Indian Journal of Agricultural Sciences **94** (3): 286–290, March 2024/Article
https://doi.org/10.56093/ijas.v94i3.142727

Effect of lime, blended fertilizer and vermicompost on maize (*Zea mays*) yield in Assosa district, north-western Ethiopia

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Received: 21 September 2023; Accepted: 19 January 2024

ABSTRACT

Application of organic and mineral fertilizers improves crop productivity and availability of plant nutrients. Further investigation into their integral application is crucial to obtaining optimum crop productivity. A field experiment was conducted during 2020–21 and 2021–22 at experimental field station in Benshangul Gumuz, Assosa University, Assosa, Ethiopia to investigate the response of maize (*Zea mays* L.) yield to lime, blended NPSZnB fertilizer and vermicompost. Two lime levels, three vermicompost levels, and three blended fertilizer levels were factorially combined and laid out in a randomized complete block design (RCBD). The integral application of organic fertilizer with blended fertilizer with lime significantly affected the agronomic parameters. Grain yield, number of grains per cob, 1000-seed weights, plant height, and days to 50% tasseling were parameters most affected by the amendments. Integral application of 50% of the recommended rate of blended fertilizer and vermicompost with lime improved maize yield by 53%, while the application of NPSZnB and vermicompost individually improved maize yield by 34% and 22% over the control treatment. One tonne of vermicompost and lime could substitute 38 kg and 23 kg of blended fertilizer, respectively. In conclusion, the integrated application of NPSZnB and vermicompost with the recommended amount of lime was the best soil fertility management option. In terms of grain yield and net benefit, 4 t/ha lime, 2.5 t/ha vermicompost and 100 kg/ha blended fertilizers were recommended for optimum maize production in the Assosa area and similar agroecologies.

Keywords: Blended fertilizer, Integrated application, Lime, Maize, Urea, Vermicompost

Maize (*Zea mays* L.) is the first world ranked cereal in the volume of production next to rice and wheat (Erenstein *et al.* 2022). Ethiopia is Africa's fourth biggest maize producer next to South Africa, Nigeria and Egypt. Maize is the first and second crop in terms of volume of production and area coverage in Ethiopia even though the yield of the crop is low in the country (CSA 2020). The national, Benshangul Gumuz region and Assosa area average maize yields are 4.18 t/ha, 4.23 t/ha, and 4.27 t/ha respectively (CSA 2020; CSA 2021) which is lower than the global average yield of 5.48 tonnes/ha (USDA 2022).

Effective and efficient soil fertility amendment activities with integrated application of organic and inorganic fertilizers are very important in amending the acidity of the soil and improving soil fertility as well as crop yields (Majee *et al.* 2021) because soil nutrient depletion and organic matter loss are the critical limiting factors for cereal crop yield and yield component reduction (Workineh 2020). Like all other crops, maize plants also require at least 17 essential nutrients to grow and produce grain (Kumar *et al.* 2018). The treatment of acidic soil by application of lime was widely practiced and recommended to minimize the negative effects of soil acidity on nutrient availability and crop productivity (Geremew *et al.* 2020, Wegene *et al.* 2021). The integral addition of lime with vermicompost (VC) ameliorates the adverse effects of soil acidity, improves soil fertility, nutrient availability and minimizes the concentration of Al concentration, and increases sustainable maize production with improved productivity (Wegene *et al.* 2021, Negese and Wogi 2023).

In western Ethiopia, the integral application of organic and chemical fertilizers to solve the soil infertility problem, and create optimum soil conditions to improve crop yield in acidic soil has been growing (Getahun *et al.* 2020). The low productivity of crops in the study area exposes the farmers to food insecurity. Therefore, the study was carried out to evaluate the response of maize yield to the effects of lime, blended fertilizer, and vermicompost under field conditions.

MATERIALS AND METHODS

The experiment was conducted during 2020–21 and

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2021–22 under rainfed cropping seasonsa at experimental field station in Benshangul Gumuz region, Assosa University, Assosa, Ethiopia. The experimental station is located in a lowland area of Ethiopia with an altitude of 1560 m amsl. The mean monthly minimum and mean maximum temperature in the study area were 13.2°C and 30.4°C, respectively during the experiments carried out while the average annual rainfall of 1244 mm. The meteorological data during the experiments carried out was very similar to the long-term data.

