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Research article

Effect of bioslurry and chemical fertilizer on the agronomic performances of maize

Tsehay Kebede [a], Yadessa Gonfa Keneni [a], Abate Feyissa Senbeta [a], Getachew Sime [a,b,*]

[a] Department of Biology, College of Natural Sciences, Hawassa University, Hawassa, Ethiopia
[b] Center for Ethiopian Rift Valley Studies, Hawassa University, Hawassa, Ethiopia

A R T I C L E I N F O

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A B S T R A C T

The objective of this study was to determine the effects of bioslurry (BS) and chemical fertilizer (CF), as a sole BS and CF and their mixed application, on the agronomic performances of maize (Zea mays var. BH- 546). Field experiment was conducted at Hawassa University Research Farm, in the Sidama Region in Ethiopia. The experiment consisted of six treatments, arranged in a randomized complete block design with three replications. Relevant agronomic characteristics were recorded for each plot, from planting to harvest. Results show yield and yield characteristics of maize increased by both sole and combined application of fertilizers compared to no fertilizer application. The combined BS and CF application at the dose of 25% BS +75% CF gave the highest plant height (251.3 cm), grain yield (7.09 t ha^{-1}), biomass yield (24.4 t ha^{-1}) and stover yield (11.5 t ha^{-1}). The agronomic performances generally increased with increasing proportion of chemical fertilizer in the combined application until the proportion of bio-slurry reaches 75%. Moreover, the combined application generally tended to increase the agronomic performance better than the sole application of both BS and CF. In addition to improving the agronomic performances; both sole BS and its combination with CF reduce the cost of chemical fertilizers. In conclusion, the combined BS and CF application at the dose of 25% BS +75% CF appears an optimal combination and rate for the production of maize in the study area. Yet, as this finding is only one season, further studies determining the optimum dose of sole BS, sole CF, and combined CF and BS for improved maize agronomic performance is commendable in future research.

1. Introduction

Agriculture is the overwhelming segment of the Ethiopian economy. On average, agricultural employment is growing by 2.5% annually. The segment contributes 80.8% of total commodity exports. The diversity in topography, climatic conditions, and soil types enable the country to grow a wide variety of crops. In terms of both area coverage and total cereal output, Teff (*Eragrostis tef* (Zucc.) Trotter), maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L.), and wheat (*Triticum aestivum* L.) are among the four major cereal crops cultivated in Ethiopia (Ermias Engida et al., 2019). Maize is used directly as human food in different forms [1].

However, there are a number of factors constraining the production of maize. Among the major problems affecting its production in most smallholder farms in Ethiopia, include the rapid depletion of nutrients, and erosion of soil nutrients and the wide traditional

* Corresponding author. Department of Biology, College of Natural Sciences, Hawassa University, Hawassa, Ethiopia.
E-mail addresses: abigiag@yahoo.com, getachew.sime@hu.edu.et (G. Sime).

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farming practices. As a result, the yield of maize in such farms is low and stagnant [2]. Declining soil fertility has also become a global concern mainly due to soil erosion and nutrient mining (Faheed et al., 2008, [3,4]. Not only is the rate of chemical fertilizer application low since it is expensive for the majority of resource-poor smallholder farmers, but there is also a significant lack of understanding regarding chemical fertilizer application rates, time, etc. [2]: Alemu Assefa et al., 2016) and the application methods [2]. Fertilizer application increases agricultural productivity through enhancing soil fertility or replacing the nutrients taken from the soil by previous crops. Organic materials, such as bio-slurry and composts, have long been recognized in agriculture as important source of plant nutrients. When combined with the widely used chemical fertilizers, they become promising (Faheed et al., 2008). In this regard, organic fertilizers are one of the possible options for chemical fertilizer application [3,4]. Therefore, the utilization of bio-slurry, which is a byproduct of biogas technology, as an organic fertilizer could improve soil fertility and agricultural production for smallholder farmers. It is particularly important for farmers who cannot afford to buy chemical fertilizers and do not have easy access to chemical fertilizers. Chemical and organic fertilizers can also be used alone or mixed with chemical fertilizers [5,6]. Bio-slurry is a high quality organic fertilizer, which can be applied to soils in a variety of ways [7]: [8]. Bio-slurry constitutes 1.4–1.8% N, 1.0–2.0% P_2O_5, 0.8–1.2% K_2O and 25–40% OC (Warnars and Oppenoorth, 2014). The application of bio-slurry increases yields of crops (Warnars and Oppenoorth, 2014).

