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Combined Application of Bioslurry and Inorganic Fertilizers on Quality Traits of Cabbage and Soil Properties

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Abstract

Background and Objective: Sustainable soil quality improvement is among the top priority problem in the era of climate change. Organic sources of fertilizer have the potential to address both crop and soil quality issues. However, insignificant work has been done in Ethiopia to optimize the use of organic sources of fertilizer as a means for crop and soil quality improvement. Therefore, the current study was conducted to assess the quality performance of cabbage (*Brassica oleracea* L. var. capitata) and soil properties improvements in response to combined application of bioslurry and NP inorganic fertilizers. **Materials and Methods:** Treatments consisting of four levels of bioslurry (10 m³, 30 m³, 50 m³ and 70 m³ ha⁻¹) and five levels of NP (0, 25, 50, 75 and 100% of the recommended rates) were laid out in randomized complete block design with three replications. **Results:** The interaction of bioslurry and N and P significantly affected head diameter, marketable yield, head firmness, head compactness, total soluble solids (TSS), pH and titratable acidity of cabbage juice. Among quality characters the highest marketable yield, head diameter, TSS concentration and pH were for the combined application of 50 m³ bioslurry with 75% of the recommended N and P, ha⁻¹. Higher titratable acidity was obtained with the combined application of 10 m³ bioslurry, ha⁻¹ with all levels of N and P. Application of bioslurry also found to improve soil properties. **Conclusion:** The combined application of 50 m³ ha⁻¹ bioslurry with 75% RNP can be recommended for quality cabbage production and soil properties improvement in the research area and similar agro-ecologies.

Key words: Head cabbage, organic production, product quality, sustainability, yield

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Vegetables are important sources of vitamins, fiber, minerals, anti-oxidant and plant proteins in the human diet¹. Vegetable cultivation is becoming more costly due to increasing use of purchased inputs such as pesticides and fertilizers to sustain production². Cabbage is an important vegetable crop grown in Ethiopia. In spite of its wide utilization, cabbage production is constrained by lack of adapted cultivars, scarcity of seed and high cost of inorganic fertilizers. The dependency on inorganic fertilizer should be minimized due to highcost, release of greenhouse gases and loss due to ineffective application^{3,4}. Alternatively, organic fertilizer is used for cabbage production. There is little research conducted to determine the optimum rate for bioslurry use. The sole dependency on chemical fertilizer is not recommended particularly for small scale farmers who have options of using organic sources of fertilizer. Organic fertilizers release nutrients slowly relative to inorganic fertilizers. Optimizing combined use of inorganic and organic fertilizers could be a better option to balance high productivity and environmental sustainability and be cost effective. Traditionally, vegetable producers use of raw manure, organic residues and other wastes as a source of fertilizer. Use of bioslurry as a source of fertilizer is common.

Quality is an important characteristic in marketing products. The market demand for cabbage heavily depends on the heads being firm, free of defects, proper size and proper taste. Yield of cabbage increases by 18% when liquid bioslurry is applied⁵. The liquid form produces 6.6% higher yields than manure. Bioslurry in compost form produced around 11% higher yields than liquid slurry. Cabbage size increases when bioslurry is used. When cabbage is treated with bioslurry, yield increases to 56.5 Mt ha⁻¹. Treatment with 16 Mt ha⁻¹ of compost and 250 kg urea-nitrogen appears to be a better combination for growth of cabbage. Bioslurry application with 120 kg per unit area, 0.6 kg chemical fertilizer and 75 kg bioslurry as top dressing increases cabbage yield and vitamin C content by 16.06 and 16.21%, respectively, but decreases nitrate, cadmium, palladium and chrome contents². The soil pH value and organic matter content also increases. Cabbage yield can be increased with an application of 250 mL of bioslurry as nutrient liquid fertilizer, mixed with 3 g of urea, 2 g of magnesium sulphate and 2 mL of trace element². The highest yield of cabbage (68.6 Mt ha⁻¹) is produced with an application of the full recommended dose of fertilizers together with 20 Mt ha⁻¹ of slurry compost⁵. The 2nd highest yield was reached with just a bioslurry compost treatment at 20 Mt ha⁻¹. Bioslurry increases the yield of Chinese cabbage⁶.

Bioslurry improved contents of soil-available N, P and K as compared to the control (no fertilizer) and conventional methods (inorganic fertilizer containing N, K and P)⁷. Effect of bioslurry on cabbage yield and soil properties clearly indicated but effect of combine application on quality aspects not clearly indicated. The aim of this study was to examine optimal combined rates of bioslurry and inorganic fertilizer for quality characteristics of cabbage and soil properties.

MATERIALS AND METHODS

Description of study area: The experiment was conducted at Hawassa University, Hawassa, Ethiopia, from March-June 2017. The experimental site is situated at 7°3'N, 38°28'E and 1708 masl with mean annual rainfall of 952 mm. Mean minimum and maximum annual temperature is 13 and 27°C, respectively. The soil was an andosols⁸.

Experimental materials: The experiment was conducted using cabbage cv. copenhagen market the seed obtained from the Hawassa seed enterprise PLC. Urea and DAP (Di-ammonia phosphate) were used as a sources of N and N and P, respectively. Bioslurry obtained from Gebrekristos hotel (Hawassa, Ethiopia).

