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Effect of Integrating Poultry Manure and Inorganic NP Fertilizers on Growth, Yield and Yield Component of Maize (*Zea mays* L.) at Ambo, Ethiopia

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Abstract

Soil fertility decline is a major constraint to sustain higher agricultural production and productivity in tropical soils due to removal of crop residues from crop fields, low inherent soil fertility and the repeated suboptimal fertilization. A field experiment was conducted at Ambo University research farm, Ethiopia to investigate the effect of different levels of poultry manure (PM) and NP fertilizer rates on growth, yield and nutrient uptake of maize (Zea mays L.). The experiment consisted of eight treatments: control, 15 t ha^{-1} PM, 30 t ha^{-1} PM, 15 t ha^{-1} PM + 25% rec. NP, 15 t ha^{-1} PM + 50% rec. NP, 30 t ha^{-1} PM + 25% rec.NP, 30 t ha^{-1} PM + 50 % rec.NP and 100% recommended dose of NP fertilizer rates which were laid out in randomized complete block design (RCBD) with three replications. The results showed significantly (P<0.001) higher values of plant height, number of leaves per plant, leaf area, leaf area index, number of cobs per plant, cob girth, cob length, number of grains per cob, 1000-grain weight, dry biomass yield, harvest index and grain yield with the application of 30 t ha^{-1} PM plus 50% recommended NP fertilizer compared to both the absolute and standard controls. The highest maize grain yield (132.7q ha^{-1}) was recorded for the treatment that received 30 t ha^{-1} PM combined with 50% recommended NP fertilizer. The lowest values of growth parameters, yield and yield components were recorded from the absolute control where no PM and chemical NP fertilizer were applied. Higher total N and P uptake was recorded with the application of 30 t ha^{-1} PM plus 50% recommended NP fertilizer. Correlation analysis indicated a positive relationship between grain yields and all growth and yield parameters. Moreover, the economic analysis showed higher net benefits from the application of 30 t ha^{-1} PM plus 50% rec. NP fertilizer rates. The integrated use of organic manure along with inorganic fertilizer improved the total nitrogen and phosphorus uptake.

Keywords: Maize, poultry manure, growth, yield and yield components, nutrient uptake

Introduction

Maize is the second most important cereal crop in area coverage and first in total production in Ethiopia (CSA, 2010). The diet of peoples in most part of Ethiopia (more than 85%) is primarily based on Maize. Despite its significance as food crop, the national average yield is about 3.01 t ha^{-1} according to the central statistical agency (CSA) report of 2013, which is far below the world's average yield of 5.21 t ha^{-1} (FAO, 2011).

The productivity of crops in most African countries is on the decline due to soil fertility problems, including Ethiopia. In order to sustain productivity, it is necessary to explore alternatives strategies to soil fertility management that is affordable and accessible to smallholder farmers. In Ethiopia, besides the low and mid altitude areas, maize has also become an important cereal crop in the highland areas following the release of highland maize varieties by the national maize research team at Ambo Plant Protection Research Center. Negassa *et al*., (2005) reported that low soil fertility is one of the major factors limiting maize production and productivity in Western Oromiya. He also reported that low fertilizer application and lack of proper crop residue management contributed to a rapid soil fertility decline in most maize growing regions.

Soil fertility and hence crop yield can be enhanced through the application of inorganic NP fertilizers. However, due to the high cost of fertilizer, farmers do not apply the recommended rates and this has affected both yield and maintenance of soil fertility resulting in gradual decline of soil fertility. This calls for alternative ways of soil fertility management involving the integrated management of nutrients through the combined application of chemical and organic fertilizers as a suitable strategy for overcoming the current problem of soil fertility decline. The application of poultry manure (PM) in combination with reduced level of recommended inorganic fertilizes was reported to increase soil fertility and also enhance crop growth and yield (Boateng *et al.,* 2006).

The use of manure along with chemical fertilizers has been reported to enhance percent fertilizer recovery by the crop resulting in higher crop yield (Negassa *et al*., 2002a). Thus, crop production can become more sustainable with judicious and balanced application of chemical fertilizers combined with organic fertilizers. Fewer research has been conducted Information on the integrated use of poultry manure and NP fertilizer on maize grown on vertisol to assess growth, yield and yield component. Therefore the objective of this study was to determine the optimum NP and poultry manure rates to combine for improved growth, yield and yield component of highland hybrid maize.

