International Journal of Sustainable Agricultural Research
2019 Vol. 6, No. 4, pp. 183-197
ISSN(e): 2312-6477
ISSN(p): 2313-0393
DOI: 10.18488/journal.70.2019.64.183.197

EFFECT OF INTEGRATED APPLICATION OF POULTRY MANURE AND CHEMICAL NP FERTILIZERS ON GROWTH, YIELD AND YIELD COMPONENTS OF HIGHLAND MAIZE VARIETY ON VERTISOL AT AMBO UNIVERSITY ON STATION, ETHIOPIA

Tulu Kusse[1]
Tesfaye Balemi[2+]
Tolera Abera[3]

[1,2]*Debre Zeit Agricultural Research Center, Ethiopia.*
[2]*Email: tesfayeb2005@yahoo.co.uk*
[3]*Ambo Agricultural Research Center, Ethiopia.*

(+ Corresponding author)

Article History
Received: 17 June 2019
Revised: 23 July 2019
Accepted: 27 August 2019
Published: 8 October 2019

Keywords
Chemical fertilizers
Maize grain yield
Nitrogen
Phosphorus
Poultry manure
Zea mays.

ABSTRACT

A decline in soil nutrient and organic matter content as a consequence of removal of crop residues from crop fields, repeated suboptimal fertilization resulting in periodic nutrient mining, is a major constraint to increasing maize productivity in a sustainable manner in tropical soils. A field experiment was conducted at Ambo University research farm, Ethiopia with the objectives to investigate: the effect of combining different levels of poultry manure (PM) and NP chemical fertilizer rates on growth, yield and yield components of maize (*Zea mays* L.). The experiment consisted of eight treatments: control, 15 t ha^{-1} PM alone, 30 t ha^{-1} PM alone, 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. Results showed that 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, biomass yield, harvest index and grain yield were significantly higher for the treatment in which 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied compared to both the absolute and standard controls. The highest maize grain yield (132.7q ha^{-1}) was recorded for the treatment in which 30 t ha^{-1} PM along with 50% recommended NP fertilizer was applied. The lowest values of growth, yield and yield components parameters were recorded for the negative control where no PM and chemical NP fertilizer were applied. Results of the correlation analysis revealed the presence of significant positive relationship between grain yields and all growth and yield component parameters. Integrating poultry manure with chemical fertilizers can considerable reduce the quantity of the later required for optimum maize production.

Contribution/Originality: This study contributes to the existing literature that reports the positive contribution of co-application of poultry manure and inorganic fertilizer as part of integrated nutrient management in enhancing growth, yields and yield components in crop plants in general and in maize in particular.

Abbreviations: DAS =days after sowing; Recom= recommended.

1. INTRODUCTION

Maize is the second most important cereal crop in area coverage and the first in total production in Ethiopia (Central Statistical Agency (CSA), 2017). Maize became increasingly important in the food security of Ethiopia following the major drought and famine that occurred in 1984 (Tsedeke *et al*., 2015). Despite its significance as food crop, the national average yield of maize is about 3.7 t ha^{-1} (CSA, 2017) which is far below the world's average yield of 5.21 t ha^{-1} (Food and Agriculture Organization Statistics (FAOSTAT), 2016). 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 by Ambo Plant Protection Research Center (Gudeta *et al*., 2011).

The decline in soil fertility has led to reduced crop productivity in most African countries, including Ethiopia (Belay, 2015). Wakene *et al.* (2005) reported that low soil fertility is one of the major factors limiting maize production and productivity in Western Oromia, in particular. He also reported that application of fertilizer at lower rates and lack of proper crop residue management contributed to a rapid soil fertility decline in most maize growing regions. Although soil nutrient levels can be maintained above the critical levels through application of chemical NP fertilizers the reality is that most smallholder farmers do not apply the recommended amount of chemical fertilizers due to high fertilizer cost (Tsedeke *et al*., 2015) and this has led both to yield reduction and nutrient mining through time. The current trend of low fertilizer input use by farmers however dictate us to questions whether sustainable intensification of crop production as a means to cope with ever increasing human population, would really be possible or not. In order to sustain high crop productivity under limited small holders' resources it is necessary to explore alternative cheaper soil nutrient management strategies, which resource poor smallholder farmers can easily adopt. Such soil nutrient management options may include the integrated use of chemical and organic fertilizers (Hashim *et al*., 2015; Singh *et al*., 2017).

