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Title: Enhancing Growth, Yield, and Quality of Kohlrabi (*Brassica oleracea* var. *caulorapa* L.) with Biofertilizers: A Sustainable Approach for Reducing Chemical Fertilizer Dependency

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ABSTRACT

Chemical fertilizers significantly degrade soil health, prompting the exploration of biofertilizers as a viable alternative to reduce dependency and mitigate environmental impacts. This study aimed to evaluate the impact of a combination of bio-fertilizer and reduced chemical fertilizer application on the growth, yield, and quality of kohlrabi. The experiment employed a Randomized Complete Block Design (RCBD) with three replications, consisting of two factors: Factor A encompassed three kohlrabi varieties: V1 = Quick Star, V2 = Challenger, V3 = Rapid. Factor B involved different fertilizer management strategies: F0 = Recommended dose (160:120:60 kg/ha) of NPK (Control), F1 = 90% NPK + 2 kg/ha biofertilizer, F2 = 80% NPK + 4 kg/ha biofertilizer, and F3 = 70% NPK + 6 kg/ha biofertilizer. The experimental results demonstrated that both the choice of kohlrabi varieties and the application of various doses of bio-fertilizers significantly influenced the growth, yield, and quality of kohlrabi. The Challenger variety, when treated with a combination of 70% NPK and 6 kg/ha of biofertilizer, exhibited significant enhancements in various parameters compared to the untreated Challenger variety, including a 36.47% increase in fresh weight of knobs, a 26.7% boost in yield, a 13.3% rise in magnesium content, an 127% increase in potassium content, a remarkable 126.5% augmentation in manganese levels, and a 42.86% elevation in Vitamin C content. Hence, it is recommended that employing the combination treatment, consisting of 70% NPK along with 6 kg/ha of biofertilizer, during the cultivation of the Challenger variety could effectively stimulate plant growth and substantially improve both yield and quality of kohlrabi.

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INTRODUCTION

Kohlrabi (*Brassica oleracea* var. *caulorapa* L.), a member of the Brassicaceae family, stands out as a rich source of essential minerals, vitamins, and antioxidants (Paśko

et al., 2021). Kohlrabi has not been commercially grown on a big scale in Bangladesh, and its actual production is quite low compared to its potential output. However, by using appropriate agronomic techniques, this crop's yield can be increased and made more widely known. Bangladesh's kohlrabi crop is not growing or yielding enough (Biswas et al., 2016). Lack of high yielding varieties and appropriate cultural management techniques may be the primary cause of such poor development and production. Variety is a genetic element in and of itself, and it has a significant role in yield and yield components of a given crop. Because of both internal and external plant influences, crop output varies from variation to variety. The majority of seed companies import crop varieties from other nations and sell them to farmers without conducting tests for adaptation. Finding a good variety is therefore essential for both increased production and financial return.

Proper strategies are needed for vegetable production in order to protect farmers' interests and guarantee year-round supply to a rising population at affordable prices. Using chemical fertilizers carelessly has led to numerous issues at the same time. Therefore, the goal of the integrated plant nutrition system strategy is to maintain productivity while minimizing the harmful impacts of chemicals on the environment, soil health, and human health. Inoculating vegetable crops with biofertilizers such as Azotobacter and Azospirillum, which are known to synthesize chemicals that promote growth biologically, have been found to be highly significant in supplying atmospheric nitrogen.

The application of biofertilizers offers an economically attractive and ecologically sound means of reducing external inputs and improving the quality and quantity of vegetable produce. They contain microorganisms capable of mobilizing nutrient elements from unavailable to available forms through various biological processes. Furthermore, they increase soil productivity and control many harmful pathogens and microorganisms (Singh et al., 2011). Biofertilizers are organic in origin and are safe. Therefore, it is essential to adopt a strategy of integrated nutrient management using a combination of chemical fertilizers and bio-fertilizers to minimize the cost of production and to maintain the biological productivity of soils, particularly in areas where the soils are impoverished in fertility status with high pH, and farmers are also reluctant to adopt recommended fertilizer doses. Owing to the high cost of fertilizers and the risk of crop failure due to aberrant weather conditions, the integrated nutrient management supply system provides crop nutrition packages that are technically sound, economically viable, practically feasible, and environmentally safe (Lamessa, 2016). Information on the balanced use of chemical fertilizers and bio-fertilizers on vegetables is very important for different types of soils in Bangladesh.