Design and arrangement of experiment: The experiment was arranged in factorial combination bioslurry (10, 30, 50 or 70 m³ ha⁻¹) and inorganic fertilizers (0, 25, 50, 75 or 100%) of the recommended N and P fertilizers (Table 1). The experiment was arranged in a randomized complete block design with 3 replications. In each plot 60 and 40 cm inter and intra-row spacing were used, respectively. The distance between plots and blocks was 0.5 and 1.0 m, respectively. The N and P application followed the general recommendation for cabbage varieties: of 82 kg ha⁻¹ of N and 92 kg ha⁻¹ P₂O₅; the bioslurry rate was modified from previous work⁹.

Management of experiment: Before the experiment, seedlings were raised in nursery bed. The nursery was prepared by removing plant residues and breaking soil clods. The size of the seed bed was 1.05 m² (1 m length, 7 rows, 0.10 m spacing between rows). The soil of the seed bed was turned with a spade and prepared into loose friable dried masses to obtain good tilth to provide a favorable condition for vigorous growth of seedlings. Weeds, stubble and dead roots of the previous crop were removed. The seedbed was dried in the sun to obtain a degree of control of insects and diseases. Seed were sown on raised bed and watered once

Table 1: Interaction effect of bioslurry and NP fertilizer on quality parameters of cabbage

Treatments						
Bioslurry (m ³)	RNP (%)	MY (t ha ⁻¹)	HD (cm)	FH (newton)	pH	TA (g L ⁻¹)
10	0	70.4 ^j	17.9 ⁱ	79.6 ^j	6.02 ^{def}	4.67 ^{cde}
	25	79.7 ^{ij}	18.4 ^{hi}	106.2 ⁱ	5.99 ^{ef}	5.23 ^{bcde}
	50	85.5 ^{hj}	19.1 ^{ghi}	106.0 ⁱ	5.91 ^f	4.83 ^{bcde}
	75	101.5 ^{efg}	18.4 ^{hi}	109.4 ^{hi}	6.02 ^{def}	7.80 ^a
	100	108.7 ^{cdef}	19.3 ^{ghi}	121.0 ^h	5.97 ^f	7.7 ^{ab}
30	0	93.6 ^{gh}	20.2 ^{efgh}	155.47 ^f	6.25 ^{bc}	4.47 ^{cde}
	25	93.2 ^{gh}	21.3 ^{def}	140.8 ^g	6.16 ^{cde}	5.30 ^{bcde}
	50	103.1 ^{efg}	19.6 ^{fghi}	145.7 ^g	6.25 ^{bc}	4.97 ^{bcde}
	75	115.9 ^{bcd}	20.8 ^{defg}	148.6 ^g	6.25 ^{bc}	5.97 ^{abcd}
	100	105.9 ^{defg}	20.8 ^{defg}	169.1 ^e	6.32 ^{bc}	4.23 ^{de}
50	0	107.5 ^{cdef}	22.1 ^{bcd}	203.2 ^{ab}	6.29 ^{bc}	4.00 ^{de}
	25	120.3 ^{bc}	21.6 ^{cde}	185.4 ^{cd}	6.34 ^b	5.90 ^{abcd}
	50	125.5 ^b	21.3 ^{def}	180.3 ^{de}	6.27 ^{bc}	5.43 ^{bcde}
	75	150.6 ^a	24.8 ^a	211.5 ^a	6.78 ^a	4.30 ^{de}
	100	109.9 ^{cdef}	23.4 ^{ab}	178.9 ^{de}	6.17 ^{cd}	6.10 ^{abcd}
70	0	113.1 ^{bcde}	23.8 ^{ab}	203.2 ^{ab}	6.20 ^{bc}	5.50 ^{bcde}
	25	105.1 ^{defg}	23.8 ^{ab}	188.9 ^{cd}	6.27 ^{bc}	5.00 ^{bcde}
	50	100.6 ^{efg}	23.7 ^{ab}	170.5 ^e	6.19 ^{bc}	5.03 ^{bcde}
	75	125.1 ^b	22.3 ^{bcd}	196.9 ^{bc}	6.17 ^{bcd}	7.7 ^{ab}
	100	98.9 ^{fg}	22.2 ^{bcd}	198.4 ^{bc}	6.24 ^{bc}	6.63 ^{abc}
CV		17.5	10.4	24.6	3.2	28.54

Means followed by the same letters are not significantly different at 5% level of significance, LSD (0.05): Least significant difference at 5% level, CV (%): Coefficient of variation in percentage, MY: Marketable yield, HD: Head diameter, FH: Head firmness, pH: Power of hydrogen, TA: Titratable acidity and RNP (%): Recommended nitrogen and phosphorus (%)

daily until the seedlings emerged. Irrigation was then on a 3 day intervals until transplanting. No fertilizer was used. Seedlings of 30 day old was used.

All doses of phosphorus were applied once at transplanting and 50% of nitrogen was applied at transplanting and the remaining 50% before head initiation. Liquid bioslurry was applied by diluting with water directly on plot together with tillage operations during transplanting. The bioslurry was applied in a prepared row between transplant rows.

Other agronomic practices including weeding, irrigation and cultivation were done uniformly as per required in all plots. Cultivation were done 3 time during growing period whereas weeding were done all time when weed present. Irrigation were done two day interval until reach to maturity.

Data collection: Before transplanting and after harvest soil samples were taken for analysis. Before planting, composite soil samples were taken in a zigzag pattern down to a 15 cm depth using an auger. The soil was oven dried for 24 h at 105°C, ground, mixed thoroughly and passed through a 2 mm sieve. Analysis for soil textural class, pH, CEC, organic carbon, EC, organic matter, total nitrogen, available P, available K and exchangeable bases. Before use the water content, pH, CEC, organic carbon, EC, organic matter, total nitrogen, available P, available K and exchangeable bases were determined in the

bioslurry. After harvest, soil samples were taken from all plots to a depth of 20 cm to analyze soil textural class, pH, CEC, organic carbon, EC, organic matter, total nitrogen, available P, available K and exchangeable bases.