The application of poultry manure (PM) alone or in combination with reduced levels of recommended inorganic fertilizes increased soil fertility (Ayeni and Adetunji, 2010; Dikinya and Mufwanzala, 2010; Enujeke, 2013) and also enhanced crop growth and yield (Boateng *et al*., 2006; Ayeni and Adetunji, 2010; Enujeke, 2013) in maize; Awodun (2007) in Pumpkin). The use of manure along with chemical fertilizers also enhanced fertilizer recovery efficiency by the crop resulting in higher crop yield (Wakene *et al*., 2002a). Dikinya and Mufwanzala (2010) reported an increase in soil fertility level with increasing PM rates. Enujeke (2013) and Farhad *et al.* (2009) reported increased growth, yield and yield components in maize with increasing PM rates. Application of poultry manure increased soil nutrient and organic matter contents implying that poultry manure enhances soil fertility (Boateng *et al*., 2006; Ayeni and Adetunji, 2010).

These findings confirm that crop productivity becomes sustainably higher with judicious application of balanced proportion of chemical and organic fertilizers such as manures. However, currently information on the optimum levels of PM and NP chemical fertilizer to be integrated for optimum maize growth, yield and yield component is scant, especially for maize grown on vertisol in highland areas. This study was, therefore, designed to determine the optimum NP chemical fertilizer and PM rates for better growth, yield and yield components of highland maize hybrid on vertisol in Ambo areas.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted during 2013 main cropping season at the Ambo University's research farm which is located in West Shoa Zone of Oromia Regional State, Ethiopia. The University is located at approximately 112 km west of Addis Ababa. The study area lies at an altitude of 2,100 meter above sea level and has a unimodal rainfall pattern with a total rainfall of 942.2 mm. The rainy season occurs during April to December and maximum rain is usually received in the months of June, July and August. The average maximum and minimum temperatures of the study area are 25^{o}C and 10^{o}C, respectively. The soil type in the study area is Vertisol.

2.2. Weather Condition at the Experimental Field

The meteorological data for the growth period of the experimental crop were obtained from the meteorological station of Ambo University.

Table-1. Meteorological data showing weather condition during the experimental period.

Weather parameters	Months								
	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Max.T^{0}c	32.4	29.3	26.5	24.9	24.8	27.5	27.0	28.9	28.0
Min.T^{0}c	10.0	11.1	11.0	11.5	10.6	9.5	7.0	9.8	5.6
Total RF(mm)	88.0	119.8	158.8	226.3	172.3	73.4	100.9	2.7	0.0
Ave. RH (%)	33.7	49.5	60.3	73.2	72.7	60.4	48.0	43.4	35.1
Av. sun shine	8.4	5.7	5.2	2.6	2.8	4.8	7.2	9.0	9.9

Source: Ambo University, metrology section.
Max.T^0= Maximum temperature, Min.T^0=Minimum temperature, Ave. RH=Average.
Relative Humidity, RF=Rain Fall.

2.3. Experimental Materials and Procedures

A newly released high yielding highland hybrid maize variety AMH851 (Jibat) was used for the study. Nitrogen (N) and phosphorus (P) fertilizers were applied in the form of urea and DAP, respectively. DAP was applied at sowing time while urea was applied in two splits (half at planting and the remaining half at 35 days after planting). For plots receiving poultry manure as a treatment, it was applied one month before planting and incorporated in to the soil quite very well. The poultry manure used in the experiment was air dried and sieved through 5 mm sieve and the rate used was determined on oven dry basis.

2.4. Treatments and Experimental Design

The experiment consisted of eight treatments:T1= Negative control, T2=100% recommended dose of NP fertilizer rates (standard control/ 110 kg ha^{-1} N and 46 kg ha^{-1} P_2O_5), T3=15 t ha^{-1} PM, T4=30 t ha $^{-1}$PM, T5=15 t ha^{-1} PM + 25% rec. NP, T6=15 t ha^{-1} PM + 50% rec. NP, T7=30 t ha^{-1} PM +25% rec.NP, T8=30 t ha^{-1} PM + 50% rec.NP. The experiment was laid out in randomized complete block design (RCBD) with three replications.

2.5. Planting and Crop Management

The experiment was conducted during 2013 main cropping season. Planting was done during the second week of June. Initially, two seeds per hill were planted and later on thinned to one plant per hill. A plot size of 6.75 m^2 (1.5 m X 4.5 m) was used. The seeds were sown at spacing of 75 between rows cm and 30 cm between plants. A total of six rows were kept on each plot with each row consisting of 5 plants. Weeds were controlled uniformly for all plots through hand weeding. Late-emerging weeds were also removed by hoeing to avoid competition with maize plants for nutrients and light. Data were recorded from pre-tagged maize plants that are in the central furrows.

