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Response of maize (*Zea mays* L.) to foliar and soil applied fertilizers in the Semi-deciduous forest zone of Ghana

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This experiment was conducted in 2019 major cropping season in the Semi-deciduous forest Agro-ecological zone of Ghana to solve low maize yield and improve maize productivity and enhance farmer's income using foliar and soil applied fertilizers as nutrient sources. Eight treatments (T) were used; T1= {N, P_2O_5, K_2O (90-60-60) kg/ha} at 2 and 6 weeks after sowing (WAS); T2= {Poultry manure (4 t/ha)} at 2 weeks before sowing (WBS); T3= {Foliar fertilizer (4 L/ha)} at 2, 4 and 6 WAS; T4= {Poultry manure (2 t/ha)} at 2 WBS + {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 WAS; T5= {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 WAS + {Foliar fertilizer (2 L/ha)} at 4 WAS; T6= {Poultry manure (2 t/ha)} at 2 WBS + {Foliar fertilizer (2 L/ha)} at 2 and 6 WAS; T7= {Poultry manure (2 t/ha)} at 2 WBS + {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 WAS + {Foliar fertilizer (2 L/ha)} at 4 WAS and T8= Control (No Fertilizer). The results showed that T7 performed better than T8 (Control) in terms of plant height, stem girth, cob length, 1000-grain weight and grain yield as well as economic net benefit.

Key words: Semi-deciduous forest, agro-ecological zone, 1000-grain weight, economic benefit analysis, foliar fertilizer, integrated nutrient management.

INTRODUCTION

Cereals continue to be the main fundamental means of energy for greater than 962 million human population in the Africa region and are very important for food safety increase (OECD/FAO, 2016). Maize holds an important position among the cereal crops, and used as food for human beings as well as animals feed. Maize is also used as a raw material in industrial manufacturing of starch related items, lubricant, protein, alcoholic drinks, biofuel, food candies, pharmaceuticals, make-ups, films, fabrics, gums, packaging and paper industries (Naveenkumar et al., 2018). Its production accounts for 50-60% of aggregate cereal crops produced in Ghana. In

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sub-Saharan Africa, the usual low yield obtained mostly hovers around 1.7 tonnes per hectare in West Africa, 1.5 tonnes per hectare in East Africa, and 1.1 tonnes per hectare in the Southern part of Africa (Smale et al., 2011). In Ghana, the national average maize productivity on farmers' field is about 2.26 tonnes per hectare whereas the projected achievable grain yield is around 5.50 t/ha (MoFA, 2018). The major underlying cause for the low yields is low soil fertility which is often addressed by recommended mineral fertilizer applications. However, the application of mineral fertilizers on degraded lands do not always produce the expected yield, primarily due to low organic material and reduced soil microbial activity (Bot and Benites, 2005). The mineral nutrients released by organic matter through the recycling by soil microbes enhances the capacity of the soil to provide nutrition for plant growth and development. Organic nutrients help to maintain plant nutrients and avoid nutrient loss through leaching beyond the soil horizons that cannot be reached by plant roots (Miller, 2018).

The majority of soils in maize producing areas in Ghana contains low quantities of less than 1.5% organic carbon, less than 0.2% total nitrogen and less than 100 $mgkg^{-1}$ exchangeable potassium (Benneh et al., 1990). Organic materials like compost, poultry manure and farmyard manure and mineral fertilizers when added to the soil, provide crop nutrients that enhance plant growth and development and help the plant's physiological functions which is an essential tool for yield development (Amujoyegbe et al., 2007).

Although, adding fertilizers to the soil is the commonest practice of supplying plant nutrients, foliar fertilization was reported to be more cost effective than soil applied nutrients (Lovatt, 2013). This is mainly due to the lower but effective quantities applied through the leaves. Proper timing and foliar fertilization at key crop developmental stages are necessary to achieve expected yield (Lovatt, 2013).