Materials and Method

Description of the study area

The experiment was conducted during the main cropping season in 2013 at the Ambo University's research farm located in West Shoa Zone, Oromiya Regional State, Western Ethiopia, and approximately 112 km West of Addis Ababa. The study area lies at an altitude of 2100 meter above sea level and has a unimodal rainfall pattern with a total rainfall of 942.2 mm. The rainy season occurs from April to December and maximum rain is received in the months of June, July and August. The average maximum and minimum temperatures of the study area are 25°C and 10°C, respectively. The soil type of the study area is characteristic of vertisol.

Treatments and experimental design

The experiment consisted of eight treatments; control (T1), 100% recommended dose of NP fertilizer rates (T2), 15 t ha^{-1} poultry manure (PM) (T3), 30 t ha^{-1} PM (T4), 15 t ha^{-1} PM + 50% rec. NP (T5), 15 t ha^{-1} PM + 25% rec. NP (T6), 30 t ha^{-1} PM + 50 % rec.NP (T7), 30 t ha^{-1} PM + 25% rec. NP (T8). The experiment was laid out in randomized complete block design (RCBD) in three replications.

Planting and crop management

A high yielding highland hybrid maize variety AMH851 (Jibat) was used in the experiment and planting was done in the second week of June. Two seeds per hill were initially planted and later thinned to one plant per hill on a plot size of 6.75 m^2 (1.5 m x 4.5 m) using an inter and intra row spacing of 75 cm and 30 cm respectively. Each plot consists of six rows with 5 plants per row. Data recording was done from the central four rows. Urea and diammonium phosphate (DAP) were the sources of nitrogen and phosphorus respectively. The urea was applied in two splits (at planting and 35 days after planting) while DAP was applied basally. The poultry manure was applied and incorporated into the soil one month before planting. All necessary agronomic management practices were timely carried out as per the crop requirement.

Soil sampling and analysis

Soil samples were randomly collected from the experimental field following the zig zag pattern to a depth of 30 cm and composited before treatment application for soil physicochemical analysis. The soil samples were air-dried and ground to pass through 0.2 mm sieves and analyzed for soil texture by Bouyoucos hydrometer method, pH was measured (1:2.5 soil: water) using a portable pH meter, available P (Olsen *et al*., 1954) total N was determined by the Kjeldahl method as described by Jackson (1958) and organic carbon following the wet digestion method as described by Walkley and Black (1934).

Data Collection

Plant growth parameters

Five plants from each plot were randomly selected and pre-tagged and used for measuring growth parameters; plant height, number of leaves per plant, total leaf area and leaf area index at 30, 60, and 90 days after sowing and at harvest. In order to determine the leaf area, the lengths of all the fully opened leaf lamina per plant were measured from the base to the tip of the leaf. The breadth was taken at the widest point of the leaf lamina. The products of leaf length and breadth were multiplied by the factor 0.75 (Saxena and Singh, 1965) and was expressed in cm^2. The leaf area index was calculated by dividing total leaf area per plant by the land area occupied by single plant (Sestak *et al.,* 1971).

Yield components such as number of cob per plant, cob length, cob girth, number of grain rows per cob, number of grains per cob, 1000 grain weight; harvest index and grain yield were determined at the time of harvest from the cobs produced by the five randomly selected plants. .

To determine the cob girth (cm), the diameter of a cob was measured using vernier calliper and average cob girth was recorded. The inner four central rows were harvested for grain yield determination. Grain yield per plot was adjusted following Birru, (1979) and Nelson *et al.,* (1985) procedures and converted to kg ha^{-1}.

The harvest index was determined as the ratio of economic yield to total biological yield expressed in percentage according to Donald, (1962).

Dry Biomass yield (kg ha^{-1}) at maturity was determined from two harvested central rows in each plot, dried to constant weight and weighed, while the total nitrogen and phosphorus uptake was calculated for each treatment using the formula as shown below.

$$\text{Nutrient uptake (mg plant}^{-1}\text{)} = \text{nutrient concentration x dry biomass weight}$$

Economic analysis

Mean grain yield was used for partial budget analysis (CIMMYT, 1988). The price of N fertilizer (urea) was estimated to 10.03 Eth. Birr kg^{-1} and that of P fertilizer (DAP) to 13.45 Eth. Birr kg^{-1}. The price of poultry manure was estimated to be 25 birr 100 kg^{-1}. Gross income was computed on the basis of the market price of 5 Birr for 1 kg of maize. The Gross benefit was calculated as average adjusted grain yield (kg ha^{-1}) multiplied by the field price of maize that farmers received and net benefit calculated.

Data analysis

Collected data were subjected to analysis of variance (ANOVA) using statistical analysis software (SAS) version 9.2. Where significant differences exist among treatments, means were compared using the Turkey test at a significance level α = 0.05 probability.