For cabbage quality parameters, plants in outer rows and the extreme end of the middle rows were excluded to avoid the border effect. Cabbage heads free of defects (diseased, sunken, physical damaged, irregular shape) were separated and measured. Heads were collected from 5 plants from each experimental plot and all loosely attached leaves were trimmed and weight measured. Five heads from each treatment plot were sectioned vertically at the middle and the horizontal distance from side to side of the widest part measured. Head firmness was measured on 3 plants from each treatment plot using a digital texture analyzer, with a ball probe. The maximum load was 500 N, thread size 6 mm and ball diameter 6.35 mm. The reading in Newton at which the cabbage head was punctured indicated head firmness. Head compactness was calculated using the formula of Riad *et al.*¹⁰.

A representative sample of cut pieces of cabbage heads was obtained at final maturity and chopped. The juice was produced by squeezing the ground leaves with clean piece of cloth. Total soluble solids was determined by adding an equal number of drops from the prepared juice and placed onto the refractometer prism plate. After each test the prism plate was cleaned with distilled water and wiped dry with a soft tissue.

Readings were reported as °Brix. The pH was adjusted using 2 buffer solutions (pH 4.00 and pH 6.83) and juice pH directly measured with a pH meter. Titratable acidity was determined with a NaOH 0.1 M solution prepared and diluted in 1 L distilled water. About 10 g of juice was added in to beaker. Three drops of phenolphthalein was added to the juice in each beaker from a dropping pipette. The tap on the burette was shut and the 0.1 M solution of NaOH poured into the burette to the zero mark. The NaOH was slowly titrated into the juice with a 25 mL burette. Using phenolphthalein as an indicator, the point of neutrality was reached when the indicator changed from colorless to pink. Titratable acidity was calculated using the formula of Proulx *et al.*¹¹.

Data analysis: Data was subjected to analysis of variance using Proc Mixed model procedures of SAS (ver. 9.3, SAS Institute Inc., Cary, NC). A two-way ANOVA was used to determine significant difference among bioslurry and inorganic fertilizer and their interaction. If the interaction was significant it was used to explain the results, if the interaction was not Means were separated using to Fisher's protected LSD at $p < 0.05$. Pearson correlation analysis was used to determine correlations between marketable yield and other traits.

RESULTS AND DISCUSSION

Marketable yield of cabbage: Interaction effects of bioslurry and NP fertilizer had significant ($p < 0.05$) influence on the marketable yield of cabbage (Table 1). Wide variation was noted in marketable yield of head cabbage. As a result of these interaction effects. The highest marketable yield of head cabbage was obtained from the treatment combination of 50 m³ bioslurry with 75% of the recommended NP ha⁻¹ fertilizer. Numerically, the lowest marketable yield was recorded from the treatment 10 m³ bioslurry combined with 0% NP ha⁻¹ fertilizer. The combined use of 50 m³ bioslurry and 75% of the recommended NP increased cabbage marketable yield by 128% over the combined use of 10 m³ bioslurry and 0% of recommended NP (Table 1). In generally the marketable yield of cabbage increased as level of bioslurry and NP fertilizer increased, this only true up to treatment combination of 50 m³ bioslurry with 75% NP ha⁻¹ fertilizer. Then the yield had both increasing and decreasing nature (Table 1). The probably reason of this observation is plants use the nutrient early for more vegetative growth and they depressed at critical time of economic yield production.

The marketable head yield of cabbage showed increment up to 49.83 t ha⁻¹ with increasing rates of N to 180 kg ha⁻¹ and 25 t farm yard manure (FYM) ha⁻¹, but marketable yield decreased with further increase in N and FYM rates¹². Similarly, Olaniyi and Ojetayo¹³ reported that marketable head yield was increased in response to increased rate of nitrogen fertilizer up to 150 kg ha⁻¹ and thereafter it declined. The highest cabbage marketable head yield (76.53 t ha⁻¹) which is 191% increase over control), were recorded from the plot receiving N, P, K and B at the rate of 150, 50, 100 and 3 kg ha⁻¹, respectively¹⁴.

Plants treated with both nitrogen (200 kg ha⁻¹) and FYM (15 t ha⁻¹) gave significantly higher marketable yield (64.4 t ha⁻¹) than the treatments receiving no fertilizer¹⁵. Similarly, excessive use of inorganic nitrogen (250 kg ha⁻¹) and organic manure (25 t ha⁻¹) caused reduction in yield and yield components of cabbage due to unavailability of other essential nutrients inhibited by over fertilization¹⁶. White and Forbes¹⁷ reported that cabbage yield responded positively to N and FYM combination application up to the level of 308 kg N ha⁻¹ and 15 t FYM ha⁻¹, beyond that caused yield reduction. The combination of FMY with and inorganic fertilizer significantly influenced cabbage yields compared to FYM and nitrogen fertilizer alone especially at higher rates of application¹⁸. From the current experiment the total and marketable yield of head cabbage by far greater than what other scholars obtained.