Altering soil-applied nutrients with foliar fertilizer contributes to the best fertilizer management practices as well as minimizes the possibility of nutrient accumulation in the soil and in the aquatic systems such as runoff, streams, lakes, rivers and sea, which can cause eutrophication, salinity, and NO_3^- contamination by N, that may cause health problems to human beings and the environment (Lovatt, 2013). Many different studies have been conducted on the use of organic and soil applied mineral nutrients but there is scarce information on integration of foliar with organic and soil applied mineral fertilizers. Foliar fertilization is relatively new and not widely tested on maize in Ghana, especially in the humid forest. Currently, no recommendation rates of foliar fertilizers and application regimes have been developed for integrated nutrient management (INM) in maize production. Also, there is insufficient information on the profitability of the integrated nutrient management using different nutrient sources. The unavailability of information on crop-fertilizer profitability implies that crop producers may not be able to predict how much profit they can make or lose by adopting the INM in the cultivation of maize in the humid forest zones. Therefore, the main objective of the study was to indicate the possibility of maize yield increased at a minimal production cost using different nutrient sources in addition to foliar fertilizer.

MATERIALS AND METHODS

The study was conducted in Wiawso Municipality from March to July, 2019, which is the major farming season in the Semi-deciduous forest Agro-ecological zone of Ghana. Sefwi Wiawso Municipality lies in the North East part of the Western North Region between latitudes 6°12′57″N and longitudes 2°29′6″W (Sefwi-Wiawso Municipal District, 2019). The Municipality falls within the tropical rainforest climatic zone. Rainfall during the year recorded a total annual mean value of 143.6 mm in 2019 compared to 2014-2018 multi-year mean of 119.4 mm (Figure 1). Mean temperature throughout the 2019 was 33°C same to that of 2014-2018 multi-year mean temperature of 33°C. Rainfall value in April, 2019 was higher than the same April 2014-2018 multi-year mean (Figure 1) In June, 2014-2018 multi-year mean rainfall was higher than 2019 same month in June, however in September 2019, the rainfall was higher than the same period in 2014-2018 multi-year mean (Figure 1). The soil in the study area is Chromic Acrisol (Clayic) (Asikumu Series) and deep moderately well drained clay.

Core soil samples were collected from 0-15 cm depth at different parts of the experimental site and bulked for routine soil analysis before field experiment started. The experimental plot was laid out using Randomized Complete Block Design (RBCD). The total experimental field was 3,299 m^2. The individual plot size was 5 m × 4 m, 0.80 m apart and the blocks were 1 m apart with four replications. The experimental crop was Obatanpa Maize-White Open Pollinated Variety/Quality Protein Maize (WOPV/QPM). The tested fertilizer included: N, P_2O_5, K_2O (15-15-15) mineral fertilizer; poultry manure and foliar fertilizer (Boost Xtra NPK 20-20-20 with trace elements). Seven treatments and a control plot were used in the study. The treatments were T1= {N, P_2O_5, K_2O (90-60-60) kg/ha} recommended rate at 2 and 6 Weeks After Sowing (WAS); T2= {Poultry manure (4 t/ha)} at 2 Weeks Before Sowing (WBS); T3= {Foliar fertilizer (4 L/ha)} at 2, 4 and 6 Weeks After Sowing (WAS); T4= {Poultry manure (2 t/ha)} at 2 WBS + {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 (WAS); T5= {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 WAS + {Foliar fertilizer (2 L/ha)} at 4 WAS; T6= {Poultry manure (2 t/ha)} at 2 WBS + {Foliar fertilizer (2 L/ha)} at 2 and 6 WAS; T7= {Poultry manure (2 t/ha)} at 2 WBS + {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 WAS + {Foliar fertilizer (2 L/ha)} at 4 WAS and T8= Control (No fertilizer).

Poultry manure rates of 4 tonnes per hectare and 2 tonnes per hectare were incorporated into the soil of the designated plots. No fertilizer was applied to the control plots. After two weeks, three maize seeds per hole were sown on the 10^{th} April, 2019 at a distance of 0.80 m × 0.40 m between and within plant stands. Three days before planting, Glyphosate was applied at the rate of 100 ml per 15 L Knapsack to control pre-emergence weeds. Thinning was done 15 days after sowing, maintaining two vigorous plants per stand to give a total maize population of 60,000 plants/ha. The granular NPK fertilizer was applied 2 weeks after sowing as basal fertilizer and top dressed at 6 WAS with Urea to the designated plots. Mineral fertilizer was applied as side placement in holes

