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Fertilizer and Genotype Effects on Maize Production on Two Soils in the Northern Region of Ghana

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Abstract

Soils in the Guinea Savanna agro-ecological zone of Ghana are depleted in major nutrients by continuous cropping and residue removal, resulting in low maize yields. While many studies have assessed the fertilizer requirements for maize, most did not account for the role of the soil type and maize genotype. A study was conducted on Plinthosol and Lixisol in the Tolon district of the Northern Region of Ghana to assess fertilizer and genotype effects on maize productivity. Two maize genotypes (i.e. Obatanpa -110 days to maturity) and (Dodzie - 75 days to maturity) were compared at three fertilizer application rates (i.e. 0-0-0, 60-15-35 and 90-25-50 kg ha^{-1} N, P K) in a randomized complete block design using four replications, with genotype allocated to the main plots and fertilizer levels to the subplots. Soils were characterized, revealing very low total N and available P concentrations in the top layers. Grain yield was significantly affected by maize genotype, irrespective of the soil type. The longer-duration (Obatanpa) tended to out yield the short duration genotype (Dodzie), and generally outperformed Dodzie in all yield parameters except for the harvest index on Plinthosol. Inorganic fertilizers significantly ($P<0.001$) increased yield and all yield parameters over the control on both soils, with yield increases of 84 and 90% at 60-15-35 and 90-25-50 kg ha^{-1} N, P K, respectively. Genotype by fertilizer interaction was highly significant ($P<0.001$) for grain yield on both soils. We conclude that farmers in the Guinea Savannah agro-ecological zone of Ghana need to supply nutrients to enhance grain yields of maize, irrespective of the prevailing soil type.

Keywords: fertilizers, genotype, Lixisol, Plinthosol, soil, Zea *mays* L.

1. Introduction

Food security is an issue of global concern and a dire problem to people in the sub(tropics) particularly Sub Saharan Africa (SSA). Rapid population increase in synergy with factors such as low soil fertility and climate variability are putting enormous pressure on natural resource, i.e. land, water, nutrients etc. (Collier et al., 2008). Rainfed agriculture, dominant production system in the region accounts for about 80% of global agricultural land (Rockström et al., 2003). This system is however low in productivity year in year out due to its over reliance on natural rainfall which is fast becoming unpredictable (in quantity and in time) as well as natural resources which is also becoming limited due to excessive exploitation.

These aberrations are common to the Northern region of Ghana where farming and livestock rearing are the main source of rural farm livelihoods (Wiredu et al., 2010; Ekboir et al., 2002) and which produces a major fraction of the country's cereals and grains. Agricultural production in the area is mainly for subsistence, producing wide varieties of field crops including maize, an important component of small scale farming in West Africa (Fosu et al., 2004). Maize is widely grown in a range of agro ecological environments (www.iita.org/maize) and has been reported as a staple food in many places in Africa e.g. Nigeria (Ismaila et al., 2010), Malawi (Ephraim & Chirwa, 2007), and Ghana (Fening et al., 2011). The overall maize production in Ghana (in terms of area harvested and volume) has however remained stable because of reliance on traditional farming methods (MiDA, 2010). These methods have been negatively affected for some time now by factors such as climate (Ismaila et al., 2010), declining soil fertility and low application of external inputs (Fening et al., 2011; Fosu et al., 2004) and continuous mono-cropping (Wopereis et al., 2006).

The situation thus requires that immediate action be taken to accelerate agricultural productivity to meet the rising food demand of the country (Mwangi, 1996).

One most efficient way of replenishing and reversing soil nutrient depletion is through the application of mineral fertilizer (Bationo et al., 2007). Maize as a gross feeder requires substantial amount of soil nutrients especially nitrogen (N) for growth and development. Again one major adaptation strategy to the influence of climate variability as manifested in drought is planting of short season varieties (Fosu-Mensah et al., 2012).

The study was carried out to investigate the response of maize to two maize genotypes and different fertilizer levels as well as their interactions on two different soil types in the Tolon district of the Northern Region of Ghana with respect to yield and water productivity.

2. Materials and Methods

2.1 Study Area

The study was conducted in 2011 in the northern region of Ghana on two (2) soil types namely Pisoplinthic Plinthosol and Pisoplinthic Lixisol in Akukayili (CSIR-SARI research field) and in Cheshegu (farmer's field) respectively. Both soils developed from crystalline acid rocks. The area lies within the interior Northern Guinea Savannah agro-ecological zone of Ghana on latitude 9^{o} 25' 141", longitude 0^{o} 58' 142" and an average elevation of 183m a.s.l. (Lawson et al., 2008).