In Ethiopia, particularly around the study areas there is huge potential for using bio-slurry for agricultural production as a good number of rural households have already installed bio-gas plants as part of the National Biogas Program of Ethiopia. This national program promotes the installation of the plants for its biogas energy and bio-slurry. Both the government and NGOs promote the use of the bio-slurry as a substitute and/or complement of chemical fertilizers and biogas for domestic energy supply. Previous studies conducted on the sole and integrated application of chemical and organic fertilizers in Ethiopia have focused on vegetable production, include Mussie et al. (2020) on yield and yield attributes of green bean (*Phaseolus vulgaris* L.) and soil properties [5], on growth and yield of kale (*Brassica oleracea* L.) [9], on the growth and yield of tomato (*Lycopersicon esculentum* Mill.) and soil properties. Similar studies focusing the effect of bio-slurry and chemical fertilizers on maize agronomic performances are lacking. There is also a lack of evidence on the sole and combined effects of bio-slurry and chemical fertilizers on the vegetative and yield of maize, which is the objective of the present study. Therefore, this study specifically answers questions related to the effect of sole bio-slurry, sole chemical and the various combinations of bio-slurry and chemical fertilizers on the vegetative growth and yield of maize.

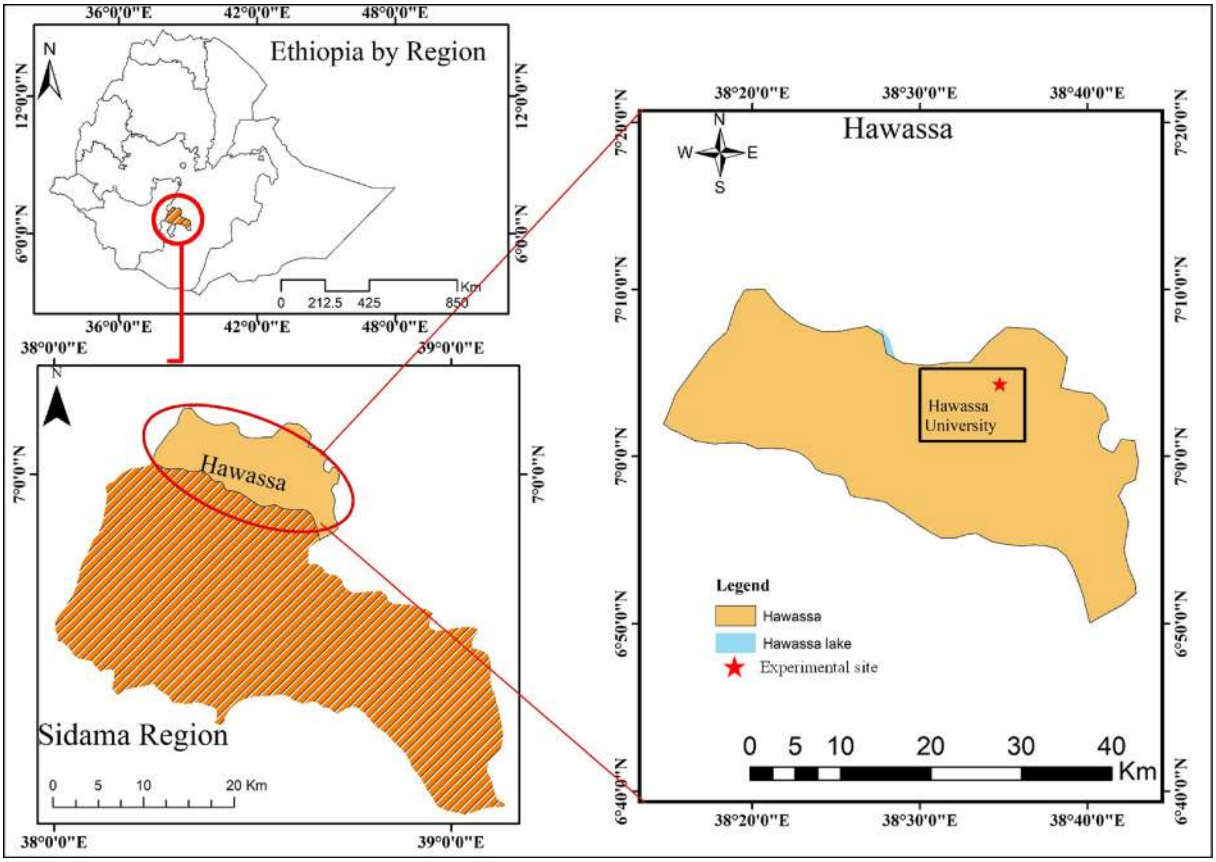

Fig. 1. Physical map of the study area.

