OPEN ACCESS American Journal of Plant Physiology

ISSN 1557-4539
DOI: 10.3923/ajpp.2018.36.43

Research Article
Agronomic and Yield Response of Cabbage (*Brassica oleracea* L. var. *Capitata*) to Combined Application of Bio-slurry and Inorganic Fertilizers

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Abstract
Background and Objective: Organic waste recycling for agriculture is an important practice that has a high potential to improve soil fertility and crop yield with little environmental cost. A sole or combined application of waste sourced bio-fertilizers are an option for sustainable crop production in the era of climate change. However, a limited and site-specific research has been reported on the combined effects of organic and inorganic fertilizers. Therefore, the current study was designed to optimize the combined rates of bio-slurry and inorganic fertilizer in order to improve agronomic performance and yield of cabbage. **Materials and Methods:** A field experiment was conducted to evaluate the plant growth performance and head yield of cabbage in response to combined application of bio-slurry and NP inorganic fertilizers at Hawassa in southern Ethiopia during the 2017 cropping seasons under rain-fed condition. Treatments consisting of four levels of bio-slurry (10 m, 30 m, 50 m and 70 m 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 results revealed marked effect of the organic treatments on agronomy and head yield of cabbage. The interaction effects of bio-slurry and NP had significantly ($p<0.05$) affected plant height, number of expanded leaves, days to head initiation, days to 50% heading, days to first harvest, head height, total yield, above ground fresh and dry biomass and harvest index. Highest value of plant height, number of unfolded leaves, above ground fresh weight, above ground dry weight, head weight and total yield were recorded for the combined application of 50 m^3 bio-slurry with 75% of the recommended NP ha^{-1}. Treatments that received 50 m^3 bio-slurry in combination with 75% recommended nitrogen and phosphorous RNP ha^{-1} gave the highest marginal rate of return of 6891%, indicating that for every 1.00 birr invested for 50 m^3 bio-slurry with 75% of the RNP ha^{-1} of fertilizer, farmers can obtain an additional 68.91 ETB. **Conclusion:** Therefore, the combined application of 50 m^3 ha^{-1} bio-slurry with 75% RNP can be recommended for cabbage production in the research area and similar agro-ecologies.

Key words: Bio-slurry, agronomic performance, yield of cabbage, inorganic fertilizer, agro ecology

Citation: Tsegaye Terefe, Tewodros Ayalew and Hussien Mohammed Beshir, 2018. Agronomic and yield response of cabbage (*Brassica oleracea* L. var. *Capitata*) to combined application of bio-slurry and inorganic fertilizers. Am. J. Plant Physiol., 13: 36-43.

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Competing Interest: The authors have declared that no competing interest exists.

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

INTRODUCTION

Vegetables are very significant sources of vitamins, fiber, minerals, anti-oxidant and plant proteins in human diet which are useful for normal functioning of body systems and prevention of cancer[1]. Vegetable cultivation is becoming more costly due to the increasing use of purchased inputs such as pesticides and fertilizers to sustain production levels[2]. In Ethiopia, cabbage (*Brassica oleracea* var. *capitata*) ranks 5th in total area coverage (7,197.70 ha) after red pepper, Ethiopian cabbage, tomato and green pepper and ranks 4th in production after Ethiopian cabbage, tomato and green pepper from vegetable crops cultivated. In southern Ethiopia, head cabbage ranks second in total area coverage (1,738.49 ha) and production (9,515.423 t) from vegetable crops cultivated in the region. However, the mean yield of cabbage in southern region is 5.473 t ha^{-1} which is less than national mean yield[3] of 6.435 t ha^{-1}.

In spite of its wide production and utilization, the optimum production of cabbage has not been attained in the country, which partly attributed by sub-optimal application of fertilizers due to the high cost of synthetic fertilizers. This high cost of chemical fertilizers (DAP and Urea) enforced farmers to stick to the application of sub-optimal rate of on average 14.7 kg ha^{-1}, which is far below the world average of 82.4 kg ha^{-1}[4]. Moreover, this rate deviates much from the nationally recommended rate of 200 kg ha^{-1} DAP and 100 kg ha^{-1} urea.