2.6. Soil Sampling and Analysis

The soil samples were randomly collected from the experimental field before treatment application in a zigzag manner from a depth of 0-30 cm and composite samples were made. The soil sample was analysed for soil texture, pH, available P, total N, and OC (Organic Carbon) contents. The soil samples thus collected were air-dried and ground to pass through 0.2 mm sieves. Organic carbon was determined following the wet digestion method as described by Walkley and Black (1934). Total N was determined by the Kjeldahl method as described by Jackson (1958). Available P was determined using Olsen methods (Olsen *et al.*, 1954). Soil texture was analysed by Bouyoucos hydrometer method. The pH of the soils was measured (1:2.5 soil: water) using a portable pH meter.

2.7. Data Collection

2.7.1. Plant Growth Parameters

Five plants from each plot were randomly selected and pre-tagged and used for measuring growth parameters such as plant height, number of leaves per plant, total leaf area and leaf area indexat different stages (30, 60, 90 days after sowing and at harvest). In order to determine the leaf area, the lengths of all 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). Likewise, the cobs from the five randomly selected plants at the time of harvest were used to determine yield and yield components. 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 was determined. To determine the cob girth (cm), the diameter of a cob was measured at three places by using vernier calliper and average diameter was recorded as an average cob girth. The grain yield was determined after harvesting from the central furrows of each plot. Unshelled grain yield, from total ears harvested, was measured from the central four rows.

Grain yield: Moisture (12.5 %) adjusted grain yield was determined using the formula:

$$\text{Grain yield} = FW * \left(\frac{100-A}{100-M}\right) * 0.81 \qquad (1)$$

According to Biru (1979) and Nelson *et al.* (1985) where FW= unshelled field weight of maize; A= actual moisture content of the grain at harvest; M= standard moisture content of maize (12.5 %); 0.81= correction factor (shelling percentage of maize). The adjusted grain yield per plot of maize at 12.5% moisture level was converted to kg ha^{-1}.

Harvest index (HI): Harvest index (%) is defined as the ratio of economic yield to total biological yield and expressed in percentage as described in Donand (1962). The harvest index for maize was calculated as follows:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biologica yield (kg/ha)}} \times 100$$

Dry biomass yield (kg ha^{-1}): At maturity two central rows in each plot were harvested, dried to constant weight and weighed.

2.7.2. Statistical Analysis

The analysis of variance (ANOVA) was computed PROC GLM procedures using the Statistical Analysis System (SAS) statistical software version 9.2. To compare treatment means, Tukey test was used at a significance level $\alpha = 0.05$ probability level.

3. RESULTS AND DISCUSSION

3.1. Physico-Chemical Properties of Soil and Poultry Manure

The physico-chemical properties of the pre-planting soil samples collected (0-30 cm) from the experimental site and the chemical composition of poultry manure (PM) used for the experiment were analyzed. Results of the analysis indicated that texture of the soil was dominated by the clay fraction (75% clay) and hence was classified as Clay Table 2. The pH of the soil was 7.1, which is neutral. The total N content of the soil was 0.12% (rated as low) while that of the PM was 16.15 (rated as very high) according to Landon (1991) rating. Thus, the PM was rich especially in nitrogen content Table 2 as it was 135-fold higher than that of the soil. The organic matter content of the soil was 2.9% (rated as medium) while that of the PM was 5.4% (rated as very high) according to Murphy

(1968). Such low OM and total N content of the soil of the experimental site indicate the low fertility status of the soil, which if used without fertilization can potential limit maize growth and hence grain yield. Such rapid decline in fertility status of vertisol, a relatively younger soil compared to nitisol, 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.

Table-2. Physico-chemical properties of soil and poultry manure before planting.