2. Materials and methods

2.1. Description of the study area

A field experiment was conducted at Hawassa University main campus experimental farm area (Fig. 1). Hawassa is located at 7°4′ N latitude, 38°31′ E longitude, and lies at an altitude of 1675 m.a.s.l. It is located at 275 km south of Addis Ababa, the capital city of Ethiopia.

Hawassa receives a bimodal rainfall, with March to June, being the main cropping season for growing mid and late -maturing maize varieties. Months from June to October are used for growing early maturing plants such as maize and pulses [2]. The average mean monthly rainfall during the cropping season was 146.78 mm, while the maximum and minimum temperature during the experimental season was 30.8 °C and 14.3 °C, respectively. Fig. 2 presents the mean monthly rainfall, and maximum and minimum temperature during the experimental period and mean monthly rainfall and maximum and minimum temperature of a long range of years.

2.2. Experimental design

Six treatments were used in the experiment, which was carried out using a randomized full block design with three replications. Standard recommendation rates were followed for fertilizer rates, 92 kg N + 31.3 kg P + 13 kg S per hectare for the NPS fertilizer and 5 ton/ha for the bio-slurry (Fantaw Ijigu, 2010). The plot size was 4.5 m × 2 m. There were a total of 18 plots with six rows in each plot having 75 cm distance between rows, 25 cm within rows (between plants) and 1 m between blocks. Fresh dry bio-slurry (BS) and chemical fertilizer (CF) were used. The treatments were 100% BS (5 ton bio-BS ha^{-1}), 75% BS + 25% CF (3.75 ton BS ha^{-1} +23 kg N ha^{-1}+7.5 kg P ha^{-1} + 3.25 kg S ha^{-1}), 50% BS + 50% CF (2.5 ton BS ha^{-1} + 46 kg N ha^{-1}+15 kg P ha^{-1} + 6.5 kg S ha^{-1}), 25% BS +