Bio-slurry, the residual manure generated through anaerobic decomposition of various organic materials is considered as quality organic fertilizer. About 25-30% of organic matter is converted into biogas during the anaerobic fermentation process, while the rest becomes available as bio-slurry. This residual bio-slurry is normally rich in macro and micronutrients[5]. It is obtained after extraction of the energy content of animal manure and it is an excellent source of bio-fertilizer. Bio-slurry is rich in major nutrients (nitrogen, phosphorous and potassium) and organic matter (humus) that determine the soil fertility and yield of vegetables crops. Due to the decomposition and breakdown of parts of its organic content, digested bio-slurry provides fast-acting nutrients that can easily enter into the soil solution, thus becoming immediately available for plant uptake[5]. Indeed, bio-slurry form and content stabilizes with double nitrogen content, which is different from Farmyard Manure (FYM). Bio-slurry contains readily available plant nutrients and it contains higher amounts of macro and micro-nutrients than FYM and composted manure. Hence, bio-slurry can be a good alternative to chemical fertilizers[6].

In Hawassa area, southern Ethiopia, vegetable crops play an important role through contributing for household food security, generation of income and employment opportunity. However, relying on the use of chemical sources of fertilizers is not wise in small scale or garden level vegetable production due to the high cost of chemical fertilizers, accessibility and reduced profit margin. Moreover, considering environmental and human health, sole dependency on chemical fertilizer is not recommended at least for small-scale farmers who can have options of using organic sources of fertilizer. Traditionally, vegetable producers use manures, organic residues and other wastes as an alternative source of fertilizer to produce vegetable crops. However, these organic materials are not processed and applied as a raw. On the other hand, the owners of the biogas processing plant are facing a challenge where to dispose the bio-slurry. Moreover, the use of bio-slurry as a source of fertilizer is not common in Hawassa area. Even if very few vegetable producers used to apply bio-slurry to fertilize their farm, no research was conducted to determine the effect of sole application and its combined application with Nitrogen and Phosphorus (NP) fertilizers on yield, yield related traits and traits of cabbage. This indicates the existence of current research gap in determining the optimal rate of bio-slurry and/or in combination with NP fertilizers application from productivity and economical feasibility point of view.

Therefore, the aim of the study was to determine the optimal combined rates of bio-slurry and inorganic fertilizer for agronomic and yield response of cabbage and to estimate the economic benefit.

MATERIALS AND METHODS

Description of the study area: The experiment was conducted from March-June, 2017at the experimental field of Hawassa University, Hawassa, Ethiopia. Hawassa is located at 270 km south of the capital, Addis Ababa. Geographically, the experimental area is situated at 7°3' N, 38°28' E and 1708 m.a.s.l with mean annual rainfall of 900 mm, mean minimum and maximum annual temperature of 13 and 27°C, respectively[7]. The climatic condition of the area is a hot to warm sub-moist humid climate zone with warmer temperature especially during the dry season. The type of the soil of the experimental area is andisol. The farming system of the area is characterized by cultivation of enset, maize, potato, vegetables (head cabbage, tomato, onion, garlic and carrot), coffee and common bean. A cattle rearing is an integral part of the farming system[3].

Description of the experimental materials: The cabbage variety Copenhagen market was used as experimental material. The seeds of this variety were obtained from Hawassa seed enterprise PLC. The variety is well adapted, widely cultivated and available in the study area and has a short vegetative cycle. Urea (46% N) and DAP (18% N+46% P_2O_5) were used as a sources of nitrogen and nitrogen (N) and phosphorus (P), respectively, whereas, bio-slurry was obtained from Gebrekiristos Hotel, Hawassa and used as organic fertilizer.

Before transplanting a soil samples were taken for physico-chemical analysis. Soil samples were taken up to 15 cm depth by using auger following zigzag manner. The soil was oven dried for 24 h at 105°C, grinded and mixed thoroughly and passed through a 2 mm sieve. Then a composite soil was analyzed for determining the soil textural class, pH, CEC, organic carbon, EC, organic matter, total nitrogen, available P, available K and exchangeable bases. The bio-slurry was also analyzed for water content, pH, CEC, organic carbon, EC, organic matter, total nitrogen, available P, available K and exchangeable bases. The values for each physico-chemical characteristics of the experimental soil and bio-slurry were presented in Table 1.