2.2 Climate

The climate is relatively dry compared to the middle and southern (transition and forest zones) parts of the country. The rainfall of about 1000 mm occurs in a monomodal distribution pattern (April-October, with a peak in August - Kasei and Afuakwa, 1991) and tends to be highly variable between years (15-20%). Average annual minimum and maximum temperatures are 25 ^{o}C and 35 ^{o}C, respectively. The annual rainfall in 2011 was 1047 mm with about 500 mm (genotype Dodzie) and 590 mm (genotype Opatanpa) occurring during the crop growth period in both soil type regions

2.3 Soil

Soils of the study region are inherently very low in fertility. They are low in organic matter (less than 2% in the top soil) and macro nutrients especially phosphorus reserves. These together with the occurrence of plinthite and erodible sandy top soils make the soils inherently infertile (Braimoh, 2004). These conditions make it imperative that manure be incorporated regularly into the soils in the Savannah zones (MoFA, 1998). After soil characterization, soils at Akukayili and Cheshegu were classified as Pisoplinthic Plinthosol (Plinthosol) and Pisoplinthic Lixisol (Lixisol) respectively. Both soils were generally low in soil organic carbon and macro nutrients (Table 1) and are occurring at the upper part of the slopes and crests of the undulated landscape.

2.4 Soil Characterization, Sampling and Laboratory Analysis

Soil characterization was done by digging a 1.5 m profile pit at the borders of the two experimental fields. Soil samples were taken at different layers of the profile by experts from the CSIR – Soil Research Institute in Kumasi for soil classification. Stratified soil sampling of the profile pit was done at 10 cm intervals to analyse for the physical and chemical properties. In total, fifteen (15) soil samples were taken. The World Reference Base for Soil Resources (WRB 2006) was used for classification. The first two (2) layers (i.e. 10 cm and 20 cm depth) will be reported for the purpose of this study. Soil samples were air dried ground and sieved with 2 mm mesh. Gravimetric gravel content was determined. The samples were stored for physical and chemical analysis at the Savanna Agricultural Research Institute's Soil Chemical Laboratory. Particle size analysis was done by the hydrometer method (Anderson & Ingram, 1993). Soil PH was determined in 0.01 M $CaCl_2$ solution in a 1:2.5 soil:solution ratio, soil organic carbon was determined using Walkley-Black method (Nelson & Sommers, 1982), total nitrogen by Kjeldhal method (Tel & Hegatey, 1984), available P by Bray 1 procedure (Bray & Kurtz, 1945), exchangeable calcium, potassium, sodium and magnesium were extracted with ammonium acetate and determined by Atomic Absorption Spectrophotometry (AAS). Total exchangeable bases (TEB) were calculated as the sum of exchangeable Ca, Mg, K and Na. Acid exchangeable zinc (Zn) was extracted with 0.01 M HCl solution (Nelson et al., 1959) and determined by AAS.

2.5 Experimental Design

Treatments comprised a combination of two genotypes and three fertilizer levels. The experimental design was a Randomized Complete Block Design (RCBD) in a split plot arrangement with four repetitions. Maize genotype was allocated to main plots and fertilizer levels to sub plots. Each plot size was 12 m long and 6.4 m wide on Plinthosol and 12 m long and 5 m wide on Lixisol. Maize genotypes obtained from the CSIR-Savanna Agricultural Research Institute were Dodzie (75 days maturity period) and Obatanpa (110 days maturity period). The fertilizer levels applied were 0-0-0, 60-40-40 and 90-60-60 kg ha^{-1}Nitrogen (N), Phosphorous (P_2O_5) and Potassium (K_2O). The two maize genotypes were planted in rows and on flat with a spacing of 80 cm x 40 cm and two (2) plants per hill. Planting on Plinthosol was done on July 1, 2011 and July 5, 2011 on Lixisol. 50 % Nitrogen fertilizer was applied together with 100 % P_2O_5 and K_2O two weeks after planting. The remaining 50 % N fertilizer was applied as top dressing at five weeks after planting. Mode of application was dibbling few centimeters away from the maize plant and burying the fertilizer. Compound fertilizer 15-15-15, Triple super phosphate and muriate of potash (MOP) where used in calculating fertilizer rate during basal application. Sulfan (26% N and 35% SO_3) was used during top dressing. Harvesting was done for Dodzie and Obatanpa on September 30 and October 11, 2011 respectively on Plinthosol and on October 4 and October 24, respectively on Lixisol.

