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Comparative study on the effect of bio-slurry and inorganic N-fertilizer on growth and yield of kale (*Brassica oleracea* L.)

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Kale is one of the nutritious leafy vegetables with a high nitrogen fertilizer requirement. However, soil fertility is declining progressively due to the imbalanced use of inorganic fertilizer. Discharging bio-slurry as waste will lead to environmental pollution and disposing will also lead to costs because of its large volume. Consequently, replacing chemical fertilizers with bio-slurry can not only achieve efficient resource utilization and disposal cost, but also reduce the amount of chemical fertilizer used and environmental pollution attributed by chemical fertilizers. Therefore, a pot experiment was conducted in a mesh house at Hawassa College of Agriculture to evaluate the combined effect of bio-slurry and inorganic nitrogen fertilizer for growth and yield performance of kale. Five combinations of liquid bio-slurry and inorganic nitrogen fertilizer were used, that is, 25% bio-slurry + 75% nitrogen, 50% bio-slurry + 50% nitrogen, 75% bio-slurry + 25% nitrogen, 100% bio-slurry, 100% nitrogen and 0 use of either fertilizer source as a control. Data on phenology, growth and yield attributes were recorded. Results revealed that the treatment had significant effect on growth and yield attributes of kale. The highest (455.10 g) leaf fresh weight and fresh biomass (814.86 g) was obtained when 100% sole application of liquid bio-slurry was used. Based on these results, it can be concluded that application of 100% bio-slurry can improve the production of kale in the study area.

Key words: Bio-slurry, chemical fertilizers, growth, yield attributes, kale, nitrogen.

INTRODUCTION

Green leafy vegetables occupy an important place among the food crops as they provide adequate amounts of many vitamins and minerals for humans (Fasuyi, 2006; Chinma and Igyor, 2007). Kale (*Brassica oleracea* L.) is one of the highly nutritious green leafy vegetables which belong to the Brassicaceae family, along with Cabbage, Collards and Brussels sprouts (Fadigas et al., 2010).

Kale is a heavy feeder of nitrogen and therefore, good nitrogen source is a paramount importance to optimize its economic yield (Onyango et al., 2012). However, soil fertility is declining progressively due to the imbalance use of inorganic fertilizer and loss of nutrient from the

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soil. Moreover, in the tropical countries including Ethiopia, high cost, scarcity, nutrient imbalance in the soil and soil acidity are problems associated with the use of inorganic fertilizer while bulkiness, low nutrient quality and late mineralization are the bottleneck to the sole use of organic manures for crop production (Uyovbisere et al., 2000). Moreover, alternative soil nutrients sources are expensive for small-scale farmers and the poor timing and awareness of application for improved productivity of kale (Onwonga et al., 2013).

Organic materials are important soil amendments that sustain the productivity of soils in tropical and subtropical regions where there is low soil organic carbon content and low input of organic materials (Huang et al., 2010).

Therefore, there is an urgent need to identify and investigate a cheap, easily available, environmentally friendly source of fertilizers to enhance balanced supply of crop nutrition, sustainable nutrient availability, treat soil acidity and thereby maximize the yield of leafy vegetables. In this regard, bio-slurry can play a vital role in combination with chemical fertilizer and it seems that there is a general consensus on the ability of bio-slurry to improve the physical and biological quality of soil besides providing macro and micro-nutrients for vegetables. At the same time it prevents adverse environmental impacts of urban wastes and reduces the dependence on chemical fertilizers (Karki, 1997).

In Ethiopia, evidence is lacking on the combined effects of bio-slurry and inorganic nitrogen fertilizers on growth and yield of kale. Therefore, the present study was designed to find out the optimum combination of bio-slurry and inorganic nitrogen for better growth and yield performance of kale.

