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Priya Kondal
Faculty of Agricultural Sciences, DAV University, Sarmastpur, Jalandhar, Punjab, India

Ramandeep Kaur
Faculty of Agricultural Sciences, DAV University, Sarmastpur, Jalandhar, Punjab, India

Narayan Singh
[1] Faculty of Agricultural Sciences, DAV University, Sarmastpur, Jalandhar, Punjab, India
[2] Department of Biotechnology, DAV University, Sarmastpur, Jalandhar, Punjab, India

Vasudha Maurya
[1] Faculty of Agricultural Sciences, DAV University, Sarmastpur, Jalandhar, Punjab, India
[2] Department of Biotechnology, DAV University, Sarmastpur, Jalandhar, Punjab, India

Ashutosh Sharma
Faculty of Agricultural Sciences, DAV University, Sarmastpur, Jalandhar, Punjab, India

Rahul Kumar
Faculty of Agricultural Sciences, DAV University, Sarmastpur, Jalandhar, Punjab, India

Corresponding Author:
Rahul Kumar
Faculty of Agricultural Sciences, DAV University, Sarmastpur, Jalandhar, Punjab, India

Effect of organic and inorganic fertilizers on the growth, yield and quality of beetroot (*Beta vulgaris* L.)

Priya Kondal, Ramandeep Kaur, Narayan Singh, Vasudha Maurya, Ashutosh Sharma and Rahul Kumar

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Abstract
The present investigation was conducted to determine the effect of organic and inorganic fertilizers on growth, yield and quality of beetroot. The experiment consisted of variety (Ruby queen) which was laid out in randomised block design with three replication and ten treatments comprising of organic and inorganic fertilizers *viz*., T_1 (50% RDF + 50% Vermicompost), T_2 (100% Vermicompost), T_3 (100% Poultry manure), T_4 (50% RDF + 50% Poultry manure), T_5 (100% Farmyard manure), T_6 (50% RDF + 50% FYM), T_7 (50% RDF + 50% Poultry manure), T_8 (50% Vermicompost + 50% FYM), T_9 (50% Poultry manure + 50% Vermicompost), T_{10} (control). The result of experiment showed that the treatment T_4 (50% RDF + 50% Poultry manure) showed minimum days to 50% germination and maximum number of leaves per plant, root diameter, fresh root weight, dry root weight, root yield per plot, root yield per hectare, phenolic content, betalains while, 50% Poultry manure along with 50% FYM recorded maximum root length. Among quality parameters, TSS and ascorbic acid content was recorded maximum with combination of 50% RDF + 50% Vermicompost. The maximum chlorophyll, carotenoid content, anthocyanin and betalains were recorded with 100% Poultry manure. The economic analysis depicted the maximum gross income, net income and benefit-cost ratio from treatment T_4 (50% RDF + 50% Poultry manure).

Keywords: Beetroot, inorganic fertilizers, growth, yield, benefit cost ratio, poultry manure, vermicompost, FYM

Introduction
Beetroot (*Beta vulgaris* L.) is one of the major root vegetable which belongs to the Chenopodiaceae family is consumed as salad though leaves can also be eaten as the spinach [19]. Beetroot is also known as 'garden beet' or 'table beet'. It is originated from Mediterranean region and widely grown in continents of Europe, America and Asia recently due to increase in its nutritional popularity [9]. It is grown in northern and southern part of India. Beetroot is binneal crop although grow as annual crop. It produces swollen root and green tops during growing season.

Beets root prefer fertile, well-drained, deep, loamy soils rich in organic matter with a pH of 5.8 to 7.0 for best growth and it can tolerate a pH up to 7.6. Most light soil is well suited for beetroot production. It is propagated by seeds and the germination period ranges from 10 to 24 days. It ranks among the ten most potent vegetables with respect to antioxidant property.

Beetroot is grown for its high dietary value and good flavour, and it can be processed in many different ways. Red beetroot has many other compounds such as ascorbic acid, carotenoids, phenolic acids and flavonoids [28], also high levels of betalain pigments [32]. The bright red colour of beet root is due to the red pigments known as betalains *i.e.* red- purple betacyanins and yellow betaxanthins [18]. The colour effect depends on the ratio of red pigments to yellow pigments. Additionally, in recent years, the pigments of red beetroot have also been used as a natural colorant for the food industry and additive in food products [10].

