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Effect of Tillage System and Soil Amendment on Growth and Yield of Maize in Northern Ghana

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Abstract: The experiment was conducted in 2007 growing season at the Savanna Agricultural Research (SARI) experimental station in the Guinea savannah agro-ecological zone of Ghana to assess the effect of different tillage system and different soil amendment and their interactions on growth and yield of maize. Tillage system evaluated includes minimum tillage, manual tillage, bullock plough and tractor tillage. Soil amendment evaluated includes inorganic fertilizer (NPK) at 60-30-30 kg ha^{-1}, manure at 6 t ha^{-1}, combination of inorganic fertilizer (NPK) and manure at half rates and control. Field layout was a split-plot design with four replication. Results revealed that, tillage system showed a significant difference on plant height at 20 days to maturity ($p \leq 0.01$), grain yield, cob weight and total biomass of maize ($p \leq 0.05$). Soil amendment showed a significant difference on plant height after 10 days to maturity, grain yield and other yield components ($p \leq 0.0000$). Synergistic effect of the integrated soil fertility management was more evident under bullock tillage. There was no interaction between tillage type and soil amendment. Tillage system did not show significant correlation among plant height, grain yield and other yield components under soil amendment. However, among plant height, grain yield and other component under soil amendment correlations were highly significant.

Key words: Tillage system, soil amendment, growth, yield, Northern Ghana

INTRODUCTION

Maize is a major staple in Ghana especially in Northern Ghana where it is used to replace sorghum and millet which were the major staple food some years ago. Maize is used in the preparation of tuo-zaafi, banku, kenkey, porridge and many other dishes. It features prominently in infant weaning food and it is eaten fresh when cooked or grilled (Okoruwa, 1997). Poor nature of soil and erratic rainfall are the limiting factors affecting crop (maize) yields in Northern Ghana. Soils of Northern Ghana are low in organic carbon (<1.5%), total nitrogen (<0.2%), exchangeable potassium (<100 mg kg^{-1}) and available phosphorus (<10 mg kg^{-1}) (Adu, 1995). The method of land preparation also affects the availability and incorporation of nutrients into the soil for plant uptake. This intend affect yield of crops. There is also scanty information on effect of tillage system on the yield of maize in Northern Ghana. The use of soil amendment such as organic fertilizers, inorganic fertilizers or combination of both has been used to enrich fertility of soils of Northern Ghana to produce more yields.

However, there is little information on the combine effect of tillage system and integrated soil fertility amendment on the yield of maize. Therefore, an experiment was conducted to assess the effect of tillage system and soil amendments on growth, yield and other yield components of maize.

MATERIALS AND METHODS

The experiment was conducted in 2007 growing season at the Savanna Agricultural Research (SARI) experimental station in the Guinea savannah agro-ecological zone of Ghana. The area lies between 09°23' and 22.5'' north latitude of the equator and 001° and 00' 26.5'' west longitude of the zero meridian with an elevation of 186 m above sea level. It has a mono-modal rainfall pattern with an average annual rainfall of 1100 mm and monthly mean of 88.1 mm (SARI, 2001). The mean monthly minimum and maximum temperature was 23 and 38°C, respectively. The mean relative humidity during the day was about 40-50% (SARI, 2001).

The land was prepared based on the four existing tillage system. The tractor tillage plot was prepared by using tractor to plough the land. The bullock plough plot was also prepared by using bullock. A hoe was used in preparing the manual tillage plot. Roundup herbicide (glyphosate) at 2 L ha^{-1} was used to spray the minimum tillage plots two weeks before planting.

The total amount of nitrogen contained in the 6 t ha^{-1} of organic matter was similar to the amount of nitrogen in the mineral fertilizer (NPK) (Table 1). However, only 3% of this total amount of nitrogen (1.8 t) would mineralize and

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Table 1: Nutrient contents of organic manure (cow dung)

N (%)	N in 6 t	P (%)	P in 6 t	K (%)	K in 6 t
0.99	59.3 kg	0.40	24.2 kg	0.89	53.2 kg

be available to the plants. The phosphorus content of the 6 t ha^{-1} of organic manure was lower compared with the phosphorus content of the mineral fertilizer (NPK). The potassium content in the 6 t ha^{-1} of organic matter was higher than the potassium content in the mineral fertilizer (NPK) (Table 1).