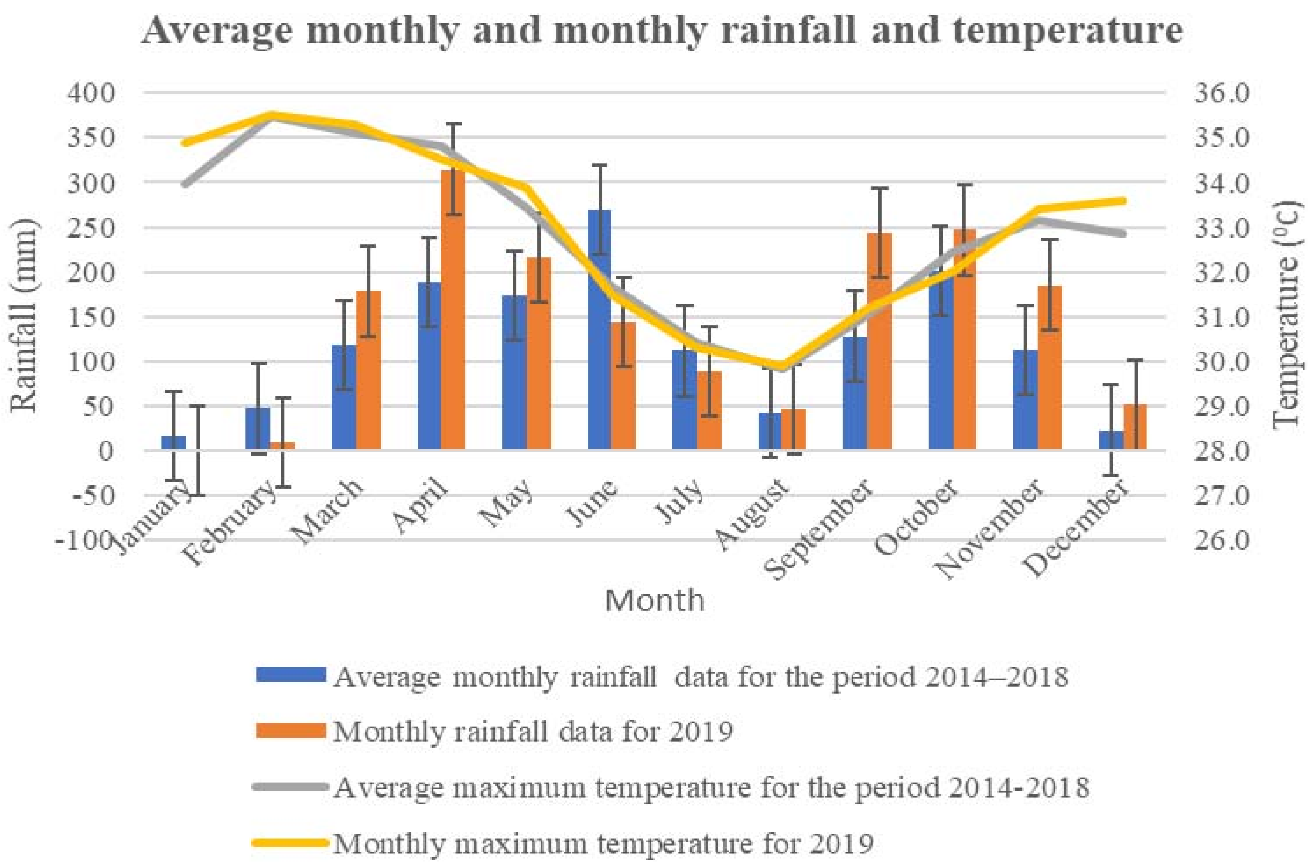

Figure 1. Monthly rainfall data and maximum temperature for 2019, average monthly rainfall and average maximum temperature for the period of 2014-2018 at the Sefwi Wiawso Municipal.