Hence, considering all the viewpoints, the present study was undertaken to determine a suitable combination of biofertilizer with a reduced amount of inorganic fertilizer on the growth and potential yield of Kohlrabi.

MATERIALS AND METHODS

Experimental site and materials

The experiment was conducted at a horticulture farm in Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh. The experiment was conducted from October 2020 to January 2021 during the Rabi season. The experimental site was geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meters above sea level. The soil texture was silty clay, with a pH of 5.6 (Table 1). Three hybrid varieties of Kohlrabi,‘Quick Star’, ‘Challenger’, and ‘Rapid’ were used in this experiment. Seeds of these varieties were collected from Siddique Bazar, Dhaka.

Table 1. The initial physical and chemical characteristics of soil of the experimental site (0- 15 cm depth

Physical characteristics	
Constituents	**Percentage**
Clay	29
Sand	26
Silt	45
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Experimental treatment

There were two factors in the experiment, Kohlrabi varieties and fertilizer management. The treatment consist of three varieties, V1 = Quick star, V2 = Challenger, and V3 = Rapid and four fertilizer doses; F0 = Recommended dose (160:120:60 kg/ha) of NPK (Control), F1= 90 % NPK + 2 kg/ha biofertilizer, F2= 80 % NPK + 4 kg/ha biofertilizer, and F3= 70 % NPK + 6 kg/ha biofertilizer.

Seedbed preparation and seed sowing

After the site was selected, the soil was plowed to a good tilth. All weeds, stones, and other undesirable materials were collected and removed from the field. A nursery bed of 1.0 m wide and 30 cm high from ground level was prepared for raising seedlings. Before sowing, the seeds were treated with mancozeb @ 2.0 g/kg + carbendazim @ 1.0 g/kg of seed to avoid damage to the seedlings from the disease (Purushothamet al., 2023). The seeds were sown in well-prepared beds in lines 2-3 cm deep, spaced 5 cm apart, covered well with fine soil, and mulched with dry grass (doob grass) to facilitate early and uniform germination. Light irrigation was administered immediately. Sowing was done on the 25th of October 2020.

Experimental design

The experiment was laid out in a randomized complete block design with two factors and three replicates. There were 12 treatment combinations and 36 plots in total. The unit plot size was 1.08 m^2 (0.9 m × 1.2 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively.

Fertilizer management

Different doses of inorganic and biofertilizers were applied according to the treatment requirements. Azotobactor and Azospirillium used as a biofertiizer in1:1 proportion. Biofertilizer applied as a basal dose during land preparation. The nutrient sources were nitrogen (Urea), phosphorus (TSP), and potash (MOP). Half the doses of nitrogen, total TSP, and MoP were applied as basal doses. The remaining dose of nitrogen was administered in Kolhrabi, 20 days after transplanting. Other intercultural operations and crop management practices were conducted using the recommended practice package (BARI, 2019).

Transplanting and intercultural operations

Thirty-eight-day-old seedlings of uniform height were selected and transplanted into the field with a spacing of 30 cm row to row and 20 cm plant to plant. Gap filling was performed five days after transplantation. Optimum soil moisture was maintained in the field through the drip irrigation system. Irrigation was performed according to weather conditions and soil moisture (Table 2). Two-hand weeding with shallow hoeing was performed at 20 and 40 days after transplanting. Earthing was done by taking the soil from the space between the rows 15 days after transplanting. The crop is attacked by cutworms, mole crickets, and field crickets during the early stages of seedling growth in December. The insect was controlled by spraying Dursban 20 EC at 0.1%.

Table 2. Monthly meteorological information during the period from October 2020 to January, 2021

Year	Month	Air temperature (°C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2020	October	31.2	23.9	76	52 mm
	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2021	January	25.5	13.1	41	00 mm

Harvesting

Whole plants with knobs were harvested during the correct maturation period. The main knobs were harvested as plant-shaped compact knobs. The final harvest was completed in January 2021.

Potassium content in knob

To determine the potassium concentration, the samples were dried in an oven at 80°C for 48 hours, pulverized, and then treated with nitric acid for digestion. The elements were quantified using inductively coupled plasma mass spectrometry (ICP-MS). The data were expressed on a fresh weight basis, taking into account the ratio of fresh weight to dry weight.

