Asian Journal of Advanced Research and Reports

8(3): 10-22, 2020; Article no.AJARR.54070
ISSN: 2582-3248

Polycultural Productivity of Maize (*Zea mays* L.) as Affected by Tillage Practices, Fertilizer Rates and Intercropping Systems in the Guinea Savannah Agroecology, Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. Author PG designed the study and wrote the first draft of the manuscript. Author JXK wrote the protocols and performed the statistical analysis. Author BKB managed the literature searchers. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJARR/2020/v8i330199
Editor(s):
(1) Dr. Chunhua Zhou, Professor, College of Horticulture and Plant Protection, Yangzhou University, China.
Reviewers:
(1) Addam Kiari Saidou, Nigeria.
(2) Tumiar Katarina Manik, Lampung University, Indonesia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/54070

Original Research Article

Received 25 November 2019
Accepted 31 January 2020
Published 10 February 2020

ABSTRACT

Soil impoverishment remains a major constraint to food crop production in the Guinea Savanna agroecology of Ghana. Most soils identified in this ecology are fragile and deficient in nutrients due to inappropriate management practices. To resolve this challenge, field studies were conducted to assess the polycultural productivity of maize as affected by tillage practices, fertilizer rates and intercropping systems. The study was however conducted in two cropping seasons (2016 and 2017) at Yagaba in the Mamprugu Moaduri District of Northern Ghana. Treatments consisting of 2 tillage practices (direct seeding and ploughing), 2 fertilizer application rates (zero rate [0-0-0 kg/ha NPK] and recommended rate [60-30-30 kg/ha NPK]) and 3 intercropping systems (sole maize, cowpea [*Vigna unguiculata* L. Walp] and soybean [*Glycine max* L.]) were factorially examined in three replications using randomized complete block design. Although the maize responded differently to the varied treatments, its exposure to ploughing, 60-30-30 kg/ha fertilizer rate and soybean intercropping system were in general influential in enhancing vegetative growth, yield and

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yield components. The responsiveness of maize to ploughing and 60-30-30 kg/ha fertilizer rate increased grain yield by 8.60% and 37.68%, respectively than their untreated controls. Regardless of not directly supplying the intercrops with the inorganic fertilizer, nodulation count and effectiveness of cowpea and soybean were improved under ploughed fields treated with 60-30-30 kg/ha fertilizer rate. The combined impact of ploughing, 60-30-30 kg/ha fertilizer rate and soybean integration resulted in higher profit returns. Hence, this study recommends to small-holder farmers in the Guinea Savannah agroecology of Ghana to adapt to the implementation of ploughing, 60-30-30 kg/ha fertilizer rate and soybean intercropping system for yield improvement and profit maximization.

Keywords: Maize yield; tillage practices; fertilizer rates; intercropping systems.

1. INTRODUCTION

Maize (*Zea mays* [L.]) is a versatile and major food crop for resource-poor farmers in sub-Saharan Africa. Averagely, maize production covers a total land area of 27 M ha [1] and occupies 30% of the arable lands cropped with cereals [2]. As an important cereal-fodder and grain crop, its cultivation can be established under both irrigated and rain-fed agriculture systems [1], either as a monocrop or included in an intercropping system. Principally, maize serves as a major staple food crop for almost every household in SSA with varied and preferential consumption forms [3]. According to [4], maize also forms a rich source of livestock and poultry feed pertinent for its dry matter transformation into meat, milk, and eggs. Industries also benefit from the raw material by processing it into corn starch, corn flakes, gluten germ-cake, lactic acid, alcohol and acetone. In view of that, corn oil is becoming popular due to its non-cholesterol character. However, across sub-Saharan Africa, maize yield remains low and highly variable between years, with a mean less than 1.5 t/ha [5], only just enough to reach self-sufficiency in many areas including Ghana,where soil characterization have been described to be low in organic carbon (<1.5%), total nitrogen (<0.2%), exchangeable potassium (<100 mg/kg) and available phosphorus (<10 ppm) [6]. Aside its low production, demand for maize has been predicted to increase exponentially due to the anticipated increase in global population [7], indicating a triple demand preference in SSA by 2050 [3]. Besides, achievable yield under low recognition levels in the Guinea Savanna agroecology can be reflected upon to be the major cause of the acute poverty and hunger since maize remains the most cultivated crop in the region [8].

The problem of low maize yield still persist in the region due to soil restoration practices and crop improvement techniques which are not efficiently harnessed. Although most soils in this ecological zone are inherently poor [9], inappropriate fertilizer application rates contributes critically to the negative-nutrient balances of the soils [10]. Similarly, the continuous monoculture system under repeated practice year after year and the concurrent use of obsolete farm tools (hoes and cutlasses) adversely affects the productivity of the soil with time. Their exacerbated effect has been noted to decrease the productiveness and responsiveness of rain-fed, irrigated and range lands at a greater extent [11]. In contrast, tillage practices, soil fertilization, and intercropping systems have been found feasible in soil nutrient rejuvenation and fertility improvement [10]. Tillage practices provide a good tilth of the soil for improved soil structure, water holding capacity, weed control and soil protection against erosion [12,13]. Intercropping system on the other hand does not only provide food-crop diversification, but also contribute to soil fertility improvement through on-farm nutrients establishment [14]. Legumes in an integrated management system enhance soil aggregation and carbon sequestration critical in sustaining the ecosystem for climate change mitigation [15]. Principally, soil fertilization expands as soil health promoter coupled with plant production potential [16]. Hence, this study was evaluated to assess the polycultural productivity of maize as affected by tillage practices, fertilizer rates and intercropping systems in the Guinea Savannah agroecology of Ghana, where soil productivity remains a serious challenge to food crop production.