It is a rich source of calcium, magnesium, phosphorus, copper, iron and vitamin A, C, B_1, B_2 and B_6 [34, 38]. Green leaves are rich in iron (3.1 mg), Vitamin A (2100 I.U.), thiamine (110 g) and ascorbic acid (50 mg / 100 g). Beetroots are rich in other valuable compounds such as

carotenoids [15], glycine betaine (de Zwart *et al*., 2003), Saponins [6], folates [22], betanin, polyphenols and flavonoids [51].

It has been reported that beetroot is used to cure the stones of kidney and gall bladder [9]. Fresh juice of beetroot mixed with tablespoon of honey taken every morning before breakfast helps in healing of gastric ulcer. It is one of the natural food which boosts the energy in athletes as it has one of the highest nitrates and sugar contents plant [53]. The rich fiber content in beetroot exerts favourable effects on bowel function thereby preventing constipation and helps to lower cholesterol levels too [51].

Optimum application of N fertilizers promotes growth and in turn increases both yield and quality, however, excessive application of N fertilizer negatively impacts the soil ecosystem and can reduce yield [16]. Therefore, integration of inorganic fertilizers with organic fertilizers is important for sustainable agriculture [14]. In recent years use of organic manures like FYM, vermicompost and neem cake for improving the productivity of crop, biological traits and maintaining soil fertility and productivity of soil is gaining prominence [25, 33]. FYM helps to improve crop growth by providing nutrition and improving the physical, chemical and biological properties of soil [35]. Vermicompost encourages soil microbial activity, enhances oxygen availability, maintains normal soil temperature, and improves plant development, yield, and quality [5]. Similarly, another organic manure i.e. poultry manure has a high amount of nitrogen, phosphorus and potassium than manure of other animals. Poultry manure also helps to improve the water holding capacity, aeration and fertility status of soil [26].

The integrated nutrient management system approach utilizes a judicious combination of inorganic fertilizer and organic manure in building soil fertility, to the increase the production potential of crop [30]. Keeping this view the work was done to study the effect of organic and inorganic fertilizers on growth, yield and quality of beetroot (*Beta vulgaris* L.).

Materials and Methods

A field experiment was carried out during rabi season 2022-2023 at the experimental field of faculty of Agricultural sciences, DAV University, Sarmastpur, Jalandhar (Punjab), to study the effect of organic and inorganic fertilizers on growth, yield and quality of beetroot (*Beta vulgaris* L.). Geographically the farm is located at 75o56'99" East longitude and 31o33'00" North latitude, with an average elevation of 230 meters.

a) Plant material: Seeds of beetroot variety i.e. Ruby queen (Indo American Pvt. Ltd. Bangaluru, Karnataka) was procured from Ludhiana, Punjab.

b) Fertilizers: Commercial fertilizers *i.e.* NPK (IFFCO) and organic manures *i.e.* FYM (Farmyard manure), vermicompost and poultry manure were procured from the university as well as local market of Jalandhar, Punjab, India.

c) Experimental design: The experiment was laid out in a randomized block design with three replication consisting of ten treatments represented in table 1, *viz*. T_1 (50% RDF + 50% Vermicompost), T_2 (100% Vermicompost), T_3 (100% Poultry manure), T_4 (50% RDF + 50% Poultry manure), T_5 (100% Farmyard manure), T_6 (50% RDF + 50% FYM), T_7 (50% RDF + 50% Poultry manure), T_8 (50% Vermicompost + 50% FYM), T_9 (50% Poultry manure + 50% Vermicompost), T_{10} (control).

The soil texture of experimental field was sandy loam. The land was brought to fine tilth through ploughing and divided into 30 plots. The plot size was 2 m × 4 m. The seeds were sown at spacing of 30 ×10 cm in a net area of 260 m^2 on 4th November. The recommended dose of fertilizers was 120 Kg N, 160 Kg P_2O_5 and 120 Kg K_2O_5 per hectare in the form of urea, single super phosphate (SSP) and muriate of potash (MOP). The fertilizers were incorporated into soil before the sowing. Intercultural operation such as weeding and earthing up were done thrice during the crop growth period.