Manganese & Magnesium content in knob

Mn was determined by digesting dried plant samples with a tri-mixture of HNO_3, H_2SO_4, and NaOH and was estimated using the flame photometer method (Achikanu et al., 2013).

Vitamin C content in knob

The Vitamin Cwas determined in fresh matter using the capillary izotachoforesy method.

Statistical analysis

The collected data were compiled and statistically analyzed using the analysis of variance (ANOVA) technique with the help of the Statistix 10 software package. Significant differences among the treatment means were compared by Least Significant Difference (LSD) at a 5% level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height (cm)

Plant height is an essential characteristic of the vegetative stage of a crop plant and indirectly affects its yield of crop plants. Variety and different doses of bio-fertilizer application had significant effects on kohlrabi plant height on different days after transplantation (Figure 1). The results of the experiment showed that a combination of 70% NPK and 6 kg/ha of biofertilizer increased plant height 53.5%, 17.7% and 12.5% in Challenger variety at 25, 35 and 45 DAT respectively compare to control. Chaudhari et al. (2015) reported that the plant height of knolkhol varied significantly among varieties, and Purple Vienna achieved higher growth parameters. Maximum growth under higher doses of biofertilizer application may result from enhanced soil nutrient availability, macro- and micronutrient supply, and water-holding capacity, which increases photosynthetic and assimilation rates and heightens Kohlrabi plants. The current results are consistent with those of Zaki et al. (2012), who found that the use of biofertilizers promotes the secretion of substances that aid root development, water transportation, nutrient uptake, and decomposition, ultimately leading to the highest levels of vegetative growth in broccoli plants.

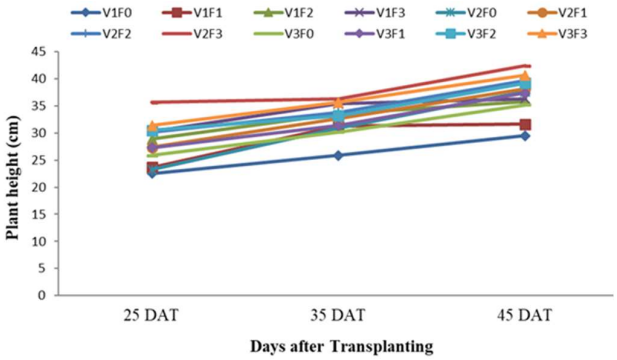

Figure 1. The combined effect of variety and different doses of bio-fertilizer on plant

height of Kohlrabi on different days after transplanting

V1 = Quick star, V2 = Challenger, V3 = Rapid, F0 = Recommended dose of NPK (Control), F1= 90 % NPK + 2 kg/ha biofertilizer, F2= 80 % NPK + 4 kg/ha biofertilizer and F3= 70 % NPK + 6 kg/ha biofertilizer.

Number of leaves plant^{-1}

Kohlrabi leaves number plant^{-1} on various days after transplanting had shown a significant impact depending on the variety and different doses of bio-fertilizer application (Table 3). The results showed that a combination of 70% NPK and 6 kg/ha of biofertilizerincreased number of leaf 76.36%, 62.5% and 55.6% in Challenger variety at 30, 45 and 60 DAT respectively compare to control.

The reason for the difference in the number of leaves among varieties is the genetic makeup of the varieties, which is influenced primarily by heredity. Shivran et al. (2021) found a significant difference in the number of leaves per plant among knolkhol varieties. The reason for the increase in vegetative growth (leaf number) in plants treated with biofertilizer may be the ability of the bacterial inoculation to dissolve the precipitated phosphate compounds and release them to any soil solution available H_2PO_4 and HPO_4^{2-} by lowering the soil pH, which leads to increased absorption of nutrients, thereby increasing vegetative growth of the plant. This result was similar to the findings of Zaki et al. (2012) reported that interaction among Southern Star cultivar, inoculation of bio-fertilization, and 75% organic N + 25% mineral N gave the highest values of the number of leaves plant^{-1} of broccoli.

