE

Rice is one of the most important staples in sub-Saharan Africa and its demand has been rapidly increasing recently (WARDA, 2007). Aggregated rice consumption is projected to rise from 19.8 million tons in 2010 to 35.0 million tons by 2020 under the scenario of using each country's rice consumption growth rate for the period 1980 to 2010. Thus, sub-Saharan Africa would import roughly 14.0 million tons of milled rice in 2020 to fill the gap between consumption and production (WARDA, 2011).

In 2010, rice production in Ghana reached 492,000 metric tonnes which is 25 % increment from the 2009 output (MOFA, 2011). The area of rice cultivated also increased from 162,000 hectares in 2009 to 181,000 hectares in 2010. Despite the increase in production and land use, rice produced in Ghana can satisfy only 30 % of the nation's demand and therefore the need for high importation of rice (MOFA, 2011). Seven research activities carried out on rice are reported here.

3.1 Survey of rice diseases and insect pests in Northern Ghana

Biotic factors especially diseases, bird damage, insect pests and weeds reduce substantially rice crop yield annually (Nutsugah, 1997). Although losses have not been accurately assessed, they could be similar to those reported for other similar areas in West Africa where yield losses caused by arthropod pests, diseases and weeds are generally estimated to be about 30% or more (WARDA, 1991). The identification of types and species of weeds, disease pathogens and insect pests in the cropping systems in Northern Ghana could support development of varieties with tolerance to these diseases, insect-pests and weed-pests and be of considerable benefit in stabilizing and increasing rice production in Ghana. This survey was undertaken during the rainy seasons of August-November, 1996-98 with the objectives of (i) defining the rice diseases, insects- and weed-pests situation in rice fields in northern Ghana, (ii) investigating farmers' perception of the importance of rice diseases, insect pests and weeds in their farms and (iii) assessing their relative importance in the northern sector of the country.

We reported that noxious weed species at the Nyankpala hydromorphic experimental site consisted of 27% grasses with C4 photosynthctic pathways. These species, *Brachiaria deflexa, Digitaria horizontalis, Echinochloa pyramidalis, Eleusine indica, Eragrostis atrovirense, Paspalum orbiculare and Rottbocllia cochinchincnsis* have competitive edge over arable rice, most especially in the savannah ecology probably because of their higher water use efficiencies (Moody, 1994). *Cyperus difformis* and *Ipomoea aquatica* have also been reported to cause economic yield loss in rice in Nigeria (Akobundu, 1987). In addition, wild rice *Oryza barthii* which could serve as alternative host to rice fungal pathogens is a dangerous weed in rice ecology because it mimics the vegetative and reproductive stages of rice and possesses similar biochemical constitution of the crop which cannot be controlled with herbicides selective to rice (Source: Nutsugah *et. al.*, (2003).

3.2 Electronic support tools (*AFROweeds*) and (*Weedsbook*) for identification and management of rice weeds in Africa for better-informed Agricultural Change Agents

In 2016, we developed an interactive electronic weed identification tool, *AFROweeds,* and an online network, *Weedsbook,* for agricultural change agents to aid communication and offer assistance to rice farmers with specific weed problems. We collected quantitative and qualitative weed data to assess effectiveness and usefulness of these products with potential users. With the online version of *AFROweeds,* used on an electronic tablet, average weed identification time in the field was 7 min 6 s with 44% successful identifications. Poor mobile network coverage and slow internet were the main reasons for the relative long identification time and low success rate. A second trial was done with the offline version, pre-installed on a tablet. The average identification time was 6 min 34 s, with a success rate of 75%. The online network *Weedsbook*, established alongside *AFROweeds*, was assessed by the test users as a useful additional aid, enabling Agricultural Change Agents (ACAs) and agronomists to exchange information or request assistance on all aspects of weed identification and weed management.

The *identikit* enables the user to select common and important morphological character states (such as flower color, leaf shape, stem shape or form) of the plant under consideration and to indicate in the pictorial multiple-choice menu what the character looks like (Figure 5A-F). The *identikit* calculates the probability of the species' identity corresponding to the combination of choices. The user can view a list of species with percentages of fit with the selected character shapes, forms, or colors, and check the most likely species (e.g., those with 100% fit) with the actual plant to be identified (Figure 5G). Clicking on the species names in the list provides access to species' pages from the database with information on botanical descriptions, ecology, biology, management, and local uses (Figure. 5H). Users can also compare the plant being examined with field and herbarium photos or illustrations. The *AFROweeds identikit* currently contains close to 200 species encountered in Africa, primarily for lowland rice. The database can also be consulted directly, hence without any identification, by clicking on 'Results' which opens the list of species alphabetically sorted.

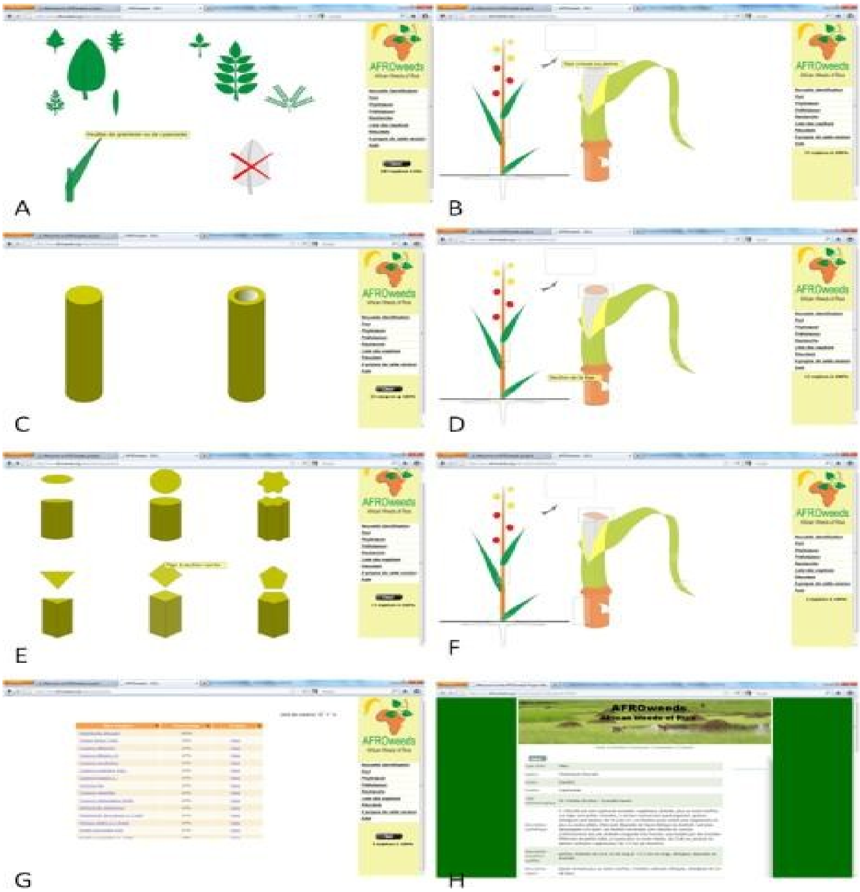

Figure. 5. Example of a stepwise identification of a weed species using the multiple-choice menu of *AFROweeds.* A: selecting the leaf shape; B, C: selecting the stem filling; D, E: selecting the stem section shape; F, G: the result; H: the species datasheet. (Source: Rodenburg *et al*., 2016).

3.3 Survey on Soil Fertility Management for Sustainable Lowland Rice Production in Ghana-Farmer's Perspectives and Soil Physicochemical Properties

Howell and Martens (2000) reported that the type of soil fertility amendment applied to an agricultural soil is a major determinant of the weed pressure in terms of both weed density and weed species diversity. This was because the presence of organic materials and the decomposition activities of soil microorganisms were essential in shortening the life of dormant weed seeds and perenneting propagules, through degradation. This action reduces the potential population of germinable weed seeds and subsequent weed pressure. Earlier, Sanchez *et al*. (1997) reported that low soil fertility in smallholder farms is a major biophysical constraint to increasing per capita cereal production in Africa. As such soil fertility restoration should be considered as an imperative investment for mitigation of poor rural livelihood. Several reports indicated that the soils in Northern Ghana are low in soil fertility and cannot adequately support advanced crop yield (Buri *et al*., 2004; Senayah *et al*., 2008; Buri *et al*., 2009; Issaka *et al*., 2009; Abe *et al*., 2010).

