Vol. 17(3), pp. 472-478, March, 2021
DOI: 10.5897/AJAR2020.15213
Article Number: 70CEE5466341
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Effects of soil amendments and weeding regimes on growth and yield potential of rice (*Oryza sativa* L.) under different water sources in the Guinea Savanna

Louis Tiebu, Rashad Awal Mohammed and Shirley Lamptey*

Department of Agronomy, Faculty of Agriculture, University for Development Studies, P. O. Box TL 1882, Tamale, Ghana.

Received 16 September, 2020; Accepted 3 December, 2020

Enhancing soil fertility and reducing the devastative effect of weed competition in rice is increasingly important and critical for ensuring a sustainable increase in rice production and secure food supply. Field experiment was conducted at Bontanga in the Northern Region of Ghana to investigate the effect of soil amendments and weeding regimes on growth and yield of rice under different moisture sources. The experiment was a three-factor experiment laid in a split plot design with three replications. The factors were water source (irrigation and rainfed), four levels of soil amendments [no fertilizer (NF), poultry fertilizer (PF), mineral fertilizer (MF), cow dung (CD)] at the same N rate (60kg N ha^{-1}) and four levels of weeding regime (weedy check (W1), weed free (W2), one hand weeding + twice herbicides application (W3) and twice hand weeding + one time herbicides spray (W4). Parameters measured were tiller count, weed biomass, weed control efficiency, grain yield and cost analysis. Results showed that water source, soil amendments and weeding regimes had influenced rice yield. Irrigation increased rice grain yield by 49% compared to rainfed. Application of CD, MF and PL at the same N quantity increased grain yield by 5.4, 28 and 8%, respectively compared to NF. Among weeding regime, weed free reduced weed density and biomass, this translated to greater tiller counts and increased grain yield. Weed interference in weedy check reduced grain yield by 48, 30 and 26% compared to W2, W3 and W4, respectively. Irrigation increased cost of production by 7%, however, cost:benefit ratio increased by 44% compared to rain fed conditions.

Key words: Soil amendments, weed control, irrigation, rain fed, yield, rice.

INTRODUCTION

The role of the rice crop is inevitable in current and future global food security (Chauhan et al., 2017). In Ghana, it is the second most consumed cereal after maize (Nyarko and Kassai, 2017). In 2017 Ghana produced 721,610

*Corresponding author. E-mail: naalamp2009@yahoo.com.

tonnes of rice but consumption was at 1.3 m tonnes, far outstripped the production and left a deficit of 580,300 tonnes (MOFA, 2017). Consequently, the nation imports 53% of its consumption to augment the demand short fall (MoFA, 2017). Ghana spends $4.5 million from its limited resources annually on rice imports (Ayisi and Kassai, 2017). Government and policy makers in sub-Saharan Africa, including Ghana are striving hard to achieve self-sufficiency in rice production to ensure food security and reduce expenditure on rice importation (Hossain, 2006). This can be achieved largely by increasing the area under rice cultivation or increasing its productivity per unit area (Kranjac-Berisavljevic et al., 2003). Rice production is highly sensitive to climatic, environmental and soil conditions. Northern Ghana experiences one rainfall season (May-October), which often is highly erratic (Ndamani and Watanabe, 2013). Thus, irrigated rice production must be given the needed attention. Rice production has a direct bearing on soil fertility and for that matter the use of inputs. Nitrogen is a crucial nutrient element associated with crop yield (Bouman et al., 2007) and the most limiting plant nutrient in the tropics (Adigun et al., 2017). Rice require large amount of nitrogen for growth and development compared to other essential macro nutrients (Alim, 2012). Ghana is among few countries in sub-Sahara Africa with high nutrient depletion, probably due to low fertilization (IFPRI, 2014), and farmers inability to afford the required dose accounting to low yields (Adigun et al., 2017). Meanwhile organic fertilizer contains nutrient that can support rice growth and are readily available at relatively cheaper price. Organic manure apart from supplying plant nutrient also contributes to maintaining soil quality by improving soil organic matter, soil structure, soil chemical properties and activities of soil microorganism (Morris et al., 2007). The nutrients held in organic manures are released more slowly through microbial action ensuring continues nutrient supply (Rakshit et al., 2008; Senyah, 2009).