Table 3. The Combined effect of variety and different doses of bio-fertilizer application on number of leaves plant^{-1} of kohlrabi on different days after transplanting

Variety	Fertilizer combinations	Number of leaves plant^{-1}		
		30 DAT	**45 DAT**	**60 DAT**
Quick star	Recommended NPK	5.00 g	7.00 f	8.00 g
	90 % NPK + 2 kg/ha biofertilizer	6.33 e	8.33 de	9.00 f
	80 % NPK + 4 kg/ha biofertilizer	8.67 b	10.67 c	11.33 d
	70 % NPK + 6 kg/ha biofertilizer	9.00 b	11.00 bc	12.00 cd
Challenger	Recommended NPK	5.67 f	8.00 e	9.00 f
	90 % NPK + 2 kg/ha biofertilizer	7.00 d	8.67 de	10.33 e
	80 % NPK + 4 kg/ha biofertilizer	7.67 c	10.67 c	12.67 bc
	70 % NPK + 6 kg/ha biofertilizer	10.00 a	13.00 a	14.00 a
Rapid	Recommended NPK	5.33 fg	8.00 e	9.00 f
	90 % NPK + 2 kg/ha biofertilizer	7.00 d	9.00 d	10.00 e
	80 % NPK + 4 kg/ha biofertilizer	8.00 c	11.00 bc	12.33 bc
	70 % NPK + 6 kg/ha biofertilizer	9.00 b	11.67 b	13.00 b
$LSD_{(0.05)}$		0.50	0.67	0.88
CV(%)		4.00	4.07	4.80

Leaf length and breadth

The leaf length of kohlrabi on different days after transplanting was significantly influenced by the kohlrabi varieties and different doses of bio-fertilizer application (Table 4). The combination of 70% NPK and 6 kg/ha of biofertilizertreatment produced the highest leaf length of kohlrabi which were 65% and 57.2% at 25 and 35 DAT, respectively in Challenger variety compare to control.Leaf breadth followed similar trend as well which increased 91.8% and 59%at 25 and 35 DAT respectively.

The reason for the varying leaf lengths of kohlrabi among different varieties is that each variety has a unique growth stage and uses resources from its environment differently. Shivran et al. (2021) reported that the leaf length of kohlrabi varied among different varieties.

Variation in leaf length was caused by the application of biofertilizer, which encourages plants to take up nutrients sequentially. This improved plant growth by increasing the leaf length of plants. Akbar et al. (2009) reported that the application of bio-fertilizer influences the leaf length of cabbage.

Table 4. The Combined effect of variety and different doses of bio-fertilizer on leaf length and leaf breadth of kohlrabi on different days after transplanting

Variety	Fertilizer combinations	Leaf length (cm)		Leaf breadth (cm)	
		25 DAT	35 DAT	25 DAT	35 DAT
Quick star	Recommended NPK	9.53 h	20.67 h	5.13 g	9.40 g
	90 % NPK + 2 kg/ha biofertilizer	11.46 g	23.87 ef	7.20 ef	11.13 ef
	80 % NPK + 4 kg/ha biofertilizer	13.20 f	25.33 de	9.83 d	13.60 d
	70 % NPK + 6 kg/ha biofertilizer	15.67 d	28.53 c	11.40 c	15.87 bc
Challenger	Recommended NPK	13.83 ef	22.73 fg	8.20 e	11.73 e
	90 % NPK + 2 kg/ha biofertilizer	18.20 c	25.53 de	11.67 c	13.67 d
	80 % NPK + 4 kg/ha biofertilizer	20.87 b	30.67 b	13.33 b	15.20 c
	70 % NPK + 6 kg/ha biofertilizer	22.83 a	35.73 a	15.73 a	18.67 a
Rapid	Recommended NPK	9.87 h	21.53 gh	6.73 f	10.06 fg
	90 % NPK + 2 kg/ha biofertilizer	11.73 g	24.87 de	8.27 e	12.00 e
	80 % NPK + 4 kg/ha biofertilizer	14.33 e	26.20 d	11.07 c	14.87 cd
	70 % NPK + 6 kg/ha biofertilizer	16.20 d	30.73 b	13.33 b	16.67 b
$LSD_{(0.05)}$		0.79	1.80	1.13	1.44
CV(%)		3.15	4.05	6.61	6.29

Fresh weight of root

The Challenger variety, when treated with a combination of 70% NPK and 6 kg/ha of biofertilizer, exhibited significant enhancements compared to the untreated Challenger variety, including a 67.96% increase in fresh weight of root (Table 5). In case of Quick star and Rapid variety, it increased 47% and 51.68% respectively. This is probably because biofertilizers in combination with inorganic fertilizers help in better root proliferation, which facilitates more uptakes of nutrients and water, higher leaf number, and more. They are also responsible for effective

photosynthesis and enhanced food accumulation, resulting in increased fresh weight of kohlrabi roots. This result was similar to the findings of Atal et al. (2019). EI-Bassiony et al. (2014) reported that the variation in the fresh weight of the roots of kohlrabi varieties might be due to prevailing climatic conditions and the genetic makeup of the different cultivars.