2. MATERIALS AND METHODS

2.1 Experimental Site Description

The study was carried out during the cropping seasons of 2016 and 2017 at Yagaba, in the Mamprugu Moaduri district of the Northern region of Ghana. The experimental site is located within longitudes 0°35'W and 1°45'W and Latitude

9°55'N and 10°35'N in the Guinea Savanna vegetational zone of Ghana. The area experiences a short pattern of unimodal annual rainfall, averaging between 900 and 1100 mm. A mean annual temperature (25 and 30°C) of uniform distribution and a long period of dryness are experienced which makes the district very vulnerable and susceptible to bush fires [17,18]. Shrubs with dispersed shea (*Parkia biglobosa*) and neem (*Azadirachta indica*) trees forms the dominant vegetation of the area coupled with sandy-loam soil characterization.

2.2 Land Preparation and Seed Viability Test

A two-year antecedent period of fallow was allowed before the commencement of the study. Prior to that, the field was heavily infested with annual and perennial weeds which necessitated their control with glyphosate ($C_3H_8NO_5P$) at 1.4 kilogram per hectare active ingredient (kg a.i./ha). Half of the experimental units were mechanically ploughed leaving the other half under direct seeding treatment. The experimental units were arranged in a manner that directly seeded plots preceded the ploughed plots in each replicate. Seeds with about 80% viability level were used for planting. Three seeds of maize genotype (Panner 35), acquired from the Integrated Water and Agriculture Development in Yagaba were planted per hill at a recommended spacing of 80 x 40 cm. The seeds were then thinned to two per stand a week after emergence. Three seeds of locally inoculated cowpea and soybean genotypes (Songotra and Jenguma, respectively) procured from the Savannah Agriculture Research Institute in Tamale were drilled manually as intercrops. This was done at two (2) weeks after the emergence of the component crop (maize).The legumes were sown manually at a spacing of 80 cm x 10 cm and thinned to two per hill a week after emergence. Weeds which emerged after planting were manually controlled with a hoe as it has been a traditional practice by the farmers in the area. Fertilizer application involving NPK and sulphate of ammonia were respectively incorporated as basal and top dressing amendments during the third and sixth week after planting.

2.3 Experimental Design and Treatment

The study was a 2 x 2 x 3 factorial experiment, indicating 2 tillage practices (ploughing and direct seeding), 2 fertilizer application rates (no fertilizer [0-0-0 kg/ha] and recommended fertilizer rate [60-30-30 kg/ha]) and 3 intercropping systems (sole maize, cowpea and soybean). The experiment was laid in a randomized complete block design with three (3) replications. A block made up of a replicate was separated by 2.0 and 1.0 m alleys between replications and unit plots, respectively. A field dimension of 73 x 17 m with a unit plot size of 5 x 5 m was utilized.

2.4 Fertilizer Application and Weed Control

NPK fertilizer grade 15:15:15 was applied as basal treatment for the maize at a recommended rate of 60-30-30 kg/ha. This activity occurred at 3 weeks after planting (WAP) and was followed by sulphate of ammonia [$(NH_4)_2SO_4$] (21% N) as top dressing amendment at 6 WAP. Both fertilizers were established under band placement method. Manual weeding with hoe was conducted at 3, 6 and 10 WAP before the fertilizer treatment.

2.5 Soil Sampling

Initial and post-harvest soil samples were collected at a depth of 0 – 20 cm. Soil samples of the same treatment was bulked together as a composite sample for content and compositional analysis. Initial and post-harvest soil samples were respectively collected a week before land preparation and after harvest. To effectively achieve a fine earth fraction, the soil samples were exposed to natural air-drying treatment under room temperature of which soils were then ground and sieved through 1.0 mm mesh. Soil pH was measured in supernatant of 1:5 (w/v) soil-water mixtures with glass electrode pH meter following the procedure of [19]. The elemental analyzer (vario MICRO cube, Elementar, UK) was used in assessing total organic carbon (OC) concentration after hydrolysis with 6 M HCl [20]. The total nitrogen (TN) content of the fine earth fraction was measured using Kjeldahl digestion procedure [21]. With available phosphorus and exchangeable potassium, measurements were respectively done using the spectrophotometer and the flame emission photometry [22,23].

2.6 Data Collection

Analysis on soil chemical properties and plant productive parameters were carried out during the study. Soil samples collected were analyzed for pH, total nitrogen (TN), available phosphorus (AP), exchangeable potassium (EK), and organic carbon (OC) content. Growth and yield parameters encompassing plant height, height of cob attachment, cob length, grain number per cob, hundred seed weight and grain yield were also evaluated as productive measurements on the maize. Nodule count and effectiveness were equally evaluated on the leguminous intercrops. A total of six (6) plants were randomly selected as sampling representatives except grain yield which was carried out using the entire plant population on each unit experimental plot. Economic analysis of the entire production system was conducted to effectively assess its benefit/cost ratio.

2.7 Statistical Analysis

Data collected were compiled and processed using Microsoft Excel (version 2010). The processed data were then subjected to analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS version 22.0). Separation of treatment means were done using least significant difference (LSD) approach at 5% probability level.

