

Intercropping and Fertilizer Rate Combinations Impact on Maize (*Zea Mays L.*) and Soybean (*Glycine Max L (Merill)*) Productivity: The Case Study in the Guinea Savannah Agro-Ecological Zone of Ghana

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Abstract

Production of food in resource-constrained environments that have poor inherent soil nutrition depends on tillage and cropping systems that provide high yields, preserve soil, water and biodiversity. This research was conducted in the Guinea savannah agroecology of Ghana, during the 2015-2016 cropping seasons to evaluate the impact of tillage and cropping systems on sustainable production of maize and soybean by resource-poor farmers. The experiment was a split-split plot design with four replications. The factors consisted of tillage system at three levels (plough, ripping and direct-seeding) laid out as main plots, fertilizer rate at three levels (0 kg/ha, half the recommended rate of 30-15-15 kg/ha and the recommended optimum rate of 60-30-30 kg/ha NPK) laid as sub-plots and cropping system at two levels (sole maize, maize-soybean intercrop) laid on the sub-sub plot. Apart from leaf area that had significant three-way interaction of tillage, cropping system and fertilizer rate ($p < 0.05$), all other growth parameters were affected by either two factor interaction or a sole factor. Grain yield of maize was significantly influenced by sole maize and fertilizer rate with highest yield occurring under the full rate (3.4 t/ha) compared with the half rate (2.7 t/ha), amounting to yield difference of about 700 kg/ha. Yield of soybean under the integrated production was affected by interaction of tillage system and fertilizer rate. Highest soybean yield (1.4 t/ha) was recorded under the ploughed condition at the full rate of fertilizer application. Though sole maize, ploughed and with full rate of fertilizer application, gave similar benefit/cost ratio as that of the integrated production with half rate of fertilizer application, the intercropped system with half fertilizer rate resulted in 45% more increases in profit compared to the sole production with full fertilizer rate. Integrated production of maize and soybean, with half the recommended rate of NPK (30-15-15 kg/ha) is therefore recommended to resource-poor farmers in northern Ghana.

Keywords: Maize-soybean intercrop; Tillage practices; Fertilizer rates; Yield and Guinea savanna.



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1. Introduction

Tillage operations are often performed by most resource-poor farmers who lack supporting finances for hiring tillage services and have insufficient knowledge on the effect of these operations on soil physical properties and crop responses [1]. According to Srivastava, *et al.* [2], the objective of tillage is to develop a desirable soil structure or suitable tilth for a seedbed. Tillage is carried out mainly to loosen the upper layer of the soil, to mix the soil with fertilizer and organic residues, to control weeds, and to create a suitable seedbed for germination and plant growth [3]. Tillage is crucial for crop establishment, root growth and ultimately, yield [4]. Tillage is known to influence soil physical, chemical and biological characteristics, which in turn alter plant growth and yield [5-7]. Though with varied geolocated beneficial impact, tillage systems are site specific and depend on crop, soil type and the climate [3]. The appropriate tillage system in a given location and crop production system can promote crop growth, yield, hunger reduction and sustenance of crop production.

Intercropping involves cultivating one main crop with one or more added crops, where the main crop is of primary importance due to economic reasons [8]. Egbe, *et al.* [9], and also Ijoyah [10], reported that intercropping increases total yield per given piece of land and results in higher land equivalent ratio. Furthermore, if grain-legumes are involved, the legumes help to maintain and improve soil fertility [11, 12]. For these reasons, intercropping is often promoted to resource-poor farmers with limited access to land.

Maize (*Zea mays L.*) is an important cereal crop worldwide. It is the most important cereal crop in Ghana and Africa as a continent, and is an important component of sustainable cropping systems in most countries world-wide, contributing significantly to household security in most developing countries. The crop is consumed by people with varying food preferences and socioeconomic backgrounds in Ghana [13], necessitating constant research needs to reduce cost of production and enhance the crop's production.

Soybean is a legume crop, grown extensively in most resource-constrained agricultural production systems of Africa, including northern Ghana. The crop can positively contribute to soil health, human nutrition and health,

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livestock nutrition, household income, poverty reduction and overall improvements in livelihoods and ecosystem services [14, 15]. Soybean is also beneficial in the management of *Striga hemonthica*, an endemic parasitic weed of cereal crops [16], which makes the crop a good candidate for integration with maize under limited resource and land-constrained environments.

Cereal-grain legume intercropping has the potential to address the soil nutrient depletion on smallholder farms [11]. The Guinea Savannah zone of Ghana has limited productive lands with increasing rates of soil nutrient depletion [17]. The area is associated with increasing human population, which, together with practices such as slash and burn, mono cropping of cereals, and the recent proliferation of surface mining have endangered shifting cultivation as practiced in the past by most farmers to conserve the soil and maintain productivity [18]. In view of these developments, resource-poor farmers continue to grow maize on the same piece of land season after season. This has affected crop production significantly [19], since the evolving systems are incapable of efficiently conserving soils and restoring soil fertility, thus resulting in temporal deterioration of the resource base of the soil [20].

To arrest this problem and increase maize production, small-holder farmers have resorted to apply different rates of fertilizers to the soils. Different tillage systems have also been employed. While some farmers plant maize after disc ploughing, others plough and harrow before planting [21]. Continuous soil tillage is reported to be associated with some negative impacts on soils and crop productivity [22], and may have negative impacts on maize production. While such knowledge is important, information on it are limited in literature-hindering maize production. In intercropping, the crops are so selected that they take advantage of the different root stratification, varying nutrient requirements and differences in plant architecture so as to maximize resource use [23]. Intercropping offers potential advantages for resource utilization, decreased inputs utilization by the resource-poor farmer and increased sustainability in crop production [9]. Across the northern savannah system of Ghana, such knowledge is limited, limiting maize and soybean production. The aim in this research was to determine the combined advantage of tillage, intercropping and fertilizer rate on productivity and yield of the crops in a maize-soybean intercrop system.

2. Material and Method

The study was conducted during the 2015 and 2016 cropping seasons at Yagaba in the Mamprugu Moagduri District of northern Ghana. The site is located within the Guinea Savanna agroecological belt and has a unimodal rainfall pattern [24]. Average annual rainfall is between 1000 mm and 1400 mm, with rains occurring between May and October [25]. July to September is normally the peak period for rainfall. Floods occur during the peak period, after which there is a prolonged dry season from November to April. Temperatures are generally high all year round with the hottest month being March. Average monthly temperature is between 25°C and 30°C. The vegetation of the site is savanna grassland, characterized by shrubs and few scattered trees [26].

The geology is made of middle voltain rocks. It is largely covered by a flat and undulating terrain. The most significant river in the district is the White Volta and its tributaries include: Sissili and the Kulpawn rivers. Along the valleys of these rivers are large arable lands good for the cultivation of maize and other cereals. The soils are rich in nutrients especially along the valleys. Alluvial soils are quite extensive around the valleys which are also suitable for maize production. There is considerable soil erosion due to bad farming practices and rampant burning of the bush [24].

2.1. Land Preparation and Experimental Layout

A 3 x 2 x 3 factorial experiment arranged in a split-split plot design was used for the study. Each treatment was replicated three times. The treatments structure was composed of tillage system at three levels (plough, ripping and direct seeding) that were laid as the main plot, cropping system at two levels (sole maize, intercrop) that were laid as sub plots, and fertilizer rate at three levels (0 kg/ha, half the recommended rate of 30-15-15 kg/ha and the recommended optimum rate of 60-30-30 kg/ha) laid as sub-sub plots. For ploughing, a single plough operation, followed by a single harrow was carried out using a tractor prior to lining and pegging. For direct-seeding, all pre-planting mechanical seed bed preparation were eliminated, except for the creation of a narrow (2-3 cm wide) strip in the ground for seed placement to ensure adequate soil contact. For ripping, the implement was adjusted to create ripped lines at a spacing of 80 x 40 cm. Each plot measured 5 x 5 m. Seeds of maize (Panner 35 variety) and soybean (Jenguma variety) were drilled on ploughed, and ripped plots and by direct seeding technique.