Root length

The root length of kohlrabi was found to be significantly affected by varietal differences and different doses of bio-fertilizer application (Table 5). The maximum root length of kohlrabi was observed in Challenger variety. Due to treatment with a combination of 70% NPK and 6 kg/ha of biofertilizer, the root length increased 33.65% compared to control treatment. Similar trend also observed in Quick star and Rapid variety. The increase in growth parameters could be because of certain growth-promoting substances secreted by the biofertilizer inoculants, which in turn might have led to good root development, better water absorption, and high uptake of nutrients from the soil body, which ultimately enhance root length. Atal et al. (2019) reported that the application of biofertilizer influenced the root length of broccoli. The result obtained from the present study was similar to the findings of Paudel et al. (2019), who noted that the root length of the plant varied among different varieties of cauliflower.

Table 5. Combined effect of variety and different fertilizer managements on fresh weight of root, root length and knob weight with leaves of kohlrabi at harvest

Variety	Fertilizer combinations	**Fresh weight of root (g)**	**Root length (cm)**	**Fresh weight of knob (g)**
Quick star	Recommended NPK	3.76 f	6.89 g	102.53 h
	90 % NPK + 2 kg/ha biofertilizer	4.13 def	7.46 f	112.67 fg
	80 % NPK + 4 kg/ha biofertilizer	4.50 cd	7.50 ef	120.40 de
	70 % NPK + 6 kg/ha biofertilizer	5.53 b	8.00 de	130.86 c
Challenger	Recommended NPK	3.87 ef	8.38 cd	110.40 fg
	90 % NPK + 2 kg/ha biofertilizer	4.76 c	8.83 bc	120.87 de
	80 % NPK + 4 kg/ha biofertilizer	5.87 b	9.00 b	130.53 c
	70 % NPK + 6 kg/ha biofertilizer	6.50 a	11.20 a	150.67 a
Rapid	Recommended NPK	3.87 ef	7.06 fg	107.53 gh
	90 % NPK + 2 kg/ha biofertilizer	4.27 cde	7.50 ef	115.40 ef
	80 % NPK + 4 kg/ha biofertilizer	4.50 cd	8.00 de	126.67 cd
	70 % NPK + 6 kg/ha biofertilizer	5.87 b	8.20 d	140.40 b
$LSD_{(0.05)}$		0.50	0.51	7.10
CV(%)		6.28	3.69	3.43

Fresh weight of knob

The maximum fresh weight (150.67 g) of knobs was obtained with a combination of 70% NPK and 6 kg/ha of biofertilizer in Challenger variety and which was 36.47% more than control treatment (Table 5). The

increase in fresh weight of kohlrabi knobs could be attributed to certain growth-promoting substances secreted by biofertilizer inoculants, which could have resulted in good root development, better water absorption, and high uptake of nutrients from the soil body, increasing fresh weight of kohlrabi knobs. Divya (2010) reported that integrated application of organic manures with biofertilizers had a beneficial effect on growth and yield attributes of knolkhol and best to RDF+FYM and with RDF which influences the fresh weight of knobs of knolkhol comparable to individual organic fertilizer treatment.

Diameter of knob (cm)

Analysis of variance revealed that combine effect of 70% NPK and 6 kg/ha of biofertilizerincreased diameter of knob of different varieties significantly (Table 6). It increased 27.6%, 28.32% and 25.71% of knob diameter compare to control treatment in Quick star, Challenger and Rapid variety respectively.