The justification behind the yield reduction under high dose of fertilizer particularly bioslurry might be that causes excessive vegetative development, limit photo inorganic capacity of the plant by reducing the total sugar and vitamin content of the plant and also causes abnormal growth like color change, morphology and physiology of the plant altered in ways that impact cabbage yield. In fact, all of the plots receiving low and higher fertilizer rates show yield reduction. Generally excessive application cannot increase economic yield rather plants used for luxury consumption. Application of optimum NP and bioslurry not only increased crop productivity, but also improved quality of the product as expressed in terms of its highest marketable to unmarketable yield ratio, mainly due to reduced cracking and improved size, particularly for the reduced or balanced application of fertilizer.

Head diameter: Diameter of head cabbage was significantly affected ($p < 0.05$) by bioslurry and NP and their interaction effects. Combined application of 50 m³ bioslurry with 75% NP ha⁻¹ resulted in numerically the highest head diameter,

whereas, the lowest was obtained from 10 m³ bioslurry and 0% NP ha⁻¹ treatment (Table 1). The value of head diameter increased as the level of both bioslurry and NP increased until the combined application reached 50 m³ bioslurry ha⁻¹ and 75% NP. Beyond this combination it showed a trend of slight and non-significant decline (Table 1). The positive effects of optimal combinations of bioslurry and NP fertilizers on head diameter of cabbage might be due to the better availability of soil nutrients that produced healthy plants with good vegetative growth, which reflected in the plant height and head¹⁹. This result was in accord with the findings of Peck²⁰, where the largest diameter (23.33 cm) of the cabbage head was found in combined treatment of 200 kg N ha⁻¹ with 15 t FYM ha⁻¹ and the lowest diameter (8.33 cm) were found in control treatment. This was possibly due to higher synthesis of carbohydrate and their translocation to the sink, i.e., cabbage head which subsequently helped in the formation of larger and comparatively broader head of the cabbage.

The combined application of organic manure and inorganic nitrogen increased head diameter of cabbage plants²¹. Similarly, Subhan²² observed that the application of 15 t ha⁻¹ FYM with 200 kg N ha⁻¹ recorded higher head diameter (15.87 cm) as compared to control treatment (9.41 cm). Significantly higher diameter (19.9 cm) of head in cabbage with the application of 120-90-80 kg NPK ha⁻¹ in combination with 20 t FYM ha⁻¹ were recorded²³. Other studies indicated that application of poultry manure resulted in the highest values of cabbage head diameter followed by NPK 15-15-15, wood ash and rice bran, respectively²⁴. Even though, this scholar used higher rates of both inorganic and organic fertilizers, the highest head diameter was not comparable with the current result. This difference may be due to the genetic variations of the cultivars, soil conditions and agro-ecology difference of the areas.

Head firmness: Head firmness is the primary indicatory of head cabbage maturity. The result of the experiment clearly depicted that the application of varying level of bioslurry with varying level of NP significantly affected the head firmness ($p < 0.05$). The reading in force (N) at which the cabbage head was punctured indicated the head firmness. The one required minimum force to punctured head means the head have low firmness and the reverse also true. Minimum head firmness was observed from combined application of 10 m³ bioslurry ha⁻¹ with 0% NP ha⁻¹, whereas, the highest obtained by increasing combination rate up to 50 m³ bioslurry ha⁻¹ with 75% NP ha⁻¹ (Table 1). As level of bioslurry and NP increased beyond this the head firmness decreased. Plants supplied with

excessive nitrogen accumulate nitrate in their vacuoles and exhibit slow growth and their foliage become pale green, yellow and unable to form firm head²⁵.

Titrateable acidity and pH of cabbage: Titrateable acidity and pH of head cabbage were significantly affected ($p < 0.05$) by the interaction effects of bioslurry and NP (Table 1). Combined application of 50 m³ bioslurry with 75% NP ha⁻¹ gave the highest pH whereas numerically the lowest obtained from 10 m³ bioslurry with 50% NP ha⁻¹ (Table 1). The result in general depicted that more acidity of juice were flashed in treatment combination of 10 m³ bioslurry with all level of NP. This agrees with Zekri and Obreza²⁶, who noticed that low levels of phosphorus will increase acidity of fruit juice. In contrast a progressive increase in acidity of tomato juices was observed with increasing levels of nitrogen.

Combined application of 10 m³ bioslurry ha⁻¹ with 75% NP ha⁻¹ resulted the highest titrateable acidity whereas the lowest obtained from treatment combination of 50 m³ bioslurry ha⁻¹ with 75% NP ha⁻¹ (Table 1). The response of titrateable acidity was not patterned for varying rates of both bioslurry and NP. The lowest value obtained at treatment combination of 30 m³ bioslurry with 75% of NP, 30 m³ bioslurry with 100% of NP and 50 m³ bioslurry with 75% of NP implies suitability for consummation. This is because the amount of acids is one of taste determining factor. The products which have high sugar and low acidity have better taste²⁷. In this current investigation the higher total soluble solid were attained at treatment combination of 50 m³ bioslurry with 75% NP ha⁻¹ and at 70 m³ bioslurry and 75% NP ha⁻¹. At the same time lowest amount of acids obtained at these points.

N improves the quality and quantity of dry matter in leafy plants and protein in grain crops²⁸. Nitrogen fertilization increased the vegetative growth, fixed oil, total carbohydrate, soluble sugars and NPK content of *Nigella sativa* L. plants²⁹. But current investigation result was not agreed with previous researcher, they reported that higher NP rates result higher titrateable acidity on different crops. While our result revealed that higher value of titrateable acidity observed not only on higher rates but also at lower rates of bioslurry and NP.