MATERIALS AND METHODS

A pot experiment was conducted under mesh house conditions in 2017 at the experimental site of Hawassa College of Agriculture. The site is located at 273 km from the capital Addis Ababa. It is found at an altitude of 1669 masl and 7°4' N latitude with 38°31' E longitude. The annual rainfall ranges from 900 to 1100 mm and mean annual temperature is 19.5°C. Experimental soil at a depth of 0 to 30 cm was collected from the teaching and research farm of Hawassa University. A 3 kg of sieved (2 mm sieve) soil was filled in the bucket perforated at the bottom to allow air and water movement. The pots were placed on saucers to avoid treatment contamination and leaching and also the leached water on saucers were reapplied on the experimental pots accordingly. Local cultivar of kale seed and liquid bio-slurry were collected from Ziway market and Hawassa town, respectively. Treatment wise liquid bio-slurry was incorporated on the prepared soil containing experimental pot a week before sowing and split application was carried out for the inorganic N (at the time of thinning and 1 month after emergency).

Treatment having five recommended combinations of bio-slurry and inorganic N fertilizer with control treatment were used. The treatments were adjusted based on the N recommendation (100 kg/ha N) for brassica species. The details are presented as follows: T_1 - Control (where no urea/Bio-slurry applied); T_2 - 25% N by Bio-slurry + 75% N by recommended dose of inorganic fertilizer; T_3 - 50% N by Bio-slurry + 50% N by recommended dose of inorganic fertilizer; T_4- 75% N by Bio-slurry + 25% N by recommended dose of inorganic fertilizer; T_5 - 100% N by Bio-slurry; and T_6 - 100% N by recommended dose of inorganic fertilizer.

The treatments were arranged in complete randomized design (CRD) with three replications. The experiment has six level of N source including control treatment. In each treatment there were two pot and two plants per pot with a total of 4 plants per treatment in each replication. Following the usual media preparation practice the pot was conventionally filled with 3 kg of 2 mm sieved soil a weeks before planting. Seeds (15) were sown directly on each pot at a depth of 1 cm and thinning was conducted until it remains two plants per pot just before inorganic N treatment was applied. In accordance with the specifications of the design, each treatment was assigned randomly to the experimental units. Recommended cultural practices (watering, thinning, cultivation and weeding) were applied uniformly throughout the growing period (Haile et al., 2017; Mbatha, 2008; Onwonga et al., 2013).

Data on phenology, growth and yield parameters of kale were recorded. Phenology: days to emergence; growth parameters: plant height (cm), number of leaves per plant, leaf area (cm^2), leaf area ratio (cm^2/g), specific leaf area (cm^2/g); yield parameters: leaf fresh weight (g/plant), leaf dry weight (g/plant), total fresh biomass and total dry biomass (g/plant) was recorded (Mbatha, 2008; Li et al., 2013; Amanullah et al., 2007).

The data recorded for each of the parameters considered in this study were subjected to analysis of variance (ANOVA) using a General Linear Model in SAS software and mean separation was made based on LSD at 5% (P<0.05) level of significance (SAS institute, 2002).

RESULTS AND DISCUSSION

Physicochemical characteristics of the soil and bio-slurry

The physicochemical characteristics of the experimental soil and bio-slurry are shown in Table 1.

Phenology and growth parameters

Days to 50% emergence

The days to 50% emergence were not significantly (P<0.05) influenced by the combined application of bio-slurry with inorganic nitrogen (Table 2). The result is in contrary to the findings of Vaithiyanathan and Sundaramoorthy (2016) who noted that application of recommended doses of organic manures, inorganic fertilizers and bio-fertilizers increased the seed germination percentage of Green Gram.

Number of leaves per plant

Number of leaves per plant of kale was (P<0.001) influenced by the application of liquid bio-slurry with inorganic nitrogen fertilizer (Table 2). The highest (11) number of leaves per plant was obtained from T5 (100% bio-slurry) and it was statistically similar with the pots which received 100 kg/ha of inorganic N (T6). The lowest (4.17) number of leaves per plant were recorded from the treatment that did not receive any N sources (the control

Table 1. The physicochemical characteristics of the experimental soil and bio-slurry analyzed at Hawassa University soil laboratory for the grand project on the effects of combined application of head cabbage, 2017.

