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Effect of integrated nutrient management on growth, yield and quality of broccoli (*Brassica oleracea* L. var. *italica*)

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Abstract
The present investigation entitled "Effect of integrated nutrient management on growth, yield and quality of broccoli (*Brassica oleracea* L. var. *italica*)" was conducted during 2016-17 at the Experimental Research Farm Department of Agriculture, Mata Gujri College, Sri Fatehgarh Sahib, Punjab, India. The experiment was laid out in a randomized block design with three replication. The treatments consisted of T_0: Control, T_1: RDF, T_2: Biofertilizers, T_3: Vermicompost, T_4: 100% RDF + Biofertilizers, T_5: 75% RDF + Biofertilizers, T_6: 100% RDF + Vermicompost, T_7: 75% RDF + Vermicompost, T_8: 100% RDF + Vermicompost + Biofertilizers and T_9: 75% RDF + Vermicompost + Biofertilizers. Application of different levels of fertilizers in combination with organic manures and biofertilizers significantly increased the growth, yield and quality of broccoli. Maximum plant height (73.25 cm), plant spread (66.12 cm), leaf length (61.80 cm), leaf width (22.53 cm), number of leaves (15.77), stalk length (22.51 cm), days to curd initiation (84), curd diameter (32.91 cm), average curd weight (427.73 g), curd yield per hectare (35.97 t) and dry matter content (9.88 %) were recorded with the combined application of 100 per cent RDF + biofertilizers + vermicompost. Whereas, maximum ascorbic acid (84.17 mg 100 g^{-1}) and TSS (14.77 °Brix) were recorded in T_9 (75% RDF + Biofertilizers + Vermicompost) and net returns of Rs. ₹ 2,29,029.00 along with benefit: cost ratio (3.26:1) were recorded with the conjoint application of 100 per cent RDF + biofertilizers + vermicompost. These results suggested that the optimum production of broccoli can be obtained with integrated application of 100 per cent RDF + biofertilizers + vermicompost.

Keywords: Biofertilizers, vermicompost and recommended dose of NPK, growth and quality

Introduction
Broccoli (*Brassica oleracea* L. var. *italica*) belongs to family Brassicaceae (Cruciferae). It is biennial and herbaceous winter vegetable crop. This crop is considered as commercial crop in India (Hossain *et al.* 2011) [6]. In India, broccoli is grown over an area of 4 lakh hectare with annual production 85 lakh metric tonnes. Area under broccoli is about 13 lakh hectares in the world with annual production of about 20 million metric tonnes (Anonymous, 2015) [1]. The use of biofertilizers in combination with chemical fertilizers and organic manures offers a great opportunity to increase the production as well as quality of broccoli (Shree *et al.* 2014) [16]. The incorporation of organic nutrients in the form of vermicompost, farmyard manure and biofertilizer is known to influence favorably the physico-chemical and biological properties of the soil resulting in enhanced uptake of nutrients from soil (Lal and Kanaujia, 2013) [11].
Integrated nutrient management having chemical fertilizers applied along with organic sources of nutrients is an effective method for economization of production cost as well as maintenance of soil fertility (Kumar *et al.* 2011) [10]. The crops grown with integrated nutrient management techniques are nutritionally and environmentally superior to those fertilized with inorganic forms of nutrients. Thus, the use of all forms of sources in a combined way i.e. integrated nutrient management practices is the only answer for the production of good quality produce without any ill effect on environment. Therefore, keeping in view the above facts in mind, an attempt has been made in the present investigation to study the effect of integrated nutrient management on growth, yield and quality of broccoli (*Brassica oleracea* L. var. *italica*).

Method and Material
Broccoli (*Brassica oleracea* L. var. *italica*) cv. 'Lucky F_1' (Bejo Zaden – The Netherlands**)**