Fig 1: General view of experimental field

Table 1: Treatment details

Treatment No.	Details of treatments
T_1	50% RDF + 50% Vermicompost
T_2	Vermicompost (100%)
T_3	Poultry manure (100%)
T_4	50% RDF + 50% Poultry manure
T_5	100% FYM (Farmyard manure)
T_6	50% RDF + 50% FYM (Farmyard manure)
T_7	50% Poultry manure + 50% FYM (Farmyard manure)
T_8	50% FYM (Farmyard manure) + 50% Vermicompost
T_9	50% Poultry manure + 50% Vermicompost
T_{10}	Control

Data recorded

Randomly five plants were tagged from each plot for recording data. Growth parameters (Days to 50% germination, plant height, number of leaves and leaf area), yield parameters (root length, root diameter, fresh weight of root, dry weight of root, yield per plot and yield per ha) and quality parameters (TSS, chlorophyll and carotenoid content, ascorbic acid content, phenolic content, flavonoid content, betalains and anthocyanin content) were recorded from tagged plants.

Statistical analysis

The data collected was subjected to Analysis of Variance (ANOVA) in RBD with Fisher's test to find the critical difference (CD) among different treatment means using OPSTAT to check the significant differences among treatments at $p \leq 0.05$.

Results and discussion

Effect of various combinations of organic and inorganic fertilizers on growth of beetroot

The growth parameters recorded in the present study *viz*, days to 50% germination, plant height, numbers of leaves per plant, leaf area are presented in table 2. The combination of organic and inorganic fertilizers significantly increased the days to 50% germination, plant height and number of leaves per plant after 45, 90 DAS and harvest. The minimum days to 50% germination (3.66 days) was recorded in T_4 (50% RDF + 50% poultry manure) and T_7 (50% FYM +50% poultry manure) followed by T_3 (100% poultry manure) (4.00 days), whereas the maximum days to 50% germination (9.66 days) was recorded in treatment T_{10} (control). Poultry manure decompose rapidly and release all the nutrients which improves soil chemical properties such as soil pH, total N, available P, organic matter which helps in early germination [7, 22]. Similarly, the maximum plant height at 45 DAS (20.16 cm), 90 DAS (25.32 cm) and at harvest (20.16 cm) and leaf area (127.40 cm^2) was recorded in treatment in T_3 (100% poultry manure) followed by T_4 (50% RDF + 50% poultry manure) whereas minimum leaf area (60.16 cm^2) and plant height was recorded in T_{10} (Control) (9.7 cm), (14.19 cm) and (21.53 cm) respectively at 45, 90 and harvest. It might be because the nitrogen present in poultry manure is easily available to plants because 30% of nitrogen is in nitrate or ammonical form and it enhances the physicochemical properties of the soil [44, 50].

The maximum number of leaves per plant at 45 DAS was observed in treatment T_3 (100% poultry manure) (8.20), at 90 DAS and 120 DAS was recorded in T_4 (50% RDF + 50% poultry manure) (13.73), (16.83) whereas the minimum was observed in treatment T_{10} (Control) (5.26), (9.73) and (12.66). This may be due the integrated use of nutrients resulted in rapid cell division, multiplication, and elongation in the meristematic region of plants, which promoted vegetative growth [36]. Therefore, a significant improvement in the above three growth parameters was recorded in beetroot at 45, 90 and 120 DAS, suggesting the efficacy of incorporation of organic manure.

Table 2: Effect of organic and inorganic fertilizers on growth of beetroot

Treatments	Days to 50% germination	Plant height (cm)			Number of leaves per plant			Leaf area (cm^2)
	45DAS		90DAS	Harvest	45DAS	90DAS	Harvest	
T_1	5.33	12.96	16.72	22.12	6.26	11.10	14.43	90.11
T_2	5.00	11.34	15.76	21.88	5.73	10.93	14.66	84.01
T_3	4.00	20.16	25.32	28.55	8.20	13.06	16.70	127.40
T_4	3.33	17.37	22.57	28.02	7.36	13.73	16.83	102.70
T_5	5.00	13.44	18.26	24.95	6.20	11.20	14.46	84.03
T_6	5.33	12.63	19.48	27.48	6.26	10.63	12.66	67.84
T_7	3.33	16.16	20.86	26.75	6.80	12.20	14.16	98.47
T_8	4.66	14.08	18.38	25.72	6.93	11.36	13.46	86.28
T_9	3.66	15.13	19.55	26.02	6.66	11.03	12.93	83.95
T_{10}	9.66	9.7	14.49	21.53	5.26	9.73	13.00	60.16
SE (m)±	0.39	1.423	1.573	1.605	0.42	0.51	0.66	5.43
CD @5%	1.19	4.298	4.711	4.805	1.26	1.53	1.98	16.26