Property	Value	
	Soil	Bio-slurry
Chemical		
Total nitrogen (%)	0.50	1.53
Available P (mg P_2O_5/kg soil)	71.6	301.4
Available K (mg K_2O/kg soil)	162.4	715.25
Organic matter (%)	10.1	30.6
pH-H_2O(1:2.5)	6.36	7.33
Exch.Ca^{2+}(cmol/kg soil)	71.97	114.4
Exch. Na^+(cmol/kg soil)	0.59	33.2
Exch. K^+(cmol/kg soil)	6.50	28.6
Exch.Mg^{2+}(cmol/kg soil)	9.5	17.4
CEC (cmol/kg soil)	30.2	64
Organic carbon (%)	5.9	17.7
Physical		
Sand (%)	61	93.93% Water
Silt (%)	21	6.07% Dry matter
Clay (%)	18	-
Texture class	Sandy loam	-

Table 2. Days to 50% emergence, leaf number and plant height (cm) of kale as affected by the combined application of bio-slurry and inorganic nitrogen**.**

Treatment	Days of 50% emergence	Number of leaf/plant	Plant height (cm)
T1= Control (no urea/Bio-slurry applied)	3.33	4.17^{d}	16.17^{e}
T2= 25% Bio-slurry + 75% recommended inorganic N	3.67	$7b^{c}$	22.33^{cd}
T3= 50% Bio-slurry + 50% recommended inorganic N	3.33	6.17^{c}	17.83^{de}
T4=75% Bio-slurry + 25% recommended inorganic N	3.67	8^{b}	24.33^{bc}
T5=100% Bio-slurry	4.33	11^{a}	37.33^{a}
T6=100% recommended inorganic N	3.33	10^{a}	28.93^{b}
LSD (5%)	12.11	1.62	5.52
CV (%)	7.44	11.80	12.66

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance.

treatment); whereas the other treatment combinations were in between the two. From the data presented subsequently, it is evident that, leaf number per plant was the lowest at the control treatment, increased with increasing the concentration of bio-slurry reaching maximum at the maximum concentration of bio-slurry (Table 2). The lowest number of leaves per plant in the control treatment could be due to the insufficient nitrogen supply of plants and resulting in reduction of plant productivity and thereby reducing the number of leaves per plant (Shangguan et al., 2000). Moreover, the finding is also similar to the results reported by Rahman et al. (2008).

Plant height

The result of the comparative study of liquid bio-slurry and inorganic N fertilizer on plant height of kale revealed significant differences ($P<0.001$) amongst the treatments (Table 2). Application of 100% liquid bio-slurry gave the highest (37.33 cm) plant height. The lowest (16.17 cm) plant height was recorded from the treatment which received no fertilizer treatment (T1, control) and it was statistically at par with T3. The highest value in plant height of kale was significantly increased by 130.86% more than the control treatment. From the aforementioned data obtained, plant height of kale was

Table 3. Leaf area, leaf area ratio and specific leaf area of kale as affected by the combined application of bio-slurry and inorganic nitrogen.

Treatment	Leaf area/plant (cm^2)	Leaf area ratio (cm^2/g)	Specific leaf area (cm^2/g)
T1= Control (no urea/Bio-slurry applied)	548.0[d]	5.56[c]	5.22[d]
T2= 25% Bio-slurry + 75% recommended inorganic N	1822.6[c]	7.19[b]	7.94[bc]
T3= 50% Bio-slurry + 50% recommended inorganic N	1830.6[c]	7.03[b]	7.64[cd]
T4=75% Bio-slurry + 25% recommended inorganic N	2465.3[bc]	8.05[ab]	8.44[bc]
T5=100% Bio-slurry	4890.3[a]	10.03[a]	10.97[a]
T6=100% recommended inorganic N	3172.6[b]	9.11[ab]	10.08[ab]
LSD (5%)	1032.90	2.19	2.44
CV (%)	23.65	16.09	16.17

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance.