The experiment was a 4×4 factorial experiment in a split plot design. The main factor treatments were bullock, tractor, manual and minimum tillage. The sub plot factor treatments were also control (no soil amendments), inorganic (NPK) fertilizer at recommended rate of 60-30-30 kg ha^{-1}, manure only at 6 t ha^{-1} and combination of manure and inorganic (NPK) fertilizer at half rates. The main plot size was 30×5.25 m and the sup plot was also 7×5.25 m. It was replicated four times.

A known area of 9 m^2 was marked in middle of each plot for data collection from reproductive to maturity stage on plant height at 10 days interval to anthesis stage, number of plants per harvest area, number of cobs at harvest, cob weight and grain yield calculated from dry cob weight after harvest as 80% of the cob. Stover weight was measured as the weight of the number of above ground plants within the harvest area, total biomass as the sum of weights of stover, cob and husk and harvest index as ratio of grain yield and total biomass (biological yield).

A Soil profile pit was excavated at the site to a depth of 105 cm. Systematic sampling was taking at 0-15, 15-30, 30-45, 45-60, 60-75, 75-90 and 90-105 cm. Sieved (<2.0 mm) air-dried samples were analyzed for pH (1:2.5 w/v 0.01 M $CaCl_2$), total N by Kjeldahl distillation and titration method (Bremner and Keeney, 1965), available P by Bray 1 extraction solution procedure (Bray and Kurtz, 1945), Exchangeable bases (Ca, Mg, K and Na) content in the soil were determined in 1.0 M ammonium acetate extract (Thomas, 1982) and organic carbon by modified Walkley and Black procedure as described by Nelson and Sommers (1982).

The general linear model of statistics was used to perform ANOVA on the above data. Treatment means with significant difference were separated using Least Significant Difference (LSD) at 5%. Correlation analysis was also performed among tillage system, soil amendment, plant height, yield and yield component to determine co-efficient of correlation at a probability level of 5%.

RESULTS AND DISCUSSION

The soil was Tingoli series (SARI, 2001; FAO, 2006). Tillage had influence on the soil pH, total N, OC and Ca. The highest values of these parameters were recorded under the fallow plot followed by the minimum tillage plot. The soils under bullock and tractor tillage were very strongly acidic as compared with the reaction of the soils under minimum and manual tillage which was strongly acidic and the fallow being moderately acidic (Table 2).

Plant height showed significant difference among tillage systems ($p = 0.0050$) and soil amendments ($p = 0.0000$). There was no interaction effect of tillage systems and soil amendments on plant height (Table 3). Tillage system and soil amendment had significant influenced on plant height at 20, 30 and 75 days after planting with the exception of 10 days after planting (Table 3). Tractor tillage had the highest plant among the tillage system and inorganic fertilizer also obtained the highest plant height under soil amendment (Fig. 1).

Tillage system did not affect number of plants at harvest significantly at p level of 0.05 (Table 4). Soil amendment showed a significant difference on number of plants at harvest with a p value of 0.0001. Inorganic fertilizer had the highest number of plants at harvest but was not significant different from the number of plants obtained by combined manure and inorganic fertilizer at half rates and manure only (Table 5). There was no interaction between tillage system and soil amendment at p level of 0.05 (Table 6).

Number of cobs at harvest was not affected by tillage system ($p \leq 0.5345$) (Table 4). Soil amendment significantly affected number of cobs at harvest with a p value of 0.0000. Higher number of cobs at harvest was recorded by inorganic fertilizer but was not significantly different from number of cobs recorded under combined manure and inorganic fertilizer at half rates (Table 5). Tillage system and soil amendment did not show any interaction at a p level of 0.05 (Table 6).

Tillage system affected cob weight at probability level of 0.05. High cob weight was obtained by bullock tillage but was not significantly different from cob weight recorded under tractor tillage (Table 4). Cob weight was significantly affected by soil amendment at p level of 0.01. Inorganic fertilizer recorded the highest cob weight but was not significant from cob weight obtained under combined manure and inorganic fertilizer at half rates (Table 5). There was no interaction effect between tillage system and soil amendment at p level of 0.05 (Table 6).