3. RESULTS

3.1 Basal and Post-harvest Soil Chemical Properties

The evaluation of baseline and post-harvest soils for their chemical properties were slightly acidic in pH and low in total nitrogen, and organic carbon content. However, content of available phosphorus and exchangeable potassium were found to be moderate among soil samples (Table 1).

3.2 Growth and Yield Response of Maize

The fertilizer (P=.01) and the tillage (P=.03) treatments significantly produced plants with taller heights. Plant height showed a consistent trend of increase throughout the period of maize growth (Fig. 1). Besides, improvement in height was established on ploughed experimental plots supplied with NPK fertilizer application rate at 60-30-30 kg/ha. Under the intercropping system, cowpea was suitable in promoting maize height. Difference in height facilitated by ploughing (88.89 cm) was 10.1% greater than of the directly seeded (72.57 cm) treatment. Averagely, the impact of nutrient amendment curtailed from the application of 60-30-30 kg/ha fertilizer rate (90.19 cm) increased plant height by 11.72% when compared with its untreated control rate (71.26 cm).

Height of cob attachment differed significantly by the fertilizer treatment (P=.01) in the 2016 cropping season. However, that of 2017 cropping season differed by both the tillage practices (P=.01) and the fertilizer application rates (P=.01).The combined effect of ploughing, 60-30-30 kg/ha fertilizer rate, and soybean integration influenced higher heights at which cobs were attached to the maize (Fig. 2). The fertilizer treatment at 60-30-30 kg/ha rate in 2016 (79.94 cm) and 2017 (87.11 cm) cropping seasons respectively resulted in 4.58% and 5.80% increases in height of cob attachment than when compared with the 0-0-0 kg/ha rate (72.94 cm [2016]; 77.56 cm [2017]). Unlike the inter-cropping system, soybean integration influenced higher height of cob attachment in both seasons but was statistically similar with that of the cowpea. In general, height of cob attachment was 76.44 cm (2016) and 82.33 cm (2017) on the average.

Variation in cob length was significantly affected by the interaction effect of tillage practices and the fertilizer rates (P=.02) in 2016 cropping season. Similarly, the sole treatment levels involving the fertilizer rates (P=.01) and the tillage practices (P=.03) significantly improved the length of cobs in both seasons (Fig. 3). Cob length was least (14.67 cm) enhanced by the control treatment levels (0-0-0 kg/ha fertilizer rate, direct seeding and sole maize). Conversely, higher length of cobs (27.33 cm) was ascertained prior to the combined impact of 60-30-30 kg/ha fertilizer rate, ploughing, and the leguminous cover crops. Under the two-way interaction effect, the combined impact of ploughing, and 60-30-30 kg/ha fertilizer rate in 2016 (26.27 cm) and 2017 (27.51 cm) cropping seasons were phenomenal in the maximization of cob length. Notwithstanding, the reverse was ascertained through the combined impact of 0-0-0 kg/ha fertilizer rate and the sole maize treatment (15.11 cm [2016]; 15.56 cm [2017]). Differences among the intercropping systems were statistically ranked as 19.59>19.83>19.91 cm in 2016 and 20.41>21.18>21.42 cm in 2017 for sole maize, cowpea and soybean, respectively. Ploughed plots treated with 60-30-30 kg/ha fertilizer rate increased cob length by 24.12% (26.27 cm) in 2016 and 21.64% (27.51 cm) in 2017 when compared with the directly seeded maize devoid of fertilizer application (16.06 cm [2016]; 17.72 cm [2017]).

The fertilizer treatment significantly (P=.01) affected grain number per cob in both cropping seasons (Fig. 4). Grain number per cob was maximized under experiment plots subjected to ploughing, 60-30-30 kg/ha fertilizer rate and intercropping with cowpea. Fertilizer application resulting from the 60-30-30 kg/ha rate in 2016 and 2017, respectively accounted for 26.74% (378.39) and 27.84% (385.44) increases than the untreated fertilizer control rate (218.72 [2016]; 217.61 [2017]). Averagely, the fertilizer treatment involving 60-30-30 kg/ha rate (382) was 27.34% higher than that of the untreated control rate (218). Comparatively, variations in grain number per cob as influenced by the 60-30-30 kg/ha fertilizer rate was one-third greater than that of the 0-0-0 kg/ha rate. Generally, an average count of 299 and 310 grains were counted respectively per cob during the 2016 and 2017 cropping seasons.

Table 1. Initial and post-harvest soil chemical properties during the 2016 and 2017 cropping seasons

Sampling type	(1:2.5 H_2O) pH	(%) OC	(%) N	(mg/kg) P	(mg/kg) K
Basal	5.71	0.07	0.09	11.22	10.79
Post-harvest	5.48	0.05	0.14	10.87	10.44