Treatments and experimental design: The experiment was arranged in factorial combination of four level of bio-slurry (10, 30, 50 and 70 m^3 ha^{-1}) and five levels of inorganic fertilizers which were 0, 25, 50, 75 and 100% of the recommended NP fertilizer. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Spacing of 60 and 40 cm between rows and plants were used, respectively. The distance between plots and blocks were 0.5 and 1.0 m, respectively. Four rows per plot and six plants per row with a total of 24 plants per plot were established. The size of the plot was 2.4×2.4 m which is 5.76 m^2. The NP portion from inorganic fertilizer was calculated from the general national recommendation for cabbage varieties (82 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}), whereas, the bio-slurry rate was adopted and modified from previous experiment (39-60 m^3 ha^{-1}).

Management of the experiment: The nursery was prepared by removing plant residues and breaking big soil aggregates. Seedlings of the cabbage was raised in a seed bed of 1.05 m^2 (1 m length, 7 rows, 0.10 m spacing between rows). The soil of the seed bed was well ploughed with a spade and prepared into loose friable dried masses and obtained good tilth that can provide a favorable condition for the vigorous growth of young seedlings. The seedbed was dried in the sun to destroy the soil insect and protect the young seedlings from the attack of damping off and other diseases. The seeds of the cabbage were sown on raised bed and watered once in a day until the seedlings were emerged and ready for transplanting. In the nursery fertilizer was not applied. Five days before transplanting the seedlings were hardened by reducing irrigation frequency and volume. Then healthy and uniform seedlings were transplanted to a treatment plots after 30 days of sowing on March 24, 2017. All doses of phosphorus were applied once at time of transplanting and the doses of nitrogen were applied 50% at time of transplanting and 50% before head initiation as per treatment dose. Liquid bio-slurry were applied by diluting with water directly on plot together

Table 1: Physico-chemical characteristics of the experimental soil and bio-slurry

Description soil		Description of bio-slurry	
Profile code	Quantity	Profile code	Quantity
Sand (%)	61	Water (%)	93.93
Silt (%)	21	Dry matter (%)	6.07
Clay (%)	18	Organic matter (%)	30.6
Texture class¥	sandy loam	Organic carbon (%)	17.7
pH-H_2O (1:2.5)©	6.36	pH-H_2O (1:2.5)	7.33
Exch.Ca^{2+} (cmol (+) kg^{-1} soil)®	71.97	Total nitrogen (%)	1.53
Exch.Na (cmol (+) kg^{-1} soil)*	0.59	Available P (mg P_2O_5 kg^{-1} BS	301.4
Exch.K^+ (cmol (+) kg^{-1} soil)*	6.50	Available K (mg K_2O kg^{-1} bio-slurry	715.25
Exch.Mg^{2+} (cmol (+) kg^{-1} soil)®	9.5	Exch.Ca^{2+} (cmol (+) kg^{-1} BS)	114.4
CEC (cmol(+) kg^{-1} soil) α	30.2	Exch.Na (cmol (+) kg^{-1} BS)	33.2
Organic carbon (%) €	5.9	Exch.K^+ (cmol (+) kg^{-1} BS)	28.6
Organic matter (%)	10.1	Exch.Mg^{2+} (cmol (+) kg^{-1} BS)	17.4
Total nitrogen (%)™	0.50	CEC (cmol (+) kg^{-1} BS)	64
Available P (mg P_2O_5 kg^{-1} soil)@	71.6		
Available K (mg K_2O kg^{-1} soil)*	162.4		

¥: Dispersion hydrometer, ©: Potentiometrical, €: Titration, ™: Kejeldahl, ®: Atomic absorption (AAS), @: Olsen, *Flame photometer, α: Ammonium acetate with tillage operations during transplanting. Other agronomic practices including weeding, irrigation and cultivation were done uniformly when necessary in all plots.

Data Collection: The phenological data of the crop was collected on plot basis, while data for other agro-morphology traits were collected from plants at central rows. The plants in the outer rows and the extreme end of the middle rows were excluded to avoid the border effect and the specified representative sample amount for each of below listed parameters carried out through random selection.