Maize grain yield was significant influence by tillage system ($p \leq 0.05$). Bullock tillage recorded significantly higher yield among the tillage system

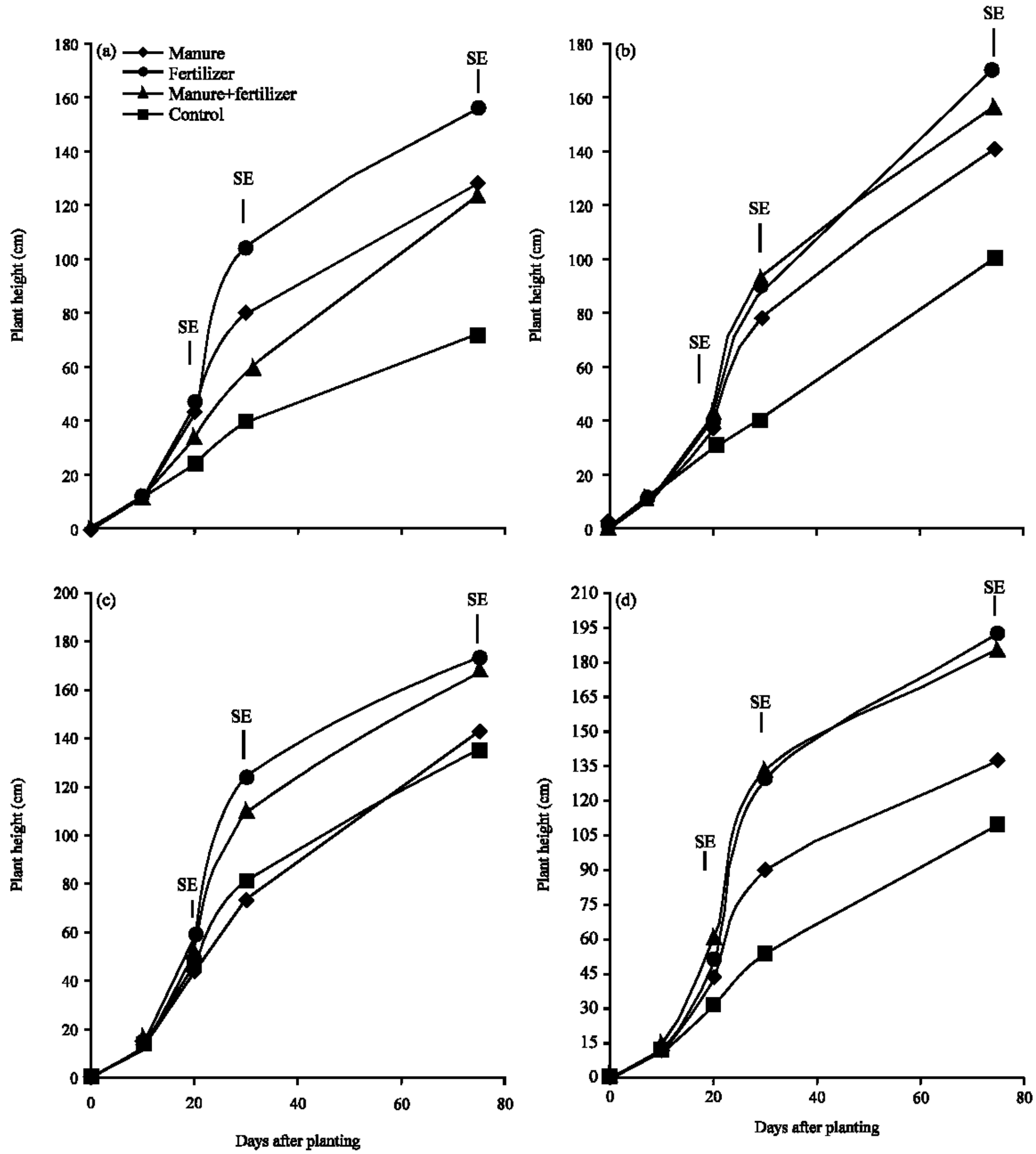

Fig. 1(a-d): Maize plant height as affected by soil amendment under tillage system. SE: Standard Error bars, (a) Minimum, (b) Manual, (c) Bullock and (d) Tractor

Table 2: Chemical properties of ferric lixisol under different type of tillage systems

Tillage types	pH	N (%)	P (mg kg^{-1})	K (mg kg^{-1})	OC (%)	Ca (mg kg^{-1})
Fallow	5.59	0.09	0.55	121.1	1.04	624.8
Minimum	5.22	0.06	2.88	70.2	0.71	507.6
Manual	5.10	0.05	1.85	94.4	0.54	390.5
Bullock	4.87	0.05	1.28	74.5	0.56	429.5
Tractor	4.88	0.05	1.06	76.8	0.54	234.3

N: Nitrogen, P: Phosphorus, K: Potassium, OC: Organic carbon and Ca: Calcium

(Table 4). This was due to the ability of the bullock plough to incorporate organic matter and plant nutrients very well to a suitable depth of the soil. Thomas and Blevins (1996) indicated that conventional tillage gives higher yield in initial years than conservation tillage.