approximately 5 cm deep and about 7 cm away from the plant. The foliar application was carried out in the early mornings at 2, 4 and 6 WAS. T3 plots received foliar spray thrice, T6 plots received Foliar spray twice and both T5 and T7 plots received it once. While T8 plots did not receive any fertilizer treatment. Agronomic parameters were taken on plant height, stem girth at 30 cm high from the ground level, maize stover yield consisted of the leaves, stalks and cobs, harvest index was calculated as the ratio of grain yield to above ground biomass, cob height taken from the ground level of the maize plant bearing the cob up to the first node bearing the cob, cob length was measured from the length of dehusked maize cob, 1000-grain weight was measured from one thousand (1000) grains picked at random at 13% moisture content from the shelled maize cobs and grain yield per hectare (kg/ha). The height of five tagged plants per plot were measured from the soil level to the flag leaf at 6, 8, 10 and 12 weeks after sowing. The stem girth was taken from five plants tagged per plot at 6, 8, 10 and 12 weeks after sowing. Cob height was taken at 12 WAS from the base of the maize plant bearing the ear up to the node bearing the cob from the five tagged plants using measuring tape and averaged per plot. Maize cobs were harvested from the five tagged plants per plot and dehusked. The length of five dehusked maize ears per plot were measured with measuring tape and the mean value calculated. One thousand (1000) grains were picked at random at 13% moisture content from the shelled five tagged maize plants and weighed per plot. A representative maize cobs were harvested from 1 m^2 area from each plot and were shelled and the grains weighed. Grain yields of maize for the various plots were extrapolated to grain yield in kilograms per hectare (kg/ha) at 13% moisture content for meaningful comparisons. The economic benefit analysis was conducted to evaluate the profitability of the nutrient sources (soil applied NPK fertilizer, poultry manure and foliar fertilizer) and their combinations. The economic net benefit was calculated after the grains was processed and the prices determined from the various treatments as the gross benefit minus the total cost incurred during the production. The source of data used for economic benefit analysis in the study was gathered mainly from farmers, agro-chemical dealers, and maize traders at the particular time of each activity during the farming period. As well as the cost of soil applied NPK and Urea fertilizers, poultry manure and foliar fertilizers in addition to labour cost. Data collected were subjected to analysis of variance (ANOVA) at P<0.05 using Genstat Statistical Package (12th Edition) and treatment means comparison separated using Tukey's Honest Significant Difference.

RESULTS AND DISCUSSION

Properties of soil, poultry manure and foliar fertilizer

The data on the physico-chemical properties of the soil at

Table 1. Phyisco-chemical properties of the soil at the experimental site before planting (0-15 cm depth).

Parameter measured	Value
Particle size fractions (%)	
% Sand	42.2
% Silt	9.72
% Clay	48.08
Textural class	Clay
pH (H2O) (1:2.5 Soil : Water)	5.79
% Organic carbon	0.62
% Total Nitrogen	0.08
Available P (mgkg^{-1})	11.18
Exchangeable K (cmol $_{(+)}$ kg^{-1})	0.23
Exchangeable Ca (cmol $_{(+)}$ kg^{-1})	4.40
Exchangeable Mg (cmol $_{(+)}$ kg^{-1})	1.68
Exchangeable Na (cmol $_{(+)}$ kg^{-1})	0.01

Table 2. Chemical properties of the poultry manure.

Parameter measured	Value
pH (H_2O)	7.35
% Organic matter	14.45
% Total Nitrogen	3.03
% Total P	1.06
% K	11.65
% Ca	7.20
% Mg	1.08

the study site is presented in Table 1. Among the chemical properties, the content of available P of 11.18 mgkg^{-1} and exchangeable K (0.23 cmol $_{(+)}$ kg^{-1}) of the soil were low. The chemical composition of the poultry manure in Table 2, has a pH (H_2O) value of 7.35 and suitable for the soil at the study site. The organic matter value of 14.45% in the poultry manure and K value of 11.65% respectively were high and have the ability to provide available nutrients for sustainable crop production. The soil pH value of 5.79 is moderately suitable for maize production (Sys et al., 1993). Exchangeable basic cation levels were low according to the ratings of Metson (1961). This may be attributed to the highly weathered and heavily leached nature of the soil in the study site as described by Benneh et al. (1990). The pH value of 7.35 for the poultry manure was a good complement to the soil at the study site. The chemical composition of foliar fertilizer (Boost Xtra) according to the manufacturer's label is presented in Table 3.