Physical properties					Chemical properties				
Particle size distribution (%)						pH	OM (%)	Total N (%)	Available P (ppm)
Soil	Sand%	Silt%	Clay%	Tex. class	Soil	7.1	2.9	0.12	12.8
	2.5	22.5	75	Clay	PM	8.21	5.4	16.15	19.7

3.2. Effect of Integrated Application of PM and Chemical Fertilizers

3.2.1. Effects on Maize Growth Parameters

3.2.1.1. Effects on Plant Height

The result of the analysis of variance showed that plant height at 30, 60 and 90 days after sowing (DAS) were significantly affected by the treatments ($P<0.001$). At 30 DAS, significantly taller plant height (19.34 cm) was recorded for T7 in which 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied compared to all the other treatments Table 3. However, there were no significant differences between T3, T4, T5, T6 and T8, all of which were at par with each other with respect to plant height Table 3. 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, where 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied which was statistically at par with T5, T4, T8, T3 and T6 Table 3. The shortest plant height at 60 DAS (38.28 cm) was recorded from the control treatment where no PM and chemical NP fertilizer was applied. A similar trend was also observed at 90 DAS Table 3. The taller plants at 90 DAS (251.5 cm) was recorded in response to application of 30 t ha^{-1} PM plus 50% recommended NP fertilizer which was statistically at par with T5, T8, T6, and T4. On the other hand, at 90 DAS the shortest plant height (159.3 cm) was recorded for the control treatment, where no any fertilizer was applied Table 3. In general, taller plants were recorded for the treatments in which reduced doses of inorganic fertilizer was applied in combination with PM. The taller plant height values recorded from the treatments in which organic fertilizer was co-applied with reduced doses of inorganic fertilizer, might be attributed to the availability of balanced nutrients (both macro and micro) in the PM, which through mineralization became readily available for plant uptake. The finding in this experiment is in agreement with that of Makinde (2007); Rajeshwari *et al.* (2007) and Ayoola and Makinde (2009) who also reported longer plant height in maize with combined application of organic fertilizer in combination with reduced doses inorganic fertilizers. Enujeke (2013) reported progressively increased plant height with increasing poultry manure levels from 0 to 30 t ha^{-1} in maize, with clear and significant plant height difference observed between application of 0, 10, 20 and 30 t ha^{-1} PM. However, their finding contradicts with that of our in that no difference in plant height was observed especially between 15 and 30 t ha^{-1} PM application.

Table-3. Effect of poultry manure and NP fertilizer rates on height of maize plant at different growth stages.

Treatments	Plant height(cm)		
	30 DAS	**60 DAS**	**90 DAS**
T1=Control	8.62^{d}	38.28^{b}	159.3^{c}
T2=Recom. NP(110 kg N-46 kg P_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	1.9	18.2	39.5
CV (%)	4.4	8.5	6.0

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

3.2.1.2. Effects on Numbers of Leaves per Plant

The result of the analysis of variance showed that the numbers of leaves per plant at 30, 60 and 90 DAS were significantly (P<0.001) affected by the treatments. At 30 DAS, the application of 30 t ha^{-1} PM plus 50% recommended NP fertilizer (T7) resulted in the highest number of leaves per plant (3.9) compared to all the other treatments Table 4. However, there was no significant difference between T4, T5, T6, and T8 which were all statistically at par in terms of leave number per plant. The application of recommended NP rates gave significantly more number of leaves per plant (3.3) compared only 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) Table 4. Similarly, higher number of leaves per plant (7.8) at 60 DAS was recorded for T5 where 15 t ha^{-1} PM plus 50% recommended NP fertilizer was applied compared to all the other treatments except T7 and T8. The application of recommended NP rates (standard control) gave significantly more number of leaves per plant (7.0) at 60 DAS compared only to the absolute control for which the lowest number of leaves per plant (4.4) recorded Table 4. At 90 DAS, all levels of PM or in combination with 25% or 50% recommended NP fertilizer rates produced comparable number of leaves which were statistically at par with each other Table 4. The control treatment to which no any fertilizer was applied had the least number of leaves per plant (12.0) at 90 DAS Table 4. At all maize growth stages (30 , 60 ,90 DAS), more number of leaves per plant was observed at all levels of PM alone or in combination with 25% or 50% recommended NP fertilizer rates, compared to both absolute and standard controls Table 4. The more leaf number per plant observed for 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 with these treatments during the growth period of the crop. Increase in number of leaves per plant in maize due to integrating organic and inorganic fertilizers was also reported by Makinde (2007) and Rajeshwari *et al.* (2007) and specifically due to poultry manure amendment to NP fertilizers have been reported by Enujeke (2013) which further substantiate the present findings.

Figure-1. Control plot (left) and the treatment plot (right).

Source: Photo taken by Tesfaye Balemi.

Table-4. Effect of poultry manure and inorganic NP fertilizer on number of leaves of maize plant.