Based on the principle of using organic material for management of weeds through increased soil microbial activity, a series of research was carried out to evaluate the effects of indigenous organic materials on increasing soil fertility as an indirect technology of weed management in rice (Nakamura *et al*., 2012; Nakamura *et al*., 2013; Nakamura *et al*., 2016a,b; Dzomeku, Abdul-Kareem and Rashad, 2018) and in maize (Dzomeku and Illiasu, 2015 and 2018; Dzomeku et. al., 2016; Dzomeku, Illiasu and Amegbor, 2018; Dzomeku, Illiasu and Mohammed, 2018).

Firstly, a comparative study was conducted in Ghana on soil fertility and farmers' perspectives of soil fertility management in the two major rice growing agro-ecological zones: the Guinea savanna (GS) and the Equatorial forest (EF), to examine farmers' perspectives on soil fertility, how farmers manage fertility, and to suggest proper soil fertility management for lowland rice farming. Principal component analysis was used to analyze farmers' perspectives and soil fertility characteristics of the two zones. Results showed that soil characteristics vary both within and between the two agro-ecological zones. Whilst soils in the EF zone are relatively fertile, soils of both agro-ecological zones are infertile. The soils are low in organic matter and available phosphorus. Farmer's perspectives on soil fertility management differed across the agro-ecological zones, and could be categorized into three major groups: (a) farmers having high motivation to improve soil fertility, and high awareness of soil drought; (b) farmers who have high motivation to improve soil fertility, but low awareness of the vulnerability to drought; and (c) farmers having weaker interest in soil fertility management, and preferring extensive management to proactive soil fertility management. On the basis of farmers' perspectives, the utilization of local materials would be effective in soil fertility improvement or maintenance in both agro-ecological zones, due to its high applicability for farmers (Nakamura *et al.*, 2016a).

3.4 Improvement of soil fertility with use of indigenous resources in Ghanaian rice systems

The problem of low soil fertility for enhanced crop production in sub-Saharan Africa is compounded by inability of farmers to purchase inorganic fertilizers due to relatively high cost and therefore rely mostly on natural soil fertility (Senayah *et al.*, 2008). However, there are various indigenous organic materials that have the potential and could effectively contribute to improving soil fertility within the region (Issaka *et al.*, 2009). JIRCAS (2010) reported the quantity, quality and distribution of various organic materials that are available and suitable for improving soil fertility in Ghana. Rice Straw (RS) is one of the commonest indigenous organic materials in Ghana and most accessible material to resource poor peasant farmers, because RS is produced in rice fields itself and therefore does not need to be transported. Therefore, the development of proper and improved management techniques of this material is essential for Ghanaian rice production. We studied three types of RS, CD (cow dung) and HE (human excreta) pretreatment into ash (ASH), charred

(CH) and compost (CO), and untreated raw material (RW).

The effect of Phosphate Rock (PR) on rice yield was also investigated by setting-up three levels of phosphorus i.e. CON as control (0 kgP_2O_5 ha^{-1}), BRP as (Burkina Faso phosphate rock) applied at 135kg P_2O_5 ha^{-1}, and TSP as mineral fertilizer (135kg P_2O_5 ha^{-1}). Thirty six treatments and without organic material (WOM) were applied in three replications. The quantities of the three types of organic materials applied were maintained as 3.2 kg P_2O_5 ha^{-1} at the Northern site, and applied directly to the soil surface. For all treatments, 30 kg N ha^{-1} and 30 kg K_2O ha^{-1} were applied as basal dressing.

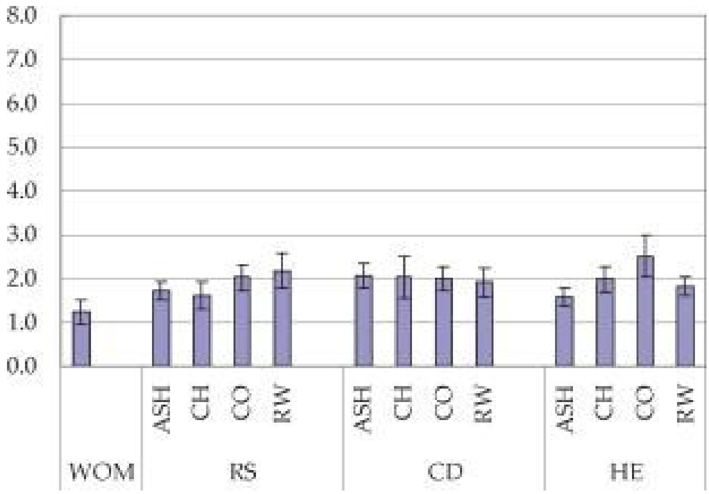

Figure 6. Effect of organic matter application on rice grain yield in Northern region. Mean values of CON, BRP, and TSP treatment are indicated. WOM: without organic matter, RS: rice straw, CD: cow dung, HE: human excreta, ASH: ashing, CH: charring, CO: composting, RW: raw material. (Source: Nakamura *et al*., 2012).

Suggestion for indigenous organic material application in Northern region, for rain-fed lowland rice cultivation

The best promising organic material for agricultural use in Northern region is rice straw (RS). CO-RS and RW-RS treatment showed high positive effect on rice yield in the Northern region trial. It seems adequate amount of mineral plant nutrients were supplied due to decomposition of RS and that soil physical and biological properties were enhanced. On the other hand, CH-RS and ASH-RS also showed positive effect on rice yield, however, it should be considered that charring needs input of labor and capital, and that ashing will impact the environmental negatively. Moreover, ashing process can reduce effectiveness of soil physical and biological properties observed under CO and RW application.

CD application showed high yield in all pretreated plots. It is well known that CD application is effective for rice production. In the Northern region, however, it is far from recommended materials because of difficulty in material gathering. Most of CD in this region was produced by cattle grazing, that means farmer needs to collect CD scattered throughout savannah. This study indicated that CD has similar effect on rice yield compared with other organic materials. The use of CD in rice cultivation can be as popular as RS due to both availability and accessibility. While RS is readily available in the rice fields extra labour is require to search and collect CD. However, after using CD as fuel, CH-CD and ASH-CD can be used in rice production since these materials increased rice yield significantly.

Rice yields average of HE application was almost same as those of CD. However, HE usage has difficulty to diffuse to farmers because of hygienic risk and psychological avoidance. These obstacles can be resolved by either combustion process such as CH and ASH, or composting process. CO-HE indicated highest yield among four pretreatment in HE treatments, the yield was almost twice higher than WOM.

According to the results from Northern region trial, we suggest that

CD and/or HE composting based on RS usage should be well examined as the effective and affordable technical options for farmers. HE composting still has the difficulty of gathering, but technology introduction on collecting and separating urine and feces, such as Eco-San toilet, will open the way for proper management of HE. Moreover CD and HE composting based RS can be expected to increase RP application effect on rice yield (Nakamura *et al.*, 2012).

3.5 Effect of Burkina Faso phosphate rock direct application on Ghanaian rice cultivation

Phosphorus is a critical nutrient for crop production. The soil phosphorus deficit in sub-Saharan Africa is one of the most important constraints on crop productions. Resulting from the high phosphorus fixation capacities of highly weathered acidic soils coupled with the relatively low total phosphorus, the impact of this deficit is particularly pronounced in the case of rice cultivation. Phosphate rock is a promising alternative to water-soluble phosphorus fertilizers, but its low solubility has so far prevented its widespread adoption in the region. This study examined the results of a direct application effect of phosphate rock produced in Burkina Faso phosphate rock (BPR) on rice yields in on-farm trials conducted in the Guinea savannah, and on a phosphate rock decision support system (PRDSS) model. We initially hypothesized that BPR direct application will show little effect on rice yield due to its low solubility. However, our study found that direct application of BPR has an effect on rice grain yield comparable to that of chemical water-soluble phosphate fertilizer (TSP) (Figures 7 and 8). We concluded that the recognition of BPR effect on rice yield can enhance rice cultivation along with the aspect of usage of indigenous phosphorus resource in sub-Saharan Africa (SSA) (Nakamura *et al.*, 2013).

