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Research paper

Grain yield response of maize *(Zea mays* L.*)* to variable rates of compost and nitrogen fertilizer integrations

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Declining soil fertility is one of the major factor limiting crop productivity in Ethiopia. This experiment was therefore, conducted to evaluate grain yield response of maize to variable rates of compost and urea fertilizer integration. The experiment was arranged in factorial combination of three level of compost (0, 5 and 10 t ha^{-1}) and three levels of mineral N fertilizer in the form of urea (0, 92 and 105 Kg ha^{-1}). The experiment was laid out in randomized complete block design with three replications at the experimental field of Hawassa University, Southern Ethiopia. The result revealed significant difference among compost levels for all of the traits studied. There is significant difference among nitrogen levels for grain yield, number of kernel per row, number of kernel per ear and hundred grins weight. Significant difference among treatments (combination of compost level and nitrogen level) were observed for grain yield, number of rows per ear, number of kernel per row, number of kernel per ear and hundred kernel weights. The combination of compost and urea at the rate of 10 t ha^{-1} and 105 kg ha^{-1}, respectively, produced the highest kernel yield (11.3 t ha^{-1}) followed by (10 t ha^{-1} and 92 kg ha^{-1}) and (5 t ha^{-1} and 105 kg ha^{-1}) with compost and urea combination 9.4 and 8.3 t ha^{-1} grain yield respectively. Generally, the combination of 10 t ha^{-1} compost with urea at the rate of 105 kg ha^{-1} resulted with 63% yield advantage compared with the control plot. It is therefore; wise to recommend 10 t ha^{-1} compost combinations with 105 kg of urea for improved maize yield for the farmers in the research area and areas with similar agro-ecology and resources availability.

Key words: compost, fertilizer integrations, inorganic fertilizer, maize, organic fertilizer

INTRODUCTION

In Ethiopia maize is one the most important strategic crop ranking second following teff in area coverage and first in total production (CSA, 2018). The average yield of maize in Ethiopia is 3.94 t ha^{-1} (CSA, 2018) which is very low compared to the world average yield of 5.4 t ha^{-1} (FAO, 2016). This wide yield gap is attributed to an array of biotic and abiotic stresses (EARO, 2002). However, in Ethiopia, low soil fertility and use of low input levels are some of the major limitations for crop production (Abreha et al., 2013). Maize is an exhaustive cereal crop having higher potential of absorbing a large number of nutrients from the soil during different growth stages. Achieving high yield of maize requires an adequate and balanced supply of nutrients as declining soil fertility is a prominent constraint for maize production (Barbieri et al., 2012). Chemical fertilizers are beyond the reach of farmers due to high price, limited availability, low nutrient composition and high labor requirement of organic fertilizers (Abera et al., 2005) make them not to meet crop demand over large area. Continuous application of inorganic fertilizers to increase crop yield, resulted in deterioration of soil physical, chemical, and biological properties. And also it cannot guarantee long term productivity on many soils since they are not effective in maintaining soil fertility, so that needs sustainable options. Hence, combined use of organic with inorganic fertilizers sources has considerable importance as to take remedial measures in fertility management and boosting the production. Therefore, keeping the above points in view, this study was conducted to evaluate the influence of organic and inorganic fertilizers on yield and yield components of maize to different rates of compost and N fertilizer.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at the experimental field of Hawassa University, Southern Ethiopia. Hawassa is 270 km far from Addis Ababa, the capital city of Ethiopia. Geographically, the experimental area is situated at 7°3' N, 38° 28'E and 1708 m.a.s.l with mean annual rainfall of 900 mm, mean minimum and maximum annual temperature of 13°C and 27°C, respectively (Abera and Wolde-Meskel, 2013). The climatic condition of the area is hot to warm sub-moist humid climate zone with warmer temperature especially during the dry season. The soil type of the experimental area is andisol. The farming system of this area is described by cultivation of enset, maize, potato, vegetables (head cabbage, tomato, onion, garlic, and carrot), coffee and common bean. A cattle rearing is an integral part of the farming system (CSA, 2016).