Two seeds of maize variety (Pannar 35) was planted at a spacing of 80 cm x 20 cm and later thinned to one seed per hill. Soybean seeds were hand-drilled at a spacing of 80 x 10 cm.

NPK fertilizer was applied at the following rates of application: recommended full rate of NPK (60-30-30 kg/ha), half the recommended rate of NPK (30-15-15 kg/ha) and zero rate of NPK (0 kg/ha). The fertilizer was banded on both sides of the plant and buried.

Weed control was carried out at 2 and 5 weeks after planting (WAP). Weeds in the ploughed and ripped plots were controlled using hand hoe, while those in the direct seeded plots were controlled using pre-emergence herbicides. During land preparation, glyphosate herbicide was applied to direct seeded plots at 1.0 kg a.i./ha. After planting, atrazine (a.i. WP 80 g/l/ha) was applied as pre-emergence herbicide. Post-emergence herbicides were used to control weeds at 2 and 5 weeks after planting.

A representative soil sample was taken at different parts of the field before ploughing and ripping. The soil auger was used to sample soil at a randomly selected site on each treatment combination plot. The samples were taken at depths of 0-15 cm and 15-30 cm. They were then mixed thoroughly, air-dried and made to pass through a 2

mm, and 0.5 mm sieves for soil texture and chemical analysis. The soil samples were analyzed for particle size distribution, pH, organic carbon, total nitrogen, available phosphorus and exchangeable bases (Mg, Ca, and K) as well as cation exchange capacity (CEC) according to Sparks [27].

Five plants were tagged per plot for measurements of growth, dry matter yield and yield components as described in Maddonni, *et al.* [28]. Plant height, number of leaves per plant and leaf area were measured at weekly intervals for twelve weeks beginning from three weeks after planting. Dry matter yield, cob weight and 100-seed weight were determined at harvest.

All data were analyzed using the SPSS statistical package. Treatment differences were compared using the Least Significant Difference (LSD) procedure at 5% level of probability.

3. Results

Table-1.

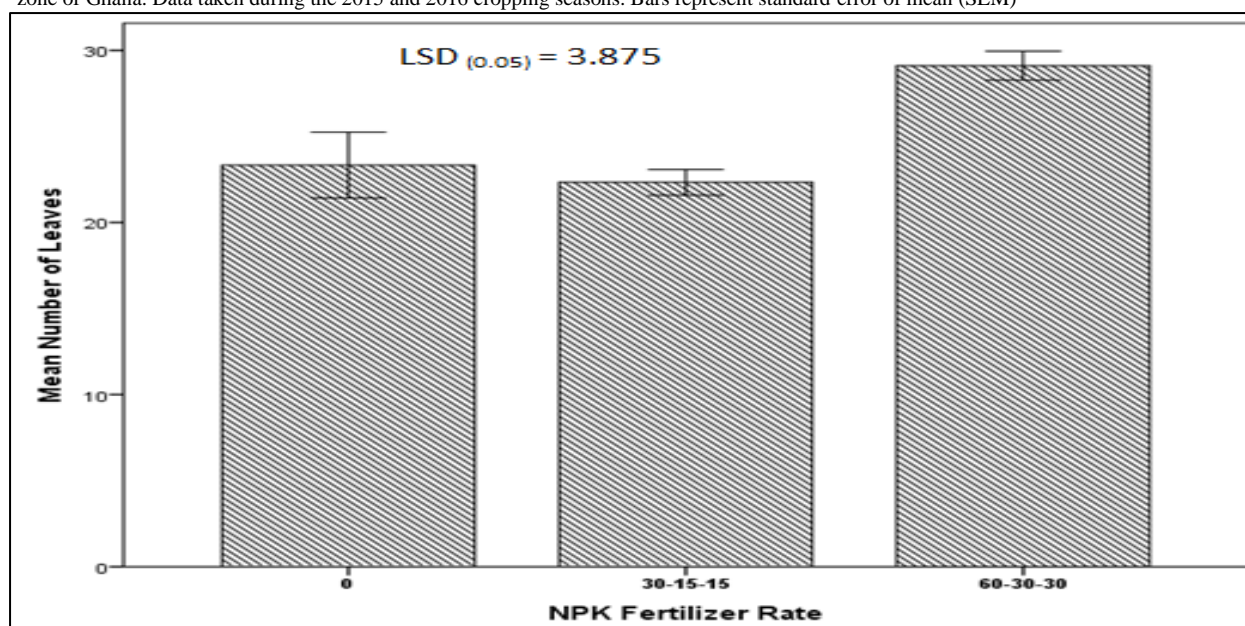
Soil parameter	Initial soil analysis	Post harvest soil analysis	LSD (0.05)
pH	5.21 ^a	5.02 ^b	0.086
Organic carbon (%)	0.05	0.04	0.053
CEC (Cmol ⁺ /kg)	2.15 ^b	2.22 ^a	0.025
Available Nitrogen (%)	0.06 ^a	0.05 ^b	0.012
Available Phosphorus (mg/kg)	8.90	8.4	0.237
Exchangeable Bases			
Potassium (Cmol/kg)	8.06	7.98	0.086
Calcium (Cmol/kg)	1.39 ^a	1.25 ^b	0.025
Magnesium (Cmol/kg)	0.45 ^a	0.41 ^b	0.043
Particle size distribution (%)			
Sand	52.05	53.01	0.099
Clay	0.32	0.28	0.053
Silt	47.63	46.71	0.075
Texture	Sandy loam	Sandy loam	

Soil parameters having different letters for initial and post-harvest analysis (horizontal) are significantly different at the 5% level of probability.

The three-way and two-way interaction combinations of tillage system, fertilizer rates and cropping systems, did not significantly ($p > 0.05$) affect leaf count in both maize and soybean. Similarly, tillage system, fertilizer rate, and cropping system as sole factors, did not significantly ($p > 0.05$) affect leaf count in maize. However, ploughing and the fertilizer application rate at 30-15-15 kg/ha promoted higher leaf count in sole maize, while ripping and direct seeding with a fertilizer application rate of 60-30-30 kg/ha recorded the same leaf count. There was a general trend of increase in leaf number during the period of maize growth with maximum leaf number recorded at 9-12 weeks after planting (WAP). Maize leaf count was generally low with respect to direct seeded plots intercropped with soybean and with the absence of fertilizer application.

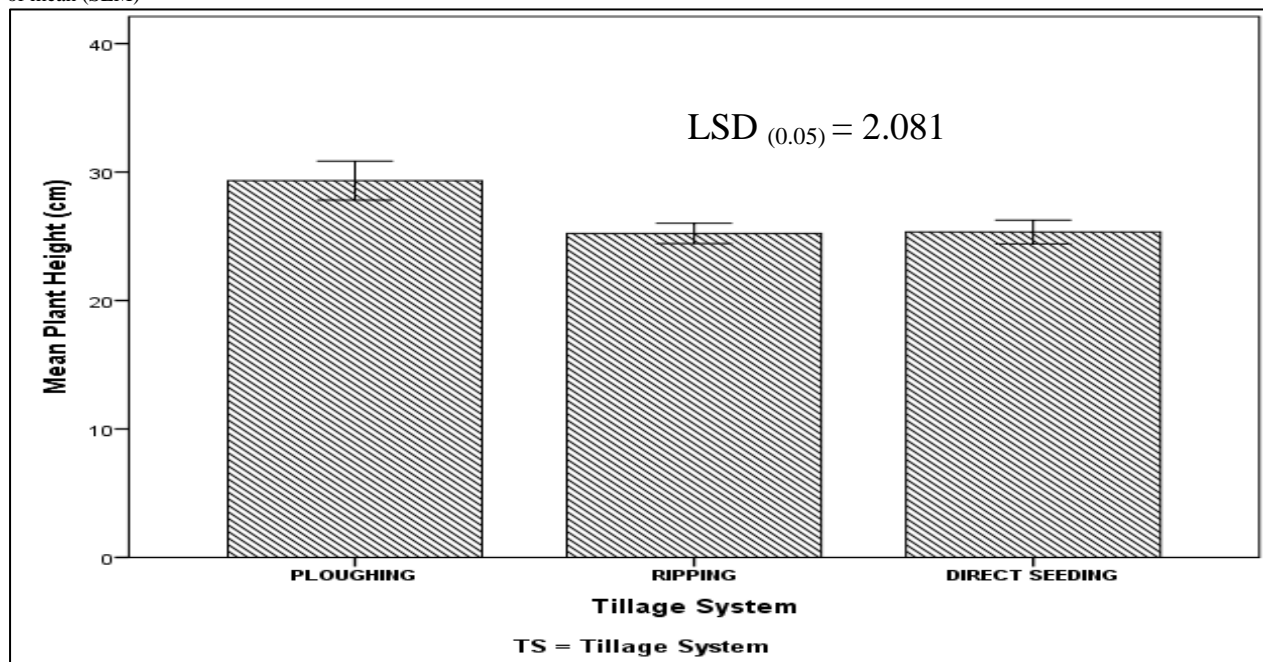
While, tillage system, and cropping system as sole factors did not significantly ($p > 0.05$) affect number of leaves of soybean, leaf number of soybean was significantly ($p < 0.05$) affected by fertilizer rate as a sole factor (Figure 1). There was an increase in leaf number of soybean at a fertilizer application rate of 60-30-30 kg/ha. Experimental plots that received no fertilizer application recorded least number of leaves among the soybean crops. The number of soybean plant leaves ranged between 20 and 30 among the treatments.