There were significant differences (P<0.05) between the fertilizer sources on plant height at 12 WAS (Table 4). The taller plants were found in T5 (303.90 cm) and T7 (306.40 cm) compared to T8 (control) with lower plant height value of 267.00 cm. However, T5 and T7 were not significantly different from T1, T2, T3, T4 and T6. The combination of inorganic soil applied NPK fertilizer, foliar fertilizer and poultry manure contributed to plant height development (Afe et al., 2015). Plant height development was evident in plots with the fertilizer sources due to nutrient accessibility and use than the T8 (control) plot. The slow release of nutrients from poultry manure was complemented with the addition of soil applied NPK fertilizer and foliar fertilizer (Afe et al., 2015). It was also observed in the study conducted by Makinde and Ayoola (2010) where maize plant height was significantly taller in treatment with both inorganic fertilizer and complementary foliar fertilizer than those from sole plots. Supplementary application of soil applied NPK fertilizer and foliar fertilizer was effective for growth and development of maize height. The slow release of nutrient from the organic matter contributed to nutrient management (Amujoyegbe et al., 2007). It further confirmed the finding by Ademiluyi and Fabiyi (2015) that supplementary fertilization of foliar NPK fertilizer to both poultry manure and soil applied NPK fertilizer improved maize growth and development

Table 3. Chemical properties of the Foliar fertilizer (Boost Xtra) (wt/vol) according to the label.

Parameter	Values (%)
pH (H_2O) (10% Solution)	4.0-4.5
Nitrogen (N)	20
Phosphate (P)	20
Potassium (K)	20
Magnesium (Mg)	1.5
Iron EDTA (Fe)	0.15
Manganese EDTA (Mn)	0.075
Copper EDTA (Cu)	0.075
Zinc EDTA (Zn)	0.075
Boron (B)	0.0315
Cobalt EDTA (Co)	0.0012
Molybdenum (Mo)	0.0012

Table 4. Effect of treatments on Plant height, and Stem girth at 12WAS, Maize stover yield and harvest index.

Treatment	Plant height (cm) 12 WAS	Stem girth (cm) 12 WAS	Maize stover yield (kg/ha)	Harvest Index
T1	294.40^{ab}	8.25^{ab}	2.87^{ab}	0.52^{a}
T2	290.90^{ab}	7.79^{ab}	2.55^{ab}	0.49^{ab}
T3	284.60^{ab}	7.33^{bc}	2.74^{ab}	0.41^{ab}
T4	291.90^{ab}	8.46^{a}	3.18^{ab}	0.49^{ab}
T5	303.90^{a}	7.73^{ab}	2.84^{ab}	0.45^{ab}
T6	299.90^{ab}	7.64^{ab}	3.34^{ab}	0.47^{ab}
T7	306.40^{a}	8.24^{ab}	4.07^{a}	0.49^{ab}
T8	267.00^{b}	6.24^{c}	1.95^{b}	0.39^{b}
F pr.	0.03	<.001	0.01	0.02
CV (%)	5.00	6.30	22.70	10.70

Means followed by the same letter along the columns are not significantly different using Tukey's HSD (P<0.05).

in relation to plant height, stem girth, leaf area and grain yield. The reason for this may be associated to the high nutrient availability, especially nitrogen released by the poultry manure, soil applied NPK fertilizer plus supplementary foliar fertilizer, which contains micronutrients and readily taken by the plant leaves. Similar report showed that poultry manure contains high nitrogen content which led to increase maize height (Boateng et al., 2006).

There were highly significant differences (P<0.05) among the nutrient sources and their combinations on maize stem girth at 12 WAS. There was larger stem girth in T4 compared to T3 and T8 with the lower stem girths. The lower maize stem girth of 7.33 cm in T3 was similar to T8 (6.24 cm) at the peak growth period at 12 WAS (Table 4). The large increased in stem girth in T4 was similar to T1, T2, T4, T5, T6 and T7. This finding was in line with Rudall (2007), who indicated that increase in plant height is commonly accompanied by a corresponding increase in stem thickness, which could reduce lodging. Increased stem girth could be due to the high nitrogen content from the soil applied NPK fertilizer and poultry manure. Poultry manure is also associated with high release of phosphorus for crop development.

Effect of treatment on maize stover yield and harvest index

There were significant differences (P<0.05) between nutrients sources on maize stover yield as shown in Table 4. The higher maize stover yield was recorded in T7 which was significantly different from T8 (control) with the lowest value of 1.95 kg/ha. Leaf is the primary photosynthetic functional unit, and its effectiveness on the capture and use of solar energy improves plant

Table 5. Effect of treatments on Cob height, Cob length, 100-grain weight and grain yield.