Weeds interference constitutes a major biological setback in rice production globally accounting for about 32 and 90% yield losses (Singh et al., 2007; Oerke and Dehne, 2004). Hence, the needs to improve weed managements in rice fields. Effective weed control reduces the effect of weed on crops and enhance grain yield (Dzomeku et al., 2017). Hand weeding is an oldest form of weed management practice which is costly (Gianessi, 2009) and widely practiced by farmers in northern Ghana (Dzomeku et al., 2017). Chemical weed control is faster, cheaper and gives better weed control (Pramanick et al., 2015). However, neither chemical nor manual weed management practice can solely provide the most efficient weed control against all types of weeds at minimal cost (Dubey et al., 2017).

According to the Facts and Figures (2012), the yield of rice in northern region of Ghana is less than their climatic potential (MOFA, 2012). Agronomic factors have been identified as major causes of low grain productivity. Rice production in rainfed dry areas is often challenged by inadequate water supply, soil fertility and weed management. Responses to these challenges include adequate fertilization, weed control and water supply for improved rice productivity. In light of these, the objective of this work is to determine the main effect of different soil amendments at the same N and weeding regime on growth and yield of rice as well as their profitability under rainfed conditions and irrigation.

MATERIALS AND METHODS

Site description

The experiment was carried out during the 2018 and 2019 (under irrigation and rainfed) cropping season on a farmer’s field at Bontanga near Kumbumgu in the Northern Region of Ghana. It is located between latitudes 9°30″ and 9°35″ N and longitudes 1°20″ and 1°04″ W (Abdul-Ganiyu et al (2012) in the Guinea Savannah ecological zone. Climatic condition of the study area is warm, semi-arid and characterized with a single rainy season, usually starting from June to October, followed by a prolonged dry season with annual rainfall between 800 and 1300 mm per annum (Adongo et al., 2015). The rainfed cropping season often last for about 140 to 190 days in duration (Adongo et al., 2015) and usually followed by long drought spells during the dry season. The highest rainfall normally occurs between late July and September. Annual rainfall variability within the study area is between 20 and 30%. Average monthly temperatures remain high throughout the year only falling around 26°C in August. March and April remain the hottest period of the area with temperature rising to 39°C with an average temperature of about 30°C. The average humidity ranges from 69 to 95% and 32 to 69% during day time and night, respectively (Abdul-Ganiyu et al., 2012). Prior to the experiment, rice has been cultivated continuously as a monocrop either under rainfed during the wet season or under irrigation during the dry season at the site for seven years. The soil is sandy loam with moderate acidity.

Experimental design and materials used

The study was a 2 × 4 × 4 split plot experiment (32 treatment combinations) with three replications. The plot size was 3 × 2 m (6 m^2 area) and a net harvestable plot size of 2.8 × 1.8 m. The remaining 0.2 m of either sides of each plot was treated as borders. Soil amendment at the same rate of 60 kg N/ha was used as the main factor at four levels, that is, cow dung (CD), poultry litter (PF), mineral fertilizer (MF), no fertilization (NF) as control and weeding regime was used as a sub-factor at four levels, that is, weedy check (W1), weed free (W2), one hand weeding followed by two herbicides applications (W3) and two hand weedings followed by one herbicides application (W4). Poultry and cow dung were obtained from a poultry farm and kraal close to the experimental site. Samples of poultry and cow dung were taken to the laboratory for N analysis before incorporating into the soil three days before transplanting. For N analysis, the wet Kjedahl digestion method was used. Percentage N for poultry litre and cow dung was 0.19 and 0.30, respectively.

Cultural practice

Amendments were applied as Estimated Mineralizable N (EMN) base on the N content of the materials at 60 kg N ha^{-1}. Mineral fertilizer (MF) was applied as basal and top dress urea at 60 Kg N/ha. The edges of the beds were raised to separate plots and replications to prevent nutrient drift. Two kilograms of AGRA rice seeds was pre-geminated and sown in the nursery bed close to the experimental field. The seedlings were transplanted at a square spacing of 20 cm using two seedlings per hill at 34 days after sowing (DAS). Prior to transplanting, the experimental field was sprayed with glyphosate, a non-selective herbicide, to kill all weeds to even the weed appearance on the field. No weeding was applied to weedy check (W1). Hand weeding and manual hand pulling method was applied to weed free (W2) treated plot at any time weeds were found on plots. One-time hand weeding was applied as per treatment arrangement (W3) at 25DAT followed by herbicides application at 45 and 65 DAT. Twice hand weeding at 25 and 45 DAT followed by one time herbicides application at 65 DAT to the assigned plots (W4). Bispyribac-soduim + Isotridecanol (Adjuvant Code TM 8006) is a post-emergence herbicide mixture for broad spectrum weed control in wet seeded rice. The common weed control option at the study site is hand weeding.