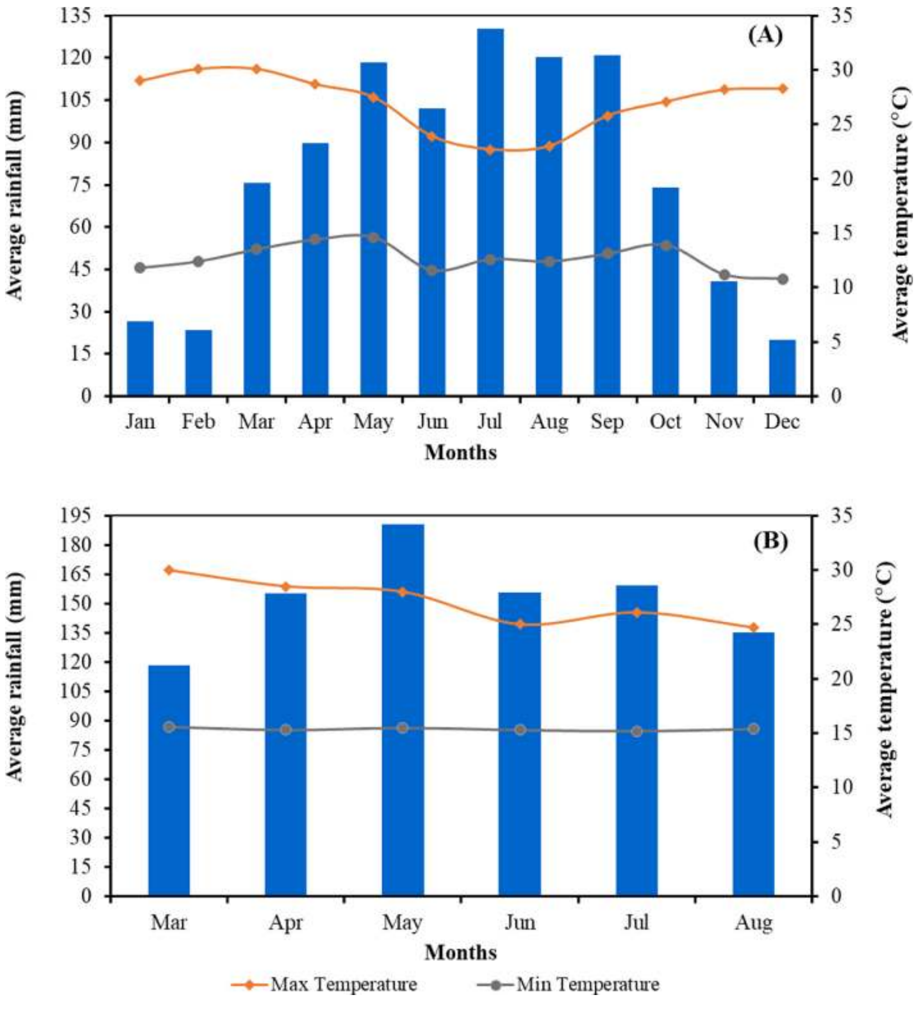

Fig. 2. Monthly average rainfall and maximum and minimum temperatures of the experimental area recorded (A) during 1990–2019 and (B) during the experimental season (Data source: National Metrology Service Agency (NMSA), Hawassa branch, 2020).

Table 1
Chemical composition of bio-slurry and physico-chemical properties of pre-experimental soil.

Item	pH (H_2O)	OC %	OM%	TN %	C:N	P (*ppm)	CEC (**cmol/kg)	Ca (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	Sandy %	Silt %	Clay %	Textural class	Bulk density g/cm^3	Porosity %
Soil	5.6	2.7	4.7	0.2	11:0	49.6	24.6	46.2	2.3	0.2	35.3	42	22.7	Silt loam	1	62.3
Bio-slurry	7.52	6.24	10.6	0.54	11.56	262.2	38	52.34	10.3	0.39						

*ppm: parts per million, cmol**(+): cent mol of cation.

75% CF (1.25 ton CF ha^{-1}+ 69 kg N ha^{-1} + 22.5 kg P ha^{-1} + 9.75 kg S ha^{-1}), 100% CF (90 kg N ha^{-1}+ 30 kg P ha^{-1} + 13 kg S ha^{-1}) and Control. Spot application was used for both BS and CF application.

2.3. Land preparation, planting and fertilizer application

A test crop of the BH-546 maize variety was used for the experimentation. Hoes were used to manually loosen a layer of soil that was up to 20 cm deep. Each planting hole contained two seeds, which were thinned to one after 21 days. At planting, the required rates of NPS and bio-slurry were pre-weighed for each plot by using electronic digital balance and applied at planting while urea was top-dressed after 40 days. For each treatment, the same agronomic procedures, such as hoeing, weeding, and disease and pest control, were used. Weeding was carried out three times in the 15, 40 and 75 days after planting by using hand, while hoeing was carried out in the 15 days and during urea application at the 40 days after planting. Additionally, to control disease and pest Syngenta Karate insecticide-250 ml was used.

2.4. Pre-experiment soil and bio-slurry samples for physico-chemical analysis

Before planting, zigzag-method surface soil (0–20 cm) samples were taken at random from 10 locations in the experimental field. The samples were then combined using standardized techniques for physicochemical property examination. Similar to that, samples of the bio-slurry were gathered and their chemical composition examined.

The soil in the experimental area had a silt loam texture with bulk density of 1 g/cm^3 and porosity of 62.26%. It had moderately acidic pH value of 5.64 in a 1:2.5 soil to water solution, 2.73% SOC, 4.74% OM, 0.24% TN, 11:1C: N and 49.6 ppm P as well as 24.6, 2.29, 0.21, 46.15 cmol (+)/kg of CEC, K, Na and Ca, respectively (Table 1). The soil type of the study area is Andosol.

The bio-slurry had a pH of 7.52, 6.24% OC, 0.54% TN, 262.2 ppm available P, 11.56C: N, 10.33 ppm available K and 39 cmol (+) kg^{-1} CEC as well as 10.3, 0.39 and 52.34 exchangeable K, Na, and Ca, respectively (Table 1).