CD Critical difference calculated using Fisher's least significant difference (Fisher's LSD) at 5% level of significance
SE (m) ± Standard error of mean

Effect of various combinations of organic and inorganic fertilizers on yield of beetroot

The growth parameters recorded in the present study *viz.* root length, root diameter, fresh weight of root, dry weight of root, yield per plot and yield per ha present in table 3. The maximum root length (22.02 cm) was recorded in T_7 (50% Poultry manure + 50% FYM) followed by T_4 (50% RDF + 50% Poultry manure) (21.70 cm) whereas the lowest root length (16.63) was recorded in T_{10} (control). The increase in length of root may be attributed to solubilization of plant nutrients by addition of poultry manure and vermicompost leading to increase uptake of NPK [29, 40, 54]. Similarly, the maximum root diameter (5.97 cm) was recorded in T_4 (50% RDF + 50% Poultry manure) followed by T_3 (100% poultry manure) (5.84 cm) whereas, the minimum root diameter was recorded in T_{10} (control). The maximum fresh weight of root (118.96g) was recorded in T_4 (50% RDF + 50% Poultry manure) followed by T_3 (100% poultry manure) (103.03 g) whereas, the minimum fresh weight (57.21 g) was recorded in T_{10} (control).

Table 3: Effect of organic and inorganic fertilizers on yield and yield attributes of beetroot

Treatments	Root length (cm)	Root diameter (cm)	Fresh root weight (g)	Dry weight (g)	Root yield /plot (kg)	Root yield /ha (t)
T_1	18.96	2.57	98.06	3.89	3.47	4.34
T_2	18.20	2.48	84.46	4.50	3.43	4.29
T_3	20.08	5.84	103.03	6.02	4.54	5.67
T_4	21.70	5.97	118.96	8.10	6.23	7.79

T_5	19.24	3.80	99.90	4.98	3.75	4.69
T_6	19.26	4.22	95.56	4.85	3.80	4.75
T_7	22.02	5.40	99.22	4.93	4.80	6.00
T_8	19.72	3.28	83.43	3.30	3.09	3.86
T_9	18.49	3.06	90.16	5.19	4.00	5.00
T_{10}	16.63	1.25	57.21	2.69	1.91	2.39
SE (m)±	0.70	0.68	4.12	0.82	0.28	0.35
CD @5%	2.11	2.04	12.34	2.48	0.84	1.05

CD Critical difference calculated using Fisher's least significant difference (Fisher's LSD) at 5% level of significance
SE (m) ± Standard error of mean

The maximum root yield per plot (6.23 kg) was recorded in T_4 (50% RDF + 50% Poultry manure) followed by T_3 (100% poultry manure) (4.54 kg) whereas the minimum root yield per plot (1.91 kg) was recorded in T_{10} (control). The maximum root yield per ha (7.79 t/ha) T_4 (50% RDF + 50% Poultry manure) followed by T_7 (100% poultry manure) (6.00 t/ha). Similarly, the dry weight of root (8.10 g) was recorded maximum in T_4 (50% RDF + 50% Poultry manure) followed by T_3 (100% poultry manure) (6.02 g) whereas the minimum dry weight (2.69 g) was recorded in T_{10} (control). The highest root length, root diameter, fresh weight of root, dry weight of root, yield per plot and yield per ha in T_4 might be due to the reason that poultry manure can provide all thirteen essential plants nutrients i.e. macro and micronutrients in good amount [11]. Similarly, both liquid and solid excreta are excreated without loss of urine due to which poultry manure is rich in organic matter and essential plant nutrients than the manure of other animals [1]. Similar findings were recorded on the root length, root diameter and yield per ha of radish [16, 47].