Data collection

Total number of tillers per hill was obtained from six selected hills per plot at 60, 75 and 90 DAT. By counting tillers that are bearing panicles and expressed as number of effective tillers per hill after computing their averages. Fresh weeds samples per 1 m^2 quadrant for each plot were carefully removed at harvest and oven dried at 70°C until constant weight to achieve dry biomass. Weed dry biomass of each treatment was compared with weedy check to determine weeds suppression due to management practice and express as weed control efficiency (WCE). Weed control efficiency was calculated as described by Singh et al. (2017):

$$\text{WCE (\%)} = \frac{\textit{weed dry weight of weedy check} - \textit{weed dry weight of treatment}}{\textit{weed dry weight of weedy check}}\ 100$$

Grain was harvested at eleven weeks after transplanting (WAT) from a net plot of 2.8 m × 1.8 m using a kitchen knife. The harvested panicles were dried, threshed, cleaned and again sun-dried to maintain 12% moisture content, and final weight was taken. The grain yield per hectare was computed for each treatment from the net plot and recorded in kilograms per hectare as described by Paudel (1995):

$$\text{Grain yield kg ha}^{-1} \text{ at 12\% moisture content} = \frac{100 - \text{Mc x plot yield(kg)x10000(m}^2)}{100 - Mc\ x\ net\ plot\ area(m^2)}$$

The cost of cultivation of each treatment was calculated. Economic evaluation of each treatment was done by estimating the gross returns, net returns and benefit cost ratio. The price of the inputs at the time of their use and the prevailing market price of the produce obtained were considered for calculating the cost of cultivation, returns and benefit: cost ratio.

Statistical analysis

Data collected were subjected to analysis of variance using Genstat statistical software (12th edition) and means were separated using the LSD values at 5% level of significance. Results were presented in tables.

RESULTS AND DISCUSSION

Tiller count

Results showed that water source, amendment, weeding regime and their interactions had significant (P≤0.05) effect on tiller counts (Table 1). Irrigation, mineral fertilizer and weed free increased tiller count compared to other treatments. Irrigation increased tiller count by 25% compared to rainfed. Among the amendment treatments, CD, MF and PL significantly increased rice tiller count by 14, 22 and 16% compared to NF. No weeding (W1) recorded the least tiller count among the weeding regime whereas weed free (W2) recorded the greatest tiller count.

In rice crops, more tillers generally indicate greater yield (Li et al., 2003). The enhanced tiller count in soil amendment treatments (CD, MF and PL) compared to no amendment (NF) is in consonance with earlier report by Dzomeku et al. (2017) who also observed increased tillers in soil amended treatment compared to control. The entire weeding regime applied in this study was able to efficiently control weeds above 60%, enhancing plant nutrient uptake for growth and development including tiller production with a consequential increase in tiller count. Adhikari et al. (2018) reported enhanced effective tiller count in rice as a result of effective weed management. Weed free (W2) obtained the maximum number of tillers because it was able to efficiently reduce weed crop competition to its barest minimum compared to the other weeding regimes. The result is in agreement with Hakim et al. (2013) who observed higher numbers of effective tillers under weed free conditions than weedy treatments.

Weed biomass and weed control efficiency

Weed biomass was highly influenced (P<0.001) by water source, soil amendments and weeding regimes and their interaction with the exception of interaction between water source and weeding regime (Table 1). Rainfed increased weed biomass by 18% compared to irrigation. Among the amendment treatments, mineral fertilizer (MF) reduced weed biomass by 41, 27 and 39%, respectively compared to cow dung (CD), poultry liter (PL) and no fertilizer (NF). Among the weeding regimes, no weeding (W1) recorded significantly greater weed biomass whereas weed free (W2) reduced weed biomass by 100%. Application of one hand weeding followed by two herbicide applications (W3) and two hand weedings followed by one herbicide application (W4) also significantly reduced weed biomass, but to a lesser extent relative to W2.