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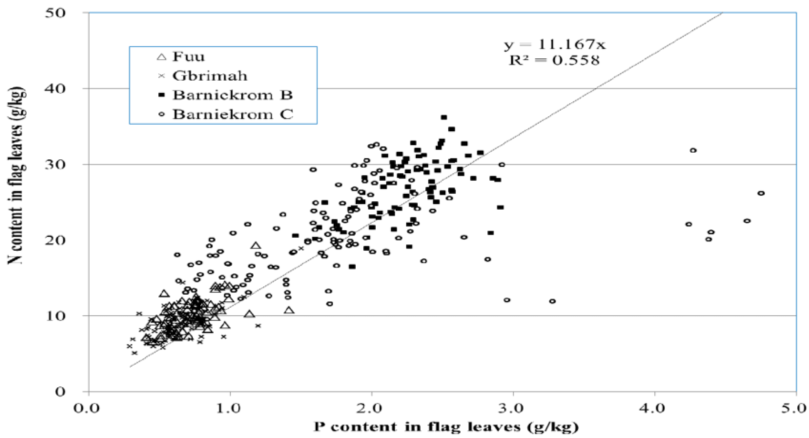

Figure 7. The relationship between P and N uptakes in rice cultivation in Northern and Ashanti regions of Ghana. Block and triangle symbols indicate Northern and Ashanti regions, respectively. (Source: Nakamura *et al.*, 2013).

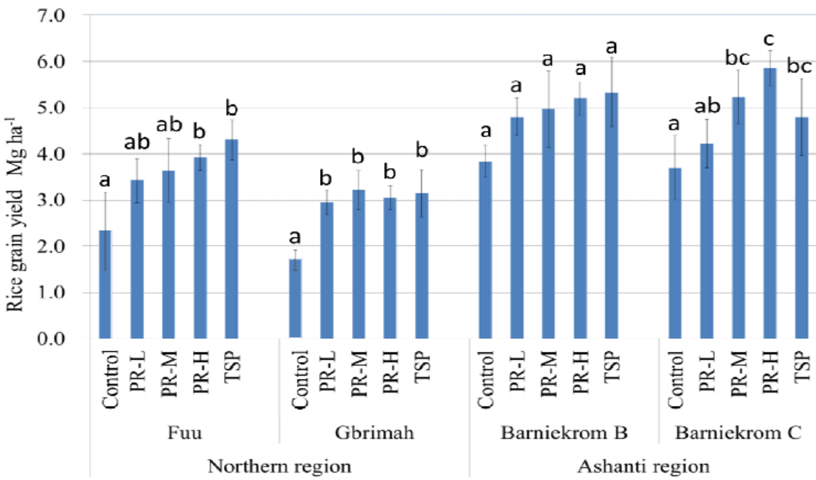

Figure 8. The effect of BPR direct application on rice yield in Northern and Ashanti region. Each treatment received 0 kg (Control), 67.5 kg (PR-L), 135 kg (PR-M), 270 kg (PR-H, and TSP) of P_2O_5 per hectare, respectively. Error bars indicate standard error (n = 3), and the same

letters are not significantly different at 5% level by Tukey's multiple comparison. (Source: Nakamura *et al*., 2013).

3.6 Effect of organic materials on availability of Burkina rock phosphate and phosphorus residual influence in lowland rice (*Oryza sativa* L.) production in Guinea savanna zone.

Rock phosphate has a high potential of substituting triple superphosphate for lowland rice production but it has received less attention due to its low level of solubility. This study employed the use of composting with organic materials as a method of improving P solubility/availability in rock phosphate as well as to determine the residual effect of rock phosphate on rice. The ten (10) treatments were ZERO, NK, NK+RP, NK-RP, RS/CD COMPOST+RP+NK, RS/HE COMPOST+RP-NK, NK+TSP, NK-TSP, RS and RS+NK. From this study, we have shown that rock phosphate solubility could be improved through composting and could be a cheaper method of increasing phosphorus availability. Also, the rock phosphate does not need to be applied in every cropping season since its residual effect could have significant effect on crop growth. Further studies should be done to determine the effect of organic amendments in improving rock phosphate solubility under upland conditions since water could play a significant role in P availability. (Source: Dzomeku, Abdul-Kareem and Rashad, 2018).

3.7 Verification of integrated soil fertility management and weed interference on NERICA rice in the Guinea savannah uplands

In spite of the economic importance of the rice crop, there is decline in grain yield due to reduced length of fallow as a result of increased human population, weed pressure and declining soil fertility (Saito *et al.,* 2010). Knowledge of soil amendment and understanding of weed-crop interference in response to rice cultivation may increase production of rice under upland conditions. A field study was conducted to verify integrated soil fertility management and weed interference on upland rice variety NERICA 1, in the Guinea savannah uplands of Ghana to determine soil amendments by weeding regimes, the preferable frequency of weeding and method of weed management and examine the synergy between organic and inorganic soil amendments on grain yield and yield components of the newly developed rice variety by AfricanRice. The result indicated that, application rate of NPK 60-60-30 kg/ha in combination with hand weeding at 3 and 6 weeks after planting (WAP) significantly enhanced plant height, number of tillers and effective tillering. Hand weeding only once at 3 WAP adequately enhanced tillering and effective tillering similar to the conventional twice hand weeding practice at 3 and 6 WAP. Weed index was minimized by twice weeding at 3 and 6 WAP with only 19% yield loss due to weed interference. Weed species dominance in rice upland ecology (Table 1) showed 55% broadleaves, 26% grasses, 12% shrub and 7% sedges. Dominant weed species were: *Panicum maximum, Commelina diffusa, Setaria barbata, Andropogon gayanus, Oldenlandia herbaccea, Ageratium conyziodes, Ludwigia decurrens, Cyperus esculentus, Dactyloctenium aegytium and Digitaria gayana*. (Source: Dzomeku, Amegbor and Ayittah, 2017).

Table 1: Effect of treatments on weediness species at the experimental site, after harvest.

Weed Species	Control	FULL OM	½Manure+½ NPK	FULL NPK	Life span
a. Broadleaves	**SDR (%)**				
Acanthospernum hispitum DC.	1.43	0.72	0.00	0.00	A
Ageratium conyziodes Linn.	5.92	1.92	1.83	3.62	A
Amaranthus spinosus Linn.	0.00	0.00	0.00	1.49	A
Aspilia africana Pers.	0.00	0.00	2.97	0.00	P
Cleome viscora L.	0.00	2.16	0.69	1.28	A
Commelina benghalensis L.	3.77	4.81	1.83	2.34	A/P
Commelina diffusa Burm.f.	6.41	5.77	3.67	4.05	P

Weed Species	**Control**	**FULL OM**	**½Manure+½ NPK**	**FULL NPK**	**Life span**
Conyza sumatrensis Retz Walker.	0.94	0.96	1.38	1.49	A
Euphorbia hirta Linn.	0.00	0.00	0.00	1.71	A
Hyptis spicigera Lam.	0.94	1.68	0.00	1.28	A
Hyptis suaveolens Poit.	1.43	0.72	0.69	0.64	A
Laportea aestuans Linn. Chew.	0.00	1.92	0.00	0.00	A
Laportea ovalifolia Schum. Chew.	0.94	0.72	0.69	1.49	A/P
Melochia corchorifolia Linn.	0.94	0.00	0.00	0.00	P
Mitracarpus villosus Sw. DC.	3.51	4.81	2.28	1.07	A
Oldenlandia corymbosa Linn.	0.00	.00	0.00	1.92	A
Oldenlandia herbaccea Linn. Roxb.	6.79	3.85	7.1	6.18	A
Phyllanthus amarus Schum & Thonn.	2.15	0.72	5.04	5.76	A
Pteridium aquilinum Linn. Kuhn.	0.00	0.72	0.00	0.00	A
Schwenkia americana L.	0.94	1.92	0.92	1.92	A
Senna obtusifolia L.	0.94	1.44	2.52	1.28	P
Sesanum alatum Thonning.	0.00	0.00	0.69	1.28	A
Sesanum indicum Linn.	0.00	0.00	0.00	1.92	A
Synedrella nodiflora Gaertn.	2.34	2.4	6.62	0.64	A
Tridax procumbens Linn.	0.00	3.37	0.00	0.00	A
Vernonia cinera Linn.	0.00	0.00	0.00	0.85	A
Waltheria indica Linn.	0.00	0.00	0.00	1.28	P
b. Grasses					
Andropogon gayanus Kunth.	6.79	9.62	4.34	6.39	P
Axonopus compressus Sw. P. Beauv.	0.00	0.72	0.00	0.00	P
Brachiaria lata Schumach.	4.26	1.44	0.69	3.2	P