2.5. Agronomic data collection

Seedling vigor of plant population on each plot was assessed and ranked from 1 to 5 (where 1 = poor, 2 = low, 3 = moderate, 4 = vigorous, 5 = very vigorous). Lodging count (fallen, inclined or with broken stalks) was considered as lodging. Plant height was measured using measuring tape for each treatment by randomly selecting five plants from the central rows. The height was measured from the ground level to the base of the tasseling. Total fresh biomass yield, grain yield and stover yield were weighted from plants in the central rows of each plot. Total fresh biomass, grain yield, and stover yield were measured by using a hanging balance. Grain moisture for each plot was measured using a multi-grain digital moisture meter, which was eventually adjusted at 12.5%. The yield in each plot was reported on a hectare basis (ha^{-1}). The measurements for the stover yield of each plot were taken after sun drying for 10 consecutive days (when there was no difference in weights between succeeding measurements) by leaving the stover on respective plots.

2.6. Statistical analysis

The analysis of variance (ANOVA) was carried out using the ''SAS'' statistical analysis system, version 9. Whenever there are significant differences, the least significant difference (LSD) is used for the mean separation. Significant differences between treatments were identified at the 5% significance level ($p < 0.05$). Pearson correlation was also used to represent the relationship between yields and its components.

3. Results

3.1. Effects of bio-slurry and chemical fertilizer on the seedling vigor, lodging count, stand count and plant height

The applications of the various levels and kinds of fertilizers significantly increased plant vigor over the control (Table 2). The

Table 2
Average maize yield characteristics as response to sole bio-slurry, sole chemical fertilizer and mixed application.

Treatment	Seedling vigor	Lodging count	Stand count	Plant height (cm)
100% BS	3.333^{b}	2.333^{ab}	45.667^{bc}	238.133^{bc}
75% BS + 25% CF	4.000^{ab}	1.667^{bc}	46.333^{ab}	248.733^{a}
50% BS + 50% CF	3.667^{ab}	1.333^{bc}	46.667^{ab}	244.000^{ab}
25% BS + 75% CF	4.667^{a}	0.667^{c}	47.333^{a}	251.333^{a}
100% CF	4.000^{ab}	2.333^{ab}	45.667^{bc}	242.00^{ab}
Control	1.667^{c}	3.000^{a}	45.000^{c}	231.933^{c}
CV	18.982	35.294	1.446	5.311
LSD ($P < 0.05$)	1.473	1.186	1.186	9.36

Mean values with different superscripts in a column are significantly different from each other ($\alpha = 0.05$).

combined application of bio-slurry and chemical fertilizers, at 25% BS and 75 CF, significantly increased seedling vigor over the sole application of bio-slurry. The lodging count of the control groups was significantly higher than treatments, which received the various combined application of bio-slurry and chemical fertilizer. That is, no significant difference was observed in the lodging count among the control group, 100% bio-slurry and 100% chemical fertilizer. The combined application, at the dose of 25% bio-slurry and 75% chemical fertilizer, significantly increased stand count over the sole application of both chemical and bio-slurry and the control groups. Except the sole chemical and sole bio-slurry, the combined application of chemical and bio-slurry significantly increased plant stand over the control. The combined application of fertilizers as well as sole the application of chemical fertilizer significantly increased plant height over the control group. The combined application of fertilizers, at 25% bio-slurry and 75% of chemical fertilizer and 75% bio-slurry + 25% chemical fertilizer, also yielded significantly higher plant height than the sole application of bio-slurry. The application of sole bio-slurry did not significantly influence plant height. Generally, the combined application of chemical fertilizer and bio-slurry performed superior to the sole application of bio-slurry on these agronomic performances of maize. Yet, there is an irregular trend in the effect of the chemical fertilizer or the bio-slurry against the agronomic performances of maize.

3.2. Effects of bio-slurry and chemical fertilizer on fresh total biomass yield

The application of both sole chemical fertilizer and bio-slurry as well as their combinations significantly increased maize biomass yield over the control (Table 3). The combined application of fertilizers, at 50% bio-slurry + 50% chemical fertilizer and 25% bio-slurry + 75% chemical fertilizer, significantly increased the total biomass over all other treatments (Table 4). The total biomass tended to increase with increasing doses of the chemical fertilizers in the combinations. The mixture, at the dose of 25% bio-slurry + 75% chemical fertilizer, gave the highest fresh total biomass followed by at 50% bio-slurry + 50% chemical fertilizer and 75% bio-slurry + 25% chemical fertilizer. The combined application of fertilizer increased biomass yield by 20.21–43.78% over the control and 11.8–16.2% over the sole application of chemical fertilizer while the sole application of chemical fertilizer increased the fresh total biomass yield by 23.7% over the control.