There was significant moisture source × amendment × weeding regime interactions for weed control efficiency (Table 1). Rainfed increased WCE by 15% compared to

Table 1. Tiller counts, weed biomass (g/m^2), weed control efficiency (%) and grain yield (t/ha) of rice as affected by water sources, soil amendments and weeding regimes.

Treatment	Tiller counts	Weed biomass (g/m^2)	WCE (%)	Grain yield (t/ha)
Water source (S)				
Irrigation	9.39	33.72	53.16	3 .70
Rainfed	7.03	40.86	62.42	1.90
LSD (0.05)	1.71	2.07	1.71	0.02
Amendment (A)				
CD	8.22	44.13	56.45	2.61
MF	9.04	26.17	56.43	3.42
PL	8.54	35.84	58.67	2.68
NF	7.04	43.03	59.59	2.47
LSD (0.05)	0.48	2.93	2.91	0.15
Weeding Regime(W)				
W1	6.90	92.98	0	1.96
W2	9.68	0	100	3.77
W3	7.99	26.28	66.98	2.81
W4	8.27	29.91	64.17	2.65
LSD (0.05)	0.56	3.46	2.46	0.25
		Sources of variations		
S × A	ns	*	*	ns
S × W	ns	ns	***	***
S × A × W	**	***	*	ns

*Significant at the 0.05 probability level. **Significant at the 0.01 probability level. ***Significant at the 0.001 probability level.

irrigation.

All the weeding regimes studied produced significantly (P<0.001) clean plots compared to the weedy check (W1). Weed free (W2) significantly recorded 100% weed control efficiency compared to W3 and W4 which recorded 67 and 64% WCE, respectively. There was no significant difference between W3 and W4. No weeding (W1) recorded zero.

The least weed biomass recorded by W3 compared to W1 and W4 treatment could be attributed to efficient weed management which reduced weed density and suppress photosynthetic activities in weeds. The results implied that controlling weeds on rice field twice or more will efficiently reduce weeds population and dry weight, leading to better nutrient, moisture and light uptake by crops. This is in agreement with Yakadri et al. (2016) who reported that the application of herbicides alongside with manual weeding produced lesser weed dry matter accumulation than the weedy check. The increased weed biomass in no weeding treatment may be attributed to the fact that the weeds were not managed, which contributed to their growth and translated into increased biomass. This agrees with Barad et al. (2016) who reported increased weed dry weight in no weed control treatment compared to hand weeding and herbicide treatments.

Weed control efficiency (WCE) represents the degree of weed reduction due to weed control treatment (Bangi et al., 2014). Eradicating or reducing harmful effects caused by weeds on arable crops is the ultimate objective of weed management (Knezevic et al., 2002). Generally, better weed control (62%) was observed under rainfed conditions compared to (53%) irrigation treatments.

All the weeding regimes studied produced significantly (P<0.001) clean plots compared to weedy check (W1). Weed control in this study confirmed the importance of reducing the weed population during the critical growth stage of the crop. The greater WCE in weed free is in agreement with Ahmed and Susheela (2012) who opined that the farmer's practice of eliminating weeds frequently reduced the weed density and weed dry matter production significantly and thereby increased the WCE (89.2%). Herbicides applied twice (W3) gave better weed control compared to double hand weeding (W4) treated plots.

Grain yield

There was no interaction between water sources, amendments and weeding regimes, however, water

Table 2. Cost of production, total revenue, net revenue and benefit/cost ratio of rice as affected by water sources, soil amendments and weeding regimes.