influenced by liquid bio-slurry and inorganic N fertilizer. Plant height was least for the control treatment, but increased with increase in the concentration of liquid bio-slurry (Table 2). 100% sole application of liquid bio-slurry showed a better result on plant height than the control treatment. This could be attributed to the improvement in soil structure and enhanced nutrient and moisture availability and uptake that may have favored plant growth due to application of organic fertilizer. The increase in plant height obtained by the application of bio-slurry incombination with inorganic N fertilizer was in line with the results reported by Sarwar et al. (2007, 2010). Moreover, Surindra (2009) noted that the increase in plant height due to increased rate of organic fertilizer like vermin-compost could be attributed to the fact that it contains a good range of some very essential macro and micronutrients other than N and P which are required for healthy plant growth.

Leaf area (LA)

Liquid bio-slurry combined with inorganic N fertilizer had a highly significant ($P<0.001$) effect on leaf area of kale (Table 3). Increasing liquid bio-slurry from 0 to 100% significantly increased leaf area. The treatment (T5) with 100% liquid bio-slurry produced 792.36% higher LA than the control treatment (Table 3); whereas, the other treatments were in between the two. The results clearly indicated that, LA was influenced by the combined application of liquid bio-slurry with inorganic N fertilizer. LA was the lowest from the plants which did not receive any of the two nitrogen sources (T1, control). It increased with increasing the concentration of liquid bio-slurry, reaching maximum at the highest concentration of bio-slurry (Table 3). Leaf area fairly gives a good idea of photosynthetic capacity of the plant. The treatment T5 (100% bio-slurry) showed significantly higher leaf area which could be due to increased cell division and elongation resulting in increased leaf expansion, more number of leaves due to beneficial influence of bio-fertilizers which release growth promoting substances and enhances the availability of nitrogen (Mog, 2007; Balcau et al., 2012).

Leaf area ratio (LAR)

Leaf area ratio is the ratio of leaf area to the total weight. It is also a measure of photosynthetic machinery per unit of plant biomass (Amanullah et al., 2007). Different concentration of liquid bio-slurry with inorganic nitrogen has highly significantly ($P<0.001$) affected leaf area ratio of kale plants (Table 3). The highest LAR of 10.03 cm^2/g was noted in those pots to which N was applied in the form of 100% liquid bio-slurry which, however, was statistically similar with T6 (100% inorganic N) and T4 (75% bio-slurry and 25% inorganic N) and the lowest (5.56 cm^2/g) was recorded from T1 (control or 0% N sources). Leaf area ratio increased with increase in the concentration of bio-slurry and decrease in the rate of inorganic N application of kale. This suggests that liquid bio-slurry increased leaf size is an attempt to maximize light interception and plant economy for acquisition of resources needed for growth and development and these results are in conformity with the work of Amanullah et al. (2007).

Specific leaf area (SLA)

Specific leaf area is a measure of leaf thickness of the plant and it was highly significantly ($P<0.001$) affected by the combined application of liquid bio-slurry with inorganic N (Table 3). Maximum (10.9 cm^2/g) SLA of kale was recorded in those plants to which N was supplied in the form of 100% liquid bio-slurry and it was statistically at par with 100% inorganic N fertilizer (T6), while the lowest (5.22 cm^2/g) SLA was recorded in T1 (control); whereas the other treatments were in between the two (Table 3). These findings showed that the specific leaf area was significantly influenced by combined application

Table 4. Yield and yield components of kale as affected by the combined application of bio-slurry and inorganic nitrogen.

Treatment	Leaf fresh weight (g/plant)	Leaf dry weight (g/plant)	Fresh biomass (g/plant)	Dry biomass (g/plant)
T1= Control (no urea/Bio-slurry applied)	104.95[d]	9.71[d]	139.61[d]	12.93[d]
T2= 25% Bio-slurry + 75% recommended inorganic N	252.19[c]	24.09[c]	366.81[c]	34[c]
T3= 50% Bio-slurry + 50% recommended inorganic N	240.10[c]	22.23[c]	347.22[c]	32.18[c]
T4=75% Bio-slurry + 25% recommended inorganic N	276.62[c]	25.61[c]	389.34[c]	36.06[c]
T5=100% Bio-slurry	455.17[a]	44.40[a]	814.86[a]	75.53[a]
T6=100% recommended inorganic N	376.09[b]	34.82[b]	667.32[b]	61.82[b]
LSD (5%)	77.77	7.55	96.22	8.89
CV (%)	15.56	16.13	11.91	11.87