3.3. Effects of bio-slurry and chemical fertilizer on stover yield

The combined application and the sole bio-slurry significantly increased stover yield over sole chemical fertilizer and the control. The combined application, at 25% bio-slurry and 75% chemical fertilizer, gave the highest stover yield (11.5 t ha^{-1}), followed by 50% bio-slurry and 50% chemical fertilizer and 100% bio-slurry, which is 11.3 and 10.17 t ha^{-1}, respectively. The lowest stover yield (8.43 t ha^{-1}) was recorded in the control group. The sole bio-slurry and its combination with chemical fertilizers increased yield in the range of 17.1–36.4% over the control and 13.4–32.2% over the sole chemical fertilizer. While the sole application of bio-slurry increased stover yield by 20.3% over the sole chemical fertilizer application and 20.6% over the control. Generally, stover yield tended to increase with increasing doses of bio-slurry application. However, the increment in stover yield of maize due to the application of fertilizers did not follow a regular pattern (Table 3).

3.4. Effects of bio-slurry and chemical fertilizer on grain yield

The application of both sole and combined bio-slurry and chemical fertilizer significantly increased maize grain yield over the control group (Table 3). All the combined fertilizer application significantly increased yield over the 100% bio-slurry. The 100% chemical fertilizer significantly increased grain yield over the 100% bio-slurry. The combined application at 25% bio-slurry + 75% chemical fertilizer significantly increased yield over the sole chemical fertilizer, sole bio-slurry, and 75% bio-slurry + 25% chemical fertilizer. Both the combined application, at 50% bio-slurry + 50% chemical fertilizer and 25% bio-slurry + 75% chemical fertilizer, significantly increased grain yield over the sole bio-slurry and chemical as well as the combined application at 75% bio-slurry + 25% chemical fertilizer. The combined application, at 25% bio-slurry and 75% chemical fertilizer, gave the highest grain yield (7.09 t ha^{-1}), followed at 50% bio-slurry and 50% chemical fertilizer and 100% chemical fertilizer, which was 6.84, 6.67 t ha^{-1}, respectively. While the low (4.9 t ha^{-1}) grain yield was recorded in the control group. An increase in maize grain yield due to the bio-slurry application was in the range of 19.8–44.7% over the control and 2.5–6.3% over the sole application of chemical fertilizer. Nevertheless, the sole application of chemical fertilizer increased maize grain yield by 13.6% over the sole application of bio-slurry and 36.1% over the

Table 3
Effect of the application of sole and combined chemical fertilizer and bio-slurry on maize yield.

Treatment No	Total biomass yield (t ha^{-1})	Stover yield (t ha^{-1})	Grain yield (t ha^{-1})
100% BS	20.00^{b}	10.17^{ab}	5.87^{d}
75% BS + 25% CF	20.40^{b}	9.87^{ab}	6.35^{c}
50% BS + 50% CF	23.47^{a}	11.30^{a}	6.84^{ab}
25% BS + 75% CF	24.40^{a}	11.50^{a}	7.09^{a}
100% CF	21.00^{b}	8.70^{b}	6.67^{b}
Control	16.97^{c}	8.43^{b}	4.90^{e}
CV	4.00	9.90	2.95
LSD ($p < 0.05$)	1.5	1.67	0.33

Mean values with different superscripts in a column are significantly different from each other ($\alpha = 0.05$).

Table 4
Pearson correlation coefficients of vegetative growth and yield of maize.

Variable	Seedling vigor	Plant height	Lodging count	Stand count	Total above ground fresh biomass	Grain yield	Stover yield
Seedling vigor	1.000						
Plant height	0.694***	1.000					
Lodging count	−0.495*	−0.534*	1.000				
Stand count	0.495*	0.534*	−1.000***	1.000			
Total above ground fresh biomass	0.757***	0.689***	−0.714***	0.714***	1.000		
Grain yield	0.806***	0.701***	−0.751***	0.751***	0.895***	1.000	
Stover yield	0.657**	0.561*	−0.582*	0.582*	0.745*	0.524*	1.000

*Significant at $P < 0.05$; **Significant at $P < 0.01$; *** Significant at $P < 0.0$.

control.