Methodology adopted

A field experiment was conducted at the Research Farm of Hawassa University during 2018 main cropping season, to assess the influence of integrated use of urea and compost on yield of maize. The experiment was arranged in factorial combination of three level of compost (0, 5 and 10 t ha^{-1}) and three levels of inorganic fertilizer (urea) which were 0, 92 and 105 t ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) with three replications. Composite soil sample at 0-30 cm was collected from the experimental field and analyzed for soil characteristics (Table 1). The compost was prepared from market residues which are vegetable wastes and food leftovers from hotel. The characteristics of compost are presented in Table 2. The field was thoroughly prepared. Lay-out was carried out according to the experimental plan, with treatment plot size of 3.2 × 3.2 m. Compost and Urea at appropriate ratios were uniformly distributed in relevant treatment plots and thoroughly mixed into the soil. Urea fertilizer was applied in the split form; half at sowing and the other half at knee height. After thorough land preparation and fertilizer application, maize (variety: BH546) was planted in four row plot of 3.2 m long with spacing of 0.8 m and 0.4 m between rows and plants, respectively, (plot area of 10.24 m^2). The trial was hand planted with three seeds per hill, which was later thinned to two plants per hill to get a total plant population of 62,500 per hectare. Planting was conducted on the onset of the main rainy season after an adequate soil moisture level was reached to ensure good germination and seedling development. All cultural practices like weeding and cultivation was done manually throughout the entire growing season as per required. Data were collected for number of ears per plant (EPP), ear length (EL) (cm), number of kernel rows per ear (NKRPE), number of kernels per row (NKPR), number of kernels per ear (NKPE), 100 kernel weight (HKW) (g) and grain yield (GY) (t ha^{-1}). Grain yield per hectare was calculated based on field weight per plot, moisture content adjusted to 12.5%, 80% constant shelling percent and t ha^{-1} adjustment factor.

Soil sampling and analysis

Soil samples were taken randomly from the experimental fields from 0-30 cm depth before planting to determine initial fertility status of the soils using augur in X pattern. The samples were mixed well and composite representative sample were prepared for analysis of physical (texture and structure) and chemical (pH, total N, available P, available potassium, exchangeable potassium, exchangeable sodium, exchangeable calcium, exchangeable magnesium, organic carbon, C: N ratio and CEC) properties of a soil (table 1). Texture, acidity and electron conductivity of the soil were tested by hydrometer, potentiometric and conductivity cell potentiometric test method respectively. Nitrogen content of the soil was determined by the Kjeldhal procedure as described by Jackson (1958) and available potassium, exchangeable sodium, exchangeable calcium, exchangeable potassium, exchangeable magnesium and sum of cations were determined by ammonium acetate method (Thomas, 1982). Also organic carbon and available phosphors were determined by Walk and lay Black and Olsen test method respectively (Watanabe and Olsen, 1965).

Table 1. Characteristics of soil of the experimental site

Parameter		Unit	Value
Acidity	PH-H_2O	-	7.07
Calcium	Ca^{2+}	Cmol(+)/Kg soil	14.82
Magnesium	Mg^{2+}	Cmol(+)/Kg soil	2.59
Sodium	Na^+	Cmol(+)/Kg soil	1.02
Potassium	K^+	Cmol(+)/Kg soil	3.76
Phosphorus	P	mg/Kg(ppm)	67.42
Sulphate	S	mg/Kg(ppm)	10.66
Iron	Fe	mg/Kg(ppm)	122.41
Manganese	Mn	mg/Kg(ppm)	254.72
Zinc	Zn	mg/Kg(ppm)	18.85
Boron	B	mg/Kg(ppm)	0.58
Copper	Cu	mg/Kg(ppm)	1.77
Molybdenum	Mo	mg/Kg(ppm)	0.19
Silicon	Si	mg/Kg(ppm)	666.28
Organic Carbon	OC	%	1.45
Total Nitrogen	N	%	0.13
C:N	C/N	-	1.13
Cation Exchange capacity		Me/100g soil	
Sand		%	43
Clay		%	27
Silt		%	30
Textural class		Clay loam	

Physico-chemical analysis of the compost

The compost was prepared at Hawassa University College of Agriculture experimental site. The sample of compost was dried for chemical analysis and the quality parameters of the compost like nitrogen, phosphorus, potassium, compost pH value, organic carbon, carbon - nitrogen ratio (C: N ratio) and heavy metals determined. Nitrogen content of the compost was determined by the Kjeldhal procedure as described by Jackson (1958) and Calcium (Ca), Potassium (K), Magnesium (Mg), Phosphorus (P) Sulfur (S),Silicon (Si),Molybdenum (Mo), and Boron (B) Copper (Cu), Iron (Fe), Manganese (Mn)and Zinc (Zn) were determined by Mehlich-3 method. Whereas Cation Exchange Capacity was determined by Ammonium Acetate Method (Black, 1965) and the percentage moisture content was calculated from the equation (MAFF, 1986).