Results and Discussion

Initial physico-chemical properties of soil and poultry manure

According to the soil textural class classification, the results of initial physico-chemical properties of the soil collected (0-20 cm) from the experimental site indicated that it contained 2.5% sand, 22.5% silt and 75% clay and thus can be characterized as clay silt loam (Table 1). High clay content indicates better water and nutrient holding capacity of the soil. The soil reaction (pH) was 7.1 which according to FAO (2008) was within range suitable for most crops for optimum N availability. The result of poultry manure analysis also showed that it was high in nutrient content.

Table 1. The Physico- chemical properties of soil before planting and chemical properties of the poultry manure

Physical properties					Chemical properties				
Particle size distribution (%)						pH	OC (%)	Total N (%)	Available P (ppm)
Soil	Sand%	Silt%	Clay%	Tex. Class	Soil	7.1	1.69	0.12	12.8
	2.5	22.5	75	Clay	PM	8.21	3.13	16.15	19.7

The organic carbon (1.69 %) and total N (0.12%) content of the soil were low. Such low OC and total N content in the study area indicate low fertility status of the soil which can potential limit optimum crop growth and hence yield. Such rapid decline in fertility status of vertisol, a relatively younger soil compared to nitosol, could be ascribed to continuous cultivation under suboptimal or no fertilizer application resulting in nutrient mining and /or lack of incorporation of organic materials or crop residues.

Effects of PM and NP fertilizer integration on growth of maize

The analysis of variance result showed that plant height was significantly ($P<0.001$) affected by the treatments at 30, 60 and 90 days after sowing (DAS). At 30 DAS, significantly taller (19.34 cm) plants were recorded in T7 (30 t ha^{-1} PM plus 50% recommended NP fertilizer) compared to all other treatments. However, there were no significant differences between T3, T4, T5, T6 and T8 (Table 2). The application of recommended NP rates gave significantly taller plants (10.3 cm) compared only to the absolute control (8.62 cm). Similarly, at 60 DAS the longest plant height (93.64 cm) was recorded for T7 (30 t ha^{-1} PM plus 50% recommended NP fertilizer) was applied which was statistically at par with T5, T4, T8, T3 and T6. The shortest (38.28 cm) plant height at 60 DAS was recorded from the control treatment (no PM and chemical NP fertilizer was applied). Similar trend was also observed at 90 DAS where the tallest (251.5 cm) was recorded with the application of 30 t ha^{-1} PM plus 50% recommended NP fertilizer which was also statistically at par with T5, T8, T6, and T4 (Table 2) and the shortest plant height (159.3 cm) was recorded in the control treatment (Table 2). The taller plants recorded for the treatments in which reduced doses of inorganic fertilizer was applied in combination with PM might be attributed to the availability of nutrients in the PM, through mineralization which became readily available for plant uptake. This finding is in agreement with that of Makinde (2007), Rajeshwari *et al.*

(2007), and Ayoola and Makinde (2009) who also reported better plant height in maize with the combined application of organic fertilizer in combination with reduced inorganic fertilizers.

Table 2. Effect of poultry manure and NP fertilizer rates on the plant height of maize

Treatment	Plant height (cm) at		
	30 DAS	60 DAS	90 DAS
T1=Control	8.62[d]	38.28[b]	159.3[c]
T2=Recom. NP (110 kg N-46 kgP_2O_5)	10.83[c]	49.76[b]	195.1[bc]
T3=15 t ha^{-1} PM	15.39[b]	78.63[a]	228.4[ab]
T4=30 t ha^{-1} PM	16.68[b]	83.63[a]	238.4[a]
T5= 15 t ha^{-1} PM + 50% Recom.NP	16.96[b]	86.36[a]	245.8[a]
T6=15 t ha^{-1} PM + 25% Recom. NP	16.53[b]	76.26[a]	243.4[a]
T7=30 t ha^{-1} PM + 50% Recom NP	19.34[a]	93.64[a]	251.5[a]
T8= 30 t ha^{-1} PM + 25% Recom. NP	16.51[b]	81.86[a]	244.4[a]
LSD(P=0.05)	1.9	18.2	39.5
CV (%)	4.4	8.5	6.0

Means within the column followed by the same letter are not significantly different at α=0.05 according to Tukey test