Climate and topography: Assosa district has two agroecological zones that are Kolla 90% and Weyna-dega 10% (MoA 2000). The agro-climatic zones of Assosa zone are hot to warm sub-humid. Based on 10 years of climatic data (2011–2020), the mean monthly minimum and maximum temperature in the study area are 12.8°C and 32.4°C, respectively while the mean monthly rainfall of 1346 mm mono-modal rainfall distribution.

Geology and soil type: On the bases of morphological classification, the study area soil was classified under nitisol (FAO 2014, Mathewos *et al.* 2023). They are conducive to agricultural production such as crop cultivation, livestock rearing, and forest tree production. Because of the high availability of rainfall, the soil resources in the district are exposed to leaching which in turn exacerbates the soil acidity problem. The rock types mainly found in the district are basalt, granite, and limestone (EARO 1998).

Land uses and farming system: The district is dominated by private farmlands that account for 65% of the total land out of which 85,747 ha (43%) of land is covered by annual crops and 2373 ha is covered by perennial crops such as coffee and fruits. Grazing and forest lands in the district cover 10% (18,021 ha) and 20% (12,488 ha), respectively. The farmers in the study area are practicing mixed and crop rotation farming systems. Farmers in the district use blended fertilizer, urea, and cow dung for soil fertility management.

Treatments, experimental design and procedures: The experiment consists of two lime levels (0 and 4 t/ha), three VC levels (0, 2.5, and 5 t/ha), and three NPSZnB levels (0, 100, and 200 kg/ha), factorially combined and Urea (46% N) to all treatments at 69 kg/ha (Table 1). Treatments were laid out in an RCBD with three replications. The plot size was 18 m^2 (4.8 m × 3.75 m) accommodating 80 maize plants with the spacing between plots and adjacent blocks of 1 m and 2 m. The seedbed was prepared well in advance of sowing maize by plowing and harrowing using oxen and leveling manually. Maize (BH 546) was hand planted with a spacing of 75 cm between rows and 30 cm among plants within a row on 18 May 2020 for the 2020–21 cropping season and 20 May 2021 for 2021–22 rain-fed cropping seasons. Lime and VC were incubated in the soil and well-mixed for three weeks and two months respectively. At planting, blended fertilizers and one-third of urea were placed 2 cm apart from the seed in a hole 5 cm and covered with soil. The remaining two-thirds of urea was applied at the knee height stage of the crop through incorporation into the soil. In the two years, the experiments were conducted in the same field with different plots to avoid the residual effect of the first-year fertilizer over the second year.

Table 1 Combination of treatments used in the field experiment

Treatment	NPSZnB (kg/ha)	Lime (t/ha)	VC (t/ha)
T_1	0	0	0
T_2	0	0	2.5
T_3	0	0	5
T_4	0	4	0
T_5	0	4	2.5
T_6	0	4	5
T_7	100	0	0
T_8	100	0	2.5
T_9	100	0	5
T_{10}	100	4	0
T_{11}	100	4	2.5
T_{12}	100	4	5
T_{13}	200	0	0
T_{14}	200	0	2.5
T_{15}	200	0	5
T_{16}	200	4	0
T_{17}	200	4	2.5
T_{18}	200	4	5

100 kg/ha of NPSZnB = 16.9 N +33.8 P_2O_5 + 7.3 S + 2.23 Zn + 0.67B.

Analysis of vermicompost: The VC was prepared by decomposing cow, sheep, and goat dung and crop residues using red earthworm as a decomposer (*Eisenia fetida*). Selected chemical parameters of the well-decompose VC were determined using the Pisa and Wuta (2013) procedure and analyzed according to standard methods.

Data collections and measurements: Agronomic data were collected extensively during the two seasons. Days to physiological maturity were recorded at the formation of a black layer at the point of attachment of the kernel with the cob. The plant height was measured by cm at physiological maturity. Leaf area (cm^2) was taken to calculate the leaf area index at 50% tasseling and then the leaf area was divided by sampled ground area to calculate the leaf area index. During harvesting, the cob length was measured and the number of grains per cob was recorded by counting. Grain yield was weighed in kg/plot adjusted to 12.5% moisture content and converted to t/ha. The Harvest index was calculated as the ratio of dried grain yield to the above-ground dry biomass yield.