2.6 Plant Sampling, Measurements and Analyses

Field measurement of crop parameters taken during the experiment included leaf area index (LAI) and above-ground biomass. Leaf Area Index (LAI) was measured during the course of the experiment using the destructive method. Four plants two each from the second border rows of each plot were cut from the bottom and used for LAI measurement. Leaves from each cut plant were stripped off. The length (L) and width (W) of each leave were measured. Average values of mentioned parameters of the four plants were computed for each plot. The area of leaf ($L \times B$) obtained was then multiplied by a factor of 0.75 as described in Moll and Kamprath (1977) to get the total leaf area. LAI was then computed as the ratio of the total leaf area and the area covered by each plant (Watson, 1952).

$$Total\ leaf\ area\ (m^2) = L \times B \times 0.75 \tag{1}$$

$$LAI = \frac{Total\ leaf\ area\ (m^2)}{Area\ per\ plant\ (m^2)} \tag{2}$$

Two plants per plot were sampled at 4, 6 and 8 weeks after planting (WAP) for plant biomass calculations. One each was cut from the second rows left and right of each plot. Cut samples were folded into a brown paper envelop and weighed for its fresh weight. Samples were then oven dried to obtain their respective dry weight. Shoot dry matter was then calculated on per hectare basis.

Yield and yield components were determined at maturity. Parameters measured at maturity included grain yield, above ground stover weight, 100 grain weight and harvest index (HI). HI was calculated on a dry matter basis following description by Inoue and Hagiwara (2000)

$$HI = \frac{Dry\ weight\ of\ fully\ rippened\ seeds}{Dry\ weight\ of\ above\ ground\ biomass} \tag{3}$$

System's Water Use Efficiency (WUE) defined as the ratio of output in terms of grain yield (kg ha^{-1}) to the volume of water used from planting to harvesting (van Halsema & Vincent, 2012; Araya & Stroosnijder, 2010). The volume of water used was estimated as the product of rainfall (m) and the cropped area (m^2). It is mathematically expressed as

$$WUE = \frac{Grain\ yield(kg\ ha^{-1})}{Volume\ of\ water\ used\ (m^3)} \tag{4}$$

$$Volume\ of\ water\ used\ (m^3) = Rainfall\ (m) \times Cropped\ area\ (ha) \tag{5}$$

2.6 Statistical Analysis of Field Results

GenStat version 9.2 (Lawes Agricultural Trust, 2007) statistical software was used for analysis of variance and student's T-test was used for the separation of treatment means.

3. Results and Discussion

3.1 Climatic Variables

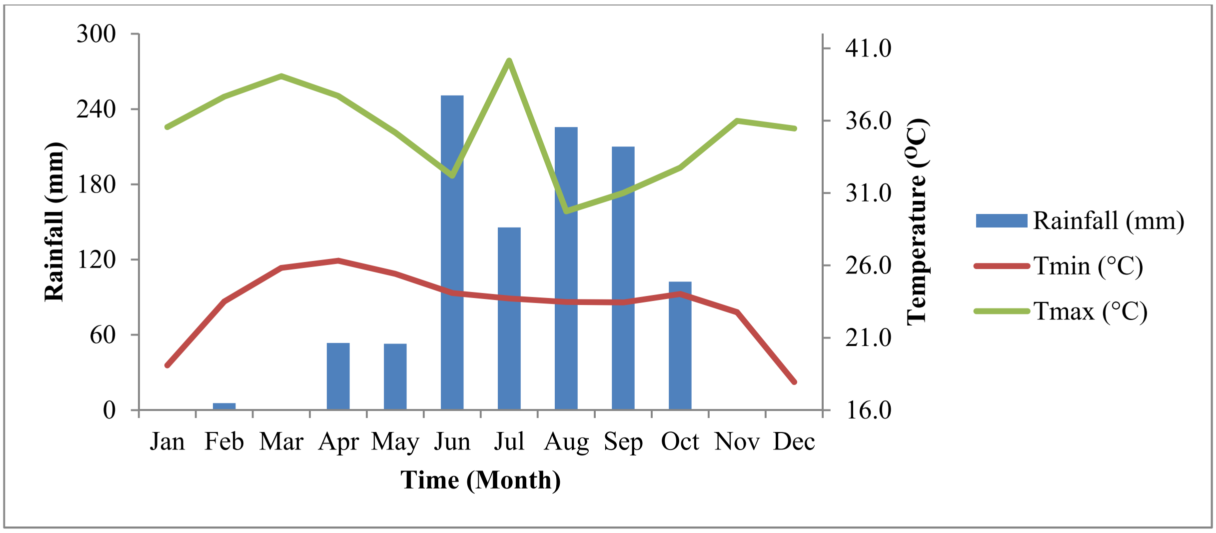

Figure 1. Summary of rainfall and temperature of study area in 2011. Tmin (°C) is minimum temperature and Tmax (°C) is maximum temperature. Data Source: Savanna Agriculture Research Institute Agro-meteorological Unit, Nyankpala