Head compactness rate: Head compactness is also the primary indicatory of head cabbage maturity. The data clearly depicted that the application of bioslurry had significantly affected the head compactness ($p < 0.05$). But NP fertilizer had not significantly affected the head compactness and also their interaction effect (Table 2). Minimum head compactness was

Table 2: Main effects of bioslurry and nitrogen-phosphorus fertilizers on some quality parameters of cabbage

Treatment	Parameters	
Bioslurry ($\text{m}^3 \text{ha}^{-1}$)	HCR	TSS
10	0.93 ^b	6.46 ^c
30	1.02 ^b	6.93 ^b
50	1.07 ^{ab}	7.15 ^{ab}
70	1.20 ^a	7.45 ^a
Cv	24.20	9.26
RNP (%)		
0	1.16 ^a	6.59 ^c
25	1.07 ^a	6.84 ^{bc}
50	1.08 ^a	6.87 ^{bc}
75	1.00 ^a	7.54 ^{ab}
100	0.98 ^a	7.13 ^a
Cv	24.20	9.26

Means followed by the same letters are not significantly different at 5% level of significance, LSD (0.05): Least significant difference at 5% level, CV (%): Coefficient of variation (%), HCR: Head compactness rate, TSS: Total soluble solid RNP (%): Recommended nitrogen and phosphorous (%)

observed from treatment of $10 \text{ m}^3 \text{bioslurry ha}^{-1}$, whereas, numerically the highest head compactness was obtained from treatment of $70 \text{ m}^3 \text{bioslurry ha}^{-1}$. The result generally indicated that application of higher rates of bioslurry yield higher head compactness. Compactness rating of 1 means the head is very compact and it contains no air. Generally the lower the rate of compactness, the less compact the head is and vice versa. The link between head compactness measurement and an increase in nitrogen was observed here and this has been reported elsewhere¹⁰.

Total soluble solid (TSS): Total soluble solid of head cabbage was significantly affected ($p < 0.05$) by the main effects of NP and bioslurry. Whereas, it was not significantly affected by interaction effect of bioslurry and NP (Table 2). Higher values of TSS were obtained from treatments $70 \text{ m}^3 \text{ha}^{-1}$ and $50 \text{ m}^3 \text{ha}^{-1}$ bioslurry. Similarly, 75% and 100% of recommended NP ha^{-1} resulted in higher TSS. Whereas the lower value of TSS obtained from lower rates of treatment for both bioslurry and NP (Table 2). The result clearly depicted that as the rate of bioslurry and NP increase the total soluble solid content increased.

Total soluble solid is one of quality parameter and govern the consumer preferences with the amount of acids that balance sugar acid ratio. The flavor metabolites such as sugar and organic acid compositions, which are measured through TSS and titratable acidity are most commonly associated with the taste of fruits juice^{4,27}. Nitrogen improves the quality and quantity of dry matter in leafy vegetables and protein in grain crops²⁸. Nitrogen fertilization increased the total carbohydrate and soluble sugars of *Nigella sativa* L. plants²⁹. Other study on

cabbage indicated that vermi-compost increased contents of sugar and vitamin C by average of 12 and 57%, respectively³⁰.

Properties of soil after harvest as influenced by the bioslurry and NP fertilizers: Soil pH, organic carbon, organic matter, total nitrogen, available phosphorus and potassium were significantly ($p < 0.05$) affected by the combined application of different rates of bioslurry and NP fertilizer (Table 3). Generally the pH the soil ranges (6.65-7.14) among the treatments. After application of organic and inorganic fertilizer the soil pH value increased by 12.46%. The result clearly depicted the value of soil pH increased as both rates of bioslurry and NP increases. The pH range of the soil is an important condition for many chemical reactions and microbial activities in the soil. In current study organic matter buffers the soil pH by keeping it towards the neutral range. The pre-planting soil analysis showed a soil pH of 6.36. However, after the experiment completion, the soil pH became in the range 6.65-7.14 indicating application of bioslurry and NP raised the pH to the neutral region.

This result agrees with the finding of² who reported that the application of liquid digested bioslurry and bioslurry compost slightly improved the pH of the soil. The residual organic carbon, organic matter and total nitrogen contents were increased by 140.5, 142.3 and 144%, respectively, after completion of the experiment. In addition to the change in soil characters after the experiment, the rates of the combined application of bioslurry and NP exerted different effects. Organic carbon, organic matter and total N value increased as the rate of the combined application of bioslurry and NP increased. Available P and K contents of the soils also significantly ($p < 0.05$) affected by the combined application of bioslurry and NP fertilizer. The residual value of available P and K in the soil increased by 31.18 and 195.3%, respectively, after the experiment. Much of the residuals soil improvements were indicated on the higher rates of bioslurry that can lead to the conclusion that bioslurry has more influence on the soil characteristics (Table 3). Organic resources of fertilizer contain slow releasing nutrients and also have advantages of building soil organic matter gradually. Organic resources enhance soil health through contributing carbon for cell building and energy source for soil micro-organisms. This result agrees with Shahabz², who reported that application of mineral fertilizer and bioslurry had shown positive contribution on the available N and K content in the soil, the author reported that P content in the soil was not changed. Application of bioslurry in two different forms showed significant difference in the available P content of the soil. Phosphorous availability is increased with

Table 3: Mean values for the chemical properties of the post-harvest soil as influenced by the combined application of bioslurry and NP fertilizers