Effect of various combinations of organic and inorganic fertilizers on quality of beetroot: The quality parameters recorded in the present study *viz.* TSS, chlorophyll and carotenoid content, ascorbic acid content, phenolic content, flavonoid content, betalains and anthocyanin content present in table 4. The maximum TSS (16.95 ºB) was recorded in T_1 (50% RDF + 50% Vermicompost) followed by T_5 (100% FYM) (16.37 ºB) whereas the minimum TSS was recoded in T_{10} (control) (14.09 ºB) and ascorbic acid (15.05 mg/100g) was recorded in T_1 (50% RDF + 50% Vermicompost) followed by T_5 (100% FYM) (13.09 mg/100g) whereas the minimum ascorbic acid content (6.55 mg/100g) was recorded in T_{10} (control). The reason reported by various researchers that organically fertilized soils generally produce plants with lower amounts of nitrogen than chemically fertilized ones because of which it would be expected that organic crops would have more vitamin C, less nitrates and less protein, and a higher chemical quality than conventional crops. Similar findings were reported [29]. It might be due to optimum dose of nutrients resulting in more scope for photosynthates and translocating to the storage organs, ultimately increasing the storage of more carbohydrates and hormonal metabolism of plant system which has direct influence for Vitamin-C content in root. These results are in line with various workers [13, 49].

Table 4: Effect of organic and inorganic fertilizers on quality attributes (TSS, ascorbic acid, betalains, anthocyanin, phenolic and flavonoid content) of beetroot

Treatments	TSS (º Brix)	Ascorbic acid (mg / 100 g)	Betalains content (mg/100g FW)	Anthocyanin content (mg/100g FW)	Phenolic content (mg/g FW GAE eq.)	Flavonoid (mg/g FW catechin eq.)
T_1	16.95	15.05	101.79	45.43	0.265	19.13
T_2	15.68	9.30	100.13	44.00	0.275	20.11
T_3	15.62	7.29	150.94	62.30	0.578	21.86
T_4	15.74	8.14	147.91	59.70	0.729	24.08
T_5	16.37	13.09	114.76	55.63	0.474	20.18
T_6	14.84	12.43	100.08	48.33	0.544	17.16
T_7	14.87	9.88	119.29	50.63	0.644	18.24
T_8	15.82	7.33	118.87	46.80	0.478	17.26
T_9	15.27	8.32	115.561	60.06	0.393	16.65
T_{10}	14.09	6.55	84.24	39.86	0.208	16.63
SE (m)±	0.48	0.58	1.76	2.24	0.02	1.55
CD @5%	1.44	1.77	5.27	6.73	0.07	4.64

CD Critical difference calculated using Fisher's least significant difference (Fisher's LSD) at 5% level of significance SE (m) ± Standard error of mean

The maximum flavonoid content (24.08 mg/g Catechin eq. /g FW) was observed in treatment T_4 (50% RDF+ 50% poultry manure) followed by T_3 (100% poultry manure) (21.86 mg/g Catechin eq. /g FW) whereas the minimum flavonoid content was recorded in T_{10} (16.63 mg/g Catechin eq. /g FW). The maximum phenolic content (0.72 mg Gallic acid eq./g FW) was recorded in treatment T_4 (50% RDF+ 50% poultry manure) followed by T_7 (50% Poultry manure + 50% FYM) whereas minimum phenolic content was recorded in T_{10} (control) (0.208 mg Gallic acid eq./g FW). Flavonoids are natural antioxidant present in plants [20]. Similarly the maximum anthocyanin content (62.30 mg/100 g FW) was recorded in T_3 (100% poultry manure) (59.70 mg/100 g FW) whereas minimum anthocyanin content (39.86 mg/100g FW) was recorded in T_{10} (control) and maximum betalains content (150.94 mg/100g FW) was recorded in T_3 (100% Poultry manure) followed by T_4 (50% RDF + 50% Poultry manure) (147.91 mg/100g FW) whereas the minimum betalains content was recorded in T_6 (50% RDF + 50% FYM) (100.08 mg/100 g FW). Applying fertilizers with high nitrogen content is a promising way to improve betalains and anthocyanin content in vegetative parts.