Days to first head formation: The number of days from the date of transplanting to the date when the first head seat opens in a plot. Days to 50% heading: The numbers of days from the date of transplanting to about 50% of the plants produce head. Days to first harvest: The number of days was counted from the transplanting date to first picking day when heads are firm. Plant height: The plant height was measured from ground level to the tip of the growing point at the end of vegetative growth phase, expressed in centimeters and the mean was computed. Number of unfolded leaves: Leaves of cabbage, which were not folded to form compact head, were counted. Length of the biggest loose leaf: The length of the biggest leaf was measured from the base of the petiole to the tip of the leaf. Fresh above ground biomass: Both folded and unfolded leaves were collected and measured by using sensitive balances. Above ground dry biomass: Both folded and unfolded leaves and heads were chopped and samples were taken, dried in the direct sun and then in an oven at a temperature of 70°C until constant weight was observed.

Total yield: Total head yield per plot was taken as it reaches to maturity. All heads of cabbage from net harvestable plots were harvested and loosely attached leaf were trimmed and measured using sensitive balance. Then the yield converted to tone per hectare. The average was taken to determine head weight.

Head weight: The heads of cabbage collected from five plants from each of experimental plots and all loosely attached leafs were trimmed and weight measured by using sensitive balance.

Harvest index: Fresh weight of head divided by above ground fresh biomass of the plant.

Partial budget analysis: The yields were adjusted by 10% downwards due to management level variability between a researcher and a farmer (CIMMYT, 1988). Costs of farm services were taken at Hawassa market in the southern part of Ethiopia. The economic indicators used were: Gross benefit was estimated as the product of the adjusted yield (t ha^{-1}) and the sale prices (3 birr kg^{-1}) and calculated by multiplying the yield in t ha^{-1} by the market price. Variable cost was calculated by current fertilizer price: Urea with the cost of 11.92 Birr kg^{-1} and DAP with cost of 13.8 Birr kg^{-1} and bio-slurry with cost of 0.4 Birr L^{-1}. Net benefit was calculated by subtracting the total cost of production from the gross benefit. Marginal analysis compares the net benefits with the total variable cost. Finally, marginal rate of returns were calculated (MRR), where the percentage change in benefit over change in total variable cost in moving from a lower cost treatment to a higher one. This was achieved by dividing the marginal revenue by the net benefit multiplied by 100:

$$\text{MMR (\%)} = \frac{\Delta \text{ Marginal benefit}}{\Delta \text{ Marginal cost}} \times 100$$

Data analysis: Data was subjected for analysis of variance (ANOVA) using Proc Mixed model procedures of SAS software version 9.3. A two-way ANOVA was applied to determine significant difference among bio-slurry and inorganic fertilizer and their interaction. Means were separated according to Fisher's protected LSD at $p<0.05$.

RESULT AND DISCUSSION

Phenological parameters of head cabbage: The analysis of variance indicated that interaction effects of NP and bio-slurry had significant ($p<0.05$) effect on days to head formation, days to 50% heading and days to maturity (Table 2). First heading of cabbage was delayed in the treatment combinations of 10 m^3 ha^{-1} bio-slurry (BS) with 0, 25, 50 and 75% recommended NP ha^{-1}, whereas early heading was observed in the treatment combinations of 30 m^3 ha^{-1} BS with each of 75 and 100% NP ha^{-1}. Moreover, 70 m^3 bio-slurry combined with all levels of NP fertilizers (25, 50 and 75 and 100% of recommended NP) facilitated first heading (Table 2). More number of days to 50% heading was attained in the treatments of 10 m^3 ha^{-1} BS combined with all levels of NP fertilizers. Less number of days were required to reach 50% heading in the treatments of 30 m^3 ha^{-1} BS with each of 75% NP ha^{-1} and 100% NP ha^{-1}. Again combined effect of 70 m^3 bio-slurry with all levels of NP fertilizers (25, 50, 75 and 100% of recommended NP) resulted in less number of days to 50% heading (Table 2). Head cabbage planted in plots

Table 2: Interaction effect of bio-slurry (BS) and inorganic fertilizer (nitrogen and phosphorus) on phenological and growth parameters of cabbage