Application of higher doses of biofertilizers could have created favourable soil conditions for better mobilization of nutrients resulting in better plant growth as compared to carrier-based biofertilizers. The beneficial effect of biofertilizers on growth can also be attributed to the occurrence of relatively readily available plant nutrients required for growth. Thus, a favorable influence of nutrients renders the production of bigger cells with thinner cell walls and its role in cell division and cell elongation, which improves vegetative growth and finally increases the knob diameter of kohlrabi. Choudhary et al. (2017) reported that the application of inorganic along with biofertilizer influenced the knob diameter of Knol-khol.

Yield (t/ha)

The kohlrabi yield was significantly influenced by kohlrabi varieties and the different doses of bio-fertilizer application (Table 6). A combination of 70% NPK and 6 kg/ha of biofertilizerincreased 27.7%, 26.7% and 30.5% in Quick Star, Challenger and Rapid variety respectively compare to control.

Yadav et al. (2013) reported that in cauliflower the variation in yield might be due to prevailing climatic conditions and genetic makeup of different cultivars. The variation in kohlrabi yield might be due to higher and continuous nutrient availability from different sources like inorganic fertilizers and biofertilizers at different stages of growth. It might have resulted in better translocation of carbohydrates to storage organs, which influenced the weight of the knob head resulting in an increased yield of kohlrabi. Similar findings have also been reported by Bhardwaj et al. (2007) on broccoli cv. CBH-1 and found maximum curd weight (260.32 g) and curd yield (133.60 q /ha) with the application of 150 kg N ha-1 and *Azotobacter* inoculation (2 kg /ha).

Dry weight of knob

The dry weight of kohlrabi knobs was significantly impacted by the variety and level of biofertilizer used (Table 6). The maximum dry weight of knobs was obtained with a combination of 70% NPK and 6 kg/ha of biofertilizer. Result showed that Challenger variety had maximum dry weight of knob compare to other variety. In challenger variety, dry weight of knob increased 22.5% compared to control.

The difference in dry weight of knobs of kohlrabi among varieties was because each variety has a unique growth stage and uses resources from its environment differently. The result obtained from the present study was similar to the findings of Tejaswini et al. (2018).

The result obtained from the present study was similar to the findings of Aliwi and Manea (2021), who reported that Kohlrabi bio-fertilizer application significantly influenced the dry weight of knobs of kohlrabi.

Table 6. The Combined effect of variety and different doses of bio-fertilizer application on diameter of knob, yield and knob dry weight of kohlrabi

Variety	Fertilizer combinations	**Diameter of knob (cm)**	**Yield (t/ha)**	**Dry weight of knob (g)**
Quick star	Recommended NPK	4.90 f	11.39 g	6.09 g
	90 % NPK + 2 kg/ha biofertilizer	5.25 ef	12.52 ef	6.93 f
	80 % NPK + 4 kg/ha biofertilizer	5.90 cd	13.38 de	6.96 f
	70 % NPK + 6 kg/ha biofertilizer	6.25 bc	14.54 c	7.53 de
Challenger	Recommended NPK	5.65 de	12.27 fg	7.37 def
	90 % NPK + 2 kg/ha biofertilizer	6.15 b-d	13.43 de	7.50 de
	80 % NPK + 4 kg/ha biofertilizer	6.65 b	14.50 c	8.74 ab
	70 % NPK + 6 kg/ha biofertilizer	7.25 a	16.74 a	9.03 a
Rapid	Recommended NPK	5.25 ef	11.95 fg	7.19 ef
	90 % NPK + 2 kg/ha biofertilizer	5.75 cde	12.82 ef	7.50 de
	80 % NPK + 4 kg/ha biofertilizer	6.15 bcd	14.07 cd	7.83 cd
	70 % NPK + 6 kg/ha biofertilizer	6.60 b	15.60 b	8.22 bc
$LSD_{(0.05)}$		0.55	1.00	0.52
CV(%)		5.46	4.38	4.06

Magnesium content

The magnesium content of kohlrabi was significantly influenced by kohlrabi varieties and the different doses of biofertilizer application (Table 7). The magnesium content of kohlrabi was significantly increased 14 to 32% in different variety due to combination of 70% NPK and 6 kg/ha of biofertilizer treatment compare to control. The variation in magnesium content among varieties was due to enhanced physiological activity and the inherent genetic makeup of the variety. Thapa and Rai (2012) reported that different levels of nutrient content varied among different varieties of broccoli. Biofertilizers can benefit plants by enhancing the uptake of nutrients, stimulating growth, regulating substances, and increasing photosynthesis. Therefore, magnesium content can be significantly increased compared to the control treatment. The result was similar to the findings of Regar et al. (2018).