Treatments		Soil chemical properties					
Bioslurry (m ³)	RNP (%)	OC (%)	OM (%)	TN (%)	Avl.P (ppm)	Avl.K (ppm)	pH
10	0	0.91 ^l	1.57 ^l	0.07 ^l	73.76 ^l	356.25 ^g	6.71 ^{def}
	25	2.61 ^k	4.48 ^k	0.22 ^k	79.24 ^{ij}	375.17 ^{fg}	6.82 ^{bcdef}
	50	3.32 ^k	5.71 ^k	0.28 ^k	80.85 ^{hi}	383.58 ^{fg}	6.65 ^{ef}
	75	4.88 ^j	8.4 ^j	0.42 ^j	88.56 ^{fg}	395.25 ^f	6.72 ^{def}
	100	4.94 ^{ij}	8.51 ^{ij}	0.43 ^{ij}	92.48 ^{def}	400.08 ^f	6.75 ^{def}
30	0	5.33 ^{ij}	9.18 ^{ij}	0.46 ^{ij}	94.32 ^{def}	474.08 ^{bcd}	6.65 ^{ef}
	25	5.72 ⁱ	9.86 ⁱ	0.49 ⁱ	81.66 ^{hi}	450.75 ^{cd}	6.86 ^{bcde}
	50	6.83 ^h	11.77 ^h	0.59 ^h	82.45 ^{hi}	385.83 ^{fg}	6.82 ^{bcdef}
	75	8.26 ^g	14.23 ^g	0.71 ^g	91.68 ^{defd}	439.83 ^{de}	6.83 ^{bcdef}
	100	8.96 ^g	15.44 ^g	0.77 ^g	86.29 ^{gh}	387.25 ^{fg}	6.81 ^{bcdef}
50	0	8.54 ^g	14.71 ^g	0.74 ^g	92.6233 ^{def}	387.83 ^{fg}	6.82 ^{bcdef}
	25	9.9 ⁱ	17.06 ^f	0.86 ^f	89.1733 ^{efg}	384.17 ^{fg}	6.72 ^{def}
	50	11.2 ^h	19.31 ^e	0.97 ^e	88.65 ^{eg}	389.92 ^{fg}	6.61 ^{def}
	75	12.31 ^g	21.21 ^{cd}	1.06 ^{cd}	89.7 ^{efg}	406.75 ^{ef}	6.8 ^{cdef}
	100	12.88 ^{cd}	22.21 ^{cd}	1.12 ^c	94.8467 ^{de}	449.67 ^{cd}	7.01 ^{abc}
70	0	14.38 ^b	24.79 ^b	1.24 ^b	97.1633 ^{cd}	465.00 ^{bcd}	7.14 ^{abc}
	25	15.75 ^a	27.15 ^a	1.36 ^a	93.93 ^{def}	479.58 ^{bc}	7.0433 ^a
	50	12.11 ^d	20.87 ^d	1.04 ^d	102.37 ^{bc}	486.33 ^{abc}	7.05 ^{abc}
	75	13.02 ^a	22.45 ^c	1.12 ^c	106.43 ^{ab}	491.42 ^{ab}	6.91 ^{ab}
	100	14.19 ^b	24.47 ^b	1.22 ^b	111.31 ^a	518.42 ^a	6.78 ^{def}
CV		28.8	38.92	18.89	10.53	11.94	2.77

Means followed by the same letter(s) are not significantly differ at 5% level of significance, LSD (0.05): Least significant difference at 5% level, CV (%): Coefficient of variation (%), OC: Organic carbon, OM: Soil organic matter, TN: Total N, Avl.P: Available P, Avl.K: Available K and pH: Power of hydrogen and RNP (%): Recommended nitrogen and phosphorous (%)

Table 4: Mean values for the exchangeable bases (Ca, Mg, K and Na) and CEC of the post-harvest soil as influenced by the combined application of bioslurry and NP fertilizers

Treatments		Exchangeable bases (cmol kg ⁻¹ soil)				
Bioslurry (m ³)	RNP (%)	CEC (cmol kg ⁻¹)	Ca	Mg	K	Na
10	0	25.3 ^{cdefgh}	43.3 ^l	3.67 ^g	5.00 ^{hij}	0.71 ^l
	25	27.5 ^{bcdefg}	49.6 ^k	3.97 ^{fg}	5.31 ^{gh}	0.8967 ^{kl}
	50	24.7 ^{defgh}	54.7 ^{hijk}	3.98 ^{efg}	4.86 ^{ijk}	1.32 ^{jk}
	75	24.2 ^{efgh}	56.0 ^{ghij}	4.46 ^{def}	5.18 ^{ghi}	1.4 ^j
	100	23.0667 ^{gh}	64.4 ^{cde}	4.99 ^{cd}	4.95 ^{hij}	1.9367 ^{fgh}
30	0	21.37 ^{hi}	52.2 ^{jk}	4.18 ⁺	4.61 ^{jk}	2.27 ^{defgh}
	25	15.5 ⁱ	58.3 ^{efghij}	3.8567 ^{fg}	4.56 ^k	1.74 ^{ghi}
	50	28.3 ^{abcdefg}	53.5 ^{ijk}	3.88 ^{efg}	5.84 ^{cde}	1.847 ^{hij}
	75	30.7 ^{abc}	61.8 ^{cdefg}	4.28 ^{efg}	6.41 ^{bcd}	2.29 ^{ghi}
	100	23.7 ^{fgh}	59.2 ^{sefghi}	3.98 ^{efg}	5.58 ^{def}	2.14 ^{defg}
50	0	30.4 ^{abcd}	56.3 ^{fghij}	4.47 ^{def}	5.87 ^{cde}	2.7 ^{efgh}
	25	24.9 ^{cdefgh}	54.8 ^{hijk}	4.57 ^{de}	5.56 ^{efg}	2.86 ^b
	50	23.4 ^{abfgh}	58.5 ^{defghi}	5.47 ^{bc}	5.79 ^{cde}	2.66 ^{fgh}
	75	28.5 ^{abcdefg}	65.8 ^{bc}	4.47 ^{def}	6.04 ^a	1.92 ^{cdef}
	100	26.3 ^{cdefgh}	60.2 ^{cdefgh}	3.89 ^{efg}	7.08 ^{ab}	2.35 ^{fgh}
70	0	29.5 ^{abcde}	62.1667 ^{cdef}	5.03 ^{cd}	6.25 ^{bcd}	2.16 ^{efgh}
	25	33.3 ^{ab}	62.6 ^{cde}	5.57 ^{bc}	6.56 ^{abc}	2.46 ^{bcde}
	50	26.8 ^{cdefgh}	64.4 ^{cd}	5.78 ^b	7.44 ^a	2.78 ^{bc}
	75	29.2 ^{abcdef}	71.7 ^b	5.99 ^{ab}	6.61 ^{abc}	3.3967 ^a
	100	33.9 ^a	78.83 ^a	6.6733 ^a	6.68 ^{abc}	3.75 ^a
CV		19.67	13.89	19.6	16.37	35.90
LSD						