Treatments										
Bio-slurry (m^3)	RNP (%)	DFHS	D50%H	DFH	PH (cm)	NUL	FB (kg)	DB (kg)	HW(kg)	Y(t ha^{-1})
10	0	45.0^{a}	55.0^{a}	70.0^{f}	12.4^{i}	14.1^{b}	3.2^{h}	0.20^{h}	2.2^{i}	76.7^{j}
	25	45.0^{a}	55.0^{a}	70.0^{f}	18.4^{h}	14.4^{b}	3.4^{gh}	0.27^{fgh}	2.4^{hi}	89.6^{hi}
	50	45.0^{a}	55.0^{a}	73.0^{c}	22.1^{fg}	14.7^{b}	3.7^{efgh}	0.27^{fgh}	2.5^{eghi}	87.9i
	75	45.0^{a}	55.0^{a}	73.0^{c}	24.1^{efg}	15.4^{ab}	4.0^{cdef}	0.30^{efgh}	2.5^{eghi}	109.3^{fg}
	100	42.3^{b}	55.0^{a}	72.0^{d}	25.2^{def}	16.0^{ab}	4.2^{bc}	0.37^{cdef}	2.8^{defgh}	116.7^{ef}
30	0	42.0^{bc}	53.7^{b}	71.0^{e}	21.3^{gh}	15.3^{ab}	4.1^{cdef}	0.30^{efgh}	2.8^{defgh}	96.2^{h}
	25	42.0^{bc}	53.0^{c}	73.0^{c}	25.1^{def}	15.8^{ab}	4.4^{bc}	0.40^{bcde}	2.9^{defg}	106.5^{g}
	50	41.3^{cd}	53.0^{c}	73.0^{c}	27.3^{cde}	16.4^{ab}	4.0^{cdef}	0.37^{cdef}	2.87^{defg}	112.5^{fg}
	75	40.0^{e}	53.0^{c}	73.0^{c}	29.4^{c}	15.9^{ab}	4.1^{bcde}	0.33^{defg}	3.1^{bcd}	122.7^{cde}
	100	40.0^{e}	53.0^{c}	73.7^{c}	29.9^{c}	15.9^{ab}	3.6^{efgh}	0.50^{b}	2.9^{cdef}	120.9^{de}
50	0	42.0^{bc}	52.0^{d}	75.0^{b}	28.6^{c}	15.3^{ab}	4.3^{bc}	0.37^{cdef}	2.6^{efgh}	110.7^{fg}
	25	41.0^{d}	52.0^{d}	75.0^{b}	24.1^{efg}	15.5^{ab}	4.4^{bc}	0.33^{defg}	2.87^{defg}	125.3^{bcd}
	50	42.0^{bc}	52.0^{d}	75.0^{b}	27.1^{cde}	14.6^{b}	4.3^{bc}	0.33^{defg}	2.83^{defg}	130.8^{bc}
	75	42.0^{bc}	50.0^{e}	75.0^{b}	27.9^{cd}	17.7^{a}	5.2^{a}	0.63^{a}	4.2^{a}	154.8^{a}
	100	41.0^{d}	50.0^{e}	75.0^{b}	29.0^{c}	16.4^{ab}	4.6^{b}	0.50^{b}	3.4^{b}	116.2^{ef}
70	0	42.0^{de}	50.0^{e}	75.0^{b}	28.6^{c}	16.2^{ab}	4.3^{bc}	0.50^{b}	3.3^{bc}	127.3^{bcd}
	25	40.0^{e}	50.0^{e}	78.0^{a}	34.8^{b}	16.6^{ab}	3.7^{defg}	0.43^{bcde}	3.0^{bcde}	111.3^{fg}
	50	40.0^{e}	50.0^{e}	78.0^{a}	36.5^{ab}	14.8^{b}	4.2^{bcd}	0.47^{bc}	3.0^{bcde}	107.9^{g}
	75	40.0^{e}	50.0^{e}	78.0^{a}	34.3^{b}	15.0^{b}	4.5^{bc}	0.50^{b}	3.4^{b}	132.3^{b}
	100	40.0^{e}	50.0^{e}	78.0^{a}	38.9^{a}	16.3^{ab}	4.4^{bc}	0.47^{bc}	3.4^{b}	104.8^{g}
CV		4.2	3.5	3.4	23.33	10.4	12.16	32.4	16.34	15.77

Means followed by the same letter(s) in the column are not significantly different at 5% level of significance. LSD (0.05): Least significant difference at 5% level, CV (%): Coefficient of variation, DFHS: Days to first head setting, D50%H: Days to 50% heading, DFH: Days to first harvest, PH: Plant height, NUL: Number of unfolded leaf, FB: Fresh above ground biomass, DB: Dry above ground biomass, HW: Head weight, Y: Total yield, RNP (%): Recommended nitrogen and phosphorus, NUL, FB, DB and HW were calculated on plant base

received a combination of the lowest rate of bio-slurry (10 m^3 ha^{-1}) with NP at the rate of 0 and 25% ha^{-1} matured earlier, while the plants treated with bio-slurry 70 m^3 ha^{-1} with NP at the rate of 25, 50, 75 and 100% of recommended NP ha^{-1} matured late (Table 2). Plots treated with lowest combination rates took shorter period to mature which might be because lower rate of NP and bio-slurry not enough to enhance the development of the crop and hastening head formation and maturity.