Potassium content

The analysis of variance revealed that the potassium content of kohlrabi was significantly influenced by kohlrabi varieties and the different doses of bio-fertilizer application (Table 7). The maximum potassium content of kohlrabi was obtained with a combination of 70% NPK and 6 kg/ha of biofertilizer which increased potassium content 79.17%, 127% and 106% in Quick star, Challenger and Rapid variety respectively compare to control. Different kohlrabi varieties have varied genetic makeup, which influences the growth, productivity, and quality of kohlrabi. Tejaswini et al. (2018) reported that potassium content varied among different varieties of broccoli.

Manganese content

The manganese content of kohlrabi was significantly influenced by kohlrabi varieties and bio-fertilizer application doses (Table 7). The combination of 70% NPK and 6 kg/ha of biofertilizer treatment resulted in the highest manganese content of kohlrabi (34.98 ppm) which was 126.5% more than control treatment in Challenger variety. The result was similar to the findings of Regar et al. (2018).

Vitamin C content

Kohlrabi variety and bio-fertilizer application doses had a significant impact on vitamin C content (Table 7). The V2F3 combination treatment recorded the higher vitamin C content (42.86%) in kohlrabi compare to control. Similar trend also observed in Quick Star and Rapid variety. Bio-fertilizer use can considerably boost macro- and micronutrients, resulting in higher photosynthate production and biomass buildup and, hence, increased nutrient and quality contents of kohlrabi. The result was similar to the findings of Regar et al. (2018), who reported that biofertilizer application increased the vitamin C content of broccoli.

Table 7. The Combined effect of variety and different doses of bio-fertilizer application on magnesium, potassium, manganese and vitamin C content of kohlrabi

Variety	Fertilizer combinations	**Magnesium content (%)**	**Potassium content (%)**	**Manganese content (ppm)**	**Vitamin-C content (mg 100 g^{-1})**
Quick star	Recommended NPK	0.55 h	1.20 g	13.20 j	20.67 g
	90 % NPK + 2 kg/ha biofertilizer	0.65 g	1.25 g	13.70 ij	24.00 ef
	80 % NPK + 4 kg/ha biofertilizer	0.71 f	1.60 ef	17.58 g	26.67 d
	70 % NPK + 6 kg/ha biofertilizer	0.73 f	2.15 c	20.67 ef	28.67 c
Challenger	Recommended NPK	0.85 cd	1.40 fg	15.44 h	23.33 ef
	90 % NPK + 2 kg/ha biofertilizer	0.84 d	2.15 c	23.63 d	26.67 d
	80 % NPK + 4 kg/ha biofertilizer	0.89 bc	2.50 b	27.46 c	29.33 c
	70 % NPK + 6 kg/ha biofertilizer	0.98 a	3.18 a	34.98 a	33.33 a
Rapid	Recommended NPK	0.79 e	1.30 g	14.31 i	22.67 f
	90 % NPK + 2 kg/ha biofertilizer	0.79 e	1.88 d	19.72 f	24.67 e
	80 % NPK + 4 kg/ha biofertilizer	0.89 bc	1.79 de	21.60 e	28.00 cd
	70 % NPK + 6 kg/ha biofertilizer	0.90 b	2.68 b	29.52 b	31.33 b
$LSD_{(0.05)}$		0.04	0.26	1.06	1.99
CV(%)		3.62	8.17	3.01	4.43

CONCLUSION

An essential component of plant development and production is fertilizer. Organic manure and other biofertilizers are environmentally friendly fertilizers that enhance plant nutrient availability, boost agricultural output, and enhance soil health. The study demonstrated that the production and quality characteristics of kohlrabi were improved when inorganic fertilizers and biofertilizers were combined. While the development and yield of plants were enhanced by all given fertilizers, the combination of 70% NPK and 6 kg/ha of biofertilizer resulted in a greater yield increment (26 to 30% over control). The Challenger cultivar, on the other hand, yielded 6–13% more than the other two varieties. On the basis of study it can be concluded that combination of 70% NPK and 6 kg/ha of biofertilizer in Challenger variety given the best result of yield and quality parameters of kohlrabi.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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