Figure-1. Effect of fertilizer rate on number of leaves of soybean in a soybean –maize intercrop production system in the Guinea savanna zone of Ghana. Data taken during the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM)



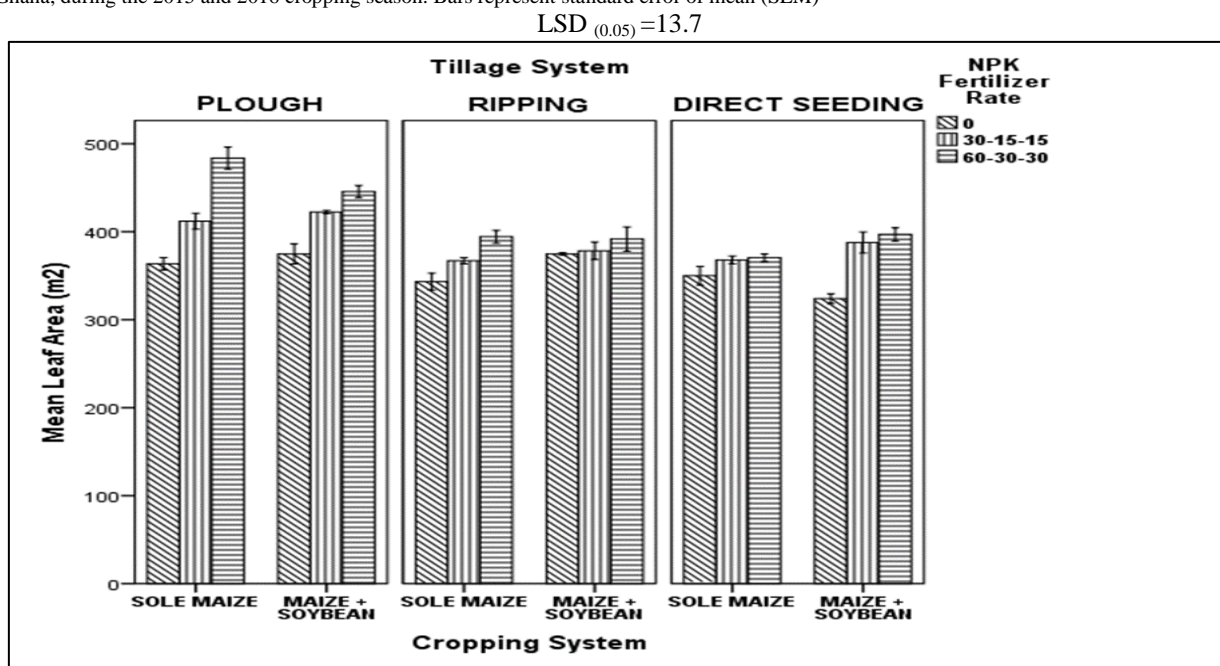
There was no 3-way interactive effect nor 2-way interactive effect on plant height of maize and soybean at all weeks ($p>0.05$). While no significant sole factor effect of fertilizer and cropping system was recorded for maize and soybean height, tillage systems as sole factor significantly ($p<0.05$) affected plant height of soybean in the soybean-maize intercropped system (Figure 2). Among the tillage systems, greater plant height was achieved under ploughing. This was followed by direct seeding and then ripping.

Figure-2. Effect of tillage system on plant height of soybean in a three factor (Fertilizer rate, cropping system, tillage system) soybean-maize intercrop system in the Guinea savanna zone of Ghana. Data collected during the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM)



There was a three-way interaction effect between tillage system, cropping system, and fertilizer rate ($p<0.05$) on leaf area of maize (Figure 3) but not on height of cob attachment. Among the treatments, ploughing and a fertilizer application rate of 60-30-30 kg/ha on sole maize, recorded the greatest leaf area. Direct seeding, in an integration of maize and soybean produced the lowest leaf area at zero fertilizer rate. Although cropping systems did not significantly affect leaf area, maize integration with soybean plots recorded higher leaf area as compared to sole maize subjected to ploughing.

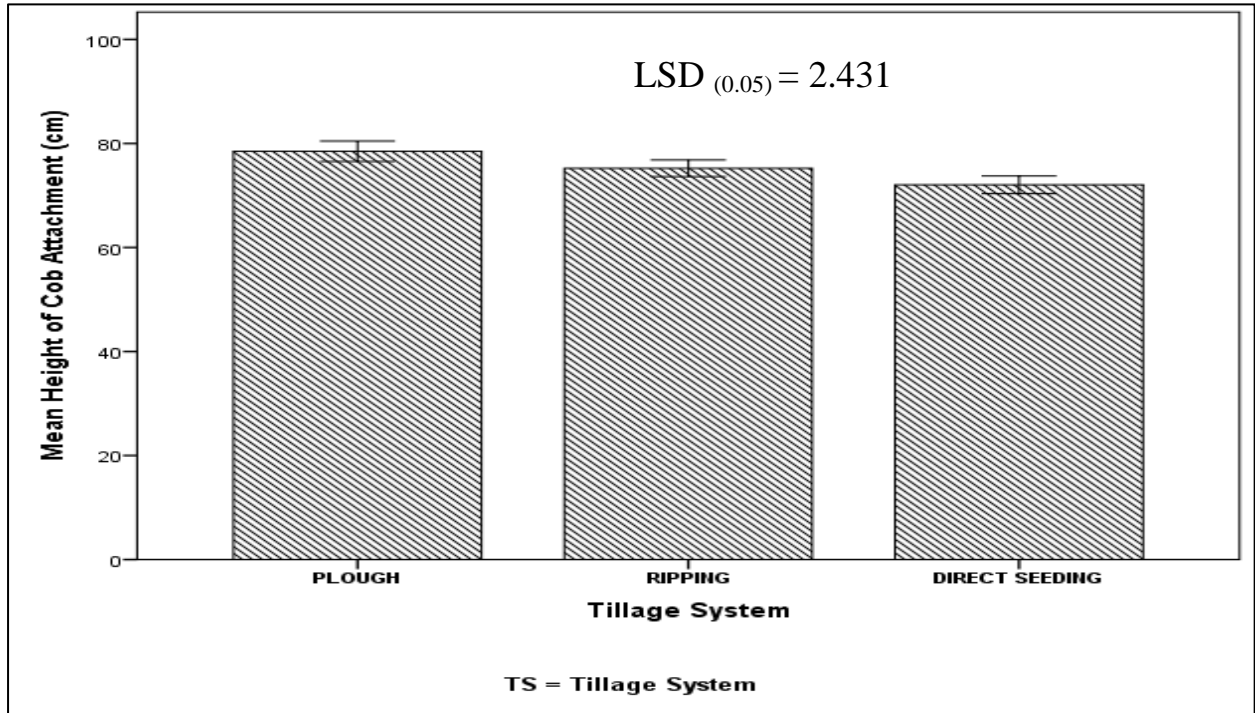
Figure-3. Effect of tillage system, cropping system and fertilizer rate on leaf area of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 and 2016 cropping season. Bars represent standard error of mean (SEM)



There was also no two-way interaction of the factors on height of cob attachment.