Treatment	Number of leaves per plant		
	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 a column followed by the same letter are not significantly different at α=0.05 according to Tukey test.

3.2.1.3. Effects on Total Leaf Areas per Plant

The result of the analysis of variance showed that total leaf areas per plant at 30, 60 and 90 DAS were significantly ($P<0.001$) affected by the treatments. At 30 DAS, the comparison of treatment means indicated that significantly larger leaf area (140.5 cm^2) was recorded for T7 in which 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied compared to all the other treatments Table 5. There was no significant difference between T5, T4, T8, T6 and T3, 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 (33.7 cm^2), where neither PM nor chemical NP fertilizer was applied Table 5. 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 Table 5. The application of recommended NP rates gave significantly larger leaf area (1756.4 cm^2) than the absolute control which recorded the smallest leaf area (1098.3cm^2). At 90 DAS, all levels of the applied PM alone or all levels of PM combined with 25% or 50% recommended NP fertilizer produced leaf area which was significantly larger compared to both the absolute and standard controls Table 5. 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. Similar observation was reported by Enujeke (2013) who also observed progressive increase in leaf area with increase in poultry manure rate.

3.2.1.4. Effects on Leaf Area Ratio

The application of PM alone or PM integrated with 25%, or 50% recommended NP fertilizer produced a leaf area ratio which was significantly higher than the controls Table 5. However, the application of 15 and 30 tons ha^{-1} PM alone and the PM levels combined with 25% or 50% recommended NP fertilizer did not produce significantly different LAI. The lowest LAI (1.7 cm^2) was recorded from the control treatment where neither PM nor chemical NP fertilizer was applied Table 5. Leaf area index of a crop at a particular growth stage indicates the photosynthetic potential at whole plant level. The higher LAI could be related to more number of leaves and/or higher leaf area per plant Table 5. The larger leaf area and LAI observed with the treatments in which PM was applied alone or in combination with reduced dose of recommended NP fertilizer rates Table 5 might be due to the ability of the organic manure to supply nutrients necessary to promote more vigorous growth and 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 co-applied. Similarly, Boateng *et al.* (2006) and Enujeke (2013) also reported higher total LA and LAI in maize for the treatments in which PM and chemical fertilizers were applied together, and the LAI also increased with increasing PM levels (Boateng *et al.*, 2006).

Table-5. Effect of poultry manure and inorganic NP fertilizer on leaf area and leaf area index of maize.

Treatments	Leaf area per plant(cm^2)			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(110kg N &46kgP_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 a column followed by the same letter are not significantly different (Tukey test) at α=0.05.

3.2.2. Effects on Grain Yield Components

3.2.2.1. Effects on Number of Cobs per Plant

The result of the analysis of variance showed that the number of cobs per plant was significantly (P<0.001) affected by the treatments. Results showed that all levels of PM alone or combination of both 15 and 30 t ha^{-1} PM with 25% or 50% recommended NP fertilizer produced similar number of cobs per plant (2 cobs), which were significantly higher than that of the two controls (zero and standard controls) Table 6. The recommended NP fertilizer rates (T2) had little effects on number of cobs per plant compared to the integrated application of PM and chemical NP fertilizers. The lowest number of cobs per plant (1.3 cob) was recorded from the control treatment where neither PM nor chemical NP fertilizer was applied Table 6. The significant increase in number of cobs per plant for the treatments in which PM was applied either alone or in combination with reduced doses of chemical fertilizers might be due to the rapid mineralization of the PM under favourable environmental conditions positively influencing availability of macro and micro nutrients and could also be due to its positive effect on soil conditioning/improved soil physical properties. These results are in agreement with those of Shah and Muhammad (2000) who also reported more number of cobs per plant when organic and inorganic fertilizers are applied together. The reason for increased cob number with combined application of PM and inorganic fertilizer may be due to adequate and balanced supply of both macro and micronutrients which enhanced crop growth and hence cob number. The integrated application of PM and chemical fertilizers 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 sink. However, no significant difference was observed between application of 15 t ha^{-1} and 30 t ha^{-1} PM on number of cobs per plant in the present investigation, indicating that increasing the level of organic fertilizer alone is not as effective as co-application of both organic and inorganic fertilizer, which is in line with the report of Farhad *et al.* (2009) who also did not observe any significant effect of PM rates on maize cob number per plant.