Weed Species	Control	FULL OM	½Manure+½ NPK	FULL NPK	Life span
Cynodon dactylon Linn. Pers.	0.00	0.00	4.11	0.00	P
Dactyloctenium aegytium Linn. P. Beauv.	4.68	1.68	1.83	1.49	A/P
Digitaria gayana Kunth.	2.79	2.16	4.57	4.48	P
Digitaria horizontalis Willd.	5.69	3.13	4.35	2.35	A
Panicum maximum Jacq.	11.69	11.78	11.42	10.23	P
Paspalum scrobiculatum Linn.	6.15	7.21	3.21	4.26	A
Pennisetum pecidellatum Trin.	0.00	0.00	0.69	0.00	A
Rottboellia conchinchinensis Lour. Clayton.	0.00	0.00	4.35	3.41	A
Setaria barbata Lam. Kunth.	4.71	6.25	5.05	5.33	A
c. Sedges					
Cyperus esculentus Linn.	4.22	7.69	2.06	1.71	P
Cyperus rotundus Linn.	0.00	0.00	4.34	2.77	P
Mariscus alternifolius Vahl.	0.00	1.68	0.00	0.00	P
d. Shrubs					
Combretum hispidum Laws.	2.34	0.00	3.20	1.49	A
Icacina trichantha Oliv.	1.89	0.96	1.60	0.00	A
Ipomoea involucrata P. Beauv.	0.72	0.00	1.38	0.85	P
Ludwigia decurrens Walt.	2.79	2.4	2.06	1.49	A
Sida acuta Burm.f.	0.00	0.00	0.00	4.26	P
Stachytarpheta cayennensis L.C.Rich. Schau.	1.89	2.64	1.83	2.77	P

† A= Annual weeds, P = Perennial weeds, A/P = Annual and Perennial weeds. (Source: Dzomeku, Amegbor and Ayittah (2017).

3.8 Influence of seed quality and soil fertility management on the productivity of rice (*Oryza sativa* L.) in the Guinea savannah of Ghana

Seed quality and soil fertility improvement are two key determinants of enhanced crop production to ensure food security in the savannah ecology. We conducted field studies at the experimental field of the Savanna Agricultural Research Institute (SARI) from July to November during the 2011 and 2012 cropping seasons, to determine the interaction effects of seed quality and soil amendments on yield components and grain yield of Gbewaa rice (Jasmine 85). Seed quality, using farmer-saved seed and certified seed, was combined with five levels of soil amendments and laid out in a randomized complete block design with four replications. The soil amendments were: (1) No-amendment control, (2) Half Recommended Rate of inorganic fertilizer (HRR) 28.8-12.5-6.3 kg NPK/ha and 60 kg urea/ha (55.2 kg N/ha) as basal and top-dressing applications respectively, (3) HRR + 1.5 tonnes of compost per hectare, (4) Recommended Rate of inorganic fertilizer (RR) 57.5-25.0-12.5 kg NPK/ha and 120 kg urea/ha (110.4 kg N/ha) as basal and top-dressing applications, respectively and (5) RR + 3 tonnes of compost/hectare. In 2011, improved seed quality in combination with soil amendments made significant improvements in panicle length ($P<0.03$), number of seeds per panicle ($P<0.01$) and thousand-grain weight ($P<0.04$). Parameters that improved in both years with improved seed quality and also soil amendments were tiller count ($P<0.01$), number of seeds per panicle ($P<0.01$), and grain yield ($P< 0.001$). Certified seed gave better results than farmer-saved seed, whilst RR + 3 t/ha compost optimized each parameter. Nevertheless, RR alone promoted grain yield similar to RR + 3 t/ha compost. Tiller count ($r=0.889^{**}$), number of panicles per hill ($r=0.834^{**}$), number of seeds per panicle ($r=0.922^{**}$) and thousand grain weight ($r=0.893^{**}$) were all positively correlated with grain yield in 2012. Tiller count consistently accounted for more than 75% of the grain yield. The food security implications of the results were discussed in the full paper. (Source: Dogbe *et al*., 2015).

4.0 RESEARCH ON WEED MANAGEMENT IN MAIZE

Maize (*Zea mays* L.) is the most important cultivated cereal crop in tropical sub-Saharan Africa. The crop is a rich source of food, fodder and feed. It provides raw material for the agricultural industry for products such as corn starch, corn flakes, gluten germ-cake, lactic-acid, alcohol and acetone which are consumed as food or for textiles. It has high carbohydrate content of about 71%, but low in protein and serves as the main source of carbohydrates for poultry industries in Ghana (MoFA, 2010),. However, annual grain production of maize in Ghana falls short of demand (MoFA, 2010), due to several abiotic limiting factors. Results of three experiments designed to improve soil fertility for weed management are reported here.

4.1 Evaluation of type and application timing of indigenous organic materials on the productivity of maize (*Zea mays* L.) in Guinea savannah of Ghana.

The first experiment designed to improve soil fertility for weed management was carried out to determine how long should the untreated indigenous organic materials be soil incorporated before planting to promote maize seedling emergence and avoid crop injury?

The experiment was a 4 x 5 factorial study which examined (1) the optimum sowing date of maize seed after the incorporation of indigenous organic materials (OM) of Biochar, Rice straw, Rice husk and groundnut shell. Five planting dates used were: 7 days after incorporation (DAI) of OM (PD1), 14 DAI of OM (PD2), 21 DAI of OM (PD3), 28 DAI of OM (PD4) and 35 DAI of OM (PD5). The twenty treatments were laid out in a Randomized Complete Block Design and replicated three times. It was concluded that at least 21 days of delay was required after the incorporation of the untreated organic materials for seed planting to avoid injury to emerging seedling and production in the Guinea savannah environment. Grounded groundnut shell (GGS) and biochar (B) enhanced crop seedling growth over rice straw (RS), with Rice husk (RH) being the least supportive. (Source: Dzomeku and Illiasu, 2015).

4.2 Effects of Groundnut Shell, Rice Husk and Rice Straw on the Productivity of Maize *(Zea mays* L.) and Soil Fertility in the Guinea Savannah Zone of Ghana

A field experiment was conducted at Nyankpala, near Tamale during the 2014 cropping season to investigate the effects of indigenous organic materials of groundnut shell, rice husk and rice straw on yield components and yield of maize. The study was a 3 x 3 x 3 factorial experiment consisting of the three organic materials at three levels (2.5, 5 and 7.5 t ha^{-1} on dry matter basis) and three NPK rate (zero control, 45-30-30 kg/ha and 90-60-60 kg/ha) laid out in a randomized complete block design with four replications. Best grain yield of 4781 kg/ha was obtained with 7.5 t/ha groundnut shell plus 90-60-60 kg NPK/ha but 5 t/ha of groundnut shell plus 90-60-60 kg NPK/ha, 7.5 t/ha groundnut shell plus 45-30-30 kg NPK/ha, 7.5 t/ha of rice husk or rice straw plus 90-60-60 kg NPK/ha gave equal yields. Yield and yield components of maize were improved by the treatments. Grain yield correlated positively with stover weight (r = 0.851**) and cob length (r = 0.601**). (Source: Dzomeku and Illiasu, 2018).