Treatment	Cob height (cm)	Cob length (cm)	1000-grain weight (g)	Grain yield (kg/ha)
T1	160.60^{ab}	19.95^{ab}	337.50^{ab}	4.21^{ab}
T2	165.30^{ab}	19.16^{ab}	322.50^{abc}	3.25^{bcd}
T3	161.50^{ab}	19.15^{ab}	302.50^{bc}	2.59^{de}
T4	173.40^{ab}	21.04^{a}	332.50^{ab}	4.04^{abc}
T5	176.40^{ab}	19.37^{ab}	305.00^{abc}	3.07^{cd}
T6	200.00^{a}	20.12^{ab}	310.00^{abc}	3.82^{bc}
T7	186.50^{ab}	22.06^{a}	345.00^{a}	4.85^{a}
T8	129.50^{b}	17.05^{b}	282.50^{c}	1.68^{e}
F pr.	0.05	0.01	<.001	<.001
CV (%)	15.70	7.40	6.50	12.50

Means followed by the same letter along the columns are not significantly different using Tukey's HSD (P<0.05).

growth and development (Rana and Rana, 2014). The accumulation of nutrient further enhances maize stover yield. There were significant differences (P<0.05) between the nutrient sources for harvest index (Table 4). The maximum value for harvest index was recorded in T1 which was significantly different from T8, but similar to T1, T2, T3, T4, T5 and T6. Most of the assimilates produced in the leaves and shoots were converted to grain production. The control plot had a harvest index of 0.39 which reflected in the grain yield since no fertilizer was applied to the control plot. The partitioning of the assimilates to the leaves and shoot exceeded that of grain production. Maize grain is the foremost economically important part of the maize plant and management decisions should be based on achieving higher profit from grain yield, thereby improving on the harvest index (Pennington, 2013).

Effect of treatment on cob height and cob length

The Cob height at 12 weeks after sowing showed significant different between T6 and T8 (Table 5) but not differently from other treatments. A report confirmed by Khan et al. (2013) that foliar fertilization with Nitrogen sources increased plant height. The high Cob height might be as a result of synergy between the poultry manure and foliar fertilizer spray in nutrient supply and assimilation by the crop. There were significant differences (P<0.05) between the nutrient sources applied for the Cob length in Table 5. The cob length in T7 has a mean Cob length of 22.06 cm and that of T4 with a mean value of 21.04 cm longer than T8 (control) with 17.05 cm. The Cob length of maize in T4 and T7 improved better than the T8 (control) which could be as result of integrated application of the nutrient sources (soil applied NPK fertilizer, Poultry manure and Foliar fertilizer).

Effect of treatment on 1000-grain weight and grain weight

There were highly significant differences (P<0.05) between the nutrient sources applied for 1000-grain weight. The heavier 1000-grain weight (345.00 g) was produced in T7 {Poultry manure (2 t/ha)} at 2 WBS + {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 WAS + {Foliar fertilizer (2 L/ha)} at 4 WAS compared to the T8 (control) with 282.50 g. However, T7 also was weightier than T3 (302.50 g) (Table 5). According to a study by Khan et al. (2013) Foliar N (urea, AS, CAN) application increased grain filling duration (tasselling to maturity) and maximum photosynthate partition to grains which resulted into heavy 1000-grain weight of maize produced in T7. There were highly significant differences (P<0.05) among the treatments for grain yield presented in the Table 5. The highest grain yield was obtained in T7 but was not significantly different from T1 and T4. The lowest grain yield was obtained in T8 (control) which was at par with T3. The highest grain yield recorded was four times (4.85 kg/ha) heavier than the control plot with lowest grain yield of 1.68 kg/ha as shown in the Table 5. The overall performance of maize grain yield in T7 was remarkably higher (4.85 kg/ha) than T2, T3, T5, T6 and T8 (control) respectively. The performance of maize yield under the sole foliar fertilizer (T3) was low due to quick assimilation of nutrients from the leaves. It was reported by Ling and Silberbush (2002) that sole foliar spray cannot replace soil applied fertilizer completely but must be a supplement because of the leaf surface area of maize plant at the time of application might not be large enough to occupy the foliar spray in place to make it effective. The performance of sole foliar fertilizer was evident in this