3.5. Correlation between yield and its characteristics

The grain yield was significantly and positively correlated with seedling vigor, plant height, stand count, total aboveground fresh biomass and stover yield (Table 4). A negative correlation was observed between grain yields and lodging count, which indicates that plant vigor and standing contribute to improvement in yield.

4. Discussion

The results of this study show that the sole application of both bio-slurry and chemical fertilizers increase the agronomic performances of maize when compared to no fertilizer application. This is because both of them provide nutrients that are essential to plant growth. Several findings from previous studies substantiate the same: Application of bio-slurry provides both macro (N, P, K) and micronutrients (Zn, Mn, B) and increase growth and yield variables of field crops, including maize [10-13]. Maize agronomic performances increased with increasing rate of bio-slurry [10]. The application of chemical fertilizers increases maize agronomic performances. Chemical fertilizers containing nitrogen and phosphorus increase the vegetative growth and yield of maize [14–16].

Similarly, the combined application of bio-slurry and chemical fertilizers increases the agronomic performances of maize. The performance is higher compared to the sole application of both chemical fertilizers and bio-slurry. Several previous studies also come up with similar findings: Combined use of organic and chemical fertilizers is advocated for improved crop production for smallholding farmers in the tropics to provide sufficient quantities of nutrients [17]. The integrated application of bio-slurry and chemical fertilizers significantly increases yield and its attributing factors in maize [18]. The combined application of bio-slurry and chemical fertilizers increases agronomic performances as compared to the sole application of bio-slurry or chemical fertilizer (Takele [19] and Fashsho, 2020). The application of combined chemical fertilizers and bio-slurry enhances maize yields than their sole application [20]. The application of combined bio-slurry with chemical fertilizer increases agronomic performances over no fertilizer application [12]. The integrated application of organic and chemical fertilizers improves agronomic performances more than their sole application [17,21]. The application of combined organic and inorganic nutrients sources improves growth, yield and related attributes of maize [22]. The application of combined inorganic and organic fertilizers increases grain yield where the inorganic fertilizer provides readily available nutrients while the organic fertilizer improves soil structure [23]. Equally [24], found higher yield with integrated use of chemical and organic fertilizers as compared to sole chemical fertilizer. Ferdous et al., (2020) stated higher maize grain yield from the combined application of mineral fertilizer and bio-slurry. Generally, the increment in maize agronomic performances due to integrated bio-slurry and chemical fertilizer application does not follow a regular pattern. The performance increases until the dose of the chemical fertilizer reaches 75% and then drops. Higher performances largely reached at higher rates (50% chemical: 50% bio-slurry and 75% chemical and 25% bio-slurry). Similar results were reported by Refs. [10,25]. Results in the same study also showed a positive correlation between the vegetative growth and yield of maize. Other previous studies also reported a positive interrelationships between grain yield and its various components (Pavan et al., 2011; [15].

5. Conclusion

Both the sole and combined application of bio-slurry and chemical fertilizers significantly increased the agronomic performances of maize over no fertilizer application. That is, both the sole and combined application of bio-slurry and chemical fertilizers increased seedling vigor, plant height, stands count, maize grain and total biomass yield. Though the agronomic performances generally tended to increase with increasing proportion of the chemical fertilizers in the combinations, it was difficult to see the clear trend of the influences of the combined application for it not following a regular pattern. Furthermore, the combined application of bio-slurry and chemical fertilizers generally performed higher than the sole application either of them. Specifically, the combined application of 25% bio-slurry and 75% chemical fertilizers gave higher vegetative growth and yield of maize, therefore, appear to be an optimal rate of increasing the productivity of maize in the study area. Nevertheless, as this finding depends only on one cropping season, further studies are required to understand the optimum rates, as both sole and combined applications, for improved maize production in the study area.

Author contribution statement

Tsehay Kebede, Yadessa Gonfa Keneni, Abate Feyissa Senbeta, Getachew Sime: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data associated with this study has been deposited at Hawassa University.

Declaration of interest's statement

The authors declare no conflict of interest.

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