4.3 Role of Residual Organic Materials on Productivity of Maize (*Zea mays* L.) for Sustainable Soil Fertility Restoration in the Guinea Savannah Zone, Ghana

A field experiment was conducted at Nyankpala, near Tamale, Ghana, during the 2014 cropping season and continued during 2015, to investigate one year residual effects of indigenous organic materials (biochar, groundnut shell, rice husk and rice straw) on the growth and yield of maize It was a 4x3x3 factorial experiment consisting of 4 organic materials at 3 levels (2.5, 5 and 7.5 t ha^{-1} on dry matter basis) and 3 nitrogen (N) levels (0, 45 and 90 kg/ha N) laid out in a Randomized Complete Block Design with four replications. The study revealed that integrated management of one year residuals of the organic materials with inorganic N supported increased plant height and grain yield, and moderated time of flowering to promote production of maize variety "Wang Dataa". Application of 7.5 t/ha biochar + 45 kg/ha N, similarly 5 t/ha biochar + 90 kg/ha N supported tallest crop of 200 cm, whilst early flowering ranged 47 to 50 days with 2.5 t/ha biochar + 90 kg N/ha, 5 t/ ha biochar + 45 kg N/ha, 7.5 t/ha biochar+ 90 kg N/ha, 2.5 t/ha groundnut shell + 90 kg N/ha and 7.5 t/ha rice straw + 45 kg N/ha. Grain yield was maximised with 7.5 t/ha biochar + 90 kg N/ha, 5 t/ha groundnut shell + 45 kg N/ha, 7.5 t/ha groundnut shell + 90 kg N/ha and 7.5 t/ha rice husk + 90 kg N/ ha in the range of 3000 - 3600 kg/ha. The results also showed strongly that residual nutrients and other plant growth conditions obtained from the organic materials determined LAI, height of cob attachment, cob length, cob weight, 100 seed weight and stover biomass. Residual conditions provided by 7.5 t/ha of biochar gave the highest LAI. Best cob length of 15 to 17 cm was obtained from 2.5 t/ha biochar and 5 t/ha groundnut shell. Cob weight under residual organic materials was in the range of 125 to 165 g/cob with 5 t/ha biochar or groundnut shell and 7.5 t/ha rice straw adequate to maximize the trait. Residual organic materials impacted on 100 seed weight with 5 t/ha of biochar and 7.5 t/ha groundnut shell impacted largest grain size of 25.5g. Stover weight was both highly significantly determined by residual effects of organic materials and N. Application of 5 t/ha biochar or 5 t/ha groundnut shell or 7.5 t/ha rice husk was adequate for highest stover weight. Pearson correlation coefficients of grain yield with other traits exhibited robust relationships signifying strong impact of integrated soil fertility management of one year residual organic materials and N on maize production in the Guinea savannah. Grain yield prediction indicated treatments were best fitted in polynomials with 7.5 t/ha biochar + 90 kg N/ha (Figure 9) as the best for optimum grain yield. (Source: Dzomeku *et al.*, 2016).

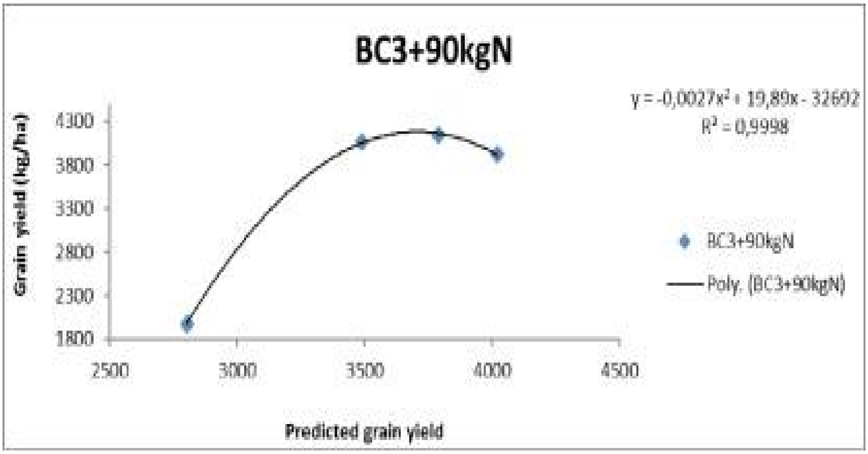

Figure 9. The polynomial for BC3 + 90 kg N. (Source: Dzomeku *et al.*, 2016).

4.4 Effects of Integrated Use of Organic and Inorganic Fertilizer on Soil Chemical Properties in the Guinea Savannah Zone of Ghana.

In the two-year field experiment conducted in 2014 and 2015 on the indigenous organic materials, an evaluation of one year residual effect of the materials on soil chemical properties was determined. The results showed that the application of 2.5 t/ha groundnut shell without sulphan N supplement was adequate in improving soil C, N, P and K but biochar plus N was superior. Rice straw without N treatments increased soil pH and Ca levels. The superior effects of groundnut shells and biochar were more pronounced at the application rate of 5-7 t/ha with or without N. Biochar treatments with or without N were the most influential treatments on Mg. We concluded that, application of either groundnut shells or biochar could improve soil chemical elements of the savanna soils for crop production whilst with acidic soils and/or Ca deficient soils, rice husk and rice straw materials are recommended for use. (Source: Dzomeku, Illiasu and Mohammed, 2018).

5.0 RESEARCH ON WEED MANAGEMENT IN GROUNDNUTS (PEANUTS) (*Arachis hypogaea* L.)

Peanut (*Arachis hypogaea* L.) production in the savanna ecology is of great potential in the West African region (Schilling and Misari, 1992). However, weed interference is a major constraint to optimum production requiring considerable investment of human labor to minimize the negative impact on pod yield (Akobundu, 1987; FAO, 1994). Yield loss due to weed interference in West Africa is estimated to be 50 to 80% (Akobundu, 1987). The relatively slow initial growth of peanut and morphological characteristics that do not allow it to grow above weeds influence susceptibility of the crop to early season weed interference (Akobundu, 1987; Subrahmaniyan *et al.,* 2002). However, information on weeds and other management constraints in Northern Ghana cropping system is limited.

5.1 Survey of weeds and management practices in peanut (*Arachis hypogaea* L.) in the savanna ecology of Ghana.

To formulate and transfer effective and sustainable weed management strategies in peanut requires documentation of distribution of weeds and characterization of agronomic and weed management practices. The objectives of this study were to (1) determine the distribution and density of weeds in peanut cropping systems, (2) document weed management practices of farmers, and (3) assess yield response of peanut to current farmer weed management strategies in northern Ghana. This was a survey conducted in 48 farmer fields during 2003 to 2005 by randomly evaluating four 1m^2 quadrats per field in the Northern, Upper East, and Upper West Regions.

We reported that weed flora dominance with more than 5% weediness included: (1) dicotyledonous weeds: *Corchorus olitorius* L. *Commelina benghalensis* L., *Commelina diffusa* Burm., f, *Desmodium scorpluras* (Sw.) Desv., *Hyptis suoveolens* Poit., *Mimosa invisa* Mart., *Mimosa pigra* L., *Mitracarpus villosus* (Sw.) DC., *Oldenlandia corymbosa* L., *Phyllanthus amarus* Schum. & Thonn., *Scoparia dulcis* L., *Tridax procumbens* L., *Trium- feta cordiflora* A. Rich., and *Vernonia galamensis* (Cass.) Less.; (2) the monocotyledonous weeds: *Axonopus compresus* (Sw.) P. Beauv., *Cyperus esculentus* L., *Cyperus rotundus* L., *Digitaria horizontalis*Willd., *Eragrostis tremula* Hochst. Ex Steud., *Hackelochloa granularis* (L.) O. Ktze., *Kyllinga erecta* Schumach. Var., *Kyllinga squamu- lata* Thonn. Ex Vahl., *Paspalum scrobiculatum* L., *Rottboellia cochinchinensis* (Lour.) Clayton, and *Setaria pallide-fusca* (Schum.) Stapf. & C.E. Hubbard; and (3) the parasitic weed *Striga hermonthica* (Del.) Benth. Land was prepared by tractors or livestock, and to less extent hoeing. Cropping systems consisted of cereals before groundnut, groundnut preceding groundnut and groundnut/sorghum or with millet or maize intercrops. Genetically-improved peanut cultivars of bunch or erect growth and distinct runner cultivars were common. Planting starts early June to early July based on rainfall pattern. 80% of the fields were hand weeded once, 3 to 5 weeks after planting (WAP), with twice weeding, 2 to 3 and 5 to 6 WAP in the minority. Poor timing and frequency of weed management resulted in high weed biomass of 600 to 2400 kg/ha and low haulm yield of less than 5500 kg/ha. Pod yield was low in the range of 200 to 1680 kg/ha. Results from this survey revealed the need for accelerated research and capacity building of farmers and agricultural extension agents for improved technology transfer to the peanut farming industry in Northern Ghana. (Source: Dzomeku *et al.*, (2009).