Means followed by the same letters in the same column are not significantly different from each other at 5% level of significance.

of liquid bio-slurry with inorganic N. SLA was the lowest for the control treatment (T1); it increased with increase in liquid bio-slurry reaching maximum at the maximum liquid bio-slurry treatment (Table 3). The specific leaf area is the indicator of leaf thickness and it was the highest in the highest bio-slurry treatment which may be due to the presence of growth promoting substances present in this organic components. These growth promoting substances were found to have established role in cell division and elongation which might have contributed to increased number of cells and facilitated the better stacking of the mesophyll cells of the leaves. The results are in conformity with the findings of Oscar and Tollennar (2006) who reported that leaf area, leaf area ratio and grain yield of baby corn increased with increase in the level of N.

Yield and yield components

Leaf fresh weight

Data on leaf fresh weight in Table 4 clearly indicated that application of liquid bio-slurry with different level of inorganic N sources has a highly significant (P<0.001) effect. Maximum (455.10 cm) leaf fresh weight of kale was recorded in T5 (100% liquid bio-slurry). The lowest (104.95 cm) leaf fresh weigh of kale was recorded from T1 (the control) and the other treatment combination is in between the two. The increase in leaf fresh weight of kale in the liquid bio-slurry was 325.13% more than that of the control. It has also been observed that there was significant difference between other combination treatments. These findings showed that the leaf fresh weight is determined by the application of liquid bio-slurry with different level of inorganic N sources. The increase in leaves fresh weight in response to increased rate of bio-slurry might be ascribed to the availability of optimum nutrients contained in bio-slurry that led to high leaf area index and leaf number per plant through facilitated vegetative growth. This result is in line with the work of Mehdi et al. (2012) who reported that the application of municipal solid waste and vermin-compost significantly increased all the growth attributes such as plant height, stem diameter, number of leaves, and leaf area index under well-watered, moderate and severe stress conditions through which it increases the leaf fresh weight per plant. Similarly, the increase in leaf fresh weight on the application of bio-slurry incombination with inorganic N fertilizer was in line with the results reported by Sarwar et al. (2007, 2010) and Qureshi et al. (2014). Moreover, Weiping et al. (2010) studied the influence of different concentrations of liquid biogas slurry on the quality of radish, and the results of their experiment showed that under applications, equal to that of nitrogen's condition, the biogas slurry was helpful to improve quality of radish, also promoted soil quality when compared with a general chemical fertilizer, and decreased chemical fertilizer quantity that was used.

Leaf dry weight

Leaf dry weight of kale per plant was the lowest (9.71 g) for the treatment that did not receive the fertilizer treatment (control or T1), while it was the highest (44.4 g) for the plants that received 100% liquid bio-slurry (T5); the other treatments scored in between the two treatments (Table 4). It is evident from the data presented subsequently that the leaf fresh weight of kale was determined by liquid bio-slurry with different levels of inorganic N fertilizers. The increase in the leaf dry weight resulting from application of liquid bio-slurry may be attributed to the presence of a readily available form of nutrient i.e. ammonia and nitrate. Moreover, its property to enhance soil aggregation, soil aeration and water holding capacity, offers good environmental conditions for the root system of kale. This better availability of soil nutrients and favorable soil condition resulted in healthy plants with large vegetative growth, which lead to higher dry weight of kale. This finding is in agreement with the results obtained by Wenke et al. (2009) who concluded that biogas slurry is an important byproduct of biogas fermentation, containing abundant nutrient element and bioactive substances and they proved that biogas slurry could significantly improve the vegetable quality and resistances to biotic and abiotic stresses of plants. Moreover, Zhou (2009) conducted an experiment to quantitatively study the effect of application of biogas slurry on growth, yield, nutrition quality of purple cabbage and soil quality and the results showed that the application of biogas slurry could remarkably improve growth and yield.