3.2.2.2. Effects on Cob Length

Cob length was also significantly affected by the treatments (P<0.001). Results showed that the longest cobs (23.7 cm) were 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 fertilizers was applied Table 6. 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 ones 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 Cob length and yield Table 8 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.

3.2.2.3. Effects on Cob Girth

Cob girth was also significantly affected by the treatments ($P<0.001$). All the treatments produced cob girths which were significantly higher than both the zero and standard controls. The biggest cob girth (16.8 cm) was recorded for T7, where 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied Table 6. There was no significant difference between T3, T4, T5, T6, T7 and T8. The smallest cob girth (10.1 cm) was recorded for the control treatment, where no fertilizer was applied Table 6. The biggest cob girth observed with the treatments in which PM alone or PM integrated with inorganic fertilizer was applied might be due to better availability of nutrients to the plants grown under these treatments and consequently better assimilate formation and transport to the sink (cob).This result was similar to the earlier reports of Tolessa and Friesen (2001) who also observed bigger cob girth from a treatment where organic and inorganic fertilizer were co-applied.

3.2.2.4. Effects on Number of Grain Rows per Cob

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 obtained for 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 more number of grain rows per cob only compared to the absolute control (10.0). Number of grain rows per cob is an important yield determining factor in maize (Farhad *et al.*, 2009). 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 both levels of PM alone or each level combined with 25% or 50% recommended NP rates compared to both absolute and standard controls Table 6. Our result is similar to that of Farhad *et al.* (2009) who also observed significantly higher number of grain rows per cob at higher PM rate.

3.2.2.5. Effects on Number of Grains per Row

The number of grains per row was also significantly affected by the treatments ($P<0.001$). The highest number of grains per rows (45.6) was recorded from T7, where 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied which was statistically at par with T8, T6, T5, T4 and T3 Table 6. The application of recommended NP rates gave significantly higher number of grains per row (39.2) compared only to the absolute control (18.5) Table 6. Number of grains per row is also an important parameter that positively contributes to the grain yield (Farhad *et al.*, 2009). 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 were in agreement with the findings of Boateng *et al.* (2006) who reported that PM significantly increased maize yield and yield components such as number of grains per row. Number of grains per row did not differ between 15 and 30 t ha^{-1} PM in our study, but differed between 4-6 t ha^{-1} and 8-12 t ha^{-1} PM rates according to Farhad *et al.* (2009).

Table-6. Effect of poultry manure and NP fertilizer rates on 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	1.3c	12.8e	10.1c	10.0c	18.5d	175.5d
T2= Reco.NP(110kgN/46kgP_2O_5)	1.6b	20.5d	13.9b	11.0bc	39.2c	431.9c
T3=15 t ha^{-1} PM	1.9a	22.4c	16.3a	12.2ab	43.6a	503.0b
T4=30 t ha^{-1} PM	2.0a	23.3b	16.5a	12.4ab	43.8a	525.8ab
T5= 15 t ha^{-1} PM + 50% Rec.NP	2.0a	23.4ab	16.7a	12.6a	44.6a	550.9ab
T6=15 t ha^{-1} PM + 25% Rec. NP	1.8ab	23.1b	16.3a	12.1ab	44.4a	516.0ab
T7=30 t ha^{-1} PM+50% Rec. NP	2.0a	23.7a	16.8a	12.8a	45.6a	565.0a
T8= 30 t ha^{-1} PM + 25% Rec. NP	2.0a	23.2b	16.3a	11.6bc	44.2a	502.8b
LSD(P≤ 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 within the same column followed by the same letter are not significantly different (Tukey test) at P=0.05.

3.2.2.6. Effects on Number of Grains per Cob

The number of grains per cob was significantly affected by the treatments ($P<0.001$). Results showed that significantly the highest number of grains per cob (565.0) was recorded for T7, where 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied, which was statistically comparable with T6, T5, and T4 Table 6. The application of recommended NP fertilizer rates gave significantly higher number of grains per cob compared only to the zero control (175.5). The application of all levels PM 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 6. 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 which contributed to grain formation and development. Enujeke (2013) observed the highest number of grains per cob at the highest PM rate (30 t ha^{-1}), compared to lower rates such as 10 and 20 t ha^{-1} and the lowest number of grains per cob for zero control. In our case, however, the number of grains per cob did not differ between 15 and 30 t ha^{-1} PM rates.