Table 5: Effect of organic and inorganic fertilizers on carotenoid and chlorophyll a, chlorophyll b and total chlorophyll of beetroot

Treatments	Carotenoids (mg/g FW)	Chl a (mg/g FW)	Chl b (mg/g FW)	Total Chl (mg/g FW)
T_1	6.69	19.58	6.64	26.88
T_2	6.23	16.86	8.30	23.77
T_3	10.3	34.31	13.44	47.74
T_4	7.11	23.38	12.34	34.38
T_5	7.12	29.05	11.16	35.40
T_6	7.19	21.84	8.91	25.07
T_7	7.74	16.31	14.63	29.28
T_8	8.34	40.07	8.83	45.89
T_9	7.47	30.50	7.38	35.89
T_{10}	6.31	25.76	6.75	33.00
SE (m)±	0.57	1.13	0.91	1.36
CD @5%	1.73	3.39	2.75	4.08

CD Critical difference calculated using Fisher's least significant difference (Fisher's LSD) at 5% level of significance SE (m) ± Standard error of mean

The maximum carotenoid content (10.3 mg/g FW) was observed in treatment T_3 (100% poultry manure) followed by T_8 (50% FYM + 50% Vermicompost) (8.34 mg/g FW) whereas the minimum carotenoid content was recorded in T_2 (50% RDF+ 50% vermicompost) (6.23 mg/g FW) presented in table 5. Similarly the maximum chlorophyll-a content was observed in treatment T_8 (40.07 mg/g FW) followed by T_3 (100% poultry manure) (34.31 mg/g FW) whereas the minimum chlorophyll A content (6.64 mg/g FW) was recorded in treatment T_1 (100% Vermicompost). The maximum chlorophyll-b content (14.63 mg/g FW) was observed in treatment T_7 followed by T_3 (100% poultry manure) (13.442 mg/g FW) whereas minimum was recorded in T_1 (6.64 mg/g FW). The maximum total chlorophyll content was observed in treatment T_3 (47.74 mg/g FW) followed by T_8 (45.89 mg/g FW) whereas minimum was recorded in T_2 (23.77 mg/g FW). Nitrogen and potassium are considered essential minerals in photosynthesis and the growth of meristematic tissues.

Effect of various combinations of organic and inorganic fertilizers on quality of beetroot

The data obtained on the economics of beetroot influenced by organic and inorganic fertilizers are presented in table 6. The maximum gross income (Rs. 438000 ha^{-1}), net income (Rs. 339762 ha^{-1}), and benefit-cost ratio (B: C ratio) (Rs. 3.45) were observed maximum in the treatment T_4, followed by the treatment T_7 with B: C ratio (Rs. 2.93). Whereas, the minimum gross income (Rs. 90000 ha^{-1}), net income (Rs. 49562 ha^{-1}), and benefit-cost ratio (B: C ratio) (1.22) were observed in the treatment T_{10}.

Table 6: Effect of organic and inorganic fertilizers on yield economics of beetroot

Treatments	Cost of cultivation	Gross return	Net return	B:C ratio
T_1	91318	290000	198682	2.17
T_2	138438	320000	181562	1.31
T_3	146438	410000	263562	1.79
T_4	98238	438000	339762	3.45
T_5	60938	215000	154062	2.52
T_6	55568	198000	142432	2.56
T_7	96688	380000	283312	2.93
T_8	92688	212000	119312	1.28
T_9	149438	380000	230562	1.54
T_{10}	40438	90000	49562	1.22

The increase in B: C ratio and other crop economic parameters might be due to an increase in yield which fetched more prices in the market [37, 52].

Conclusion

From the above experimental findings, it was concluded that the treatment that T_4 (50% RDF + 50% Poultry manure) found to be best in terms of growth, yield and quality of beetroot. Our result suggests that the combination of organic fertilizers along with chemical fertilizers may be utilized for vegetable production in a sustainable agricultural system. It also concluded that use of organic fertilizers minimizes the expensive cost of chemical fertilizers. Beetroot requires good soil condition with proper nutrients and heavy dose of nitrogen for growth and yield. Use of organic fertilizers reduced our dependency on expensive chemical fertilizers, thus it lead to sustainable and eco- friendly cultivation of vegetables. Additionally, conducting the field trial under specific conditions is important for asses the response of these fertilizers and for maximizing yield.

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