Table 1. Initial soil physical and chemical properties of Pisoplinthic Plinthosol and Pisoplinthic Lixisol at the experimental fields in the Guinea Savanna Zone of Ghana

Soil Type	PLINTHOSOL		LIXISOL	
Depth	10cm	20cm	10cm	20cm
Soil texture			Share (%)	
Clay	10	14	7	7
Silt	32	26	31	31
Sand	58	60	62	62
Gravel	33	39	16	11
Soil chemical properties				
PH	6.25	6.23	6.23	5.90
OM (%)	0.64	0.71	0.71	0.59
Total N (%)	0.03	0.04	0.04	0.03
Available P (Bray I) (mg kg^{-1})	15.0	7.3	9.2	5.0
Exchangeable cations **(**meq 100g^{-1}**)**				
Mg	3.34	3.60	2.40	2.67
Ca	2.94	2.67	4.01	4.54
K	0.30	0.23	0.30	0.33
Na	0.18	0.18	0.12	0.11

3.2 Maize Shoot Dry Biomass as Affected by Genotype and Fertilizer Level

Maize shoot dry matter is presented in Figure 2. No genotypic difference was observed on shoot dry matter between 4 and 8 WAP. With fertilizer effect on the parameter, shoot dry matter differed statistically among fertilizer levels at 8 WAP irrespective of the soil and 6 WAP on Lixisol. Generally, shoot dry matter increased with increasing levels of inorganic fertilizer application throughout time. The lowest mean dry matter was observed at 0 kg ha^{-1} NPK, a practice common with smallholder farmers, with highest means recorded at 90 kg ha^{-1} NPK, a rate rarely applied by farmers in the area. Findings from this study are consistent with reports of other studies of higher dry matter yield resulting from increasing levels of mineral fertilizer (Modupeola et al., 2011). Farming with very little or without NPK fertilizer application is a common practice of small scale rural farmers in northern Ghana. Fertilizer nutrient application in Ghana is approximately 8 kg per ha while depletion rates, which are among the highest in Africa, range from about 40 to 60 kg of nitrogen (N), phosphorus (P), and potassium (K) per hectare per year (Martey et al., 2014). This implies that, essential nutrients needed to support vegetative growth and consequently dry matter and grain yield are not present regardless of the soil type resulting in continued decline in yield. This is in support with Wormer et al. (2001) who stated that plants differ in their response to varying soil fertility. However, there was no interactive effect of genotype and fertilizer on both soils. Nevertheless, maize shoot dry matter production was always lower on the Lixisol except at 4 WAP. This could be attributed to the substantial moisture availability on Lixisol compared to Plinthosol within the first 4 WAP. On Plinthosol, planting was done a day after 23.9 mm of rain and the first four weeks recorded a total of 145.7 mm of rainfall. On Lixisol however, planting preceded two days after a 28.6 mm of rain was recorded and the first four weeks accumulated a total rainfall of 200.5 mm.

3.3 Maize Leaf Area Index (LAI) as Affected by Genotype and Fertilizer Level

Table 2 presents the leaf area index (LAI) of maize determined by the destructive (manual) method calculated at 41, 52 and 66 DAP on Plinthosol and at 41, 51 and 64 DAP on Lixisol. On Plinthosol, genotypic difference was observed at 66 DAP (P<0.01). On the Lixisol however, genotypic difference was observed only at 51 DAP. Generally, Obatanpa recorded greater mean LAI in this study.