Table 3: Effect of tillage and soil amendments on plant height at 10, 20, 30 and 75 days after planting

	Days after planting (p-value)				
Effect	10	20	30	75	Average
Tillage (T)	0.149ns	0.0068**	0.0098**	0.0048**	0.0050**
Soil amendment (S)	0.0794ns	0.0001**	0.0000**	0.0000**	0.0000**
T×S	0.2132ns	0.1153ns	0.0748ns	0.0825ns	0.2071ns

DAP: Days after planting, ns: Not significant **Significant at 0.01

Table 4: Tillage system effect on No. of plants, No. of cobs, cob weight, grain yield, stover weight, total biomass and harvest index

Tillage system	No. of plants	No. of cobs	Cob weight (kg ha^{-1})	Grain yield (kg ha^{-1})	100 seed weigt (g)	Stover weight (kg ha^{-1})	Total biomass (kg ha^{-1})	Harvest index (%)
Minimum	29189^{a}	18320^{a}	636.7^{b}	523.6^{ab}	7.2^{a}	1298.5^{bc}	1935.2^{bc}	24.2^{a}
Manual	29255^{a}	17791^{a}	538.6^{b}	400.6^{b}	6.8^{a}	1161.8^{c}	1700.4^{c}	20.5^{a}
Bullock	28111^{a}	21037^{a}	948.5^{a}	692.0^{a}	7.6^{a}	1990.0^{a}	2938.5^{a}	24.8^{a}
Tractor	28740^{a}	20597^{a}	778.7^{ab}	5880.4^{ab}	7.6^{a}	1791.3^{ab}	2570.0^{ab}	20.2^{a}

Table 5: Soil amendment effect on No. of plants, No. of cobs, cob weight, grain yield, stover weight, total biomass and harvest index

Soil amendment	No. of plants	No. of cobs	Cob weight (kg ha^{-1})	Grain yield (kg ha^{-1})	100 seed weight (g)	Stover weight (kg ha^{-1})	Total biomass (kg ha^{-1})	Harvest index (%)
Control	24537^{b}	12544^{c}	203.5^{b}	170.4^{b}	6.0^{b}	1298.5^{bc}	1032.4^{b}	17.4^{c}
Manure	29387^{a}	17923^{b}	440.9^{b}	330.5^{b}	7.4^{a}	1161.8^{c}	1616.0^{b}	20.6^{bc}
NPK	31107^{a}	22994^{a}	1200.2^{a}	895.5^{a}	8.0^{a}	1990.0^{a}	3422.4^{a}	25.2^{ab}
Manure+NPK	30264^{a}	24283^{a}	1057.0^{a}	804.3^{a}	7.9^{a}	1791.3^{ab}	3073.3^{a}	26.6^{a}

Table 6: Effect of tillage system and soil amendment on No. of plants, No. of cobs, cob weight, grain yield, stover weight, total biomass and harvest index

	No. of plants	No. of cobs	Cob weight (kg ha^{-1})	Grain yield (kg ha^{-1})	100 seed weight (g)	Stover weight (kg ha^{-1})	Total biomass (kg ha^{-1})	Harvest index (%)
Effect	(p-value)							
Tillage system (T)	0.9546	0.5345	0.0297*	0.0542*	0.5612ns	0.0512*	0.0297*	0.4977ns
Soil amendment (S)	0.0000**	0.0000**	0.0000**	0.0000**	0.0009**	0.0000**	0.0000**	0.0067**
T×S	0.9959ns	0.1383ns	0.8213ns	0.8451	0.5580ns	0.9665ns	0.9433ns	0.1437

ns: Not significant; *,**Significant at 0.05 and 0.01, respectively

Maize grain yield showed significant difference under the different soil amendment (p = 0.001). Inorganic fertilizer gave the highest maize grain yield due to immediate availability and synchrony of nutrient from the mineral fertilizer (NPK) added (Table 5). Combined organic manure and inorganic fertilizer (NPK) at half rate also increased the maize grain yield significantly over the manure only and the control. Dennis *et al*. (1994) reported that the best fertilization for savannah soil is a combination of organic and mineral fertilizer. The poor yield from the manure plots were due to low amount of N (3% of 1.8 t) available for plant absorption. The maize grain yield from the control plot gave the lowest yield which was significantly different from the other types of soil amendments (p = 0.001). This was due to the insufficient availability of plant nutrient required for growth and development.