$$\text{Moisture content (\%)}=\{(\text{wet mass-dry mass})/(\text{wet mass})\}\times 100$$

The carbon- nitrogen ratio of compost was determined following the formula (Martin, 1991).

$$C{:}N=TOC(\%)/(TN(\%))$$

Table 2. Physico-chemical characteristics of the compost used for the experiment

Parameters	Values
Moisture (%)	32
pH-H_2O	7.00
Total Nitrogen (%)	0.25
Phosphorus (mg/kg(ppm)	251.03
Potassium(Cmol(+)/Kg compost)	7.92
Sodium(Cmol(+)/Kg compost)	1.72
Organic Carbon (%)	2.15
Calcium(Cmol(+)/Kg compost)	23.53
Magnesium(Cmol(+)/Kg compost)	5.69
Sulphate (mg/kg(ppm))	132.81
Iron(mg/kg (ppm)	206.54
Manganese (mg/kg (ppm))	137.71
Zinc(mg/kg (ppm))	12.93
Boron (mg/kg (ppm))	2.37
Copper (mg/kg (ppm))	1.71
Molybdenum (mg/kg (ppm))	0.20
Silicon (mg/kg(ppm))	794.20
C:N	8.70

RESULTS AND DISCUSSION

The result revealed that as there is significant difference among compost levels for all of the traits studied. There is significant difference among nitrogen levels for grain yield, number of kernel per row, number of kernel per ear and hundred grins weight. Significant difference among treatments (combination of compost level and nitrogen level) were observed for grain yield, number of rows per ear, number of kernel per row, number of kernel per ear and hundred kernels weights (table 3). Data pertaining to grain yield as affected by integrated nutrient management is presented in table 4. Grain yield differed significantly among different rates of organic and inorganic fertilizers. It varied from the maximum (11.3 t ha^{-1}) attained in 10 t compost + 105 urea to the minimum value 4.2 t ha^{-1} observed in 0 t compost + 0 urea. The maximum grain yield was 62.83% more than the minimum value. The minimum yield was statistically different from others and also the maximum grain yield was statistically different from others. This result is similar to Shah et al., 2009 who reported grain yield was significantly affected by combined application of inorganic fertilizer with FYM. Laekemariam and Gidago, 2012; Abunyewa et al., 2007 and Rajeshwari et al., 2007 reported higher grain yield of maize from combined application of fertilizer. Ear length is an important yield contributing parameter of maize. It substantially contributes to grain yield of maize influencing both numbers of grains per cob and grain size. Ear length of maize was significantly affected by the application of fertilizer. Except the control plot all of the treatments are significantly at par. The maximum ear length (20.20) was attained in 10 t ha^{-1} compost + 105 kg ha^{-1} of urea. It was 26.24% more than the control plot (14.97). This finding is in agreement with the Fanuel L. and Gifole G. 2013; Khan 2008 and Rajeshwari *etal* 2007 who reported a significant increase in ear length with increasing rates of nitrogen fertilizer application from different sources. Response of maize plants in terms of number of kernels per ear to integrated nutrient management was indicated in table 4. Comparison of means showed that 10 t ha^{-1} of compost + 105 Kg ha^{-1} of urea showed highest number of kernels per ear (561.15) which is significantly different from others. The minimum number of kernels per ear (302.51) was attained from the control plot. This finding is in line with Fanuel L. and Gifole G. 2013; Laekemariam and Gidago, 2012; Shah *et al.*, 2009; Shah and Ahmed, 2006 and Ahmed, 2006 who reported a significant effect of integration of organic and inorganic fertilizer on number of kernels per ear. A significant effect of fertilizer application on number of kernel rows

Table 3. Mean square for grain yield and yield components of maize as affected by integrated use of urea and compost