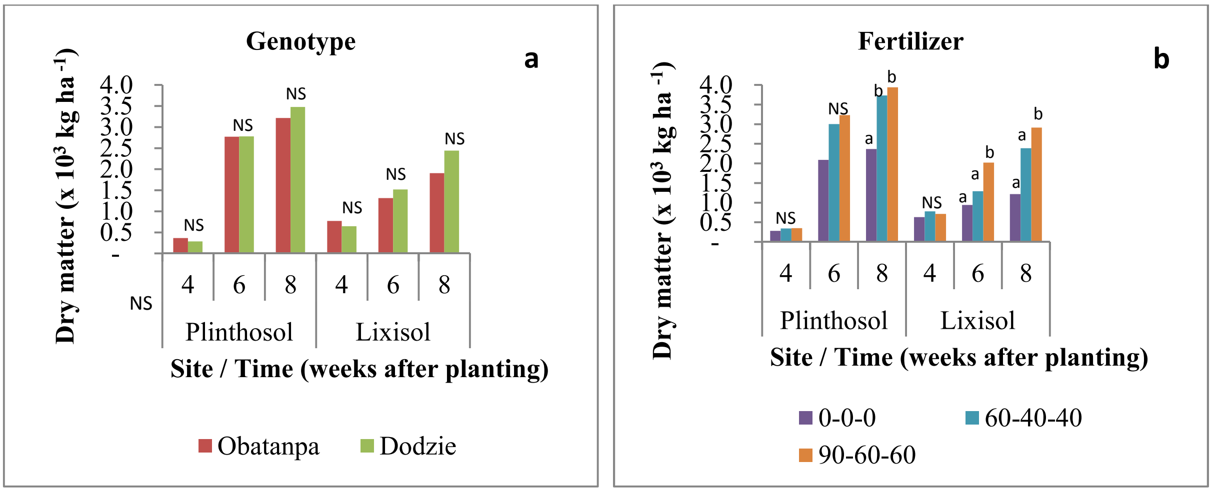

Figure 2. Maize dry matter as affected by genotype and fertilizer levels on two soils in the Guinea savanna zone of Ghana. Different letters on the bar indicate statistically significant differences at 5 % probability level. NS: Not significantly different

LAI reached its peak at 52 and 51 DAP on both the Plinthosol and Lixisol, respectively. Among mineral fertilizer levels, LAI differed significantly (P<0.05). Differences were highly significant at 41 and 52 DAP on the Plinthosol. All the stages determined recorded highest LAI at 90-60-60 kg ha^{-1} and lowest at 0 kg ha^{-1}, except at 52 DAP in Plinthosol and 64 DAP in Lixisol that recorded highest LAI at 60-40-40 kg ha^{-1}. However, differences in LAI between 90-60-60 kg ha^{-1} and 60-40-40 kg ha^{-1} were not significant except at DAP41 on the Lixisol. Just as the above growth parameters, LAI also increased with increasing levels of inorganic fertilizer. Lowest mean LAI was obtained under no fertilizer. No interaction between genotypes and fertilizer application was observed except at 41 DAP on the Plinthosol. In all of the treatments, LAI increased at 52 DAP (on the Plinthosol) and 51 DAP (Lixisol) and decreased at 66 DAP (on Plinthosol) and 64 DAP (on Lixisol). Decrease in LAI is due to aging of leaves during leaf senescence thus reducing the number of photosynthetically active leaves. Similar results have been reported by Dalirie et al. (2010) in wheat.

3.4 Grain Yield, Yield Component and Harvest index (HI) of Maize as Affected by Genotype and Fertilizer Levels

Table 3 is a summary of maize grain yield and yield components and their response to genotype and mineral fertilizer levels. Grain yield was significantly affected by maize genotype on both soils. Similar observation was made by Dalirie et al. (2010) on wheat. Obatanpa yield was significantly higher compared to Dodzie. This probably is because it is a late maturing genotype which benefits from additional time to absorb radiation and produce more assimilates which are then converted into higher biomass and yield. Genotypic effect on 100 seed weight was significant ($P < .005$) on both soils. The higher 100 seed weight in Obatanpa suggests that the extended grain filling period in the late maturing variety produced heavier seeds compared to the early maturing variety Dodzie. Above ground biomass at harvest weight differed ($P < .005$) significantly among genotypes on the Plinthosol and was highly significant ($P < .001$) on the Lixisol. In general, Obatanpa recorded higher mean values for yield parameters on both soils over Dodzie except for HI on the Plinthosol which showed opposite result. In the same way, the effect of mineral fertilizer was prominent in this study.

Table 2. LAI of maize as affected by genotype and fertilizer levels on two soils in the Guinea savanna zone of Ghana

	LAI					
	Plinthosol			**Lixisol**		
Treatments	41 DAP	52 DAP	66 DAP	41 DAP	51 DAP	64 DAP
Genotype						
Dodzie	1.70	2.37	1.88	1.57	1.93	1.63
Obatanpa	1.97	2.96	2.83	1.60	2.63	2.04
LSD (0.05)	NS	NS	0.49	NS	0.45	NS
Fertilizer Level						
0-0-0	1.19	1.93	1.88	1.29	1.82	1.43
60-40-40	2.13	3.08	2.55	1.59	2.47	2.12
90-60-60	2.18	2.98	2.63	1.87	2.55	1.95
LSD (0.05)	0.25	0.33	0.36	0.27	0.46	0.46
Interaction						
Dodzie x 0-0-0	1.21	1.83	1.45	1.26	1.40	1.23
Dodzie x 60-40-40	1.73	2.77	2.17	1.59	2.17	1.91
Dodzie x 90-60-60	2.15	2.51	2.01	1.85	2.21	1.74
OB x 0-0-0	1.17	2.03	2.31	1.32	2.23	1.63
OB x 60-40-40	2.54	3.40	2.94	1.59	2.77	2.33
OB x 90-60-60	2.21	3.44	3.24	1.88	2.89	2.17
LSD (0.05)	0.87	NS	NS	NS	NS	NS
CV (%)	12.5	11.3	13.9	15.4	18.4	23.1

NS: Not significantly different.