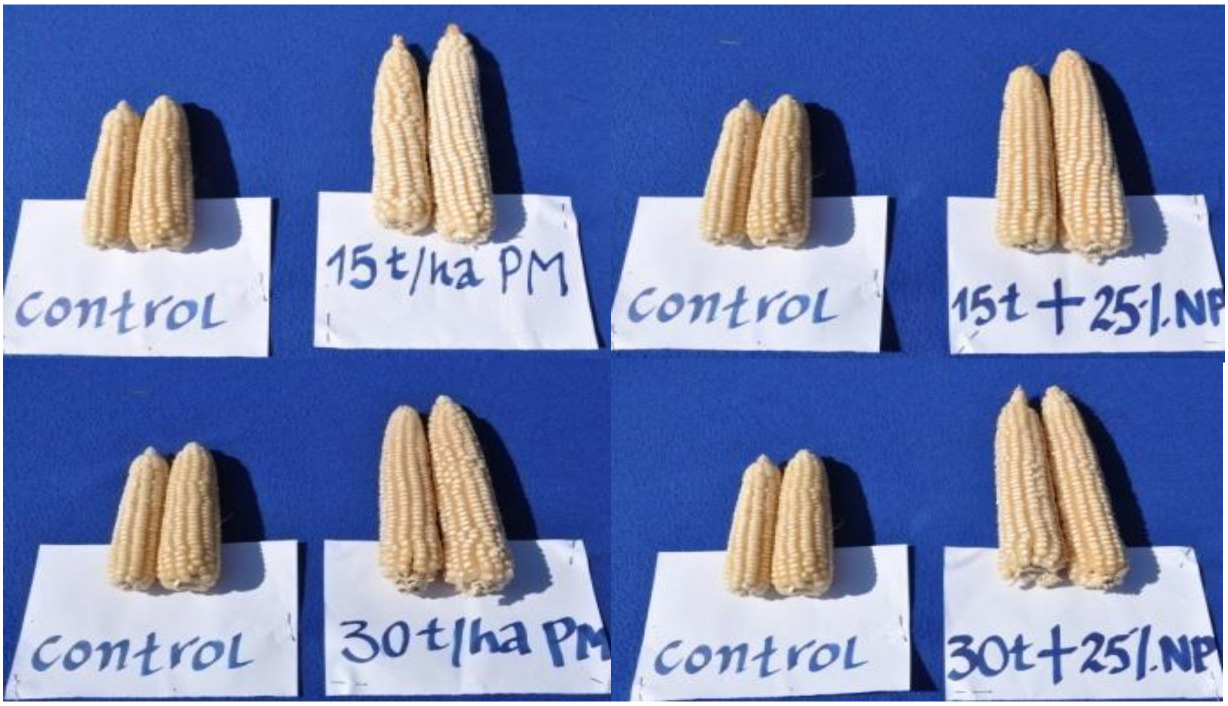

Figure-2. Picture showing the effect of PM and NP fertilizer application on maize cobe size.
Source: Photo by Tesfaye Balemi.

3.2.2.7. Effects on 1000-Grain Weight

The analysis of variance showed that 1000-grain weight was significantly ($P<0.001$) affected by the treatments. The highest 1000-grain weight (460.4 g) was recorded from T7, in which30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied which was statistically at par with T8, T6, T5, T4 and T3 Table 7. The application of recommended NP rates (T2) gave slightly higher 1000-grain weight (394.9 g) compared to the zero control (372.1 g) Table 7. The higher 1000-grain weight was recorded at all levels of PM alone or in combination with 25%, 50% recommended NP fertilizer compared to both zero and standard controls, might be due to the adequate nutrient supply especially of N from the organic source (PM), which might have enhanced the source 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 also reported significantly higher 1000-grain weight with the application of recommended dose of chemical fertilizer in combination with FYM. Farhad *et al.* (2009) observed progressive increase in 1000-grain weight with increase in PM rates from 4 to 12 t ha^{-1}, while we observed no difference between the application of 15 and 30 t ha^{-1} on 1000-grain weight.

3.2.2.8. Effects on 1000-Grain Weight

The dry biomass yield was significantly affected by the treatments ($P<0.001$). The highest dry biomass yield (46,032 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 7. The application of recommended NP fertilizer rates (T2) gave significantly higher dry biomass yield (2888.9 kg ha^{-1}) than the absolute control Table 7. 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 higher biomass yield with the integrated application of manures and synthetic fertilizers.