The result of the analysis of variance showed that number of leaves per plant at 30, 60 and 90 DAS were significantly ($P<0.001$) affected by treatments. At 30 DAS, the application of 30 t ha^{-1} PM plus 50% recommended NP fertilizer (T7) resulted in the highest number (3.9) of leaves per plant compared to all other treatments (Table 3). However, there was no significant difference between T4, T5, T6, and T8 which were all statistically at par. The application of recommended NP rates gave significantly more number of leaves per plant (3.3) when compared to the absolute control (2.4). Similar trend was also observed at 60 DAS where the application of 30 t ha^{-1} of PM plus 50% recommended NP fertilizer (T7) gave the highest number of leaves per plant (8.0) followed by T5 (15 t ha^{-1} PM plus 50% recommended NP fertilizer) with 7.8 average number of leaves per plant (Table 3). The application of recommended NP rates (standard control) gave significantly more number of leaves (7.0) per plant at 60 DAS compared to the control that recorded the lowest number (4.4) of leaves per plant. At 90 DAS, all levels of PM or its combination with 25% or 50% recommended NP fertilizer rates produced comparable number of leaves while the absolute control (no PM and chemical NP fertilizer) had the lowest number (12.0) of leaves per plant.

Higher number of leaves per plant was observed at all stages of maize (30 , 60 ,90 DAS) with all levels of PM alone or in combination with 25% or 50% recommended NP fertilizer rates. The higher leaf number per plant observed with the treatments in which PM alone or combined PM and inorganic fertilizer was applied might be due to availability of balanced nutrients following mineralization of

PM during the crop growth period. Increase in number of leaves per plant in maize due to integrated nutrient application was also reported by Makinde (2007) and Rajeshwari *et al*. (2007) which collaborates the present findings.

Fig 1. Picture showing the control plot (left) and the PM treated plot (right)

Table 3. Effect of poultry manure and inorganic NP fertilizer on number of leaves

Treatment	Number of leaves per plant (cm) at		
	30 DAS	60 DAS	90 DAS
T1=Control	2.4^{e}	4.4^{f}	12.0^{c}
T2= Recom. NP (110kgN/46kgP_2O_5)	3.3^{d}	7.0^{e}	14.2^{b}
T3=15 t ha^{-1} PM	3.4^{cd}	7.3^{d}	15.3^{a}
T4=30 t ha^{-1} PM	3.6^{bc}	7.5^{cd}	15.5^{a}
T5= 15 t ha^{-1} PM + 50% Recom.NP	3.7^{b}	7.8^{ab}	15.7^{a}
T6=15 t ha^{-1} PM + 25% Recom. NP	3.5^{bc}	7.5^{cd}	15.3^{a}
T7=30 t ha^{-1} PM+50% Recom. NP	3.9^{a}	8.0^{a}	16.0^{a}
T8= 30 t ha^{-1} PM + 25% Recom. NP	3.6^{bc}	7.6^{bc}	15.3^{a}
LSD (P= 0.05)	0.16	0.2	0.9
CV (%)	1.6	1.1	2.2

Means within the column followed by the same letter are not significantly different at α=0.05 according to Tukey test

The maize leaf area per plant at 30, 60 and 90 DAS were also significantly ($P<0.001$) affected by the treatments as shown by the analysis of variance result. At 30 DAS, the comparison of treatment means indicated that significantly higher leaf area (140.5 cm^2) was recorded in T7 compared to all the other treatments (Table 4). There was no significant difference between T3, T4, T5, T6 and T8 which were all statistically at par. The application of recommended NP fertilizer rate gave significantly larger leaf area (62.0 cm^2) compared only to the absolute control with 33.7 cm^2. At

60 DAS, all levels of applied PM alone or in combination with 25% or 50% recommended NP fertilizer produced significantly larger maize leaf area compared to the absolute and standard controls. The application of recommended NP rates gave significantly larger leaf area (1756.4 cm^2) than the absolute control (Table 4). Similar trend was recorded at 90 DAS where all levels of the applied PM alone or all levels of PM combined with 25% or 50% recommended NP fertilizer produced significantly larger leaf areas. The smallest leaf area per plant (2642.3 cm^2) was recorded from the control treatment where no PM and chemical NP fertilizer was applied.

Moreover, the application of PM alone or its integration with 25%, or 50% recommended NP fertilizer all produced a leaf area ratios that were significantly higher than the controls (standard and absolute) even as no significant differences was recorded among them (Table 4). The lowest (1.7 cm^2) LAI was recorded on the absolute control treatment. The higher leaf area and LAI observed might be due to the ability of the organic manure to supply nutrients necessary to promote more vigorous growth, improve physiological activities in the plants, thereby resulting in the synthesis of increased photo-assimilates that enhanced maize productivity. These results are in conformity with the results of Makinde (2007) and Rajeshwari *et al*. (2007) in maize who also reported higher leaf area per plant and LAI when organic and inorganic fertilizers are applied in combination. Similarly, Boateng *et al*. (2006) also reported higher LA and LAI with the integrated application of PM and synthetic fertilizer.