Means followed by the same letter(s) are not significantly differ at 5% level of significance, LSD (0.05): Least significant difference at 5% level, CV (%): Coefficient of variation (%), CEC: Cations exchange capacity, Ca: Calcium, Mg: Magnesium, K: Potassium, Na: Sodium and RNP (%): Recommended nitrogen and phosphorous (%)

the presence of organic matter³⁰. This occurs when organic matter form complexes with amorphous ion in the soil thus preventing them from binding and immobilizing phosphate ions³⁰.

Cation exchange capacity of the soil was significantly (p<0.05) affected by combined application of bioslurry and NP fertilizer (Table 4). The amount of CEC, Ca, K and Na increased by 12.3, 9.4, 2.9 and 86.6% after the combined application of

70 m³ bioslurry and 100% NP fertilizer. On the other hand the content of Mg depleted by 29.8% over the pre-planting soil Mg value. The exchange complex was dominated by Ca followed by Mg, K and Na.

This result is in line with the finding of Zebider³¹, who reported that application of digested liquid bioslurry and bioslurry compost increased the CEC of the soil. The increase in CEC is that organic matter considerably enhances the cation exchange capacity of the soil i.e., its ability to bind positively charged ions such as magnesium, calcium, potassium and ammonium. Without this binding effect, these nutrients would be rapidly leached away when it rained. Cation exchange ability of the organic matter is particularly important in acid soils and those with low clay content since such soils have low binding ability. Organic matter also forms complexes with micro nutrients such as iron, manganese, boron and copper and through binding prevent them from being lost through leaching.

CONCLUSION

Based on the results of the current study the combined application of 50 m³ bioslurry with 75% NP ha⁻¹ could be recommended for production of quality head cabbage at Hawassa and areas having similar agro-ecologies. Though it is hardly possible to make final recommendation from one season and one location experimental data. The application of bioslurry also found to improve the properties of soil; hence the use of bioslurry can also be advised for sustainable soil quality improvement in the study area. However, the experiment was conducted at one location for one season that is not significant to make final recommendations on about use of bioslurry as sole or in combination of NP fertilizers application for obtaining maximum quality yield of cabbage and soil properties improvement. Therefore, further similar studies need to be conducted over years and locations to make final recommendation of cabbage production in the study area.

SIGNIFICANCE STATEMENT

The combined application bioslurry and inorganic fertilizers have a better benefit for cabbage producers and can also be good for organic waste management. This may lead scientists to investigate the role of combined application of bioslurry and inorganic fertilizers on product quality and soil properties under different situations. Dependency on inorganic fertilizers can be minimized by combining them

with organic sources of fertilizers and the problem of organic wastes in urban areas can be minimized by further use as a fertilizer.

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REFERENCES

1. Knavel, D.E. and J.W. Herron, 1981. Influence of tillage system, plant spacing and nitrogen on head weight, yield and nutrient concentration of spring cabbage. J. Am. Soc. Hort. Sci., 106: 540-545.
2. Shahabz, M., 2011. Potential of bioslurry and compost at different levels of inorganic nitrogen to improve growth and yield of okra (*Hibiscus esculentus* L.). B.Sc. Thesis, Soil and Environmental Sciences, University of Agriculture Faisalabad, Pakistan.
3. Haile, W., 2012. Appraisal of *Erythrina bruci* as a source for soil nutrition on nitisols of South Ethiopia. Int. J. Agric. Biol., 14: 371-376.
4. Ferguson, I.B. and L.M. Boyd, 2002. Inorganic Nutrients and Fruit Quality. In: Fruit Quality and its Biological Basis, Knee, M. (Ed.), Sheffield Academic Press, Sheffield, UK., pp: 14-45.
5. Karki, K.B., 2001. Response to bioslurry application on Maize and Cabbage in Lalitpur district: Final report. Biogas Sector Partnership, Katmandu, Nepal.
6. Liu, W.K., Q.C. Yang and L. Du, 2009. Soilless cultivation for high-quality vegetables with biogas manure in China: Feasibility and benefit analysis. Renewable Agric. Food Syst., 24: 300-307.
7. Yu, F.B., X.P. Luo, C.F. Song, M.X. Zhang and S.D. Shan, 2010. Concentrated biogas slurry enhanced soil fertility and tomato quality. Acta Agric. Scand. Section B: Soil Plant Sci., 60: 262-268.
8. Abera, G. and E. Wolde-Meskel, 2013. Soil properties and soil organic carbon stocks of tropical Andosol under different land uses. Open J. Soil Sci., 3: 153-162.
9. Din, M., M. Qasim and M. Alam, 2007. Effect of different levels of N, P and K on the growth and yield of cabbage. J. Agric. Res., 45: 171-176.
10. Riad, G., G. Abdalla, A. Ahmed, A. Mahmoud and H. Amira, 2009. Cabbage nutritional quality as influenced by planting density and nitrogen fertilizer. Fruit Vegetable Cereal Sci. Biotechnol., 3: 68-74.
11. Proulx, E., Y. Yagiz, M.C.N. Nunes and S. Banyal, 2010. Quality attributes limiting snap bean post harvest life at chilling and non-chilling temperatures. HortScience, 45: 1238-1249.