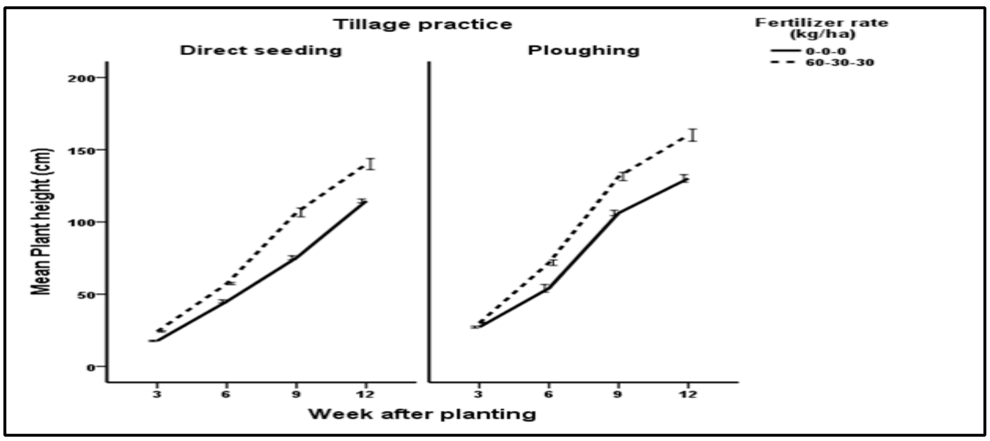

Fig. 1. Effect of fertilizer application rates and tillage practices on plant height during the 2017 cropping seasons

Bars represent standard error of the mean (SEM)

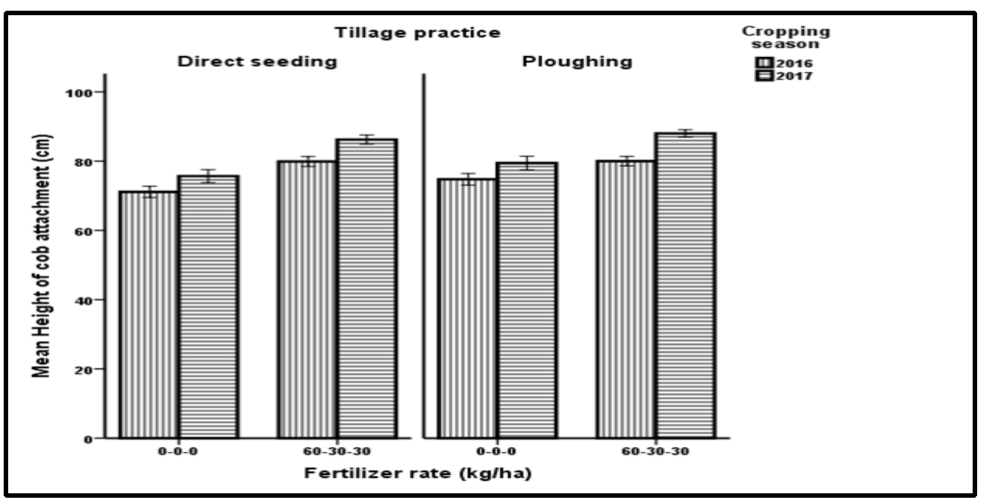

Fig. 2. Effect of fertilizer rates and tillage practices on height of cob attachment during the 2016 and 2017 cropping seasons

Bars represent standard error of the mean (SEM)

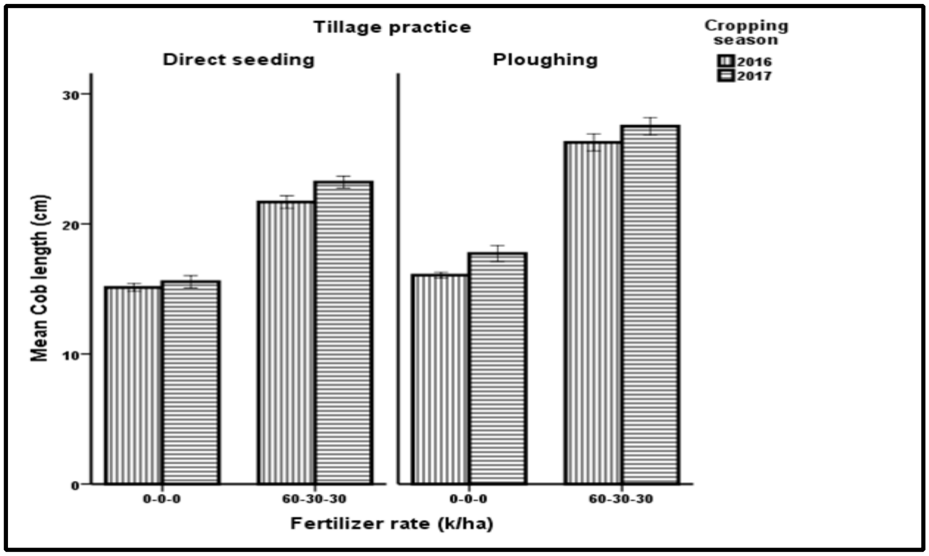

Fig. 3. Effect of fertilizer rates and tillage practices on cob length during the 2016 and 2017 cropping seasons

Bars represent standard error of the mean (SEM)

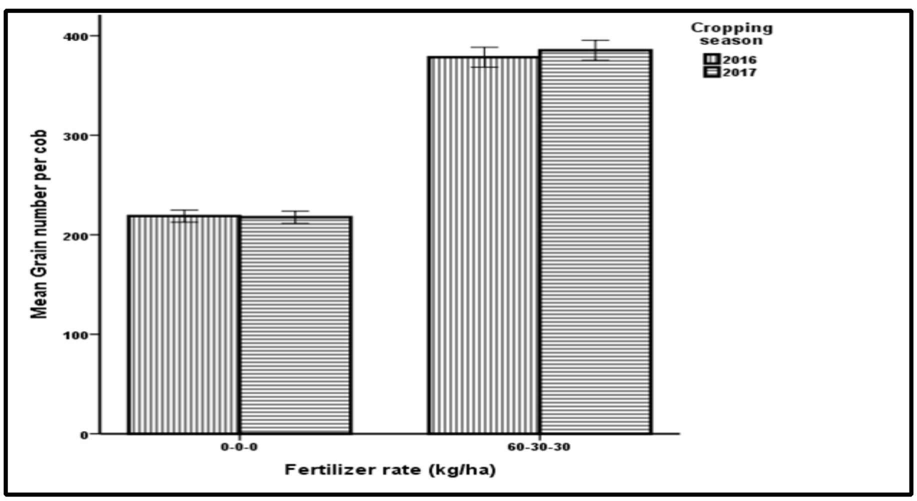

Fig. 4. Effect of fertilizer rates on grain number per cob during the 2016 and 2017 cropping seasons