Table 4. Effect of poultry manure and inorganic NP fertilizer on maize leaf area and leaf area index

Treatment	Leaf area per plant (cm^2) at			LAI
	30 DAS	60 DAS	90 DAS	90 DAS
T1=Control	33.7^d	1098.3^c	2642.3^c	1.7^c
T2= Rec. NP (110 kg N & 46 kg P_2O_5) ha^{-1}	62.0^c	1756.4^b	3824.0^b	2.6^b
T3=15 t ha^{-1} PM	119.4^b	3426.4^a	6074.4^a	4.5^a
T4=30 t ha^{-1} PM	121.2^b	3442.2^a	6286.5^a	4.6^a
T5= 15 t ha^{-1} PM + 50% Recom.NP	123.9^b	3450.3^a	6293.7^a	4.6^a
T6=15 t ha^{-1} PM + 25% Recom. NP	115.2^b	3433.6^a	6273.9^a	4.6^a
T7=30 t ha^{-1} PM+50% Recom. NP	140.5^a	3511.0^a	6320.7^a	4.7^a
T8= 30 t ha^{-1} PM + 25% Recom. NP	121.3^b	3431.1^a	6163.2^a	4.6^a
LSD (P=0.05)	13.2	281.1	797.5	0.4
CV (%)	4.3	3.3	5.0	3.9

Means within the same column followed by the same letter are not significantly different (Tukey test) at P=0.05

Effect on growth and yield components

The result of analysis of variance showed that the number of cobs per plant was affected significantly ($P<0.001$) by the treatments. All levels of PM alone or its combination (both 15 and 30 t ha^{-1}) with 25% or 50%

recommended NP fertilizer produced similar number of cobs per plant (2 cobs), which were significantly higher than that obtained from the control (Table 5). The recommended NP fertilizer rates had little effects on number of cobs per plant compared to the integrated application of PM and chemical NP fertilizers. The integrated application of PM and chemical fertilizer resulted in more number of cobs per plant through better assimilate formation as a result of enhanced plant physiological activities and subsequent transport of the photo assimilate to the sinkThe significant increase in number of cobs per plant with T7 might be due to the rapid mineralization of the PM under favourable environmental conditions that positively influence availability and adequate supply of macro and micro nutrients which enhanced crop growth and hence cob number. The result agrees with Shah and Arif (2000) who reported increase in the number of cobs with increasing level of organic and inorganic fertilizers.

Cob length per plant was also significantly affected by the treatments (P<0.001). Results showed that the longest cob length (23.7 cm) was recorded with T7, where 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied, which was statistically at par with T5 (23.4 cm). Similarly, there was no significant difference between T4, T6 and T8. The cob length (20.5 cm) obtained from the application of recommended NP fertilizer rate was significantly longer only compared to the control (12.8 cm), where no PM and chemical NP fertilizer was applied (Table 7). Cob length is an important yield related parameter in maize that substantially contributes to grain yield of maize by virtue of influencing both numbers of grains per cob and grain size (Farhad *et al.*, 2009). The cob length recorded from sole PM, recommended NP fertilizer rates and unfertilized control treatments were much inferior compared to the once obtained from combined application of PM and reduced recommended NP fertilizer rates. The reason for longer cobs length under integrated PM and chemical fertilizer application may be due to more whole plant photosynthetic activities on account of adequate supply of nitrogen and phosphorus in these treatments resulting in better assimilate formation and transport to the sink (cob). Maize cob serves as a temporary storage organ and as a conveyor of nutrients to the developing kernels (Crawford *et al*., 1982). Therefore, the better the development of cob length, the better economic yield of maize as suggested by khan *et al*., (2008). Thus, the significant positive relationship between Cobe length and yield (Table 9) confirms the earlier report of khan *et al*., (2008). The result in this experiment was in agreement with reports Rajeshwari *et al*. (2007), who also reported a significant increase in cob length with increasing rates of nitrogen fertilizer.

Cob girth per plant was also significantly affected by the treatments (P<0.001). All the treatments produced cob girths which were significantly higher than both absolute and standard controls. The largest cob girth (16.8 cm) was recorded with T7, where 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied. There was no significant difference between T3, T4, T5, T6, T7 and T8. The smallest cob girth (10.1 cm) was recorded by the control treatment. The larger cob girth of observed with the treatments in which PM alone or PM integrated with inorganic fertilizer was applied might be due to the better availability of nutrients with these treatments during the growth period of the crop. This result was similar to the earlier reports of Tolessa and Friesen (2001), who also observed larger cobe girth with combined application of organic and inorganic fertilizer.