Generally, it was observed that higher doses of the bio-slurry and recommended NP fertilizers facilitated early days to head initiation and 50% heading, whereas, the onset of days to heading was delayed in case of plants that received lower rate of bio-slurry regardless of the amount of NP. Higher nutrients supply hastens the growth and development of the plant, due to its fast physiological activities of the plant that leads to early head initiation and 50% heading of cabbage. In line with this result, Chaubey *et al.*[8] reported significantly shorter time (57.45 days) for cabbage head initiation under high rates of nitrogen (250 kg ha^{-1}) and farmyard manure (15 t ha^{-1}) over no fertilizer application (76.32 days). Similarly, Haque *et al.*[9] also observed that higher fertility level favored early head initiation and maturity of cabbage. This was because nitrogen (N) is available to the crop and enhances cell division and elongation that leads the plant to fast growth. Dinh the Loc[10] reported that 180 kg ha^{-1} N with 20 t ha^{-1} farm yard manure (FYM) resulted in earlier (49 days) to head initiation than control treatments (57 days).

On the other hand, these lower dose treatments of bio-slurry and recommended NP fertilizers resulted in early finish of heading before attaining of fully required physiological maturity and matured early as compared to these higher doses.

Agronomic and yield parameters of head cabbage: Both bio-slurry and recommended NP fertilizer and their interaction had significant ($p<0.05$) effect on plant height, number of unfolded leaves, fresh and dry biomass yield, head weight and total yield. However, length of the biggest loose leaf and harvest index were significantly influenced by only the main effects of bio-slurry and recommended NP (Table 2). Numerically, the lowest height, number of unfolded leaves, above ground fresh weight and above ground dry weight were recorded from the treatment of 0% rates of NP with combination of 10 m^3 ha^{-1} bio-slurry. Whereas, numerically the highest height, number of unfolded leaves, above ground fresh weight and above ground dry weight was obtained from the treatment of 100% recommended NP with combination of 70 m^3 ha^{-1} bio-slurry (Table 2). However, the highest number of unfolded leaves was obtained from the 75% NP with combination of 50 m^3 ha^{-1} bio-slurry (Table 2).

It was observed that plant height, number of unfolded leaves, above ground fresh and dry weight increases with increasing rates of bio-slurry and NP. This might be because organic (bio-slurry) fertilizer improves the soil structure and aggregation; this change can improve availability of nutrients as well as encourage the plant to have good root development by improving the aeration in the soil, which leads to a higher plant growth. This result was in agreement with the findings of Sarker *et al.*[11], who reported significant increase in plant height from 27.52-43.16 cm of cabbage as the rates increased from control to combined application of N (150 kg ha^{-1}) with FYM (15 t ha^{-1}). Similarly, Baloch *et al.*[12] reported that increased use of nitrogen (200 kg ha^{-1}) and FYM (20 t ha^{-1}) resulted a higher plant height of 47.14 cm. According to the study by Magnusson[13] on Chinese cabbage (*Brassica chinesis* L.), the highest numbers of leaves (14) were obtained with the application of 10 t ha^{-1} organic manure in combination with 200 kg ha^{-1} inorganic nitrogen fertilizer.