Tillage system did not show significant influence on the maize 100 seed weight (p>0.05) (Table 4). However, soil amendment showed significant difference on the 100 seed weight of maize (p = 0.0009) (Table 5). Inorganic fertilizer had the highest 100 seed weight but was not significantly from sole manure and combined manure and inorganic fertilizer at half rates.

Stover weight was affected by tillage system at probability level of 0.05. Bullock tillage recorded the highest stover weight and was not significantly different from stover weight obtained by tractor tillage (Table 4). Soil amendment affected stover weight significantly at a p level of 0.01. Higher stover weight was recorded under inorganic fertilizer and was not significantly different from stover weight obtained under combined manure and inorganic fertilizer at half rates (Table 5). Interaction between tillage system and soil amendment did not show significant effect on stover weight (Table 6).

Tillage system affected total biomass produced by maize significantly at probability level of 0.05. Highest total biomass was recorded under bullock tillage but was not significant different from total biomass recorded under tractor tillage (Table 4). Maize total biomass was significantly affected by soil amendment at p level of 0.01. Inorganic fertilizer had the highest total biomass and was significant from total biomass produced under combined manure and inorganic fertilizer at half rate (Table 5). There was no interaction effect between tillage system and soil amendment on total biomass produced by maize (Table 6). Maize harvest index produced was not significantly affected by tillage system with a p level

Table 7: Co-efficient of correlation (r) among tillage system, soil amendment, plant height, yield and yield component

Variables	Tillage system	Soil amendment	Cob weight	Grain yield	100 seed weight	Total biomass	Harvest index
Soil amendment	0.0185ns	-	-	-	-	-	-
Cob weight	0.1754ns	0.6620**	-	-	-	-	-
Grain yield	0.1380ns	0.6790**	0.9686**		-	-	-
100 seed weight	0.1363ns	0.4185**	0.4816**	0.4630**	-	-	-
Total biomass	0.2640*	0.6347**	0.9451**	0.9335**	0.4910**	-	-
Harvest index	-0.0812ns	0.4113**	0.4035**	0.5346**	0.1431ns	0.2812*	-
Plant height	0.1299ns	0.3212**	0.4245**	0.4038**	0.9885**	0.4351**	0.0982ns

ns: Not significant, ***Significant at 0.05 and 0.01, respectively

of 0.6038 (Table 4). However, harvest index produced by maize showed a significant difference under soil amendment at p level of 0.01. Control soil amendment had the highest harvest index (Table 5). Interaction effect between tillage system and soil amendment was not significant (Table 6). Correlation among tillage system, soil amendment, plant height, grain yield and yield component.

Tillage system did not show significant co rrelation co-efficient (r) among soil amendment, grain yield, cob weight, 100 seed weight and harvest index at a probability level of 0.05 (Table 7). However, tillage system showed a significant correlation with total biomass (p = 0.0350).

Correlation co-efficient among soil amendment, plant height, grain yield, cob weight, 100 seed weight, biological yield and harvest index were observed to be significant at a probability level of 0.01 (Table 7).

It was observed that grain yield showed significant correlation co-efficient (r) among cob weight, 100 seed weight, total biomass and harvest index at a probability level of 0.01 (Table 7). Rafique *et al.* (2004) reported that, grain yield showed a highly significant correlation among grain yield, biological yield and harvest index.

CONCLUSION

There was significant difference among the tillage system on plant height at 20 days to maturity, grain yield, cob weight and total biomass of maize. Tillage system did not show significant correlation among soil amendment, plant height, grain yield and other yield components. Soil amendment showed highly significant difference on plant height after 10 days to maturity, grain yield and other yield components of maize. Correlation among plant height, grain yield and other component under soil amendment were highly significant. Based upon this significant correlation soil amendment such as sole inorganic fertilizer (NPK) at recommended rate of 60-30-30 kg ha^{-1} may be used to increase grain yield and other yield component. However, the use of combined half rate of inorganic fertilizer and manure (ISFM) should be the preferred option since the organic matter content of the soils are low and this practice will maintain or increase the soil organic matter which will ensure sustainability of maize production. The use of this technology is also less expensive than the use of the recommended rate of mineral fertilizer. The synergistic effect of the Integrated Soil Fertility Management was more evident under bullock tillage. There was no interaction between tillage type and soil amendment.

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