The number of grain rows per cob was significantly affected by the treatments (P<0.001). More number of grain rows per cob (12.8 cm) was recorded with T7, where 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied which was at par with T5, T6, T4 and T3. The application of recommended NP fertilizer rates gave significantly higher number of grain per row only compared to the absolute control (10.0 cm). Number of grain rows per cob is an important yield determining factor in maize. It affects the number of grains per cob and cob weight (Farhad *et al*., 2009). Higher number of grain rows per cob was observed with the application of PM alone or in combination with 25% or 50% recommended NP rates compared to both absolute and standard controls (Table 5).

The number of grain per rows was significantly (P<0.001) affected by the treatments. The highest number of grain per rows (45.6) was recorded with T7 which was statistically at par with T8, T6, T5, T4 and T3. The application of recommended NP rates gave significantly higher number of grains per row (39.2) compared to the absolute control (18.5). Accordingly, Farhad *el al*., (2009) reported that the number of grains per row is an important parameter contributing towards the final yield of maize. The increase in number of grains per row may be attributed to the availability of more nitrogen and other nutrients from PM required for plant development up to cob formation. These results are in agreement with the findings of Boateng *et al.* (2006) who reported that poultry manure significantly increased the maize yield components.

Table 5. Effect of poultry manure and NP fertilizer rates on the yield components of maize

Treatment	Number of cobs per plant	Cob length (cm)	Cob girth (cm)	Number of rows per cob	Number of grains per row	Number of grains per cob
T1=Control	1.3[c]	12.8[e]	10.1[c]	10.0[c]	18.5[d]	175.5d
T2= Reco.NP(110kgN/46kgP_2O_5)	1.6[b]	20.5[d]	13.9[b]	11.0[bc]	39.2[c]	431.9c
T3=15 t ha^{-1} PM	1.9[a]	22.4[c]	16.3[a]	12.2[ab]	43.6[a]	503.0[b]
T4=30 t ha^{-1} PM	2.0[a]	23.3[b]	16.5[a]	12.4[ab]	43.8[a]	525.8[ab]
T5= 15 t ha^{-1} PM + 50% Rec.NP	2.0[a]	23.4[ab]	16.7[a]	12.6[a]	44.6[a]	550.9[ab]
T6=15 t ha^{-1} PM + 25% Rec. NP	1.8[ab]	23.1[b]	16.3[a]	12.1[ab]	44.4[a]	516.0[ab]
T7=30 t ha^{-1} PM+50% Rec. NP	2.0[a]	23.7[a]	16.8[a]	12.8[a]	45.6[a]	565.0[a]
T8= 30 t ha^{-1} PM + 25% Rec. NP	2.0[a]	23.2[b]	16.3[a]	11.6[bc]	44.2[a]	502.8[b]
LSD($P \leq 0.05$)	0.2	0.36	1.27	1.46	1.86	61.0
CV (%)	4.0	0.58	2.8	4.2	1.6	4.4

Means followed by the same letter are not significantly different at 5% level of probability according to Tukey test

Results showed that the number of grains per cob was significantly ($P<0.001$) affected by the treatments, highest number of grain per cob (565.0) was recorded with T7 (30 t ha^{-1} PM plus 50% recommended NP fertilizer) which was statistically at par with T4, T5, and T6 (Table 5). The application of recommended NP fertilizer rates gave significantly higher number of grains per cob compared only to the absolute control (175.5). The application of PM at all levels alone or in combination with 25% or 50% recommended NP fertilizer rates gave significantly more number of grains per cob compared to both absolute and standard controls (Table 5). The higher number of grains per cob recorded from PM alone or PM integrated with inorganic fertilizer application could be attributed to the availability of balanced nutrients with these treatments during the growth period of the crop. These results are similar to that of Legesse *et al*., (1987) who reported that proper addition of manures played a significant role in improving soil health and crop productivity. Vasanthi and Kumaraswamy (2000) also reported that PM plus half the recommended inorganic fertilizer rate, yielded much greater amount of green fodder of corn than the full rate of NPK alone.

Fig 2. Picture showing the effect of PM and NP fertilizer application on maize cob sizes

The analysis of variance for 1000-grain weight showed significant (P<0.001) effect of treatments. T7 recorded the highest (460.4 g) 1000-grain weight which was statistically at par with T8, T6, T5, T4 and T3. The application of recommended NP rates gave slightly higher 1000-grain weight (394.9 g) compared to the absolute control (372.1 g). Higher 1000- grain weight was recorded at all levels of PM alone or in combination with 25%, 50% recommended NP fertilizer compared to both absolute and standard controls. This might be due to the adequate nutrient supply especially of N from the organic source (PM) which might have enhanced the source of efficiency (more dry matter accumulation per unit area/time) as well as sink capacity (grain weight). This result was in agreement with that of Sharif *et al*. (2004) who reported that 1000-grain weight was significantly affected by recommended dose of fertilizer in combination with FYM in maize varieties.