Treatment	Cost of production ($)	Total Revenue ($)	Net profit ($)	Benefit/Cost Ratio
Source of water				
Irrigation	276.8	700.3	423.5	2.5
Rainfed	257.8	359.2	101.4	1.4
Amendment				
CD	263.3	494.7	231.3	1.8
MF	315.8	648.0	332.2	2.0
PL	283.3	468.2	184.9	1.6
NF	206.7	507.9	301.2	2.4
Weeding regime				
W1	225.0	371.6	146.6	1.7
W2	293.8	713.4	419.8	2.4
W3	271.4	532.7	261.3	2.0
W4	279.2	501.4	222.2	1.8

At the time of writing, 1 US Dollar (USD) = 5.81 Ghana cedis (GHS).

source and weeding regime showed interaction (Table 1). Irrigation increased grain yield by 49% compared to rainfed. Among the amendment treatments, mineral fertilizer recorded increased grain yield by 24, 22 and 28%, respectively compared to CD, PL and NF. However, there was no significant difference between CD and NF and also between CD and PL. Weed control in rice significantly increased grain yield. Treatments W2, W3 and W4 recorded significantly higher values of grain yield compared to W1. This resulted in 48, 30 and 26% increases in grain yield under W2, W3 and W4, respectively compared to W1.

The increased grain yield in irrigation is as a result of reduced variability of water supply to crops. This is in agreement with Zipper et al. (2016) who reported that irrigation generally increases crop yields and decouples productivity from drought. Tack et al. (2017) also reported that, irrigation increases crop yields and stabilizes food production and prices. Irrigation may help crop production meet the global demand for food, which is projected to increase by 70% compared to current demand to feed 9 billion people by 2050 (Tomlinson, 2013). The work reported in this article showed that mineral fertilization and weedy check has the potential to increase productivity of rice in the Guinea Savanna. This is supported by the fact that tiller count and weed control efficiency were maximized when the crop was mineral fertilized at 60 kg N/ha. Improved weed control efficiency and increased tiller count translated into increased rice grain yield compared with no fertilizer treatments. According to Chianu et al. (2012) mineral fertilizers normally have a higher nutrients concentration than organic fertilizers ensuring prompt nutrient availability to crop plants.

The maintenance of weed free conditions in rice fields is crucial to enhance grain yields. The results conform to other research where higher grain yield was found in weed free checks (Singh et al., 2018; Dzomeku et al., 2017; Yakadri et al., 2016; Hakim et al., 2013). The greater grain yield recorded by MF compared to CD and PL, though they were all applied at 60 kg N ha^{-1} which may be attributed to slow release of organic nutrients (CD and PL) compared to MF (Senayah, 2009).

Economic analysis

The cost of production, returns, profit and cost benefit ratio of water sources, amendments and weeding regimes are presented in Table 2. Irrigation increased cost of production, increased profit and cost benefit ratio compared to rainfed. Among the amendment treatments, mineral fertilizer recorded greater ($315.8) cost of production per hectare compared to no fertilizer which recorded least ($263.3). Weed free (W2) increased cost of production by 23, 8, and 5%, respectively and increased net profit by 65, 38, and 47% compared to W1, W3 and W4. The benefit/cost ratio under amendment treatment followed the order of NF > MF > CD > PL while under weeding regime followed the order of W2 > W3 > W4 > W1.

Increased cost of production in mineral fertilizer (MF) may be attributed to high cost of fertilizers compared to locally available organic materials (CD and PL). Weed free (W2) recorded higher cost of production because of frequent weed removal, followed by W4 while weedy check (W1) the least cost of cultivation. Mineral fertilizer supported crops growth leading to the production of maximum effective tillers leading to higher grain yields. The cumulative effect of better yield attributes obtained in mineral fertilizer is evident in the highest gross returns. The highest grain yield eventually contributed to the highest revenue obtained in W2. The combination of Mineral Fertilizer and Weed free recorded the highest cost of production. However, the weed free environment coupled with good crop development due to mineral fertilizer resulted in a greater profit compared to all other treatment combinations.