Bars represent standard error of the mean (SEM)

The weight of hundred seeds varied significantly by the fertilizer treatment (*P*=.01) in both seasons. Improvement in hundred seed weight observed under the three-way interaction effect was heavier under ploughed experimental plots treated with 60-30-30 kg/ha fertilizer rate and soybean intercropping (Fig. 5). Unlike the two-way interaction effect, seed weight of hundred grains was improved by ploughing and 60-30-30 kg/ha fertilizer rate. The variation among intercropping systems were statistically ranked as 27.35>28.74>28.85 g in 2016 and 27.98>29.27>29.65 g in 2017 for sole maize, cowpea and soybean, respectively. Comparatively, there existed an increasing margin of 4.84% in 2016 and 5.30% in 2017 prior to the fertilizer treatment (0-0-0 kg/ha rate and 60-30-30 kg/ha rate), with the application 60-30-30 kg/ha fertilizer rate noted to have ensured such differences.

The three-way interaction effect of the tillage practices, fertilizer rates, and the intercropping systems were significant (P=.02) in ensuring grain yield differences. Similarly, the two-way interaction effect of the tillage practices and the fertilizer rates (P=.01), as well as the individual treatment factors involving the tillage practices (P=.01), fertilizer rates (P<0.001), and the intercropping systems (P=.02) were also influential in facilitating grain yield differences (Fig. 6). Ploughing effect combined with 60-30-30 kg/ha fertilizer rate and the integration of cowpea were phenomenal in maximizing grain yield among the three-way interaction effect. Unlike the two-way interaction effect, increase in grain yield was ascertained from ploughing and soybean integration, 60-30-30 kg/ha fertilizer rate and soybean integration, as well ploughing and 60-30-30 kg/ha fertilizer rate. Experimental plots subjected to ploughing (1.83 t/ha) caused an increase of 8.60% over the directly seeded experimental plots (1.54 t/ha). In terms of fertilizer treatment, 60-30-30 kg/ha fertilizer rate (2.32 t/ha) resulted in a difference of 37.68% over the untreated fertilizer control rate (1.05 t/ha). Variation among the intercropping systems were statistically ranked as 1.62>1.71>1.73 t/ha for sole maize, cowpea and soybean, respectively.

3.3 Nodule Count and Effectiveness among Leguminous Intercrops

Nodule count was significantly affected by the fertilizer application rates (P=.01) in both seasons. In view of that experimental plots treated with 60-30-30 kg/ha fertilizer rate gave the highest nodule number (Fig. 7). Unlike the direct seeding treatment, the effect of ploughing resulted in a difference of 1.70% and 6.76% in 2016 and 2017 cropping seasons respectively. This in effect indicated 5.06% increases in nodule number in 2017 cropping season. Intercropping with soybean produced more nodules than the cowpea.

Variation in nodule effectiveness was significantly influenced by the combined effect of the tillage practices and the fertilizer rates (P=.02 [2016]; P=.01 [2017]). Similarly, individual treatment factors of the tillage practices (P=.01) and the fertilizer rates (P=.01) in both seasons significantly differed in nodule effectiveness (Fig. 8). Under the tillage practices, ploughing resulted in 82.66% effective nodules whereas that of the direct seeding treatment resulted in 75.33% nodule effectiveness in 2016. However, there was an increase in nodule effectiveness during the 2017 cropping season as ploughing and direct seeding treatments were found to have produced 86.67% and 79.50% effective nodules, respectively. Statistically, the effect of ploughing in both seasons increased nodule effectiveness by 14.50% when compared with the direct seeding treatment. As expected also, the fertilizer application rate at 60-30-30 kg/ha (171.67) influenced the effectiveness of nodules by 19.17% than the untreated fertilizer control rate (152.50) in both seasons. Effective nodules produced by the soybean intercrop (162.83) were 0.46% greater than that of the cowpea (161.34) in both seasons.

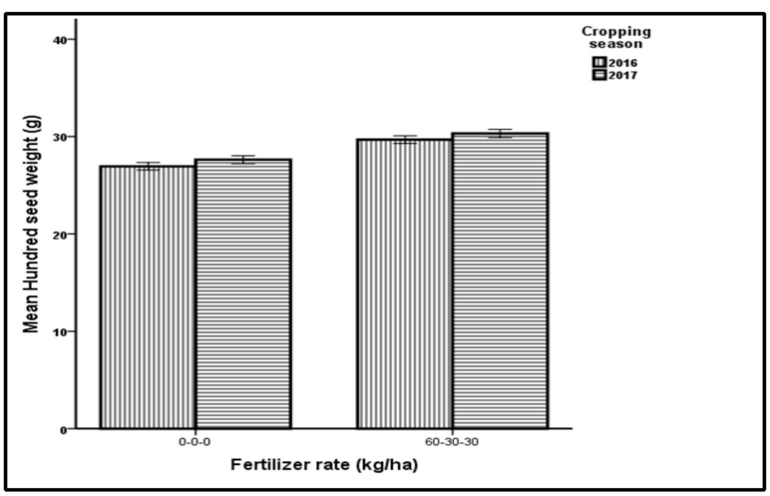

Fig. 5. Effect of fertilizer application rate on hundred seed weight during the 2016 and 2017 cropping seasons