While fertilizer rate, and cropping system as sole factors, did not significantly ($p>0.05$) affect the height of cob attachment, height of cob attachment was significantly ($p<0.05$) affected by tillage system as a sole factor (Figure 4).

Figure-4. Effect of tillage system on height of cob attachment in a three factor (Fertilizer rate, cropping system, tillage system) soybean-maize intercrop system in the Guinea savanna zone of Ghana. Data collected in the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM)



Greater height of cob attachment was recorded in the ploughed field while direct seeding resulted in lowest height of cob attachment. Statistically, differences in height of cob attachment among treatments on direct seeded maize plots was at par with same treatments on ripped plots.

There was no two-way nor three-way interaction effect of the factors on cob length of maize ($p > 0.05$). Also, fertilizer rate, and cropping system as sole factors, did not significantly ($p > 0.05$) affect cob length of maize. Tillage system, however, significantly ($p < 0.05$) affected cob length of maize (Figure 5). Ploughing recorded the longest cob length. Although, ripped plots recorded higher values than direct seeded plots, there was no statistically significant differences among them.

The interaction effect of tillage systems x fertilizer rates x cropping systems, cropping systems x fertilizer rates, and tillage systems x cropping systems, did not impact significantly ($p > 0.05$) on cob weight. In addition, tillage system, fertilizer rate, and cropping system as sole factors, did not show significant impact ($p > 0.05$) on cob weight. In contrast to these, cob weight was significantly ($p < 0.05$) affected by the interaction between tillage system and fertilizer rate (Figure 6). Ploughing as a tillage system with a fertilizer application rate of 60-30-30 recorded the highest cob weight of 12 g/cob while direct seeding at a fertilizer rate of 0 kg/ha gave the lowest cob weight of 5 g/cob. Cob weights recorded on direct seeded and ripped plots were however similar irrespective of the treatments applied on them.

Figure-5. Effect of tillage system on cob length of maize in a three factor (Fertilizer rate, cropping system, tillage system) soybean-maize intercrop system in the Guinea savanna zone of Ghana during the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM)

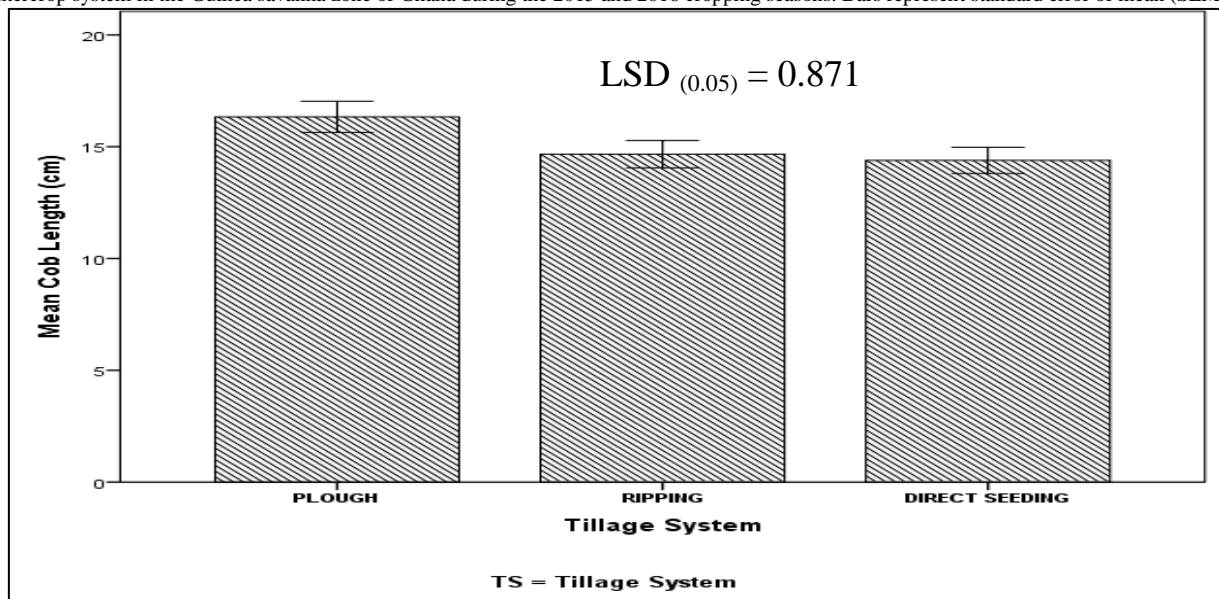
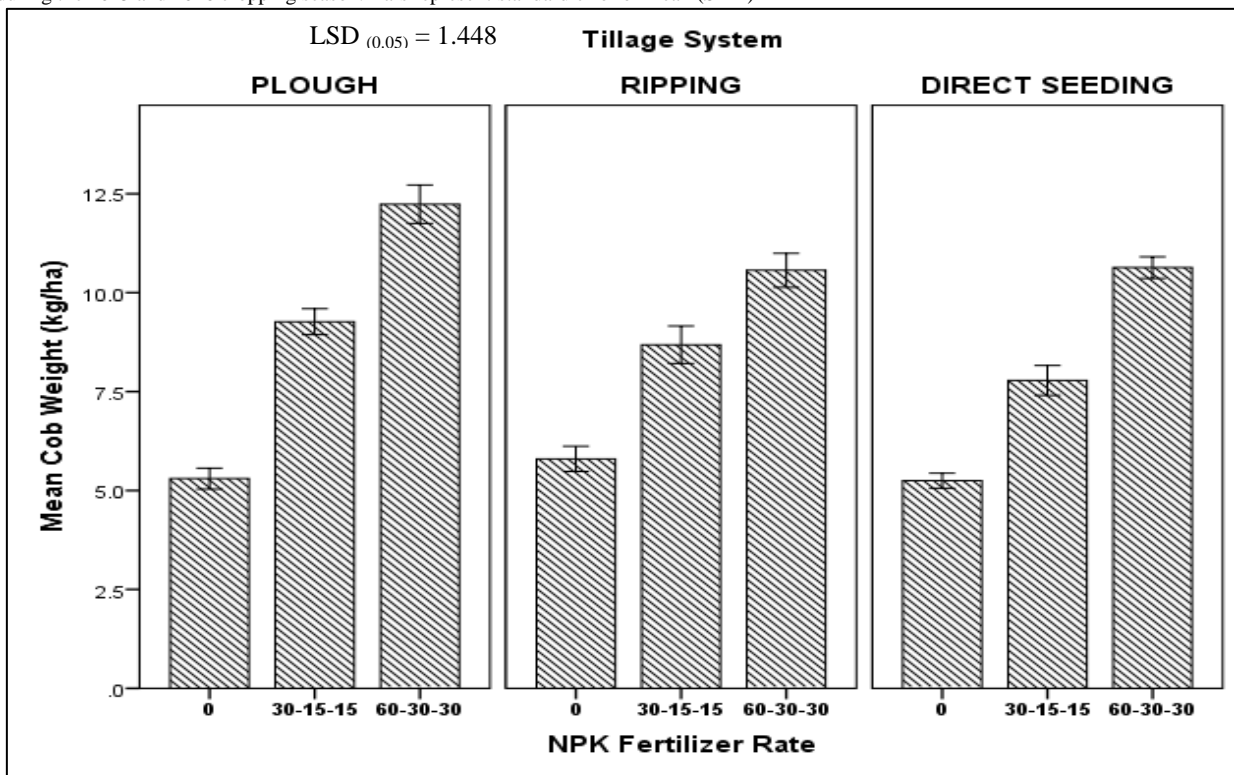


Figure-6. Effect of tillage system and fertilizer rate on dried cob weight (g) of maize, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 and 2016 cropping season. Bars represent standard error of mean (SEM)



There was no significant three-way nor two-way interaction effect of the factors on the number of pods per plant nor on number of seeds per pod ($p > 0.05$). In addition, fertilizer rate, and cropping system as sole factors did not significantly ($p > 0.05$) affect number of pods. However, number of pods was significantly ($p < 0.05$) affected by the tillage system (Figure 7). Pod number ranged between 28 and 42 per plant. Pod number at harvest was highest on ploughed treatments and least on direct seeded plots. Direct seeding under zero rate of NPK application supported least number of the soybean pod.