5.2 Evaluation of herbicides for weed control efficacy in groundnuts (*Arachis hypogaea* L.) in the Guinea savannah zone of Ghana

Efficient and appropriate use of herbicides could reduce drudgery in weed management to meet target timing of weed control (Akobundu, 1980; Abudulai *et al*., 2007). Combinations of pre-plant incorporated or pre-emergence herbicides currently registered for use in groundnut have not shown any crop injury (Wilcut *et al*., 1995). However, Akobundu (1990) reported that herbicides could be phytotoxic if not used within certain dose range. New herbicides continue to flood the Ghanaian market, necessitating the need for evaluation for best-bet acceptable and safe dose range recommendations for adoption by farmers. The objectives of this paper were to determine the most suitable combination of some new herbicides and/or hand weeding that could enhance weed control. A field experiment was therefore conducted to study the effect of pre-emergence and post emergence herbicides for weed control in groundnuts during the 2011 and 2012 cropping seasons. The study determined the most suitable combination of herbicide with or without hand weeding that could enhance efficient weed control and promote yield and yield components in the crop. Thirteen weed control treatments were laid out in randomized complete block design with four replications.

Percent Weed Index, which determines the reduction in crop yield due to weed infestation and a good guide for weed control effectiveness, was least with a four treatments including (1) pendimenthalin at 0.15kg a.i./ha plus one hand weeding at 4WAP, (2) haloxyfop at 0.03kg a.i./ha plus one hand weeding 7WAP, (3) propaquizafop at 0.02kg a.i./ha at 4WAP plus one hand weeding at 7WAP and (4) also bentazon at 0.14kg a.i./ha at 4WAP plus one hand weeding at 7WAP. The same treatments gave weed control efficiencies of 78 to 85% comparable to the farmer control.

Combination of pre- and post-emergence herbicides as a weed control package in groundnuts did not appear advantageous; but supplememtary hand weeding appeared a necessity to promote pod yield. Summed dominance ratio of weed species amplified prevalence of broadleaves such as *Ageratum conyzoides* (L), *Commelina africana* (Linn), *Corchorus olitorius* (Linn), *Hyptis suaveolens* (Poit) and *Ludwigia abyssinica* (A. Rich). Season-long weed infestation gave 43 to 69% pod yield loss. (Source: Dzomeku, 2017).

5.3 Peanut (*Arachis hypogaea* L.) response to weed and disease management in northern Ghana

Information is limited in Ghana with respect to interactions of weed and disease management practices that include herbicides and fungicides. Developing a database on peanut and pest response to management with herbicides and fungicides compared with traditional practices could lead to more informed use and potential for these inputs to increase yield and reduce labor in peanut production systems. Therefore, the objective of this research was to determine peanut response to weed and disease management practices in northern Ghana that included herbicide and/or hand removal of weeds and fungicides.

Field experiments were therefore conducted in Ghana at the research farm of CSIR-Savannah Agricultural Research Institute (SARI) in Nyankpala and in a farmer's field near Bagurugu during 2009 and 2010, using the cultivar Chinese. Treatments consisted of 2 levels of hand removal of weeds (no hand removal versus hand removal), 2 levels of pre-emergence herbicide (no herbicide versus pendimethalin), and 2 levels of fungicide for leaf spot disease. Hand-removal of weeds occurred 3 and 6 weeks after planting (WAP) using hoe and hand pulling. Pendimethalin (Stomp 440g/l) was applied within 2 days after planting at 1.0 kg a.i./ha. A total of 4 fungicide applications were delivered during the season and were initiated 4

WAP at the R1 state of peanut growth and continued at bi-weekly intervals. Weed species diversity and density were determined 12 WAP at Nyankpala using a 1 x 1m quadrat in the no-herbicide and no-fungicide control. Weed biomass and peanut haulm were taken at harvest from a 4-m row from the center 4 rows of each plot at 12 WAP and oven-dried to obtain dry weed biomass and haulm weights and pod yield. Data were subjected to ANOVA for a 4 (site/year combination) x 2 (herbicide treatments) x 2 (hand-removal of weeds) x 2 (disease management treatment) using the general linear model procedure in SAS (2006).

Similar to other experiments with peanut (Abudulai *et al.*, 2007; Dzomeku *et al.*, 2009) results from these experiments indicate that both weeds and leaf spot disease can have major impacts on peanut yield in Ghana. Suppression of weeds either from herbicide, hand removal, or the combination of these strategies was less effective than in combination with fungicide in protecting yield. Variation in herbicide performance was reported per year and location. The greater impact of fungicide in protecting yield may reflect the widespread incidence of leaf spot in northern Ghana and the sporadic presence of weeds in some fields. A limitation of this research is lack of economic assessment of management strategies. While significant increases in yield were noted when fungicides were applied regardless of year, location, or herbicide treatment, the economic return on this investment was beyond the scope of this experiment. However, in a previous research in Ghana, it was noted that the increase in yield with fungicide and improved soil fertility translated into 45 fold increase in gross margin for farmers (Naab et. al., 2009). Future research demonstrating the economic value of both herbicides and fungicides, hand-removal of weeds, and use of cultivars with resistance to leaf spot disease is needed. Nonetheless, results from these experiments provide information that can be used to determine the potential of herbicides and fungicides in peanut in

Ghana. We conclude that in these trials the combination of effective weed management through either hand removal of weeds, pendimethalin, or a combination of these weed control tactics resulted in the greatest yields when combined with an effective fungicide regime. (Source: Abudulai *et al*., 2017).

5.4 Groundnut (*Arachis hypogaea* L.) Response to Phosphorus and Weed Management in the Guinea savannah zone of Ghana

Field studies were conducted during the 2013 and 2014 cropping seasons at the experimental field of the CSIR-Savannah Agricultural Research Institute (SARI), Nyankpala, to evaluate the response of groundnut to phosphorus fertilizer and manual weed control. A total of twelve treatments comprising four levels of phosphorus (0, 15, 30 and 45 kg/ha) and three weeding regimes (weedy check, weed free, and weeding at 3 and 6 WAP) were laid out in a randomized complete block design with three replications. Figure 10 shows the decadal patterns of rainfall and cardinal temperatures taken for the two years that the experiment was conducted. The area was characterized by a unimodal rainfall distribution. Rainfall distributions in 2013 were better relative to that of 2014 cropping season (Figure 10). The mean annual temperature was 27±2 °C.

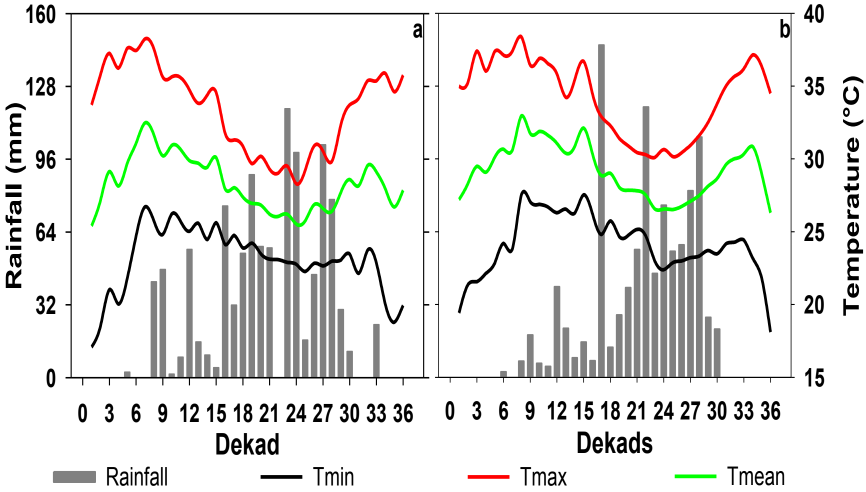

Figure 10: Dekadal patterns of rainfall and cardinal temperatures at Nyankpala in 2013 (a) and 2014 (b). A review on weed management in groundnut (*Arachis hypogea* L.) t min, t max, and t mean are averages for minimum, maximum, and mean temperatures respectively. (Source: Dzomeku *et al*., 2019).