3.2.3. Effects 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 from 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 zero control (62.2 q ha^{-1}).Grain yield obtained with the application of 30 t ha^{-1} PM plus 50% recommended NP fertilizer was by 27% higher compared to that of the recommended NP rate and by more than 2-fold higher compared to the zero control. Grain yield is a function of interaction among various yield components that were affected differentially by the growing conditions and crop management practices (Farhad *et al*., 2009). The highest grain yield in T7 is ascribed to the higher number of grains per cob and higher 1000-grain weight produced by this treatment since the relationships between these parameters were significantly positive Table 8.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. The yield increase could possibly be due to availability of both more macro and micronutrients when organic and inorganic are applied in combination. These results are in agreement with the findings of Boateng *et al.* (2006) who suggested that the combined application of PM and NPK brings about complementary and synergistic effects on maize growth and yield. Enujeke (2013) observed the highest grain yield at the height PM rate (30 t ha^{-1}), compared to lower rates such as 10 and 20 t ha^{-1} and the lowest grains yield for zero control. In our case, however, the grains yield did not differ between 15 and 30 t ha^{-1} PM rates.

Table-7. Effect of poultry manure and NP fertilizer rates on yield and yield components of maize.

Treatments	1000 grain weight (gm)	Dry biomass (kg/ha)	Grain yield(q/ha)	Harvest index (%)
T1=Control	372c	19048c	62.2c	32.6b
T2= Reco. NP(110kgN/46kgP_2O_5)	394bc	28889bc	104.4b	35.2ab
T3=15 t ha^{-1} PM	436ab	38730ab	124.6ab	35.9ab
T4=30 t ha^{-1} PM	452a	40317ab	124.7ab	36.2ab
T5= 15 t ha^{-1} PM + 50% Rec.NP	457a	40952ab	125.7ab	36.4ab
T6=15 t ha^{-1} PM + 25% Rec. NP	425abc	35873ab	125.6ab	34.5b
T7=30 t ha^{-1} PM+50% Rec. NP	460a	46032a	132.7a	39.1a
T8= 30 t ha^{-1} PM + 25% Rec. NP	431ab	37460ab	126.6ab	35.8ab
LSD (P=0.05)	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.

The physiological efficiency of maize to partition the dry matter into its economic (grain) yield is referred by harvest index (Hay, 1995). Results showed that the highest harvest index (39.1%) was recorded with T7, where 30 t ha^{-1} PM plus 50% recommended NP fertilizer was applied which was comparable with T2, T3, T4, T5, and T8 Table 7. On the other hand, the lowest harvest index (32.6%) was recorded from the control treatment where no form of fertilizer was applied. The higher the harvest index, the greater the grain yields (Farhad *et al.*, 2009). It was observed that significantly higher HI was obtained by the integrated use of organic and NP fertilizers compared to when each form is applied alone. These results is in line with that of Khaliq *et al.* (2004) who also reported higher harvest index in maize organic and inorganic fertilizers are applied combined.

3.3. Relationship between Grain Yield and Growth and Yield Components of Maize

Data presented in Table 8 showed that there is a highly significant positive relationship between growth parameters, yield components and grain yield ($P<0.001$). 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) also reported significant positive relationship between grain yield and growth and yield component parameters such as cob length, biomass yield per plant, number of rows per cob and number of grains per cob, which support the present finding.

4. CONCLUSIONS

The application of poultry manure (PM) alone or in combination with reduced doses of recommended NP fertilizers enhanced maize growth, yield and yield components over both the negative and standard controls. The results of this study showed that significantly longer plant height, more number of leaves per plant, higher leaf area and 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 30 t ha^{-1}PM plus 25% or 50% recommended chemical NP fertilizer rates compared to both negative and standard controls. The highest grain yields 132.7q ha^{-1} was obtained with the application of 30 t ha^{-1} PM plus 50% recommended NP fertilizer rates. Results of the correlation analysis indicated that, all growth and yield component parameters showed significant positive relationship with grain yield, indicating that all the parameters positively contributed to grain yield. The combined application of organic manure with reduced doses of NP fertilizer rates significantly improved maize grain yields. Therefore, on the basis of these results, it can be concluded that, the application of 30 t ha^{-1} PM along with 50% recommended NP fertilizer rate can be recommended to get higher maize grain yield on vertisol at Ambo and similar agro-ecologies. Such an integrated nutrient management approach also contributes to reducing maize production cost and environmental impact of applying large quantities of chemical fertilizers.

Table-8. Relationship between growth parameters, yield components andgrain 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.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study.

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