In addition, tillage systems, and cropping systems as sole factors did not significantly ($p > 0.05$) affect number of seeds per pod while fertilizer rate as sole factor significantly ($p < 0.05$) affected number of seeds per pod (Figure 8). Fertilizer application rate of 30-15-15 kg/ha recorded higher seed count followed by 60-30-30 and 0 kg/ha respectively.

Figure-7. Effect of tillage system on pod number of soybean in a three factor (Fertilizer rate, cropping system, tillage system) soybean –maize intercrop system in the Guinea savanna zone of Ghana during the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM)

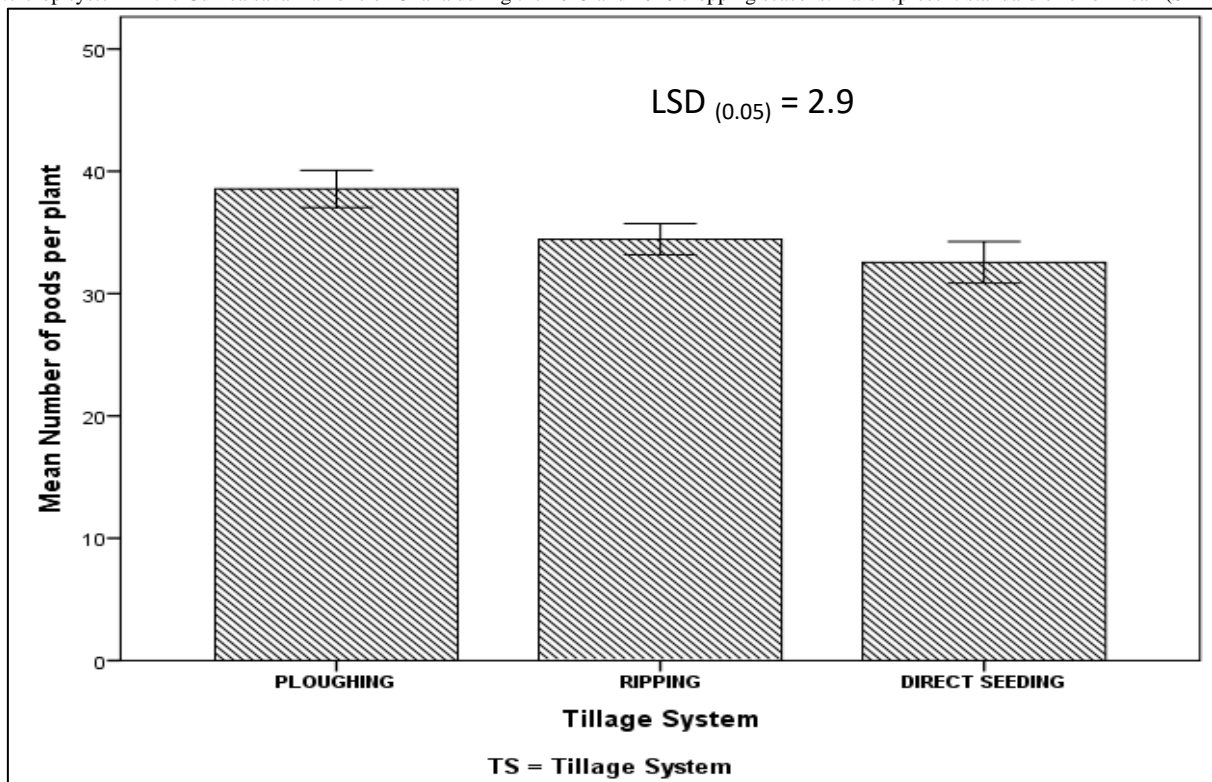
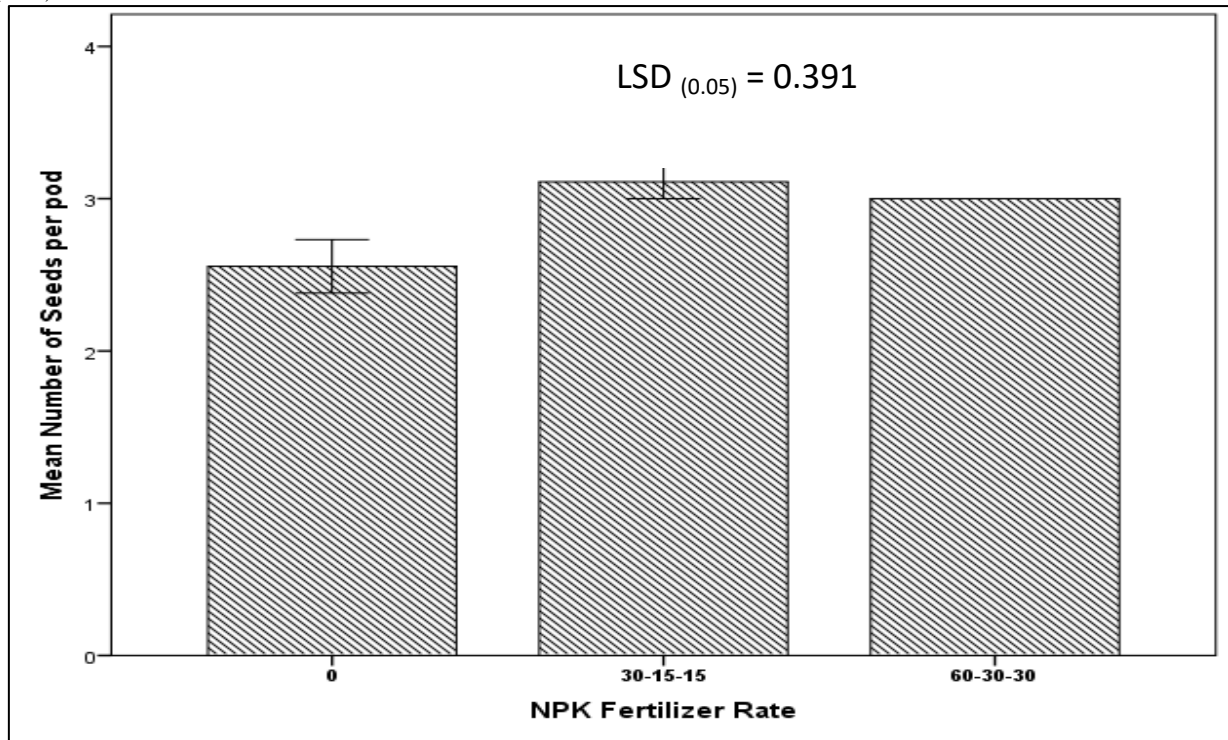


Figure-8. Effect of fertilizer rate on number of seeds per pod of soybean in a three factor (Fertilizer rate, cropping system, tillage system) soybean–maize intercrop system in the Guinea savanna zone of Ghana during the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM).



There was no significant 3-way nor 2-way interaction effect ($p > 0.05$) between tillage systems, fertilizer rate and cropping system on hundred seed weight of maize and soybean. Also, fertilizer rate, and cropping system as sole factors, did not significantly ($p > 0.05$) affect hundred seed weight of both maize and soybean. The hundred seed weight of maize and soybean were significantly ($p < 0.05$) influenced by tillage systems (Figure 9 and Figure 10). Ploughed experimental plots recorded maximum seed weight in both crops. Seed weight among direct seeded plots recorded least values in soybean weight compared with conventional ripped plots. Averagely, seed weight of 12.6 g, 11.7 g and 11.8 g were respectively recorded for the ploughed, ripped and direct seeded treatments respectively.