Fresh biomass

The results of the analysis of variance (Table 4) indicated that different concentration of liquid bio-slurry with inorganic N fertilizer significantly (P<0.001) influenced the fresh biomass of kale. Significantly, the highest (814.86 g/plant) fresh biomass was recorded in T5 (100% liquid bio-slurry) followed by T6 (100% inorganic N) which scored 667.32 g/plant. Liquid bio-slurry with inorganic N fertilizer showed significantly the lowest (139.61 g/plant) fresh biomass in the non-fertilized pots (Table 4). Fresh biomass was 82.87% higher than the non-fertilized experimental pots. This finding showed that fresh biomass of kale is significantly influenced by the application of liquid bio-slurry and inorganic N. The increases in fresh biomass of kale due to the application of liquid bio-slurry and inorganic N fertilizer could be attributed to the increase in vegetative growth and increased production of assimilate which is associated with increment in leaf area. The increase in fresh biomass yield of kale due to the application of bio-slurry (a component of several essential macro and micro nutrient) might be due to the effect of these nutrients, which are an integral component of many essential plant compounds like chlorophyll, proteins and amino acids. Plant compounds increase the vegetative growth and produces good quality foliage. These in turn, promote carbohydrate synthesis through photosynthesis and ultimately increased yield of plants (Brady and Weil, 2002). This is also in line with that of Mehdi et al. (2012) who reported that the application of municipal solid waste and organic fertilizer significantly increased growth attributes such as plant height, stem diameter, number of leaves, and leaf area index of canola under well-watered, moderate and severe stress conditions. Similarly, Ding et al. (2011) also studied the effects of biogas slurry on the growth and quality of Tabe bean and the results showed that biogas slurry could not only increase the Tabe bean production, but also improve its nutrition quality. Similar results were obtained by Qureshi et al. (2014).

Dry biomass

Dry biomass yield of kale was highly significantly (P<0.001) influenced by liquid bio-slurry with different rates of inorganic nitrogen fertilizer (Table 4). The lowest (12.93 g/plant) and the highest (75.53 g/plant) dry biomass of kale were obtained from T1 (control), which did not receive any source of N fertilizer, and from 100% liquid bio-slurry (T5), respectively. The increase in dry biomass per plant due to increase in the concentration of liquid bio-slurry might be due to the increase in number of leaf per plant. Thus, response of liquid bio-slurry in combination with different inorganic nitrogen significantly influenced the dry biomass of kale. The highest and lowest was achieved by the application of 100% liquid bio-slurry and control treatment, respectively. Nitrogen fertilizer, either organic or inorganic, always affects vegetative growth of the fodder and cereals; and therefore, the increase in the application of liquid bio-slurry and yield maximization of kale was in line with the results reported by Rahman et al. (2008). Similarly, the increase in dry biomass of kale on the application of biogas slurry in combination of N inorganic fertilizer was in line with the results reported by Yu et al. (2010). Moreover, observation and documentation made by Aktar et al. (1996) and Souza et al. (2008) are also supportive of the present findings who reported that when organic fertilizer is used in the soil, some metallic trace elements stimulated root growth that ultimately increases the dry biomass yield of kale crop. In addition, Islam et al. (2010) conducted an experiment to examine the effectiveness of biogas slurry as nitrogen source for the production of maize fodder and based on the result they conclude that application of biogas slurry has a significant effect on dry matter, ash content and it will improve the production of biomass and nutrient content in maize fodder.

Conclusion

Results from the present study showed that the application of bio-slurry as a nitrogen fertilizer stimulated the growth and yield of kale. From the current results, it can be concluded that, growth and yield of kale improved with 100% sole application of bio-slurry. Therefore, this treatment can be suggested for better growth, yield and yield attributing characteristics of kale for Hawassa and areas having similar agro-ecologies.

CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

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