The highest head weight and total yield of head cabbage was obtained from the combined application of 50 m^3 BS ha^{-1} with 75% NP ha^{-1} fertilizer. Whereas, lowest head weight and total yield was obtained from combined application 10 m^3 BS ha^{-1} with 0% NP ha^{-1} fertilizer. Tei *et al.*[14] reported that increasing FYM fertilizer level to 15 t ha^{-1} and nitrogen fertilizer to 250 kg ha^{-1} increased its net head mass from 1121-1764 g. Moreover, the applied fertilizer is sufficient to yield economic value but, excessive did not show significant difference of the head weight of the cabbage rather than the crops used for luxuries consumption and rather inhibit the plants growth by toxification[15]. This result was in agreement with the study by Preece and Read[16], who reported increases in yield of head cabbage up to 200 kg N ha^{-1} and 20 t FYM ha^{-1}, beyond these combinations a reduction in yield occurred. Similarly, Samant *et al.*[17] reported that the total and 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 FYM ha^{-1} but total yield decreased with further increase in N and FYM rates. In agreement with this result, Olaniyi and Ojetayo[18] reported that total and marketable head yield was increased in response to increased rate of nitrogen fertilizer up to 150 kg ha^{-1} and thereafter it reduced. Nitrogen application is used to produce rapid vegetative growth of vegetables. It promotes luxuriant growth and increases number of leaves rather than total yield. These encourage photosynthesis and partitioning of photo-synthesis rate into the economic parts of the plant. It is also necessary for reproduction and promotes the uptake of other nutrients. This suggested that nitrogenous sources should be optimally applied to provide required amount of head mass. So excessive application of nutrients altered the growth and photosynthetic activities of the plant by inhibiting their growth[19].

The main effects of bio-slurry and NP fertilizer rates had significant ($p<0.05$) effect on length of the biggest loose leaf. However, the NP fertilizer did not affect harvest index of head cabbage. Additionally the interaction of bio-slurry and NP fertilizer had no effect on these two parameters (Table 3). Numerically, the lowest length of the biggest loose leaf and harvest index was recorded from 10 m^3 ha^{-1} bio-slurry, whereas, the highest value was obtained from 70 m^3 ha^{-1} bio-slurry (Table 3). On other hand, application of a minimum of 50% of the recommended NP fertilizer resulted in longer loose leaf (Table 3). Numerical trend of increased loose-leaf length was observed as the levels of NP increased similar to the rate of bio-slurry. At treatment of 70 m^3 bio-slurry biggest loose-leaf length and harvest index were increased by 14.2% and 9.96% as compared to 10 m^3 treatment, respectively. Moreover, treatment of 100% of recommended NP resulted in 11.4% biggest loose leaf length increment as compared to 10 m^3. Yamaguchi[20] studied the effect of varying rates of N (0, 50, 100 and 150 kg ha^{-1}) and P (0, 40, 80 and 120 kg ha^{-1}) on yield components of cauliflower cv. Aghani at Nadia, West Bengal. In this study, the increase in nitrogen levels up to 150 kg ha^{-1} increased dry matter, height and leaf length of cauliflower. Phosphorous level up to 120 kg ha^{-1} increased loose-leaf length. The highest cabbage leaf breadth (27.13 cm) 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

Table 3: Main effect of bio-slurry and NP fertilizers on length of biggest loose leaf, harvest index and total soluble solid of cabbage

Treatments	Parameters of cabbage	
Bio-slurry (m^3 ha^{-1})	BLL	HI
10	28.05^{b}	0.6867^{b}
30	29.16^{b}	0.7267^{b}
50	31.33^{ab}	0.7033^{ab}
70	33.22^{a}	0.7627^{a}
Cv	11.98	4.30
RNP (%)		
0	29.18^{c}	0.6933^{a}
25	29.47^{bc}	0.705^{a}
50	30.95^{abc}	0.7008^{a}
75	32.17^{ab}	0.7325^{a}
100	32.93^{a}	0.7675^{a}
Cv	11.98	4.3

Means followed by the same letter(s) in the column are not significantly different at 5% level of significance, LSD (0.05): Least significant difference at 5% level, CV (%): Coefficient of variation in percent, BLL: Length of biggest loose leaf, HI: Harvest index, RNP (%): Percent of recommended nitrogen and phosphorus inorganic fertilizer