was used for present study. The plot size was 4 m × 2 m and a spacing of 45 cm × 45 cm. Recommended crop production and protection practices were followed to grow the crop (Anonymous years). The experiment was laid out in a randomized block design with three replications. The treatments consisted of T_0: Control, T_1: RDF, T_2: Biofertilizers, T_3: Vermicompost, T_4: 100% RDF + Biofertilizers, T_5: 75% RDF + Biofertilizers, T_6: 100% RDF + Vermicompost, T_7: 75% RDF + Vermicompost, T_8: 100% RDF + Vermicompost + Biofertilizers and T_9: 75% RDF + Vermicompost + Biofertilizers. Observations were recorded on randomly selected plants with different characters *i.e*. plant height (cm), plant spread (cm), leaf length (cm), leaf width (cm), number of leaves plant^{-1}, stalk length (cm), days to curd initiation (days), Curd diameter (cm), curd length (cm), average curd weight (g), curd yield plot^{-1} (kg), curd yield (t ha^{-1}), ascorbic acid (mg 100 g^{-1}), dry matter content (%), total soluble solids (°Brix), available NPK in the soil before planting and after final harvest, pH and benefit: cost ratio. The data was analyzed as per design of the experiment.

Result and Discussion

Growth parameters

The analysis of variance revealed significant differences among the treatments for all the plant growth attributes under study.

Plant Height

Data recorded on the effect of integrated nutrient management on various plant growth characters cv. 'Lucky F_1' presented in Table 1. Maximum plant height (73.25 cm) was observed in T_8 (100% RDF + Biofertilizer + Vermicompost). This might be due to the availability of more nitrogenous compounds to the plant by application of recommended dose of fertilizer (RDF) along with organic and biofertilizer, which increases the foliage of the plant and thereby increases the photosynthesis (Bhagavantagoudra and Rokhade, 2002) [2]. However, the minimum plant height (47.81 cm) was observed in T_0 (Control).

Plant Spread

Maximum plant spread (66.12 cm) was observed in the treatment T_8 (100% RDF + Biofertilizer + Vermicompost) whereas, minimum value for plant spread (38.87 cm) was recorded in the T_0 (Control). The increase in fertilizer and organic manure application may be ascertained to increase amount of nutrients such as nitrogen, phosphorus and potassium in plants, leading to increase in the formation of plant metabolites that helped to build the plant tissues (Krezel and Koota, 2004) [9].

Leaf length and leaf breadth

Highest Leaf length (61.80 cm) and leaf width (22.53 cm) was recorded in T_8 (100% RDF + Biofertilizer + Vermicompost). Whereas, minimum leaf length (41.42 cm) and leaf width (14.25 cm) was recorded in T_0 (Control). The notable improvement with respect to growth parameters like leaf length and width with the use of biofertilizers, organic manures and inorganic fertilizers may be attributed to longer and sustained supply of nutrients during the entire growth period (Singh *et al.* 2009) [17].

Maximum number of leaves

Maximum number of leaves (15.77) was observed in treatment T_8 (100% RDF + Biofertilizer + Vermicompost). The non significant difference may be due to the fact that number of leaves is a strong qualitative character under the strong influence of genotype thus did not show significant difference (Rather *et al.* 2003) [14]. Whereas, minimum number of leaves (9.19) was observed in T_0 (Control).

Maximum stalk length

Maximum stalk length (22.51 cm) was recorded in T_8 (100% RDF + Biofertilizer + Vermicompost) Minimum stalk length (13.69 cm) was recorded in T_0 (Control). It might be due to the cell elongation by the presence of nitrogenous compounds (Chaterjee *et al*. 2005) [3]. Certain growth promoting substances secreted by the biofertilizer, which in turn, might have led to better root development, better transportation of water, uptake and deposition of nutrients (Shree *et al.,* 2014) [16].

Maximum days to curd initial

Minimum days (84.00) for appearance of curd initiation was observed in treatment T_8 (100% RDF + Biofertilizer + Vermicompost). Maximum days to curd initiation (109.33) were taken by the T_0 (Control). The early curd initiation may also be due to the stimulating effect of organic and biofertilizers or presence of phosphorous on growth hormones which induces early flowering and maturity (Westerveld *et al*. 2003) [18].

Table 1: Effect of integrated nutrient management on growth contributing characters of broccoli.