Figure-9. Effect of tillage system on hundred seed weight of maize (g/100 seed) in a three factor (Fertilizer rate, cropping system, tillage system) soybean–maize intercrop system in the Guinea savanna zone of Ghana during the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM)

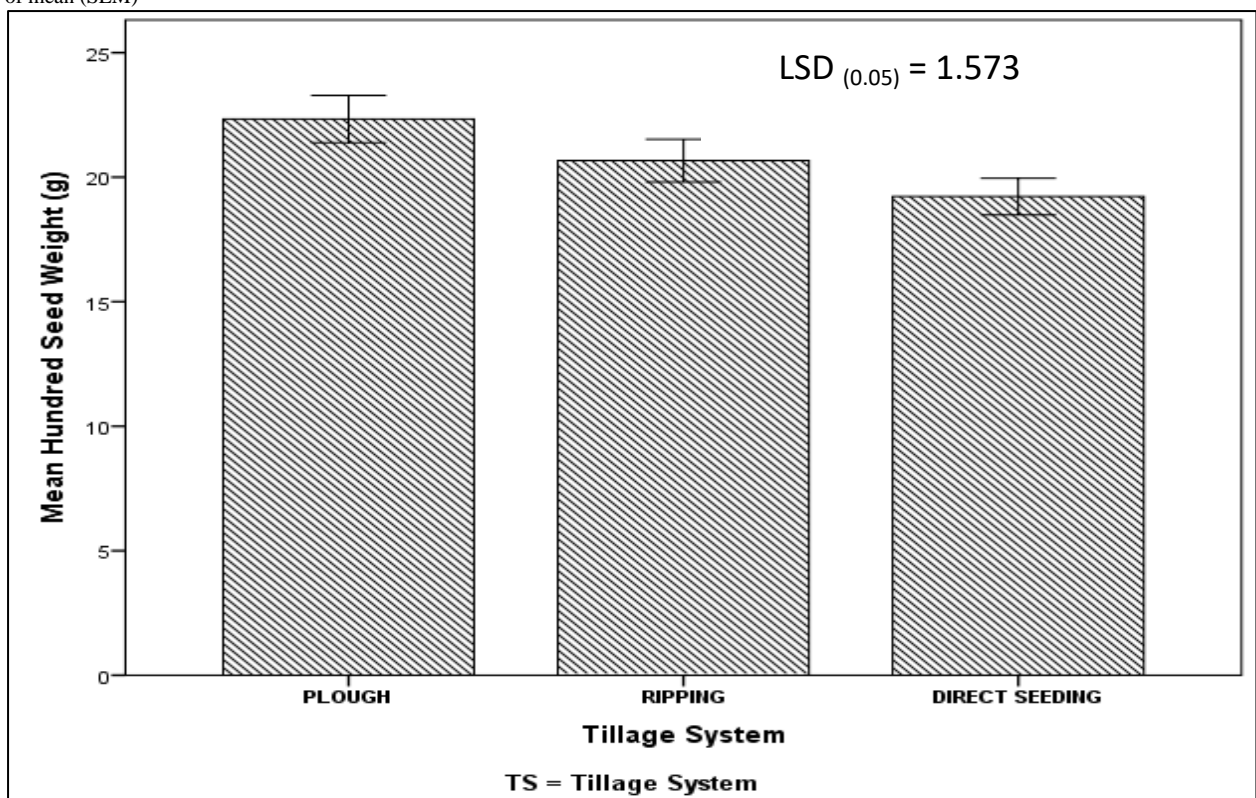
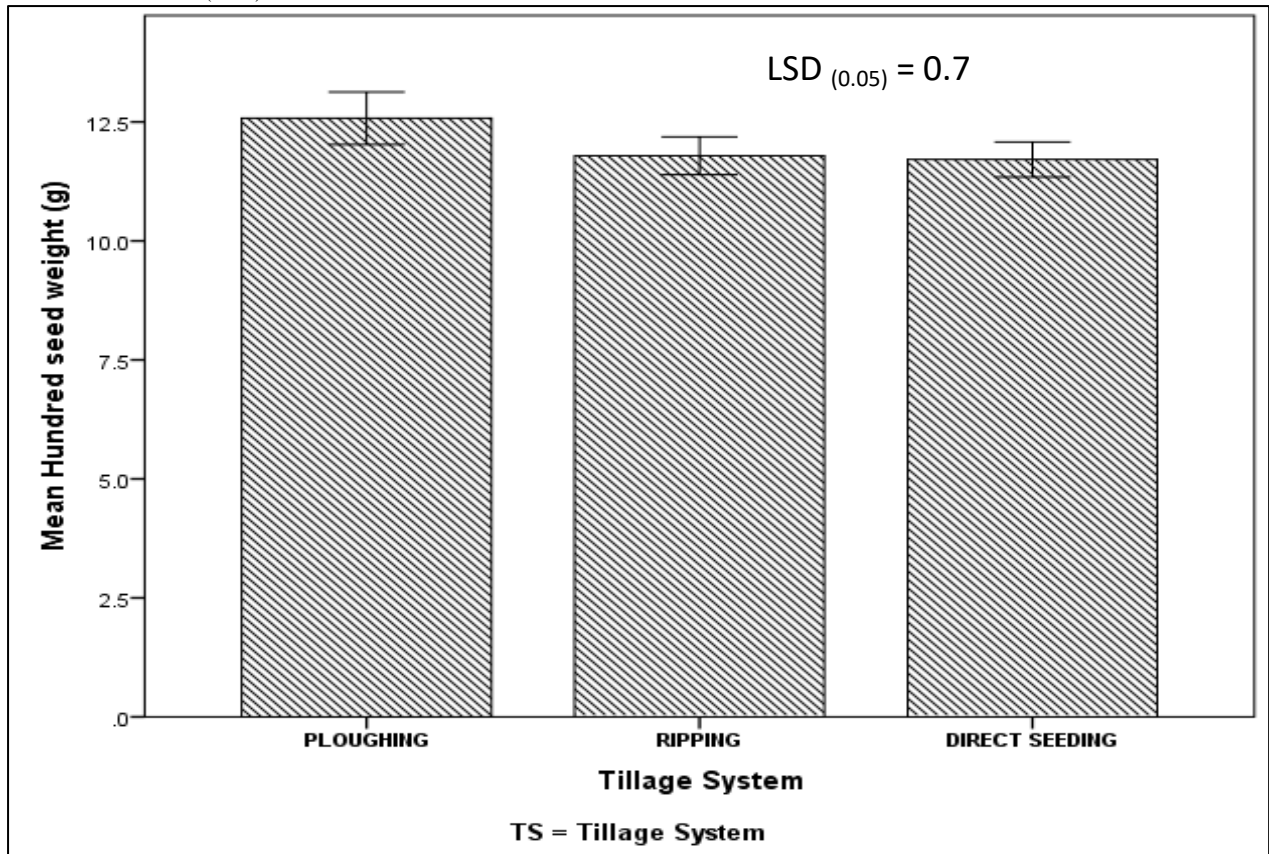
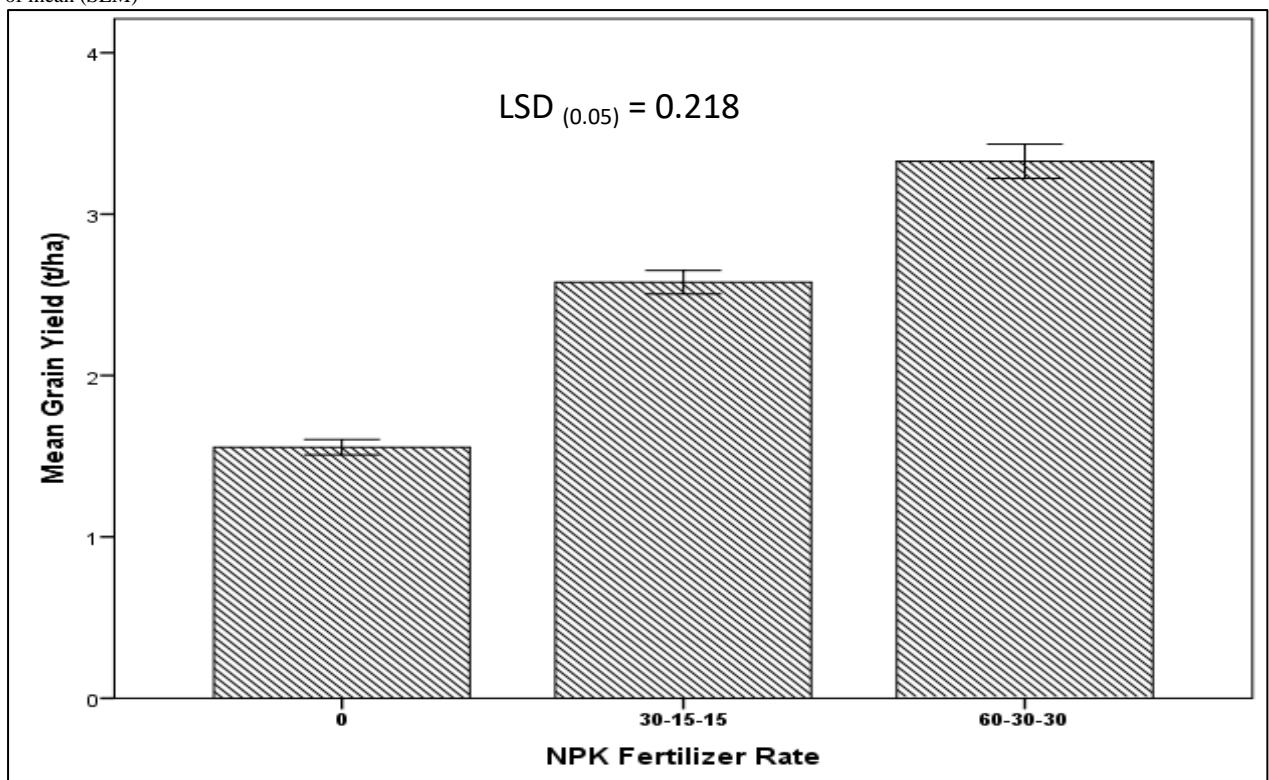