Highly significant difference ($P<0.01$) among fertilizer levels was observed for all yield parameters measured over the control on both soils. Grain yield, above ground biomass, 100 seed weight and HI responded to increasing inorganic fertilizer application. Similarly to the above growth parameters, maize grain yield increased with 90-60-60 kg ha^{-1} NPK followed by 60-40-40 kg ha^{-1} NPK, the recommended fertilizer rate for the zone for over two decades now (Fosu et al., 2012). Lowest grain yield was recorded when no fertilizer was applied on both soils. Respectively on the Plinthosol and the Lixisol, grain yield ranged from 246 and 213 kg ha^{-1} in the control plot to a maximum of 2345 and 2361 kg ha^{-1} with the application of 90-60-60 kg ha^{-1} NPK.

Table 3. Maize grain yield and yield components as affected by genotype and fertilizer levels on two soils in the Guinea savanna zone of Ghana

	Grain Yield and Yield Components							
Location/Soil	**Plinthosol**				**Lixisol**			
Parameters Treatments	**Grain weight (kg ha^{-1})**	**Above ground Biomass (kg ha^{-1})**	**100 seed weight (g)**	**Harvest Index (HI)**	**Grain weight (kg ha^{-1})**	**Above ground Biomass (kg ha^{-1})**	**100 seed weight (g)**	**Harvest Index (HI)**
Genotype								
Dodzie	1249	3615	21.7	0.30	1089	3257	19.7	0.28
Obatanpa	1552	4824	24.8	0.28	1531	4439	23.2	0.30
LSD (0.05)	75.5	356.8	0.946	0.014	24.9	154.9	0.576	0.01
Fertilizer								
0:0:0	246	1933	19.7	0.13	213	1724	17.1	0.12
60:40:40	1611	4574	23.8	0.35	1355	3943	22.6	0.34
90:60:60	2345	6151	26.4	0.38	2361	5878	24.5	0.40
LSD (0.05)	63.1	344.6	0.929	0.016	85.8	234.7	1.012	0.03
Interaction								
Dodzie x 0:0:0	222	1421	18.9	0.16	170	1326	15.3	0.13
Dodzie x 60:40:40	1437	3916	21.7	0.37	1085	3346	21.6	0.32
Dodzie x 90:60:60	2088	5509	24.5	0.38	2013	5100	22.1	0.40
Obatanpa x 0:0:0	270	2445	20.4	0.11	256	2122	18.9	0.12
Obatanpa x 60:40:40	1785	5232	25.8	0.34	1626	4541	23.7	0.36
Obatanpa x 90:60:60	2602	6792	28.2	0.38	2710	6655	27.0	0.41
LSD (0.05)	88.3	NS	1.229	0.02	99.9	285.4	1.213	0.03
CV (%)	4.1	7.5	3.7	5.2	6.0	5.6	4.3	8.3

NS: Not significantly different.

Thus the additional gain in grain yield in the 90-60-60 kg ha^{-1} treatment was 2117 kg ha^{-1} (89.3%) and 2148 kg ha^{-1} (91.0%) over the control, which is the normal practice of farmers in the area as access to inputs are always outside their reach and soils in the area are inherently low in fertility to support crop growth and development. A similar trend was observed for above ground biomass, 100 seed weight and harvest index (HI). This highlights the extent to which soil fertility of the area has deteriorated and can therefore not support crop production without the application of external input thus frustrating efforts of peasant farmers and their struggle of achieving food security and increasing income. A similar result was reported by Umar and Moinuddin (2002) who observed improved yields in groundnut genotypes by potassium nutrition under erratic rainfall conditions. Equally, Kpongor et al. (2007) reported significant grain yield increases in sorghum between homestead and bush farms for all levels of mineral phosphorus (P) and nitrogen (N) fertilizer application. Correspondingly, Fosu et al. (2012) reported that increasing levels of N up to 120 kg ha^{-1} increased maize (Obatanpa) grain yield. Similar observation was also made for millet yield in Niger by Akponikpè (2010). Interestingly, application of 90-60-60 kg ha^{-1} NPK saw an increase in maize grain yield of up to 734 kg ha^{-1} (45.6%) on Plinthosol and 1006 kg ha^{-1} (74%) on Lixisol compared to 60-40-40 kg ha-1. The interaction between genotype and fertilizer was highly significant ($p<.001$) for maize grain yield on both soils. Also in our study interactive effects were observed for 100 seed weight, grain yield (on the Plinthosol and the Lixisol) and HI (on the Plinthosol only). Similar results were reported for grain yield by Amujoyegbe et al. (2007) and support his assertion that crop varieties differ in their response to nutrient supply. This is evident for the above parameters that showed levels of significance to genotype and fertilizer interaction. Total above ground dry matter did show an interactive effect between genotype and fertilizer levels on the Lixisol. On both sites, differences between the two genotypes were highest for grain yield when 90-60-60 kg ha^{-1} NPK was applied. When no mineral fertilizer was applied, there was no significant difference in grain yield between the genotypes on both soils.