Results indicated significant differences in canopy spread, effective nodulation, fresh and dry pod weights, weed biomass, 100 seed weight, haulm weight and soil arthropod pest densities and damage due to weeding regime and phosphorus interaction in both seasons. Weeding twice at 3 and 6 WAP plus 30 or 45 kg/ha phosphorus reduced soil arthropod activity similar to weed free plots and improved yield parameters such as haulm biomass (Figure 11). Canopy spread, effective nodulation and pod yield correlated positively (r = 0.72 – 0.95) with haulm weights in both years. Although, similar growth and development were observed in the weed free and weeding at 3 and 6 WAP plots, for reasons of labour and cost envisaged in the practice of weed free farming, weeding at 3 and 6 WAP and application of 45 kg P/ha was recommended for maximizing groundnut production of groundnuts in northern Ghana. (Source: Dzomeku *et al*., 2019).

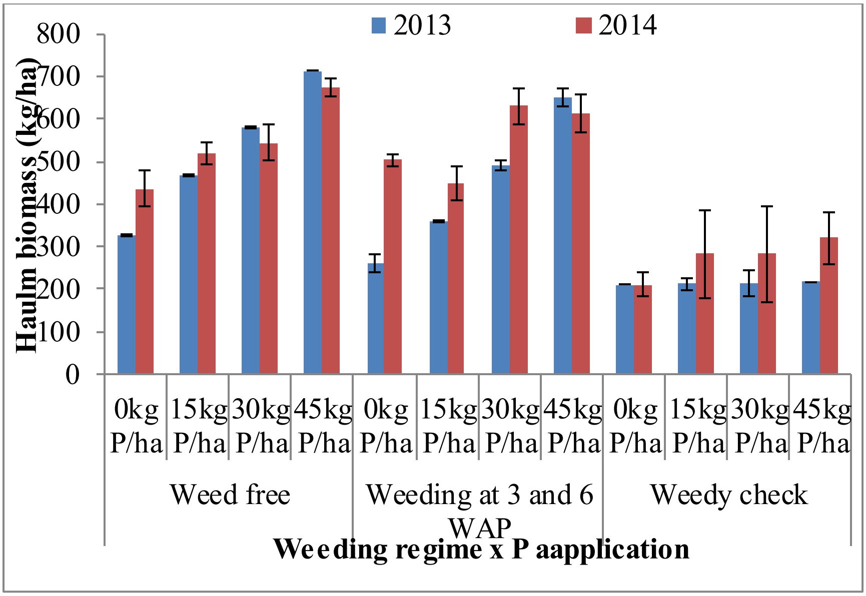

Figure 11: Effect of weeding regime and phosphorus on haulm biomass. Bars represent SEM. (Source: Dzomeku *et al*., 2019).

6.0 RESEARCH ON WEED MANAGEMENT IN COTTON

6.1. Evaluation of the Efficacy of Some Pre-Emergence Herbicides in Cotton *(Gossypium* spp.) in Northern Ghana

A field experiment was conducted at the Savannah Agricultural Research Institute to investigate the effects of pre-emergence herbicides for weed control in cotton during the 2014 and 2015 cropping seasons. The study determined the effects of different rates of three novel cotton herbicides with different formulations on weeds, yield components and yield of seed cotton, applied as pre-emergence. The treatments were laid out in randomized complete block design with four replications of Diflafenican + Flufenicent and Diflufenican + Flufenicent + Flurtamone as 500SC formulations of each and applied at the rate of 0.3, 0.4, 0.6, and 0.8 l/ha, whilst Diflufenican + Flufenicent + Flurtamone as 200SC formulation was applied at 0.4, 0.5, 0.8, and 1.0 l/ha. A reference herbicide + product with active ingredients Promotrin + Metolachlor applied at 3.0 1/ha and untreated weedy and weed free checks were included. Results showed that. Diflufenican + Flufenicent + as 200SC applied at 0.8 l/ha gave the lowest weed dry weight (65.0 g/m^2) similar to the reference herbicide (189.4 g/m^2) and Diflufenican + Flufenicent + Flurtamone as 200SC applied at 0.8 l/ha (144.8 g/m^2). Consequently, Diflufenican+ Flufenicent applied at 0.8 l/ha gave significantly ($p<0.05$) the highest number of bolls and number of opened bolls than the reference herbicide (Source: Mawunya et. al., 2017).

7.0 ADAPTIVE STRATEGIES OF RURAL FARMERS IN CROP AND LIVESTOCK PRODUCTION AGAINST EXTREME CLIMATIC VARIATIONS

Agriculture is dependent on climate. Thus, extreme variations in weather parameters such as rainfall and temperature have devastating effects on those who depend on agriculture for their livelihood. Extremes in rainfall such as flooding and droughts are the likely consequences of climate variability and may affect (either negatively or positively) plants, animals, and human beings in most communities (Ozor and Nnaji 2010). Agricultural production and access to food in many African countries and regions are projected to be severely compromised by climate variability and change. Areas suitable for agriculture, the length of growing seasons, and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease (Reid *et al.*, 2009), seriously affecting food security and exacerbating malnutrition on the continent. The livelihoods of the people of northern Ghana, particularly those in rural areas, depend to a large extent on agriculture. Farmers in these areas have noticed variations in the climate. Accordingly, they have formulated coping strategies to avoid substantial or complete losses in livestock and crop productivity. However, the extreme climatic variations in recent years have threatened the resilience of current adaptive strategies, and failures in crop and livestock productivity are on the rise. The inevitable changes predicted by the Intergovernmental Panel on Climate Change and other scientists demand an understating of the coping strategies of rural farmers and recent crop production in order to develop capacity-building programs for farmers.

7.1 Strategies of farmers in the Bawku West district of Ghana to mitigate the impacts of climate variability on farming

Field data was collected from 135 farmers and key informants in the Bawku West District using semistructured questionnaires and checklists, and the data were analyzed using descriptive statistics. The results indicate that farmers in the study area practice mixed farming with a current focus on the rearing of goats and poultry, the cultivation of new and improved crop varieties, and the planting of early-maturing crop varieties in flood prone areas. The findings suggest that the capacities of farmers should be enhanced through the provision of reliable information on climatic variations and access to farm implements, farm inputs, irrigation facilities, and credit facilities to help farmers enhance productivity and engage in other income-generating activities. (Source: Abarike, Yeboah and Dzomeku, 2018).

8.0 CONCLUSION

In conclusion, as one of the few professionally trained Weed Scientists in Ghana, I have satisfied the aspirations of the profession by achieving the following:

- Provided an additive seed conditioning model driven by temperature and modified by water potential and Urea-N to enable scientists, agricultural agents and farmers look beyond planting date techniques but focus on integrated management of the parasitic weed *Striga hermonthica*.

- The *Striga* model have been effectively validated in the Guinea savannah fields of Binaba near Zebila in the Upper East Region of Ghana with 92% precision,
- In collaboration with International Scientists, we developed a workable ICT interactive weed identification tool for lowland rice weeds; but this tool could be applicable to upland flora,
- The weed flora in the cropping systems of rice (lowland and upland ecologies) and groundnuts in Northern Ghana have been identified and well documented to enable planning of any agricultural venture in these cropping systems,
- We have demonstrated that rice straw application during land preparation and the use of compost and human excreta gave acceptable rice grain yield in the lowlands, but usage of rice straw could be the most cost effective choice,
- I have with the support of my M.Phil. and Ph.D. students demonstrated that the use of biochar, groundnut shell, rice straw and rice husk could enhance maize production on Northern Ghana soils which are already low in organic matter,
- I have with the support of my M.Phil. and Ph.D. students demonstrated for the first time in Northern Ghana, that high maize production could be achieved on residual nutrients from one year application of biochar, groundnut shell, rice straw and rice husk,
- We have demonstrated that the solubility and availability of Burkina Rock Phosphate (BRP) could be increased through compositing with organic matter (i.e. using rice straw, cow dung and human excreta).
- Composted BRP had similar effect on grain yield of lowland rice as TSP and BRP gave an additional residual advantage in the second year cropping.
- I have trained a large cohort of students; one of them is the current head of the Weed Science unit of the Savannah Agricultural Research Institute (SARI).