Source	GY	EPP	EL	NKRPE	NKPR	NKPE	HKW
Rep	3.87ns	0.0003ns	0.16ns	0.31ns	13.71 ns	884.34 ns	0.70 ns
Cm	18.49***	0.13*	14.57**	4.38***	47.82**	19917.08***	82.16***
Nr	21.47***	0.05ns	4.40ns	0.47 ns	76.01***	16669.85***	166.74***
Cm*Nr	2.55**	0.08ns	4.36ns	1.25*	35.21**	10759.89**	27.65**
CV (%)	**8.38**	**14.04**	**7.21**	**4.24**	**6.53**	**8.21**	**5.79**

GY= grain yield, EPP= number of ears per plant, EL= ear length, NKRPE= number of kernel rows per ear, NKPR= number of kernels per row, NKPE= number of kernels per ear, HKW= hundred kernels weight, Cm=compost, Nr=N rate, ***= Significant at P<0.001 level of probability, ** significant at P<0.01, * = Significant at P<0.05 level of probability.

Table 4. Grain yield and yield components of maize as affected by integrated use of urea and compost

No	Treatment		GY (t ha^{-1})	EPP	EL	NKRPE	NKPR	NKPE	HKW(gm)
	Compost (t ha^{-1})	Urea (kg ha^{-1})							
1	0	0	4.20 f	0.97b	14.97b	11.73d	25.67c	302.51c	30.55d
2	0	92	7.13 de	1.20ab	18.63a	13.33abc	35.67b	475.92b	40.67bc
3	0	105	7.54 cde	1.47a	18.17a	12.93bc	37.80ab	489.68b	42.03b
4	5	0	7.167 cde	1.27ab	18.73a	12.67cd	36.20ab	457.87b	37.49c
5	5	92	8.12 cd	1.33a	18.00a	11.87d	37.07ab	439.79b	37.95c
6	5	105	8.257 c	1.20ab	18.20a	12.53cd	35.53b	444.21b	40.09bc
7	10	0	6.763 e	1.47a	19.23a	13.73ab	35.07b	481.76b	37.65c
8	10	92	9.4 b	1.40a	19.93a	13.33abc	37.40ab	498.03ab	43.23b
9	10	105	11.30 a	1.47a	20.20a	14.00a	40.07a	561.15a	49.09a
CV(%)			**8.38**	**14.04**	**7.21**	**4.24**	**6.53**	**8.22**	**5.79**
LSD			**1.126**	**0.318**	**2.304**	**0.947**	**4.02**	**65.61**	**3.995**

GY= grain yield, EPP= number of ears per plant, EL= ear length, NKRPE= number of kernel rows per ear, NKPR= number of kernels per row, NKPE= number of kernels per ear, HKW= hundred kernels weight. Means with the same letter within a column are not statistically significant.

per ear indicated in table 4. 10 t ha^{-1} compost + 105 kg ha^{-1} urea showed the maximum number of kernel rows per ear (14.00) which was 16.4% more than the control plot (11.73). Number of kernels per row was significantly influenced by fertilizer rates (table 4). The maximum number of kernels per row 40.07 was obtained from 10 t ha^{-1} compost + 105 kg ha^{-1} urea whereas the minimum 25.67 was recorded from the control plot. Hundred kernels weight was significantly influenced by fertilizer application (table 4). 10 t ha^{-1} compost with 105 kg ha^{-1} urea showed the maximum hundred gram weight (49.09) which was 37.8% more than the control plot (30.55). Similar result was reported by Shah et al., 2009 who reported that thousand kernels weight was significantly affected by combined application of inorganic fertilizer with FYM.

CONCLUSION

The results of the current experiment revealed that the integrated use of urea and compost performed better than the use of urea or compost alone in terms of improving yields and yield components of maize in the current experiment area. The combination of 10 t ha^{-1} organic urban waste sourced compost when combined with 105 kg ha^{-1} of urea resulted with the highest maize yield (11.3 t ha^{-1}) compared with the control and the remaining treatment combinations. Therefore, the integration of 10 t.ha^{-1} compost with 105 kg ha^{-1} of urea can be recommended for enhanced yield of maize in the research area and areas with similar agro-ecology.

AUTHOR CONTRIBUTIONS

Tewodros Ayalew and Tarekegn Yoseph developed the concept and the final proposal for the research project, established the experiment and contributed for the manuscript write-up. Haimanot Beruk involved in the designing of the experiment, conducted field experiment and analyzed the data and drafted and finalized the manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

ETHICS APPROVAL

Not applicable.

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