Statistical analysis: The two-season data was subjected to analysis of variance (ANOVA) according to SAS Version 9.4. The coefficient of variation, standard error, and the least significant difference at a 5% risk level were also calculated.

RESULTS AND DISCUSSION

Chemical composition of vermicompost: The average *p*H of vermicompost was 6.96. The organic carbon and total nitrogen contents of the vermicompost were 12.6% and 1.63%, respectively while the C:N ratio 13:1 was very narrow, indicating that the vermicompost is well decomposed and nitrogen can be released into the soil for plant use. Based on the analysis of vermicompost, the total macronutrients compositions of vermicompost (kg/ha) were for control 0 kg/ha; 2.5 t/ha vermicompost contained, total nitrogen 41 kg/ha, total phosphorous 159 kg/ha, total potassium 27 kg/ha and total sulphur 108 kg/ha; while 5 t/ha vermicompost contained, total nitrogen 82 kg/ha, total phosphorous 319 kg/ha, total potassium 33 kg/ha and total sulphur 216 kg/ha.

Crop phenology: The amendments either alone or in integrated significantly affected the days to 50% tasseling and 90% maturity compared to the control. The treatment receiving NPSZnB (200 kg/ha) + vermicompost (5 t/ha) and lime (4 t/ha) showed the earliest tasseling and the most prolonged maturity while the control showed 44 days earlier maturity (Fig. 1). The highest days to 50% tasseling were recorded from the control. This indicated that lime, VC, and blended fertilizers combined at different rates have encouraged early establishment, fast growth, and crop development, thus shortening tasseling days. For the control, the grain filling period was only 56 days while it was 118 days for the maximum amounts of amendments.

Maximum plant height was observed in the same treatment and the minimum (52 cm less) was observed in the control. A similar positive response of shoot development and the prolongation of the vegetative stage to vermicompost and blended fertilizer have been reported by Bakala *et al.* (2022) who reported that application of blended fertilizers reduced days to tasseling of maize by 10 days. Late maturity in response to increasing rates of lime and vermicompost shows that increased availability of nutrients prolonged the vegetative growth and facilitated longer periods for grain filling (Abdissa *et al.* 2018, Negese and Wogi 2023). Significant maize plant height increment in response to the integral application of amendments can be attributed to neutralizing soil acidity, reducing P fixation, and enhancing the availability of major plant nutrients increasing vegetative growth.

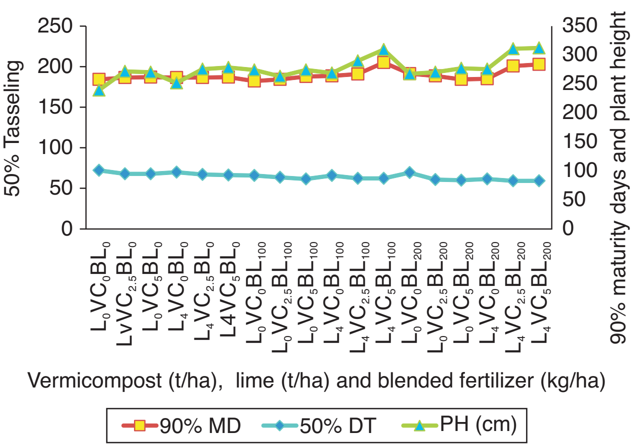

Fig. 1 The main and interaction effects of vermicompost, lime, and blended fertilizer on growth parameters (mean of two seasons, 2020–21 and 2021–22) of maize.

Growth and yield parameters: The highest mean LAI was observed under plots receiving NPSZnB (100 kg/ha) + vermicompost (5 t/ha) + lime (4 t/ha) while the lowest mean was recorded under control (Table 2). The leaf area index increment with the VC and blended fertilizer application rate might be attributed to better photo assimilates supply related to a combination of macro and micronutrients like B and N used for high vegetative growth that makes the plants have broader leaves. In consistence with this Abdela (2023) suggested the largest LAI with the greatest vermicompost and NPSZnB levels due to the vermicompost enhancing the physicochemical and biological ties properties of the soil to create a favourable environment for crop growth and yield.