3.5 Water Use Efficiency (WUE) of Maize as Affected by Genotype and Fertilizer Levels

Water use efficiency (WUE) was calculated for both soils in this study and is presented in Figures 3. WUE was significantly influenced by genotype ($P<0.05$) on both soils. In both cases, Obatanpa had significantly higher WUE than Dodzie. This could be attributed to Obatanpa being a full season genotype and continued to stay on the field after Dodzie, short season genotype, had been harvested. This implies, it will continue to benefit from additional resources (moisture, radiation and nutrient reserves) thereby utilizing the residual soil moisture for extra biomass production. The extra biomass produced results in high grain yield and consequently reflects on high WUE as they are directly proportional. Significant genotypic effect on WUE was reported on peanut (Craufurd et al., 1998), chickpea (Brown et al., 1989), and miscanthus (Clifton-Brown & Lewandowski, 2000). WUE responded to mineral fertilizer application at all levels. Fertilizer effect was highly significant ($P<.001$) on both soils. Increased WUE was recorded with increased mineral fertilizer application.

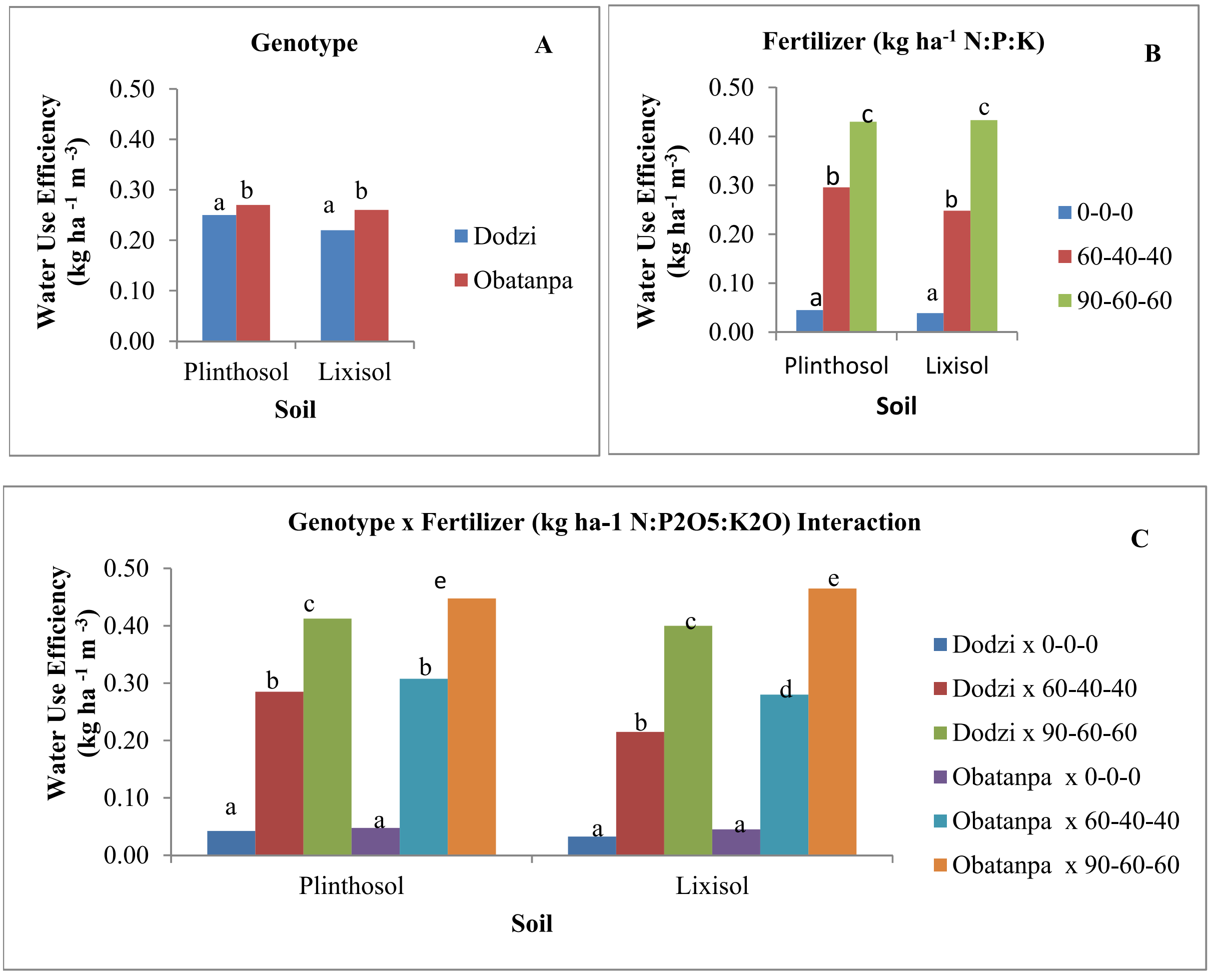

Figure 3. Maize Water Use Efficiency (WUE) as affected by genotype and fertilizer levels on two soils in the Guinea savanna zone of Ghana. Different letters on bars indicate statistically significant differences at 5 % probability level

On both soils, highest WUE was recorded with the application of 90-60-60 kg ha^{-1} NPK and the lowest WUE was recorded when no fertilizer was applied. Several authors have demonstrated the importance of mineral fertilizer in improving WUE in many studies (e.g. Stewart, 2001; Cooper et al., 1987). This indicates that soil fertility as well as cultivar choice is an important management factor to improve grain yield with a given amount of rain. Their absence limits crop ability to reach their potentials to efficiently utilize available soil moisture. Fertilizer application resulted in large increase in WUE than genotype. Meaning that with appropriate fertilizer management, maize yield can be increased with the same amount of rain, obtaining more crop yield per drop of rain. Similar observation was reported in Cooper et al. (1987). This implies that improved WUE results from either crop improvement that increases yield per unit of water transpired, or from crop management practices that maximize transpiration relative to other losses, or both (Gregory, 2004). WUE was significantly affected by interaction between genotype and fertilizer on both soils. These findings support the assertion by several authors (Turner, 2004; Gregory, 2004; Cooper et al.,1987) that water losses by soil evaporation is decreased in favor of transpiration by agronomic options such as appropriate fertilizer use and new cultivars, thereby making more water available for increased water use by the crop.