Conclusion

Increased rice yield under irrigation compared to rainfed in the current study is an indication that irrigated crops have higher yields and are less sensitive to climate variability. Soil amendments had a positive influence on physiological data and grain yield parameters of rice. The benefit of adding a mineral fertilizer was greater when there was effective weed management. This cumulatively translated in higher (50%) grain yield above the control. The devastating effect of weeds on rice production was evident in the lower yields obtained in weedy checks. All the weeding regimes efficiently controlled weeds in the field above 60%. Hand weeding once + herbicides sprayed twice (W3) and two hand weedings followed by one herbicides application (W4) improved rice yield in sandy loam soils compared to weedy checks. However, weed free (W2) gave better performance in reducing weed density and biomass compared to W3 and W4. The economic analysis of the various treatments showed that mineral fertilizer, W2 and W3 recorded more cost of cultivation but was able to give substantially higher grain yields, which resulted to maximum net returns. The combination of mineral fertilizer with W2, W3 and W4 gave greater net returns due to nutrient availability and effective weed control which improved crop growth and grain yield compared to other combinations.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdul-Ganiyu S, Amaanatu MK, Korese JK (2012). Water use efficiency and productivity for rice (*Oryza Sativa*) in the Botanga irrigation scheme of northern region of Ghana. Agricultural Science Research Journal 2(7):362-368.

Adhikari J, Abdur RS, Md Romij U, Uttam KS, Kawsar H, Umme R (2018). Effect of Nitrogen Fertilizer and Weed Management on the Yield of Transplant Aman Rice. Journal of the Bangladesh Agricultural University 16(1):12-16.

Adigun JA, Kolo ED, Adeyemi OR, Daramola OS, Badmus AA, Osipita OA (2017). Growth and yield response of upland rice to nitrogen levels and weed control method. International Journal of Agronomy and Agricultural Research 11(6):92-101.

Adongo TA, Felix KA, Kranjac-Berisavljevic G (2015). Soil Quality of Irrigable Lands of Irrigation Schemes in Northern Ghana. IJISET - International Journal of Innovative Science, Engineering and Technology 2(8):14.

Ahmed MAA, Susheela R (2012). Weed management studies in Kharif maize. Research notes. The Journal of Research ANGRAU 40(3):121-123.

Alim MA (2012). Effect of Organic and Inorganic Sources and Doses of Nitrogen Fertilizer on the Yield of Boro Rice. Journal of Environmental Science and Natural Resources 5(1):273-82.

Ayisi DN, Kassai Z (2017). High Rice Import as a Threat to Food Security and a Hindrance to Sustainable Rice Production in Ghana. Archives of Current Research International 7(2):1-13.

Bangi S, Shivalingappa S, Eugenia PL, Santosh BS, Umesh TS (2014). “Effect of Herbicides on Weed Control Efficiency (WCE) and Yield Attributes in Brinjal (*Solanum Melongena* L.).” IOSR Journal of Agriculture and Veterinary Science 7(6):59-65.

Barad B, Mathukia RK, Gohil BS, Chhodavadia SK (2016). Integrated weed management in rabi popcorn (*Zea mays* var. everta). Journal of Crop and Weed 12(1):150-153.

Bouman BAM, Humphreys E, Tuong TP, Barker R, Donald LS (2007). Rice and water. Advances in Agronomy 92:187-237.

Chauhan BS, Jabran K, Mahajan G (2017). Rice production worldwide. Germany: Springer P 247

Chianu JN, Chianu JN, Mairura F (2012). Mineral fertilizers in the farming systems of sub-Saharan Africa. A review. Agronomy for Sustainable Development 32(2):545-566.

Dubey R, Dheer S, Aakash M (2017). “Effect of Weed Management Practices and Establishment Methods on Growth, Productivity and Economics of Rice.” International Journal of Current Microbiology and Applied Sciences 6(3):65-72

Dzomeku IK, Amegbor IK, Ayittah P (2017). Verification of Integrated Soil Fertility Management and Weed Interference On Nerica Rice In The Guinea Savanna Uplands. Current Agriculture Research Journal 5(3):252-65.

Hakim A, Abdul SJ, Mohamed HM, Mohd RI, Moshiur R Ahmad S (2013). “Impacts of Weed Competition on Plant Characters and the Critical Period of Weed Control in Rice under Saline Environment. Australian Journal of Crop Science 7(8):1141-1151.

Hossain M (2006). Rice in Afric2013: Can rice help reduce hunger and poverty in sub-Saharan Africa? Rice Today 5(1), 41 Indian Journal of Weed Science 47(3):224-232.

International Food Policy Research Institute (IFPRI) (2014). Impact Simulation of ECOWAS Rice Self-Sufficiency Policy.” International Food Policy Research Institute. Online. Accessed 26th March, 2019.