The dry biomass yield was significantly affected by the treatments (P<0.001). The highest dry biomass yield (46032 kg ha^{-1}) was recorded by T7, where 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied which was comparable with T8, T6, T5, T4, and T3 (Table 8). The application of recommended NP fertilizer rates gave significantly higher dry biomass yield (2888.9 kg ha^{-1}) than the absolute control. The lowest dry biomass yield of (19048 kg ha^{-1}) was obtained from the control treatment where no PM and chemical NP fertilizer was applied. The higher dry biomass yield observed with PM or combined PM and inorganic fertilizer was due to the adequate and balanced supply of plant nutrients by the PM throughout the growth period. This result is similar to the findings of Khaliq *et al*. (2004) who also reported better results with integrated application of manures and synthetic fertilizers.

Effect on grain yield and harvest index

Grain yield was significantly affected by the treatments (P<0.001). Significantly higher grain yield (132.7q ha^{-1}) was recorded with T7 in which 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied which was at par with T3, T4, T5, T6 and T8. The application of recommended NP rates gave significantly higher grain yields (104.4 q ha^{-1}) compared only to the absolute control (62.2 q ha^{-1}) (Table 6). The highest grain yield in T7 could be as a result of the higher number of grains per cob and higher 1000-grain weight produced by this treatment. The application of organic fertilizer along with chemical NP fertilizers significantly increased grain yield compared to the treatments in which organic or NP fertilizer was applied separately. This yield increase could possibly be due to the availability of both macro and micronutrients when they are applied combined. Farhad *el al.,* (2009) reported in his study that grain yield was affected by interaction among various yield components that were affected differentially by the growing conditions and crop management practices. This result is in agreement with the findings of Boateng *et al.* (2006) who also suggested that the combined application of PM and NPK brings about complementary and synergistic effects on maize growth and yield.

The physiological efficiency of maize to partition dry matter into economic (grain) yield is referred to as the harvest index (Hay, 1995). Results showed that the highest harvest index (39.1%) was recorded with T7 (30 t ha^{-1} PM plus 50% recommended NP) even though it was comparably at par statistically with T2, T3, T4, T5, and T8, while the lowest (32.6%) harvest index was recorded from the control treatment (Table 6). The higher the harvest index, the greater the grain yields (Farhad *et al.*, 2009). It was observed that significantly higher HI was obtained from plots that received PM integrated with NP fertilizers than when both form are applied alone.The result agrees with that of Khaliq *et al*.(2004), who reported higher harvest index in maize when organic and inorganic fertilizers were combined.

Relationship between growth, yield components and grain yield of maize

Result presented in Table 10 showed that there was a highly significant (P<0.001) relationship between growth parameters, yield components and grain yield. Grain yield had significant positive relationship with number of leaves per plant, leaf area, leaf area index and number of grains per cob implying the strong dependence of grain yield on the above mentioned parameters. Singh *et al*. (2002) and Saleem *et al*. (2007) had all reported that grain yield was significantly and positively correlated with cob length, biomass per plant, number of rows per cob and number of grains per cob, which support the present finding.

Table 6. Effect of poultry manure and NP fertilizer rates on yield and yield components of maize

Treatment	1000 grain weight (gm)	Dry biomass (kg/ha)	Grain yield(q/ha)	Harvest Index (%)
T1=Control	372[c]	19048[c]	62.2 [c]	32.6[b]
T2= Reco. NP(110kgN/46kgP_2O_5)	394[bc]	28889[bc]	104.4 [b]	35.2[ab]
T3=15 t ha^{-1} PM	436[ab]	38730[a]b	124.6 [ab]	35.9[ab]
T4=30 t ha^{-1} PM	452 [a]	40317[ab]	124.7[ab]	36.2[ab]
T5= 15 t ha^{-1} PM + 50% Rec.NP	457 [a]	40952[ab]	125.7[ab]	36.4[ab]
T6=15 t ha^{-1} PM + 25% Rec. NP	425[abc]	35873[ab]	125.6[ab]	34.5[b]
T7=30 t ha^{-1} PM+50% Rec. NP	460 a	46032[a]	132.7 [a]	39.1[a]
T8= 30 t ha^{-1} PM + 25% Rec. NP	431[ab]	37460[ab]	126.6[ab]	35.8[ab]
LSD (5%)	53.8	13014	2543.9	4.0
CV (%)	4.3	12.5	7.6	3.9