4. Conclusions

Agriculture plays a pivotal role in many economies. Maize has become the most important cereal in northern Ghana serving as both cash crop and the main staple for most communities. This study has however been able to address some of the factors that have led to decline in maize productivity in the area. Paramount is the primarily poor nature of soils which today no longer support maize production without the application of external input. In addition, rainfall variability causes a decision problem to farmers as to when to plant. These impacts negatively on grain yield due to the uncertainty in water supply. For farmers to cope with this phenomenon, genotypic differences in maturity have become important in the adaptation of crops to climate variability. Maize grain yield responded positively with the use of mineral fertilizer with an increase of about 84.4% and 89.3% on Plinthosol and 84.3% and 91.0% on Lixisol at 60-40-40 kg ha^{-1} and 90-60-60 kg ha^{-1} NPK respectively over control. These findings conclude therefore that in order for the area to obtain optimum yield and increase income levels of farmers, mineral fertilizer application to maize on depleted soils is paramount to food production. Also, significant increase in grain yield of between 15.6% and 74.0% due to increase in fertilizer level beyond the recommended rate of the zone requires that the over aged blanket fertilizer recommendation for the area needs to be reviewed. With respect to genotypes, maize grain yield differed significantly among genotype from this study. Dodzie and Obatanpa recorded average grain yield of 1249 and 1585 kg ha^{-1} respectively with corresponding WUE of 0.25 and 0.27 kg grain per m^3 of water over all sites and fertilizer levels. It can therefore be concluded that Obatanpa will be a good choice in terms of genotypic selection by farmers to address issues of food security in the area. However, in a year of delayed rainfall, Dodzie, an early maturing variety could be used by farmers to avoid crop failure which might be caused by moisture stress as a result of low moisture availability both in quantity and in time within the season.

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