Figure-10. Effect of tillage system on hundred seed weight of soybean (g/100 seed) in a three factor (Fertilizer rate, cropping system, tillage system) soybean –maize intercrop system in the Guinea savanna zone of Ghana during the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM)



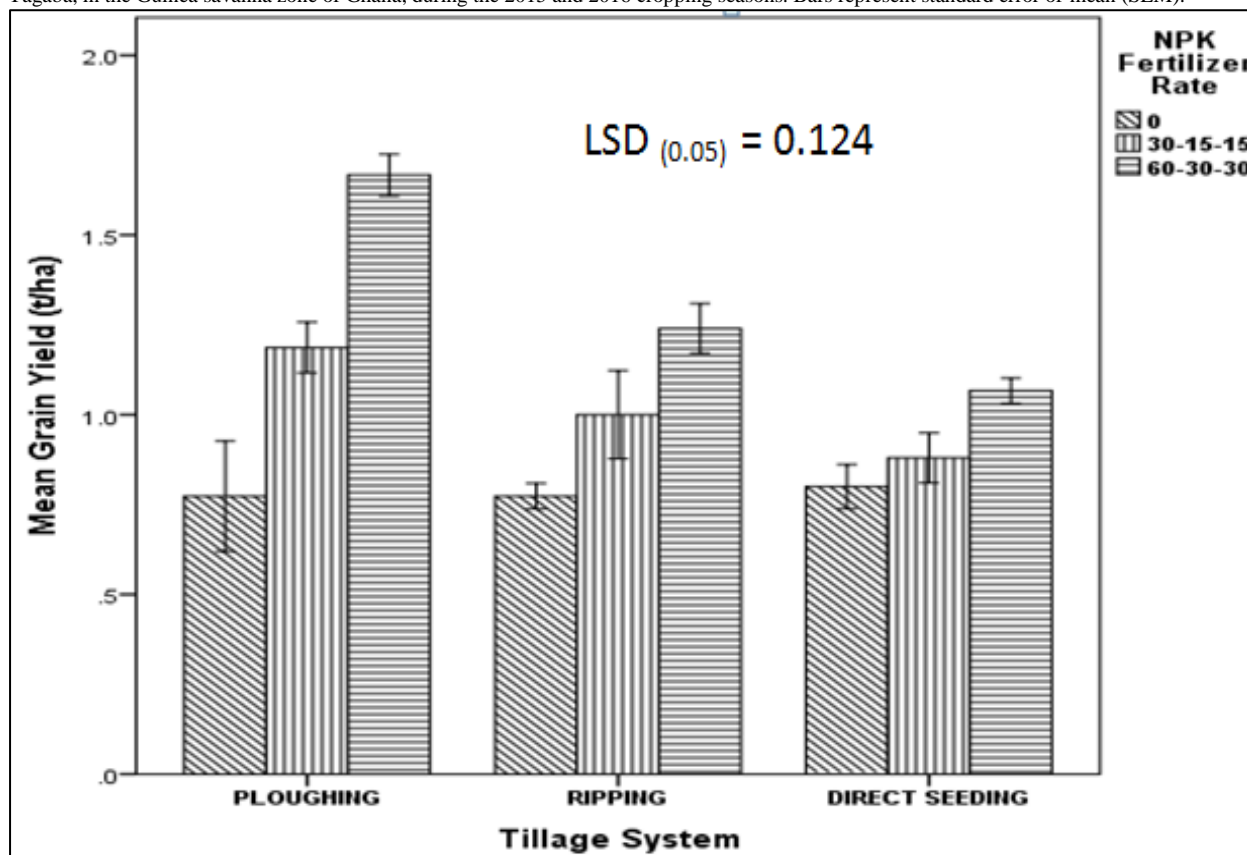
There was no three-way nor two-way interaction effect on grain yield of maize ($p > 0.05$). In addition, tillage system, and cropping system as sole factors did not impact grain yield of maize. Maize grain yield, however, significantly ($p < 0.05$) varied with fertilizer rate (Figure 11). Application of fertilizer at a rate of 60-30-30 kg/ha NPK resulted in maximum grain yield of 3.7 t/ha while lowest application rate of 0 kg/ha resulted in lowest yield of 1.5 t/ha.

Figure-11. Effect of fertilizer rate on grain yield of maize (t/ha) in a three factor (Fertilizer rate, cropping system, tillage system) soybean –maize intercrop system in the Guinea savanna zone of Ghana. Data collected during the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM)



With the exception of the interaction of fertilizer rate with tillage system, yield of soybean was also not affected by either of three-way nor two-way interaction between the three factors. In addition, tillage system, fertilizer rate, and cropping system as sole factors, had no significant effect ($p>0.05$) on grain yield of soybean. Soybean grain yield was significantly ($p<0.05$) affected by tillage systems x fertilizer rate (Figure 12).

Figure-12. Effect of tillage system and fertilizer rate on grain yield of soybean (t/ha) in a soybean –maize intercrop production system, grown in Yagaba, in the Guinea savanna zone of Ghana, during the 2015 and 2016 cropping seasons. Bars represent standard error of mean (SEM).



Maximum grain yield was recorded on ploughed plots supplied with 60-30-30 kg/ha NPK. Direct seeded treatment at fertilizer rate of 0 kg/ha NPK resulted in lower grain yield of soybean under the intercropped condition. At both 30-15-15 and 60-30-30 kg/ha rates of fertilizer application, grain yield of soybean intercropped was in the order: direct seeded < ripped < ploughed. Ploughed plots with a fertilizer rate at 60-30-30 kg/ha recorded twice the yield for the zero fertilizer treatment.

Comparative analysis of economic productivity of the maize and soybean production techniques show that intercropped maize, produced under ploughed conditions and with a fertilizer rate of 60-30-30 kg/ha NPK gave the highest benefit/cost ratio of 2.6 and profit of 3410 GHS/ha (Table 2). This was followed by intercropped maize produced under ripped conditions and with a fertilizer application rate of 60-30-30 kg/ha. Sole production of maize under ploughed conditions and with zero rate of fertilizer application gave the least benefit/cost ratio.

Production of sole maize under ploughed conditions and with full rate of fertilizer application, when compared with intercrop (maize-soybean) production under ploughed conditions and with half rate of fertilizer application, accrued the same benefit/cost ratio of 2.1. The intercropped system with half the fertilizer rate, however, resulted in higher profit of 2233 Ghana Cedis (GHS) compared to the sole production system (GHS 1524) (Table 2).