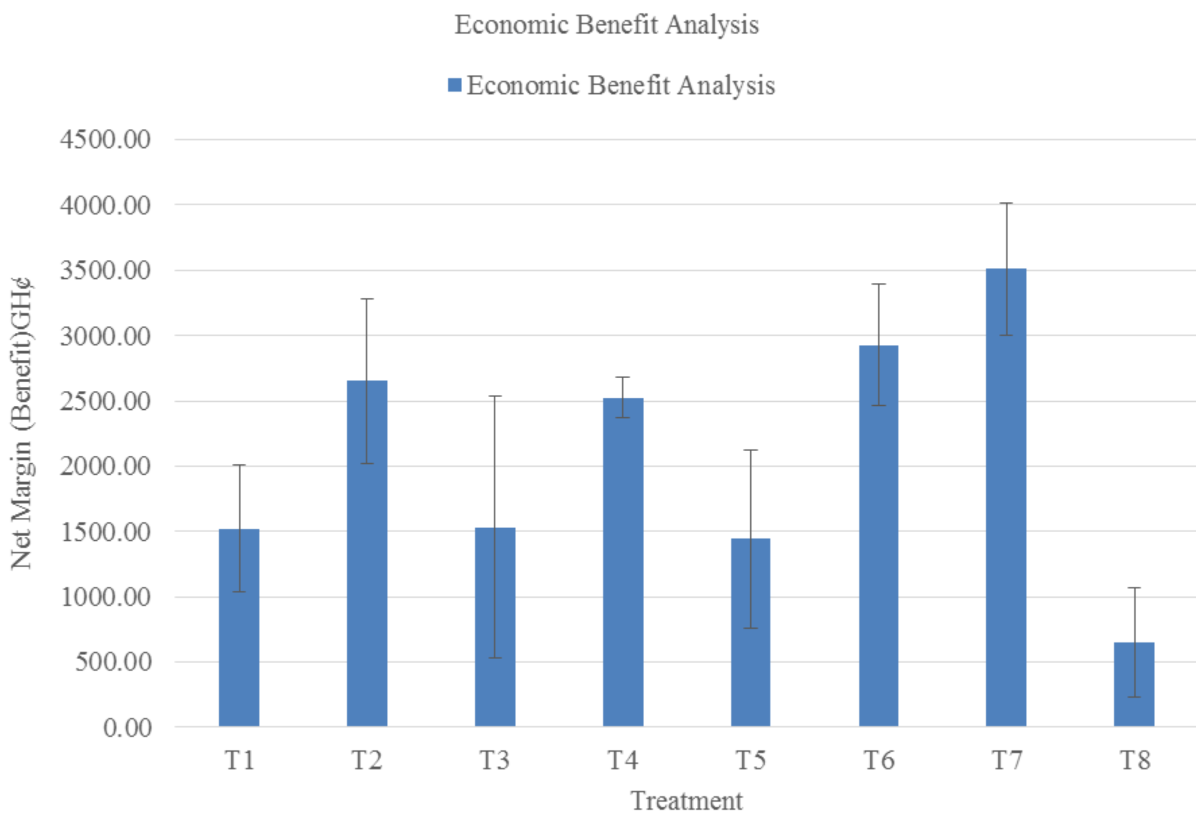

Figure 2. Economic analysis for Net benefit. Treatments: T1= {N, P_2O_5, K_2O (90-60-60) kg/ha} at 2 & 6 WAS; T2= {Poultry Manure (4 t/ha)} at 2 WBS; T3= {Foliar fertilizer (4 L/ha)} at 2, 4 & 6 WAS; T4= {Poultry Manure (2 t/ha)} at 2 WBS + {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 WAS; T5= {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 WAS + {Foliar fertilizer (2 L/ha)} at 4 WAS; T6= {Poultry Manure (2 t/ha)} at 2 WBS + {Foliar fertilizer (2 L/ha)} at 2 and 6 WAS; T7= {Poultry Manure (2 t/ha)} at 2 WBS + {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 & 6 WAS + {Foliar fertilizer (2 L/ha)} at 4 WAS and T8= Control (No fertilizer.