Bars represent standard error of the mean (SEM)

3.4 Economic Analysis

Higher benefit/cost ratio in terms of economic analysis of the production system was influenced by ploughing, 60-30-30 kg/ha fertilizer rate and soybean intercropping system. Their combined effect indicated a benefit/cost ratio of 2.1 and a profit of GH¢ 1901 (Table 2). This was however followed by the combine effect of ploughing, 60-30-30 kg/ha fertilizer rate and cowpea intercropping system. Their impact also resulted in a benefit/cost ratio of 2.0 and a profit of GH¢ 1831. In contrast, the direct seeding of maize and the absence of fertilizer and leguminous cover least influenced the benefit/cost ratio (1.31) and profit (GH¢ 266).

Table 2. Economic analysis of the production system as affected by tillage practices, fertilizer rates and intercropping systems at the end of the 2017 cropping season.

Operation input	Expenditure/ha (GH¢)	Income/ha (GH¢)	Profit/ha (GH¢)	Benefit/cost ratio
D_S+N_F+S_M	865	1131	266	1.31
D_S+ N_F+I_C	975	1279	304	1.31
D_S+ N_F+I_S	985	1335	350	1.36
D_S+F+ S_M	1380	1835	455	1.33
D_S+F+I_C	1480	2394	914	1.62
D_S+F+I_S	1490	2454	964	1.65
P+ N_F +S_M	1410	1844	434	1.31
P+ N_F+I_C	1480	1934	454	1.31
P+ N_F+I_S	1490	1994	504	1.34
P+F+S_M	1660	2991	1331	1.80
P+F+I_C	1780	3611	1831	2.03
P+F+I_S	1790	3691	1901	2.06

D_S+N_F+S_M = Direct seeding + 0-0-0 kg/ha fertilizer rate + Sole maize, D_S+N_F+I_C = Direct seeding + 0-0-0 kg/ha fertilizer rate + Cowpea intercrop, D_S+N_F+I_S = Direct seeding + 0-0-0 kg/ha fertilizer rate + Soybean intercrop, D_S+F+S_M = Direct seeding + 60-30-30 kg/ha fertilizer rate + Sole maize, D_S+F+I_C = Direct seeding + 60-30-30 kg/ha fertilizer rate + Cowpea intercrop, D_S+F+I_S = Direct seeding + 60-30-30 kg/ha fertilizer rate + Soybean intercrop, P+N_F+S_M = Ploughing + 0-0-0 kg/ha fertilizer rate + Sole maize, P+N_F+I_C = Ploughing + 0-0-0 kg/ha fertilizer rate + Cowpea intercrop, P+N_F +I_S = Ploughing + 0-0-0 kg/ha fertilizer rate + Soybean intercrop, P+F+S_M = Ploughing + 60-30-30 kg/ha fertilizer rate + Sole maize, P+F+I_C= Ploughing + 60-30-30 kg/ha fertilizer rate + Cowpea intercrop, P+F+I_S = Ploughing + 60-30-30 kg/ha fertilizer rate + Soybean intercrop

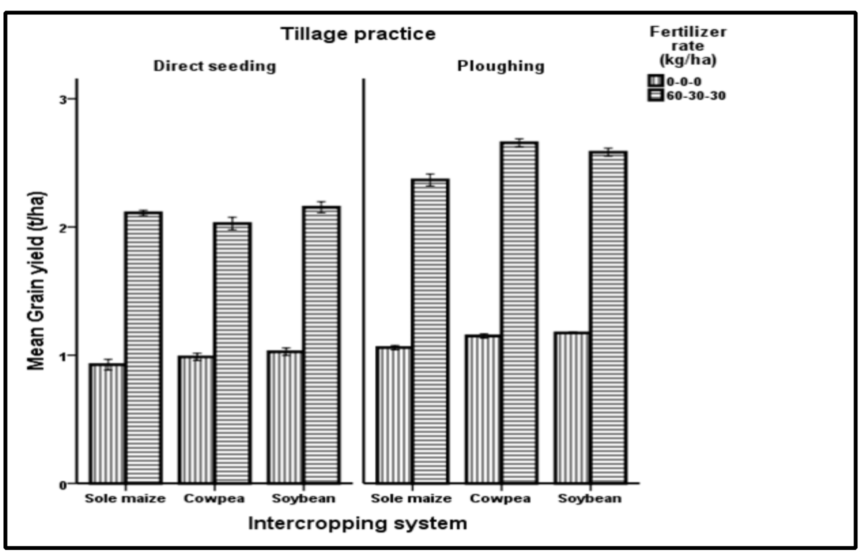

Fig. 6. Effect of tillage systems, fertilizer rates, and intercropping systems on grain yield during the 2017 cropping seasons

Bars represent standard error of the mean (SEM)