Table-2. Benefit/Cost analysis of maize and soybean production systems as influenced by tillage, cropping systems, and fertilizer application technologies in the Guinea Savanna zone of Ghana

System/ Technology	Cost of production (GH¢)/ha	Income (GH¢)/ha	Profit (GH¢)/ha	Benefit/cost ratio
SMPZ	1130	1440	310	1.3
SMPH	1258	2610	1352	2.1
SMPF	1356	2880	1524	2.1
M+SPZ	1902	2604	702	1.4
M+SPH	2039	4272	2233	2.1
M+SPF	2196	5606	3410	2.6
SMRZ	1000	1710	710	1.7
SMRH	1203	2430	1227	2
SMRF	1281	2340	1059	1.8

M+SRZ	1752	2514	762	1.4
M+SRH	1955	3234	1279	1.7
M+SRF	2016	4696	2680	2.3
DsSMZ	915	1260	345	1.4
DsSMH	1128	2160	1032	1.9
DsSMF	1241	2700	1459	2.2
DsM+SZ	1691	2412	721	1.4
DsM+SH	1927	3838	1911	2
DsM+SF	1937	4158	2221	2.1

SMZ= Sole maize ploughed with zero rate of fertilizer application SMPH= Sole maize ploughed with half rate of fertilizer application SMPF= Sole maize ploughed with full rate of fertilizer application M+SPZ= Maize+Soybean ploughed with zero rate of fertilizer application M+SPH= Maize+Soybean ploughed with half rate of fertilizer application M+SPF= Maize+Soybean ploughed with full rate of fertilizer application SMRZ= Sole maize ripped with zero rate of fertilizer application SMRH= Sole maize ripped with half rate of fertilizer application SMRF= Sole maize ripped with full rate of fertilizer application M+SRZ= Maize+Soybean ripped with zero rate of fertilizer application M+SRH= Maize+Soybean ripped with half rate of fertilizer application M+SRF= Maize+Soybean ripped with full rate of fertilizer application DsSMZ= Direct seeded Sole maize with zero rate of fertilizer application DsSMH= Direct seeded Sole maize with half rate of fertilizer application DsSMF= Direct seeded Sole maize with full rate of fertilizer application DsM+SZ= Direct seeded Maize+Soybean with zero rate of fertilizer application DsM+SH= Direct seeded Maize+Soybean with half rate of fertilizer application DsM+SF= Direct seeded Maize+Soybean with full rate of fertilizer application.

4. Discussion

The physico-chemical properties of soils used for the study (Table 1), showed that the soils were suitable for maize and soybean production [29]. The observed decline in soil organic carbon (Table 1) after harvest may be attributed to the stimulatory effect of living roots on microbial activities that enhanced soil organic matter decomposition [30, 31]. The slight increase in pH after harvest could be attributed to addition of high NPK fertilizer rate. This observation is consistent with the findings of Chukwu, *et al.* [32], who reported that application of 300 kg/ha of NPK fertilizer could lead to increase in soil pH. There was decrease in total N after harvest. This could be attributed to nutrient uptake by component crops and the absence of NPK fertilizer application on some of the fields. Similarly, the available P was depleted after harvest. The depletion may be attributed to uptake of the nutrients by component crops and probably due to fixation of the element which usually occurs at low soil pH [33].

The increase in leaf number of soybean to increased NPK fertilizer rate (Figure 1) may be attributed to the essentiality of the elements N, P and K, which are responsible for plant growth and development. This result is in line with Ijoyah [10], and Dankyi, *et al.* [34], who noted soybean as a common component in most intercropping systems in the tropics and mentioned that appropriate fertilizer formulation remains a key element in the crop's production as poor soil nutrition remains key to the cause of low yield.

The observed relatively low plant height for soybean under integration compared to sole soybean (Figure 2) is attributed to limited area to explore sunlight and nutrients in the soil as a result of competition between the soybean and maize. This observation is in line with Thwala and Ossum [35], who observed low plant height among intercrops and attributed it to limited space for resource exploitation.

The photosynthetic capacity of crops is a function of leaf area. Leaf area is important for crop light interception and therefore has a large influence on photosynthesis and crop yield [36, 37]. The lowest leaf area of maize obtained in the No-Tillage plots (Figure 3) may be due to lack of soil loosening for provision of desirable conditions that are favorable to crop growth and yield [21]. This result is in agreement with that of Videnović, *et al.* [38], who observed higher leaf area in conventional tillage plots in comparison with that of no-tillage plots. The higher total leaf area among sole maize treatments indicates greater interception of incoming solar radiation by monocrops than by maize/soybean intercrops, and this may reflect in increased grain yield in sole maize systems relative to their integrated counterparts. As postulated, nitrogen plays key role in several physiological processes and increased N levels have been associated with greater photosynthetic rates [39, 40]. Low N supply negatively affects the amount or activity of photosynthetic components [39]. Accordingly, it is postulated that biochemical limitations in the N-limited fertilizer treatments may have constrained photosynthesis and general growth in the resulting N-deficient plants. Ploughing favored higher heights of cob attachment (Figure 4). Ploughing may have provided adequate tilth for maize plants to explore water and nutrient resources in the soil horizon [3]. The height to which cobs were attached to the maize plant is a good indicator of easiness with which matured cobs can be mechanically harvested [41].

The increase in cob weight and length, hundred seed weight and grain yield of maize in relation to the fertilizer rate (Figure 5, Figure 6, Figure 9, Figure 11) may be attributed to increase in nutrient supply which in turn improves the yield parameters [42]. Increase in seed weight with increased NPK rate might be due to the increases in leaf area (Figure 3) that may have promoted interception of more sunlight for the production of carbohydrate, and translated into grain yield as reported by Ayoola and Makinde [43]. The observed low yield and yield components recorded by the absence of fertilizer treatment might be adduced in part to the deficiency of nutrients as revealed by the low nutrient status of the soil (Table 1; [20]).

The observed lowest yields of soybean under the direct-seeded fields and at NPK rate of 60-30-30, may be attributed to impeded root development that restricts root exploration and nutrient uptake even under high fertilizer

application. Ploughed and ripped treatments may have reduced soil compaction and enhanced deep root growth than direct-seeded plots, allowing for root exploration under these treatments [44, 45].

According to [Adegeye and Dittoh [46]], the higher the benefit/cost ratio, the higher the profit derived from the use of the given production system. From results of table 2, however, it would be inappropriate to judge the economic performance of the various treatments based solely on the benefit/cost ratio. Because, sole maize ploughed with a full rate of NPK fertilizer application, and intercrop (maize-soybean) ploughed with half rate of NPK fertilizer accrued the same benefit/cost ratios of 2.1 but resulted in a profit of 1524 and 2233, respectively.

5. Conclusion

Growth and yield of maize and soybean are differently affected by a given combination of tillage, cropping system, and fertilizer rate. Across the guinea savanna agro-ecological system of northern Ghana, maize growth and yield increases with increasing NPK Fertilizer rates of 60-30-30 kg/ha and 30-15-15 kg/ha while the absence of cover crop (soybean) resulted in improved vegetative growth, improved yield and yield components in sole maize production systems. The increasing maize productivity with increasing NPK fertilizer rates indicates that fertilizer application rates have profound effect on the general performance of crops in the study area. The practice of ploughing as a technique for soil manipulation promotes maize growth and yield under intercropped systems. Ploughing is essential in the mostly compact, low organic matter-containing soil as it breaks compaction and promotes root proliferation and nutrient uptake. The growth performance of maize under integrated soybean production was least, compared to sole maize production systems under the same treatment levels. The decrease in growth and yield parameters among maize-soybean intercrop is mainly due to intra and interspecific competition for nutrients, light, and space. Direct seeding, integration of leguminous cover crop and the absence of NPK fertilizer least promoted growth of maize and soybean. Though sole maize production gave highest maize yield, benefit/cost analyses and the profit analyses of the production systems show that intercrop production of maize-soybean under ploughed conditions and with half rate of the recommended fertilizer rate is more beneficial and should be promoted to the resource-poor farmer across the region.

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