The highest number of kernel rows per cob was recorded from treatments receiving NPSZnB (100 kg/ha) + vermicompost (5 t/ha), while the lowest number was recorded in the control. The effect of the amendments was thus relatively small. Instead, the effect was much greater on the cob length (Table 2). The maximum cob length was recorded in treatment that received NPSZnB (200 kg/ha) + vermicompost (5 t/ha) and lime (4 t/ha) and the shortest cobs were found in the control. Wakgari (2022) also suggested the longest cobs have occurred in plots receiving a combined application of 50% of the recommended vermicompost and blended fertilizer. Abdissa *et al.* (2018) found a linear increase in cob length with the amount of organic and inorganic fertilizer associated with the reduction in acidity and increases in nutrient availability.

The highest 1000-seed weight was again recorded under treatment receiving the maximum rates of amendments and

Table 2 Effect of different rates of liming, blended fertilizer and vermicompost (mean of two seasons, 2020–21 and 2021–22) on growth parameters of maize

Lime and VC (t/ha)		Yield parameters					
		Leaf area index			Kernel rows per cob		
		Blended fertilizer (kg/ha)					
Lime	VC	0	100	200	0	100	200
0	0	2.02^{k}	2.51^{ij}	2.67^{ih}	15.0^{d}	15.2^{dc}	15.2^{dc}
	2.5	2.43^{j}	3.11^{fg}	3.45^{cd}	15.8^{bdc}	16.2^{a}	15.1^{dc}
	5	2.52^{ij}	3.27^{fe}	3.41^{ed}	15.2^{bdc}	16.1^{ba}	15.4^{bdc}
4	0	2.10^{k}	2.72^{h}	3.01^{g}	15.2^{dc}	15.6^{bdc}	15.4^{bdc}
	2.5	2.60^{ih}	3.58^{cb}	3.52^{cbd}	14.9^{d}	15.4^{bdc}	15.0^{d}
	5	2.61^{ih}	3.82^{a}	3.64^{b}	15.6^{bdc}	15.9^{bac}	15.6^{bdc}
LSD (P=0.05)		0.20			0.37		

Means in the column within a parameter followed by the same letter(s) are not significantly different at P=0.05.

VC, Vermicompost.

Table 3 Effect of different rates of liming, blended fertilizer and vermicompost (mean of two seasons, 2020–21 and 2021–22) on yield components of maize

Lime and VC (t/ha)		Yield parameters								
		Cob length (cm)			NGPC			TSW (g)		
		Blended fertilizer (kg/ha)								
Lime	VC	0	100	200	0	100	200	0	100	200
	0	15.4^{j}	19.3^{h}	19.7^{g}	362^{j}	458^{gfh}	481^{efd}	284^{i}	361^{fge}	353^{f}
0	2.5	19.8^{g}	22.5^{d}	22.9^{bc}	416^{i}	478^{gef}	512^{cb}	345^{g}	401^{cb}	409^{b}
	5	19.6^{hg}	22.7^{dc}	22.8^{c}	450^{gh}	498^{cbd}	520^{b}	358^{fg}	403^{c}	392^{cbd}
	0	18.7^{i}	20.4^{f}	21.3^{e}	404^{i}	468^{gfh}	492^{ced}	317^{h}	368^{fge}	384^{ced}
4	2.5	21.4^{e}	22.7^{dc}	23.1^{a}	446^{h}	495^{ced}	572^{a}	366^{fge}	407^{cb}	453^{a}
	5	21.6^{e}	22.8^{c}	23.3b^{a}	463^{gfh}	520^{cb}	597^{a}	375^{fed}	412^{b}	455^{a}
LSD (P=0.05)		1.47			10.5			6.6		

Means in the column within a parameter followed by the same letter(s) is not significantly different at P=0.05.
VC, Vermicompost.

the minimum was observed in the control (Table 3). The result agrees with the findings of Abdela (2023) that the application of lime with blended fertilizer highly influenced the 1000-seed weight of maize, the highest value is observed at higher rates of vermicompost and NPSZnB fertilizer. The 1000-seed weight responds very strongly (60% increase at the maximum) to enhanced nutrient supply, compared to only moderate response of the number of seeds per cob.