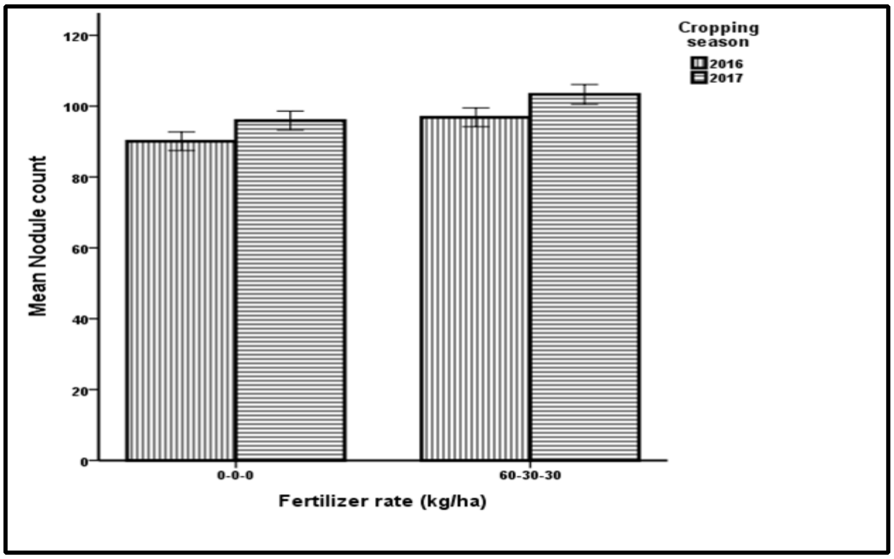

Fig. 7. Variation in nodule count of cowpea and soybean as affected by fertilizer rates during the 2016 and 2017 cropping seasons

Bars represent standard error of the mean (SEM)

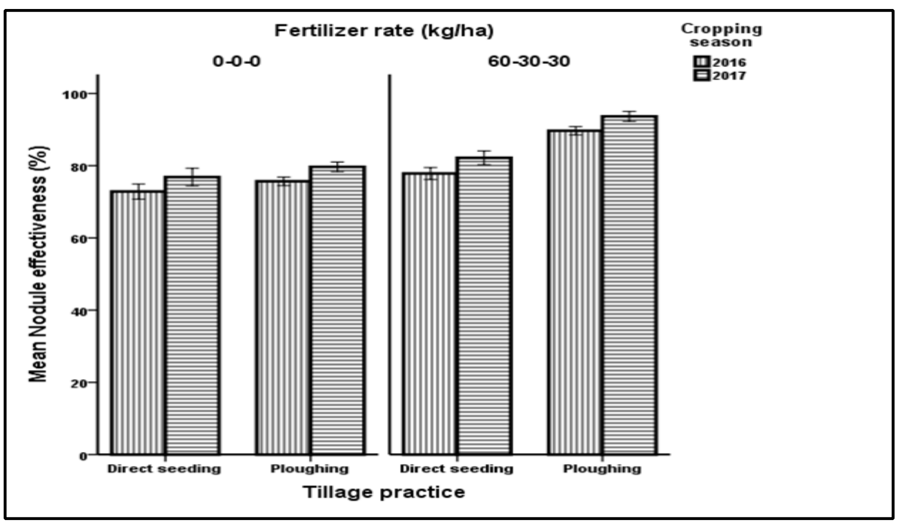

Fig. 8. Variation in nodule effectiveness of cowpea and soybean as affected by fertilizer rate and tillage practice during the 2016 and 2017 cropping seasons

Bars represent standard error of the mean (SEM)

4. DISCUSSION

4.1 Soil Chemical Properties

The variation in soil nutrient status where higher reduction incidence was curtailed from the post-harvest soil chemical properties is an inferential that the maize exploited the soil nutrient elements available for their maximum growth and development. As demonstrated, maize have increased nutrient use efficiency in soils which necessitate their production under macro and recommended fertilizer dosing [24] of which the 60-30-30 kg/ha fertilizer rate dully encouraged. Mineral fertilizer application at higher and recommended rates has been postulated by [25] to enhance the establishment of maize due to their influence on soil properties. This observation is in line with [26] who reported that nutrient from mineral fertilizers enhance the establishment of crops prior to their influence on soil properties. Although maize is a short term crop, it has a strong nutrient exhaustive effect in soils [27]. This incidence might have resulted in the low chemical properties of the soil among experimental plots despite their recommended and higher application rate. The observed decreased in pH with resultant influence in soil acidity at the end of the research can be attributed to the higher nitrogen effect received from the compound fertilizer (NPK) and the leguminous crops. This statement is in conformity with the research of [28] who observed a decrease in pH in relation to the application of nitrogenous fertilizer.

4.2 Vegetative Growth, Yield and Yield Components

As expected, the practices involving ploughing, 60-30-30 kg/ha fertilizer rate, and the leguminous intercrops were very influential in the assessment of growth, yield and yield components of the maize. Plant height as an index forms an important character in the architecture of plants due to its direct linkage with plants reproductive potential [29]. Hence, variation in height as a result of the fertilizer treatment can be deduced in part that fertilizer encourages plant growth and development at a specific recommendation rate [30]. In similar terms, the amount of the individual nutrient elements (N, P and K) present in the fertilizer grade (60-30-30 kg/ha) might have been an adequate measurement and a good nutrient balance for the maize. Besides, the amount of nitrogen (N) received from the 60-30-30 kg/ha fertilizer rate and the leguminous intercrops (cowpea and soybean) might have played a significant role in the growth of the plants as nitrogen is known to ensure robust growth and speedy development of plant shoots. In contrast, least height impacted by the 0-0-0 kg/ha fertilizer rate can however be linked to the nutrient deficiency exposure of the maize. The research of [31] confirms that increase in fertilizer application rate maximizes plant growth and development. [32] were equally of the view that rich and profuseness in plant growth relating to mineral fertilizer sufficiency facilitates activity improvement, multiplication and enlargement of plant cells. Increase in plant height by the 60-30-30 kg/ha fertilizer rate in this study is in conformity with the study of [33]. Their research observed significantly taller plants among experimental plots supplied with recommended fertilizer rate than the untreated fertilizer control. The ability of cowpea integration to have influenced maize height more than the soybean can be drawn from the assertion that legumes vary in their nitrogen fixation rate and time due to their differences in nutrient recovery rate and biomass production [34].