study. The integrated application of the nutrient sources (soil applied NPK fertilizer, poultry manure and Foliar fertilizer) contributed to the higher maize productivity and nutrient management. Vanlauwe et al. (2011) indicated that addition of both organic and inorganic fertilizers resulted into synergy and increased conservation and harmonisation of nutrient release and crop demand, causing improved fertilizer efficiency and higher crop yields. Similar observation was made by other authors. Eneji et al. (1997) indicated that an integrated fertilization of both organic and mineral fertilizers ensured abundance supply of plant nutrition and sustained enormous crop yield and profitability. Using both Foliar and soil applied NPK fertilizer was found to increase maize productivity. It was documented by Fageria et al. (2009) that foliar Phosphorus fertilization at the tasselling stage increased grain and forage Phosphorus concentration, which showed increase grain yield in some experiments. The higher values obtained for plant height, cob length and 1000-grain weight in the study could be associated to the final highest grain yield produced in T7 which was at par with T1 and T4. It further confirmed the results of Ademiluyi and Fabiyi (2015) which showed that application of organic manure and inorganic mineral nutrients significantly improved the growth and yield of maize after supplementary foliar fertilization.

The highest net return of Three Thousand Four Hundred and Twenty-Four Ghana Cedis (GH¢ 3,424.00) was obtained in T7 after the grain was processed and the price determined but was not statistically different from T2 and T6. The lowest net return of Six Hundred and Fifty-One Ghana Cedis and Fifty Pesewas (GH¢ 651.50) was obtained in T8 (control) which was at par with T1, T3 and T5 statistically (Figure 2). The highest net profit of GH¢ 3,424.00 in T7 was five times higher than the net profit of GH¢ 651.50 in T8 (control). However, T1, T3, T4 and T5 treatments were significantly different from T7. Integrated application of the three nutrient sources complemented one another to boost yield, which reflected in the farmer's net profit. The net return of Three

Thousand Four Hundred and Twenty-Four Ghana Cedis (GH¢ 3,424.00) was obtained in T7 after integrated application of half rate of the recommended sole nutrient sources (soil applied NPK, poultry manure and foliar fertilizer). However, the lowest net return of Six Hundred and Fifty-One Ghana Cedis and Fifty Pesewas (GH¢ 651.50) was obtained in the control plot where no nutrient source was applied at all. This finding was similar to Lunduka and Kelly (2009) who observed that the net benefit for no fertilizer applied plot was the least among the treatments. The integrated fertilization of organic manure plus mineral fertilizers produced the highest net cash returns and returns to labour. The sole soil applied NPK fertilizer (T1) recorded a net profit of One Thousand Five Hundred and Twenty-Six Ghana Cedis and Fifty Pesewas (GH¢ 1,526.50) as a result of the high cost of production using the recommended rate of fertilizers per hectare. T6 gave similar profit margins like the T7 due to cheap cost of poultry manure and foliar fertilizer and their ability to release sufficient nutrients which was enhanced by the major and micro nutrients in the foliar fertilizer. Integrated application of soil applied NPK fertilizer, Poultry manure and foliar fertilizer enhanced the growth and yield of maize. Integrating soil applied NPK fertilizer with poultry manure and Foliar fertilizer could reduce the high dosage of each of the fertilizers required per unit area, which would improve soil characteristics and enhance sound soil management strategy for sustainable maize production in the tropics (Afe et al., 2015). The interesting thing about the farm budget was that the highest economic return was earned when half rate of the respective nutrient sources was used at the right time. The judicious fertilizer application of both mineral and organic materials, through Integrated Nutrient Management practice, will promote an all-inclusive approach for sustainable increase in crop production in Ghana (Bationo et al., 2018).

Conclusion

The results of the study revealed significant growth and yield following the integrated application of the half rate of recommended nutrient sources (soil applied NPK fertilizer, poultry manure and foliar fertilizer) which was evident in the higher maize grain yield produced in T7 ({Poultry manure (2 t/ha)} at 2 WBS + {N, P_2O_5, K_2O (45-30-30) kg/ha} at 2 and 6 WAS + {Foliar fertilizer (2 L/ha)} at 4 WAS) and was statistically similar to T1 and T4. The highest net return was derived in T7, which was statistically similar to T2 and T6. The lowest net return was obtained in T8 (control) which was at par with T3 statistically. Resource poor farmers can adopt T7, due to relatively cheap cost of Poultry manure with a little investment in buying soil applied NPK and Foliar fertilizers instead of the full fertilizer recommended rate, which is far beyond the affordability of an ordinary farmer. Economic benefit analysis also showed that the best option for the highest net benefit in maize production is the use of T7. The ultimate financial return on investment was achieved when half rate of each nutrient source was applied integrated. However, it is suggested that further research should be carried out in other agro-ecological zones since the research was limited to one cropping season.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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