12. Samant, P.K.S., S.K. Sahu and D.N. Singh, 1992. Studies on balanced fertilizer use for cabbage in acid clay loam soils of Orissa. Orissa J. Agric. Res. Sta., 5: 45-49.
13. Olaniyi, J.O. and A.E. Ojetayo, 2011. Effect of fertilizer types on the growth and yield of two cabbage varieties. J. Anim. Plant Sci., 12: 1573-1582.
14. Naher, M.N.A., M.N. Alam and N. Jahan, 2014. Effect of nutrient management on the growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.) in calcareous soils of Bangladesh. Agriculturists, 12: 24-33.
15. Chowdhury, M.M.U., M.N. Anwar, J.U. Sarker, S.A. Firoj and M.Z. Uddin, 1998. Response of molybdenum and organic manure on the growth and yield of cabbage in Hilly region. Bangladesh J. Agric. Res., 23: 705-711.
16. Kaur, K., K.K. Kapoor and A.P. Gupta, 2005. Impact of organic manures with and without mineral fertilizers on soil chemical and biological properties under tropical conditions. J. Plant Nutr. Soil Sci., 168: 117-122.
17. White, J.M. and R.B. Forbes, 1976. Effect of spacing and fertilizer rates on cabbage yield and head weight. Proc. Florida. State Horticult. Soc., 89: 118-120.
18. Haque, K.M.F., A.A. Jahangir, M.E. Haque, R.K. Mondal, M.A.A. Jahan and M.A.M. Sarker, 2006. Yield and nutritional quality of cabbage as affected by nitrogen and phosphorus fertilization. Bangladesh J. Sci. Ind. Res., 41: 41-46.
19. Wong, J.W.C., K.K. Ma, K.M. Fang and C. Cheung, 1999. Utilization of manure compost for organic farming in Hong Kong. Bio-resource Technol., 67: 43-46.
20. Peck, N.H., 1981. Cabbage plant responses to nitrogen fertilization 1. Agron. J., 73: 679-684.
21. Roe, N.E. and G.C. Cornforth, 2000. Effects of dairy lot scrapings and composted dairy manure on growth, yield and profit potential of double cropped vegetables. Compost Sci. Utilization, 8: 320-327.
22. Subhan, A., 2008. Effect of organic materials on growth and production of cabbage (*Brassica oleraceae* L.) bulletin. Peletitian Hortikultura, 16: 37-41.
23. Arisha, H.M.E., A.A. Gad and S.E. Younes, 2003. Response of some cabbage cultivars to organic and mineral nitrogen fertilizer under sandy soil conditions. Zagazig J. Agric. Res., 30: 75-99.
24. Moyin-Jesu, E.I., 2015. Use of different organic fertilizers on soil fertility improvement, growth and head yield parameters of cabbage (*Brassica oleraceae* L.). Int. J. Recycl. Org. Waste Agric., 4: 291-298.
25. Onyango, C.M., J. Harbinson, J.K. Imungi, S.S. Shibairo and O. van Kooten, 2012. Influence of organic and mineral fertilization on germination, leaf nitrogen, nitrate accumulation and yield of vegetable amaranth. J. Plant Nutr., 35: 342-365.
26. Zekri, M. and T.A. Obreza, 2003. Plant Nutrients for Citrus Trees. Extension Service Fact Sheet SL 200. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.
27. Shiraishi, M., H. Fujishima and H. Chijiwa, 2010. Evaluation of table grape genetic resources for sugar, organic acid and amino acid composition of berries. Euphytica, 174: 1-13.
28. Nyoki, D. and P.A. Ndakidemi, 2014. Effects of *Bradyrhizobium japonicum* and phosphorus supplementation on the productivity of legumes. Int. J. Plant Soil Sci., 3: 894-910.
29. Khalid, K.A., 2001. Effect of some fertilizer on chemical composition and quality of dried apricot, prune, fig and tomato. Ph.D. Thesis, Faculty of Agriculture, Ain-Shams University, Cairo, Egypt.
30. Nurhidayati, N., U. Ali and I. Murwani, 2016. Yield and quality of cabbage (*Brassica oleracea* L. var. *Capitata*) under organic growing media using vermicompost and earthworm *Pontoscolex corethrurus* inoculation. Agric. Agric. Sci. Procedia, 11: 5-13.
31. Zebider, A., 2011. The contribution of biogas production from cattle manure at household level for forest conservation and soil fertility improvement. M.Sc. Thesis, Environmental Science, Addis Ababa University, Addis Ababa, Ethiopia.