Table 4: Cost benefit analysis of cabbage production

Treatments		Parameters of economic analysis						
Bio-slurry	NP	ADMY (t ha^{-1})	TVC	MVC	TR	Net benefit	MR	MRR (%)
10	0	63.3	4000	0	189961.9	185961.9		
10	25	71.7	4988	117.9	215105.6	210117.6	3000	2544.9
10	50	77.0	5976	186.9	230966.2	224990.2	3000	1605.3
10	75	91.4	6964	68.7	274140.9	267176.9	3000	4369.9
10	100	97.8	7952	154.1	293374.1	285422.1	3000	1946.7
30	0	84.2	12000	-298.3	252666.0	240666.0	3000	-1005.6
30	25	83.9	12988	-2711.0	251572.7	238584.7	3000	-110.7
30	50	92.8	13976	110.4	278428.3	264452.3	3000	2718.2
30	75	104.4	14964	85.6	313061.5	298097.5	3000	3505.4
30	100	95.4	15952	-109.8	286072.6	270120.6	3000	-2731.7
50	0	96.7	20000	2912.3	290242.5	270242.5	3000	103.0
50	25	108.2	20988	86.1	324672.0	303684.0	3000	3484.8
50	50	112.9	21976	210.5	338753.4	316777.4	3000	1425.2
50	75	135.6	22964	43.5	406836.5	383872.5	3000	6891.0
50	100	98.9	23952	-26.9	296631.3	272679.3	3000	-1154.4
70	0	101.8	28000	1378.1	305443.3	277443.3	3000	217.7
70	25	94.6	28988	-136.9	283793.8	254805.8	3000	-2191.2
70	50	90.5	29976	-242.9	271592.5	241616.5	3000	-1234.9
70	75	112.6	30964	44.8	337801.3	306837.3	3000	6701.3
70	100	89.1	31952	-42.0	267239.9	235287.9	3000	-7141.8

NP: Recommended nitrogen and phosphorus fertilizer, ADMY: Adjusted marketable yield, TVC: Total variable cost, MVC: Marginal variable cost, TR: Total return, MR: Marginal revenue and MRR: Marginal rate of return

3 kg ha^{-1}, respectively[21]. The reason behind this result might be due to cause of rapid performance on growth characters and rapid release of nutrients of NP and bio-slurry fertilizer for plant that promotes rapid growth, increases leaf size and quality.

Partial budget analysis: Treatments that received 75% NP ha^{-1} in combination with 50 m^3 ha^{-1} of bio-slurry gave the highest marginal rate of return of 6891% indicating that for every 1.00 ETB invested for 75% NP ha^{-1} with 50 m^{3}ha^{-1} bio-slurry ha^{-1} of bio-slurry input application in the field, farmers can obtain an additional 68.91 ETB. Moreover, the highest net benefit of 383,872.5 ETB ha^{-1} was obtained from treatment combination of 75% NP ha^{-1} with 50 m^3 ha^{-1} bio-slurry. Besides the treatment combination of 75% NP ha^{-1} with 70 m^3 ha^{-1} bio-slurry recorded the second most promising result with marginal rate of returns 67% with net benefit of 306,837.3 Birr ha^{-1}, while the lowest net benefit of 185,961.9 Birr ha^{-1} was obtained from the treatment combination of 0% NP ha^{-1} with 10 m^3 ha^{-1} of bio-slurry (Table 4). In general, the negative value of MRR percentage indicated that the loss on investment, whereas, the positive number indicated that a profit or gain on combined use of inorganic and bio-slurry fertilizer to produce the output. Therefore, the economic rates for producers with low cost of production and higher benefits were the treatment combination of 75% recommended NP ha^{-1} with 50 m^3 bio-slurry ha^{-1}.

CONCLUSION

The combined application of bio-slurry and chemical NP fertilizer showed a remarkable effect on the growth and yield of cabbage in the study area. The result revealed that, the combined use of 50 m^3 bio-slurry ha^{-1} with 75% of the recommended chemical NP ha^{-1} noticed as optimum level for production of head cabbage from growth, agronomic, yield and economic advantage point of view around Hawassa area. Therefore, the combined application of 50 m^3 ha^{-1} bio-slurry with 75% of the recommended chemical NP can be recommended for better performance of cabbage in the research area and similar agro-ecologies.

SIGNIFICANCE STATEMENT

The study revealed that, application of bio-slurry improved the performance of cabbage and the economic return obtained from cabbage production. This research will help for researchers to understand the effect of bio-slurry on the performance of cabbage, the optimal rates of bioslurry and chemical fertilizer combination and provide a background information to pursue a research on a related topic. It is also fundamentally important, for farmers producing vegetable crops using organic fertilizers.

ACKNOWLEDGMENT

The authors are grateful to Hawassa University, for the financial support provided to conduct the experiment.

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