The highest number of grains per cob was recorded under the plots that received lime (4 t/ha) + vermicompost (2.5 or 5 t/ha) + NPSZnB (200 kg/ha) whereas the minimum was again recorded for the control (Table 2). The grain number was thus increased by as much as 65% at the maximum. Compared to the control, the plots receiving the maximum amounts of amendments produced a 2.75-fold grain yield (Fig. 2). It is noteworthy that the combined addition of VC with NPSZnB fertilizers at 50% of the recommended rate almost doubled the maize yield. The increment in grain yield with the application of VC and NPSZnB fertilizer with the recommended amount of lime is attributed to the improving action of amendments on the soil's physicochemical properties and nutrient status in the soil, which enhances plant growth. One tonne of vermicompost increased grain yield by approximately 316 kg/ha whereas the increase obtained by 1 kg of blended fertilizer was 10.3 kg/ha. One tonne of vermicompost can replace/substitute 38 kg of blended fertilizer. Similarly, one tonne of lime increased grain yield by 238 kg, similar to the effect of 0.75 tonnes/ha of vermicompost and 23 kg/ha of blended fertilizer. On the other hand, the combined use of 50% recommended VC and NPSZnB fertilizers rate increased maize productivity by 42%. This indicated that the combined addition of organic and inorganic fertilizer showed an increment in maize yield by 20% and 8% more than the sole application of VC and blended fertilizer, respectively. In line with this finding, Melkamu *et al.* (2021) reported that organic and inorganic nutrient sources of fertilizers were advantageous over the sole application of inorganic fertilizer for the increment of grain yield.

The highest harvest index (20.9) was obtained from a plot that received NPSZnB (200 kg/ha) + vermicompost (2.5 or 5 t/ha) and lime (4 t/ha), whereas the lowest (11.9) was recorded for the control. Integral application of chemical fertilizer and vermicompost has caused positive responses of the growth parameters and maize harvest index Meena *et al.* (2023) and Dereje *et al.* (2023) suggested that the integrated application of lime and organic fertilizer shows a better crop performance than the sole applications. The continuous increment in harvest index at a higher rate of blended fertilizer and vermicompost in combination or separately indicates greater photo assimilates production, increasing the plant's efficiency to partition the dry matter into the reproductive seed sinks.

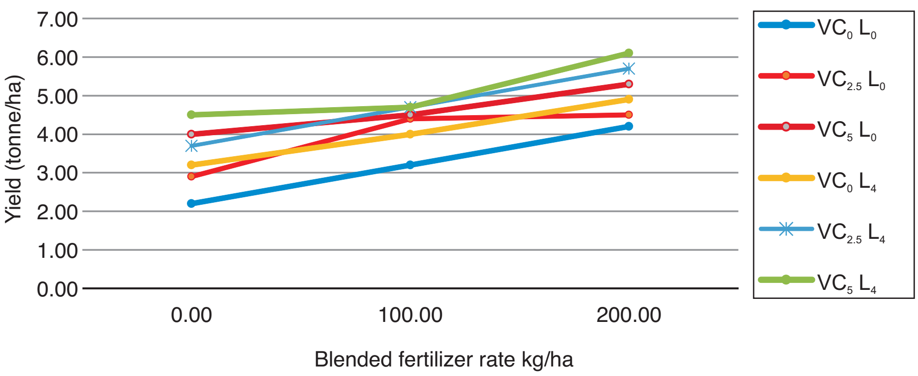

Fig. 2 The individual and combined effect of vermicompost, lime, and blended fertilizer on maize yield.

Partial budget analysis: The sole application of the recommended amount of vermicompost and blended fertilizer gave a net benefit of 79, 761 and 87, 949 birr/ha, respectively, while 50% application of VC and recommended blended fertilizer gave a net benefit of 98,096 birr/ha. Integrated application of vermicompost and blended fertilizer shows an increment over their sole application by 19 and 10%, respectively. Sole application of lime, vermicompost, and blended fertilizer was thus not very profitable. Treatment with 4 t/ha lime, 2.5 or 5 t/ha vermicompost, and 100 or 200 kg/ha blended fertilizer gave a marginal rate of return above the minimum acceptable rate of return (50%) considered in this finding.

The results of this study indicated that the current scenarios on maize production need a modification on the addition of fertilizer to the soil to obtain optimum maize productivity. Using vermicompost is a way to increase the yields of poor farmers utilizing local nutrient sources so that buying fertilizers is not needed in large quantities. With no amendments, the yields are at starvation level for people but these results demonstrate that the same land and water supply can produce high yields when some soil amendments are given. One tonne of vermicompost and lime could substitute 38 kg and 23 kg of blended fertilizer, respectively.

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