Knezevic SZ, Evans SP, Blankenship EE, Van Acker RC, Lindquist JL (2002). Critical period for weed control: the concept and data analysis. Weed Science 50:773-786.

Kranjac-Berisavljevic G, Blench RM, Chapman R (2003). “Rice Production and Livelihoods in Ghana. https://www.odi.org/publications/3049-rice-production-and-livelihoods-ghana

Li X, Qian Q, Fu Z, Wang Y, Xiong G, Zeng D, Wang X, Liu X, Teng S, Hiroshi F, Yuan M, Luo D, Han B, Li J (2003). Control of tillering in rice. Nature 422:618-621.

Ministry of Food and Agriculture (MoFA) (2017). Agriculture Sector Progress Report. Ministry of Food and Agriculture, Ghana.

Ministry of Food and Agriculture (MoFA) (2010). MoFA. Agriculture in Ghana: Facts and Figures. Statistical, Research and Information Directorate (SRID). Accra, Ghana: Ministry of Food and Agriculture; 2011. https://new-ndpc-static1.s3.amazonaws.com/CACHES/PUBLICATIONS/2016/04/16/AGRICULTURE-IN-GHANA-Facts+and+Figures-2010.pdf

Morris M, Kelly VA, Kopicki RJ, Byerlee D (2007). Fertilizer Use in African Agriculture: Lessons Learned and Good Practice Guidelines. The World Bank pp. 1-162.

Ndamani F, Watanabe T (2013). Rainfall Variability and Crop Production in Northern Ghana: The Case of Lawra District. Conference Paper. December (2013), 10.13140/2.1.2343.71.

Nyarko AD, Kassai Z (2017). High Rice Import as a Threat to Food Security and a Hindrance to Sustainable Rice Production in Ghana.

Archives of Current Research International 7(2):1-13.

Oerke EC, Dehne HW (2004). Safeguarding Production-Losses in Major Crops and the Role of Crop Protection. Crop Prot. Opportunity for Economic Development in Ethiopia. International Journal of Science and Research 2(6):2319-7064.

Pramanick B, Bera PS, Kundu CK, Badopadhyay P, Brahmachari K (2015). Effect of different herbicides used in transplanted rice on weed management in rice–lathyrus cropping system. Journal of Crop and Weed 10(2):433-436.

Rakshit A, Sarkar NC, Debashish S (2008). Influence of Organic Manures on Productivity Of Two Varieties Of Rice. Journal of Central European Agriculture 9(4):629-634.

Senayah JK, Issaka RS, Dedzoe CD (2009). Characteristics of Major Lowland Rice-growing Soils in the Guinea Savanna Voltaian Basin of Ghana. Agriculture and Food Science Journal of Ghana Vol. 7.DOI: 10.4314/afsjg.v7i1.43034

Singh I, Ram M, Nandal DP (2007). Efficacy of new herbicides for weed control in transplanted rice under rice-wheat system. Indian Journal of Weed Science 38:28-31.

Singh R, Pramanick B, Singh AP, Neelam Kumar S, Kumar A, Singh G (2017). Bio-efficacy of Fenoxaprop-P-Ethyl for grassy weed control in onion and its residual effect on succeeding maize crop. Indian Journal of Weed Science 49(1):63-66.

Singh A, Chand M, Punia SS (2018). Evaluation of Different Herbicides against Complex Weed Flora in Kharif Maize, International Journal of Pure & Applied Bioscience 6(5):803-807 doi: http://dx.doi.org/10.18782/2320-7051.6634

Tack J, Barkley A, Hendricks N (2017). Irrigation offsets wheat yield reductions from warming temperatures. Environmental Research Letters 12(11):114027.

Tomlinson I (2013). Doubling food production to feed the 9 billion: A critical perspective on a key discourse of food security in the UK. Journal of Rural Studies 29:81-90.

Yakadri M, Madhavi M, Rampraksh T, Leela R (2016). “Herbicide Combinations for Control of Complex Weed Flora in Transplanted Rice.” Indian Journal of Weed Science 48(2):155.

Zipper SC, Qiu J, Kucharik CJ (2016). Drought effects on US maize and soybean production: spatiotemporal patterns and historical changes. Environmental Research Letters 11(9):94021.