Means within a column followed by the same letter are not significantly different at α = 0.05 according to Tukey test

Table 9. Relationship between growth parameters, yield components and grain yield of maize

Traits	pH	TLA	LAI	LNP	CN	CL	CG	NGRC	NGR	NGC	1000-SW	DBW	HI	GY_{ha}
pH	1	0.858 .0001*	0.857 .0001*	0.800 .0001*	0.762 .0001*	0.882 .0001*	0.880 .0001*	0.672 .003*	0.849 .0001*	0.849 .0001**	0.713 .0001*	0.815 .0001**	0.8290. .001*	0.836 .0001*
TLA		1	0.988 .0001*	0.926 .0001*	0.794 .0001*	0.911 .0001*	0.901 .0.000*	0.820 .0001	0.891 .0001*	0.923 .0001**	0.795 .0001*	0.853 .0001**	0.514 .010*	0.908 .0001*
LAI			1	0.897 .0001*	0.748 .0001*	0.879 .0001*	0.881 .0001*	0.803 .0001	0.850 .0001*	0.887 .0001**	0.971 .0001*	0.820 .0001**	0.496 .013*	0.859 .0001*
LNP				1	0.949 .0001*	0.915 .0001*	0.892 .0001**	0.857 .0001*	0.916 .0001*	0.949 .0001**	0.796 .0001*	0.888 .0001**	0.535 .007*	0.891 .0001*
CN					1	0.951 .0001*	0.916 .0001**	0.674 .0003*	0.972 .0001*	0.939 .0001**	0.636 .0008*	0.741 .0001**	0.519 .009*	0.889 .0001*
CL						1	0.977 .0001**	0.780 .0001*	0.988 .0001*	0.976 .0001**	0.759 .0001*	0.849 .0001**	0.594 .002*	0.947 .0001*
CG							1	0.811 .0001*	0.955 .0001*	0.959 .0001**	0.783 .0001*	0.843 .0001**	0.580 .003*	0.894 .0001*
NGRC								1	0.761 .0001*	0.841 .0001**	0.833 .0001*	0.759 .0001**	0.604 .001*	0.695 .0002*
NGR									1	0.979 .0001**	0.715 .0001*	0.817 .0001**	0.581 .003*	0.937 .0001*
NGC										1	0.799 .0001*	0.867 .0001**	0.589 .002**	0.929 .0001*
1000-SW											1	0.823 .0001**	0.594 .002*	0.736 .0001*
DBW												1	0.541 .006*	0.893 .0001*
HI													1	0.541 0.006*
GY_{ha}														1

Where PH=plant height, TLA=total leaf area, LAI=leaf area index, LNP=leaf number per plant, CN= cob number, CL=cob length, NGRC=number of grain rows per cob, NGR=number of grain per rows, NGC=number of grain per cob, 1000=SW=thousand seed weight, DBW=dry biomass weight, HI=harvest index, GY=grain yield per hectare

Economic Analysis

The result of partial budget analysis based on CIMMYT (1988) technique indicated that the highest net benefit (54,361 Eth. Birr/ha) was obtained from T7 (30 t ha^{-1} PM + 50% recommended NP fertilizer rates) and closely followed by T3 (15 t PM/ha) which recorded 54, 220 Eth. Birr/ha as net benefit. The lowest net benefit (27,631 Eth. Birr/ha) was recorded from the absolute control without any treatment application

Conclusion and Recommendation

Based on the study findings, the application of poultry manure (PM) alone or in combination with reduced doses of recommended NP fertilizers enhanced maize growth, yield and yield components. Significantly taller plants, increase number of leaves per plant, larger leaf area and high leaf area index, more number of cobs per plant, larger cob girth and cob length, more number of grains per cob, 1000-grain weight, dry biomass yield, harvest index and grain yield were observed with combined application of PM plus 25% or 50% recommended NP fertilizer rates compared to both absolute and standard controls. Highest grain yield and net benefit however was obtained with the application of 30 t ha^{-1} PM plus 50% recommended NP fertilizer rates. Moreover, correlation analysis indicated that, all growth parameters and yield components showed significant positive relationship with grain yield, indicating that all contributed to yield.

Therefore, on the basis of these results, it can be suggested that, the application of 30 t ha $^{-1}$ PM integrated with 50% recommended NP fertilizer rate is suggested for higher hybrid maize grain yield at Ambo.

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