Improvement in height of cob attachment was anticipated to result from the response of maize to increased nitrogen levels received from both the fertilizer treatment and the cover crops. The responsiveness of these treatment levels can be deduced in part that nitrogen forms an essential element in plant growth and development [35; 36]. Hence, an increase in it supply received from both the inorganic fertilizer at 60-30-30 kg/ha recommendation rate and the leguminous intercrops might have effectively resulted in proficient height at which cobs were attached to the component cereal crop. Ploughing effect was comparably better than that of the directly seeded treatment due to the adequate tilth it provides seed beds with. In general, the impact of ploughing to have ensured variation in height of cob attachment can be drawn from the fact that ploughing improves root growth due to its decompaction effect on soils which thereby increases water and nutrient absorption efficiency of the plants. This result corroborate with the findings of [30] who reported on ploughing effect as a mechanism of providing a catchment area in seed beds for enhanced rooting depth among plants. The difference in height of cob attachment by the various treatments is an indication that cobs cannot be harvested together under mechanical operations.

Increase in yield (grain yield) and yield components (cob length, hundred seed weight, and grain number per cob) as influenced by the tillage practices, fertilizer rates, and the intercropping systems can be attributed to their increased treatment levels other than their control levels. The observed increase in yield and yield component agrees with the findings of [37] and [38] who indicated that yield and yield components of maize are enhanced by optimum mineral fertilizer doses. Irrespective of the cropping system, [15] also stressed on nutrient sufficiency having profound influence on yield and yield component maximization. The profound height gained by the maize over the intercrops might have served as an advantage to the maize in intercepting more sunlight for growth and development. This observation agrees with the findings of [39] on resource utilization and interception of solar radiation by plants. An attributed impact of conventional tillage practice and for that matter ploughing, has been opined by [40] to improve fracturing of inherent soil structure and reduce soil bulk density, coupled with soil porosity increment for plant growth. Similarly, ploughing as a conventional tillage practice improves air-filled pores of the soil which also influences the N availability in the soil for plant utilization [41]. This finding is consistent with the observation of [42]. They reported higher maize yield in conventionally tilled experimental plots than that of no-till plots. The varied contribution of the leguminous crops can be attributed to their genetic variability and growth habits. As postulated, legumes vary in their rate of availability and amount of nitrogen fixation due to their differences in biomass production and recovery rate of nutrients leached into the soil [34]. In a similar instance, the sequestration of nitrogen into the soil by the legumes is dependent on the amount of nitrogen stored in the seeds [43]. According to [44] and [45], inclusion of legumes in a cropping system improves the availability and uptake of phosphorus for effective root proliferation which thereby translate into enhanced crop yield. The absence of variation expressed by the cowpea and soybean reflects their similarity of impact as leguminous crops.

Low nodule count and effectiveness observed under the untilled experimental plots may be attributed to the restricted space of exploration by the roots in reaching nutrient resources and water. Notwithstanding, ploughing might have also decompacted the soil to enhance the exploration of the root. Higher profit and benefit/cost ratio derived was solely from the integrated effect of ploughing, 60-30-30 kg/ha fertilizer rate and soybean intercropping system. In view of this, the economic performance of the various treatments is in conformity with assumption of [46], who emphasized on higher production cost resulting in higher profit returns and vice versa.

5. CONCLUSION

Developing a sustainable management approach for enhancing maize yield in the Guinea Savanna Agroecology of Ghana vehemently relies on tillage practices, fertilizer recommendation rates and suitable intercropping system. Although maize responded differently to the varied treatments, it exposure to ploughing, 60-30-30 kg/ha fertilizer rate and soybean intercropping system were influential in enhancing vegetative growth, yield and yield components. The responsiveness of maize to ploughing and 60-30-30 kg/ha fertilizer rate in comparison with their untreated controls increased grain yield by 8.60% and 37.68%, respectively. Unlike the intercropping system which did not vary significantly, grain yield was statistically ranked as 1.62>1.71>1.73 t/ha, respectively for sole maize, cowpea and soybean. Regardless of not directly supplying intercrops with the inorganic fertilizer, nodulation count and effectiveness of cowpea and soybean were improved under ploughed plots treated with 60-30-30 kg/ha fertilizer rate. Observation from the entire production system validated the combined effect of ploughing, 60-30-30 kg/ha fertilizer rate and soybean intercropping system resulting in higher production cost and benefit.

ACKNOWLEDGEMENT

We are highly grateful for the research grant provided by the Integrated Water and Agricultural Development (IWAD). Authors are indebtedly grateful to small-holder farmers in Yagaba Kubore district for their immense participation and contributions during the field-days' activities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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