- Many Agricultural Extension Agents and farmers benefitted from capacity building trainings I conducted on lowland rice weed identification and integrated weed management. Cores of Agricultural Extension Agents and farmers were also trained on integrated weed management of *Striga* species on cereals and cowpea in the Upper East Region.
- Our Paper : "Nakamura S., Issaka R. N., Awuni J., **Dzomeku I. K.,** Buri M. M., Avornyo V., Adjei E. O, Fukuda M., Aware D. A. and Tobita S. (2016a). Soil fertility management for sustainable lowland rice production in Ghana. Farmer's perspectives and soil physicochemical properties. *Tropical Agriculture Development* 60(2): 119-131; **won the "Award for outstanding paper published by Japanese Society for Tropical Agriculture and Development"**. Awarded and signed on March 11, 2017, by Professor Eiji Nawata (President of the Society).

9.0 RECOMMENDATIONS

- Weed Scientists, Agricultural Extension Agents and Farmers must endeavor to address the problems of the following difficult to management weeds in their various agro-ecologies with integrated weed management, with appropriate crop rotation as major input. These include *Cyperus rotundus* (Purple nutsedge), *Ischaemum rugosum* (Saramolla grass), *Oryza longistaminata* (perennial wild rice), *Oryza barthii* (African wild rice), *Rottboellia cochinchinensis* (Itchgras), *Imperata cylindrica* (speargrass, cogon grass), *Echinochloa crus-galli* (barnyard grass), *Striga hermonthica* and *S. gesnerioides* (witchweed),
- There is the need to research further into the use of indigenous crop residues for advancement of soil fertility and reduction in weed seed banks, in both upland and lowland ecologies and document the relationship between amount of organic matter applied and the corresponding effect on weed flora seed bank and weed infestation,

- Soils in Northern Ghana are low in Phosphorus. However there is large deposit of Rock Phosphate in Burkina Faso. Further research on the solubility and availability of Burkina Rock Phosphate (BRP) is encouraged especially in upland farming systems to help farmers reduce the reliance on the more costly Triple Super Phosphate (TSP).
- Ghana needs to increase the number of professionally trained Weed Scientists to get involved in good applied research to increase knowledge and understanding in weed management beyond the art of unsolicited application of herbicides to the detriment of the environment.
- With the proliferation of herbicide usage by farmers, there is the need to upscale their capacity in knapsack calibration and appropriate safe usage of protective clothing and disposal of herbicide empty containers to avoid human health and environment pollution, social and economic losses.

10.0 ACKNOWLEDGMENTS

To God is The Glory for His Divine leadership, guidance and Grace for Life.

I am indeed grateful to my parents Mr Evans Kofi Dzomeku and Mrs Grace Akua Dzomeku both of blessed memory, who did their best to take care of me till their demise. I am severally indebted to them and will forever remember their determination and sacrifices done to see me through the course of life to date.

I am grateful to my uncles (both deceased) Mr Manase Kwaku Dzomeku, a former head teacher and Mr Leonard Hagan, a former Headmaster of Mawuli School Ho, for their support and care during my Secondary School Education.

My special thanks goes my beloved Sister Mrs Ivy Nuworkloh for her great and unflinching care and support through thick and thin during my Secondary and Tertiary Education.

I am deeply indebted and express my thanks to my Thesis supervisors, Professor Emmanuel Owusu-Benoah of the University of Ghana, Legon (B.Sc. level), Professors L. Ndahi and S K Lakoke of Ahmadu Bello University of Zaria, Nigeria (M.Sc. level) and Professor Alistair J. Murdoch of the University of Reading (Ph.D. level) for their academic guidance and quality research support.

My sincere thanks goes to past and present senior members of the Department of Agronomy, UDS, notably, Dr. Dotse Yao Innocent Lawson and the late Prof. Thomas Bayobor, (Alias TBoBo, Former Dean of FoA), Prof. Elias N.K. Sowley, Dr. Benjamin K. Badii, Dr.Rufai Mahama Ahmed, Dr. Isaac Kwahene Addai, Dr. Raphael Adu-Gyamfi, Dr. Joseph Kugbe, Dr. Shirley Lamptey, Dr. Frederick Kankam, Dr. Mustapha Sanatu Alidu, Dr. Samuel Adu-Acheampong and Mr. Vincent K. Avornyo for their support.

I equally appreciate and extend my sincere thanks to the hard working administrative and field technical staff of the Department of Agronomy, past and present, (notably Messrs Alex Faalong, Alhassan Abdul-Kareem and Mohammed Sayibu) for their assistance and hard work.

My sincere gratitude goes to the University for Development Studies for opening the door of the great Baobab tree (*Adansonia digitata*) to showcase my talents and appropriately provide the needed service to Mother Ghana. I am particularly grateful to Prof. Raymond. B. Bening (foundation Vice-Chancellor), Prof. Haruna Yakubu (immediate past Vice-Chancellor), Nutifafa Kuenyehia, Esq. OOV (current UDS Council Chairman), Prof. Gabriel Ayum Teye (Vice-

Chancellor), Prof. Seidu Al-hassan (Pro. Vice-Chancellor), Dr. A.B.T Zakariah (Registrar), Mr. Mohammed Hardi Shaibu (Director of Finance), Mr George Debrie (Deputy Registrar) and Prof. George Nyarko (Principal of the Nyakpala Campus).

My appreciation goes to Deans and Directors, past and present Dean of Students' Affairs, past and present Vice Dean of Students, Senior Hall Tutors and staff of the Guidance and Counseling Unit for their hard work. I owe tremendous thanks to the staff of Graduate School and office of the Dean of Students' Affairs, notably Mr. Messrs Gilbert Ansoglenang and Nana J.D. Thompson (Senior Assistant Registrars), Mr. Ayuba Ibrahim Alidu and Ms Lorentia Kania Wonnia (Assistant Registrars), Hajia Alima Abdul_Nasser (Principal Adm. Asst. and Mrs Judith Akanyomse (Adm. Assistant).

I sincerely thank Dr. A.B. Salifu (immediate past Director General of CSIR and a former UDS Council Chairman), Dr. Stephen Nutsugah (Director of CSIR-SARI), Dr Mumuni Abdullai (Chief Research Scientist), Dr. Roger Kanton (Chief Research Scientist), Dr. Wilson Dogbe (Principal Research Scientist), Dr. James Kombiok (Principal Research Scientist), Dr. Saaka Buah (Principal Research Scientist) and Dr Nicholars Denwar (Senior Research Scientist) all of CSIR –SARI fraternity, for providing the enabling research platform for our fruitful collaboration and useful publications and attendance at Research Conferences.

I am indeed grateful to the sponsors of some of my research activities, notably, the Ministry of Food and Agriculture, Japan International Research Center for Agricultural Sciences (JIRCAS) and USAID through the International Fertilizer Development Center (IFDC).

My thanks goes to the University Librarian Mr. Edwin S. Thompson and his staff including Dr. Florence Dedzoe-Dzokoto Plockey (Senior Assistant Librarian), Charlotte Yenbil (Jr. Assistant Librarian), Ishawu Alhassan (Jr. Assistant Librarian) and Setor Lotsu (Jr. Assistant Librarian) for their assistance in adding Book of Abstracts and souvenirs to the collection for this lecture.

Finally, behind every successful man, there is a visionary and supportive woman. I sincerely thank my wife Mrs. Mabel A. Dzomeku for her unflinching support, love, care and prayers. God graciously bless you and the four boys, namely Peter, Paul, Philip, Prince and my nephew Wisdom for their obedience and patience at all times.

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