Treatment	Plant height (cm)	Plant spread (cm)	Leaf length (cm)	Leaf width (cm)	No. of leaves plant^{-1}	Stalk length (cm)	Days to curd initiation
T_0	47.81	38.87	41.42	14.19	9.19	13.69	109.33
T_1	63.75	51.83	55.24	18.93	12.26	18.26	103.00
T_2	67.24	56.27	55.10	19.16	13.25	19.37	96.00
T_3	64.38	53.08	53.75	19.25	13.17	18.70	98.00
T_4	68.86	59.62	57.30	18.75	14.60	20.30	90.67
T_5	67.91	56.40	54.99	18.59	14.16	19.38	94.33
T_6	71.72	62.36	59.35	21.49	14.65	21.15	86.00
T_7	69.34	58.44	57.16	16.58	14.30	20.11	91.00
T_8	73.25	66.12	61.80	22.53	15.77	22.51	84.00
T_9	72.71	64.77	60.03	17.95	15.55	21.70	85.00
SE(m)±	0.64	0.66	0.70	0.50	0.99	0.27	1.16
$CD_{0.05}$	1.90	1.77	2.08	1.50	2.96	0.81	3.46

Yield Attributes

Curd diameter

Maximum curd diameter (32.91 cm) was recorded in treatment T_8 (100% RDF + Biofertilizer + Vermicompost) presented in table 2.0 Minimum curd diameter (20.51 cm) was recorded in T_0 (Control). According to Kachari and Korla (2009) [8] increase in diameter might be due to high translocation of metabolites or nutrients in plant.

Curd weight (g)

The maximum average curd weight (427.73 g) was observed in T_8 (100% RDF + Biofertilizer + Vermicompost). The minimum curd weight (275.40 g) was observed in T_0 (Control). The increase in curd weight might be due to more photosynthesis from a larger area of leaves and the translocation of photosynthates to the sink which ultimately increase curd weight (Vikrant and Singh 2005) [19].

Curd yield / plot

Highest curd yield plot^{-1} (11.97 kg) was obtained in treatment T_8 (100% RDF + Biofertilizer + Vermicompost). Lowest curd yield plot^{-1} (6.69 kg) was recorded in T_0 (Control). The increase in yield and yield components due to the application of biofertilizers can be attributed to the release of bioactive substances having similar effect as that of growth regulators besides enhancement of nutrient absorption (Londhe, 2002) [12].

Curd yield /hac

Maximum curd yield (35.97 t ha^{-1}) was obtained in T_8 (100% RDF + Biofertilizer + Vermicompost). Minimum (8.36 t ha^{-1}) curd yield was recorded in treatment T_0 (Control) as compared to rest of the treatments. The increase also might be due to the fact that these nutrients are important constituents of nucleotides, proteins, chlorophyll and enzymes, which are involved in various metabolic process which have direct impact on vegetative and reproductive phase of the plants (Raghav and Chandra, 2005) [13].

Table 2: Effect of integrated nutrient management on yield and yield contributing characters of broccoli

Treatment	Curd Diameter (cm)	Average curd weight (g)	Curd Yield (kg plot^{-1})	Yield (t ha^{-1})	B: C ratio
T_0	20.51	275.40	6.69	8.36	2.19:1
T_1	27.44	366.67	10.26	12.80	3.34:1
T_2	28.40	296.40	8.29	10.36	2.87:1
T_3	28.53	298.80	8.13	10.16	2.26:1
T_4	20.57	304.67	8.56	10.70	2.55:1
T_5	27.86	367.47	10.55	13.18	3.50:1
T_6	21.98	368.93	10.33	12.90	2.74:1
T_7	30.41	346.80	9.71	12.13	2.60:1
T_8	32.91	427.73	11.97	14.96	3.26:1
T_9	23.24	349.13	9.77	12.21	2.56:1
SE(m)±	0.62	13.98	0.33	0.42	
$CD_{0.05}$	1.86	41.56	1.00	1.25	

Qualitative Attributes

Maximum ascorbic acid content (84.17 mg 100 g^{-1}) was recorded in T_9 (75% RDF + Biofertilizer + Vermicompost) was presented in table 3. Whereas, minimum ascorbic acid content (68.24 mg 100 g^{-1}) was recorded in T_0 (Control). This may be due to the slow but continuous supply of all major and micro nutrients, which might have helped in the assimilation of carbohydrates and in turn synthesis of ascorbic acid (Jaipaul *et al*. 2011) [7].

Maximum dry matter content (9.88 %) was obtained in T_8 (100% RDF + Biofertilizer + Vermicompost). Minimum dry matter content (6.51 %) was recorded in T_0 (Control). It might be due to the release of sufficient quantity of nutrients by the process of mineralization at a constant level that in turn gave higher dry matter content (Shree *et al*. 2014) [16].

Maximum TSS (14.75 °Brix) was obtained in T_9 (75% RDF + Biofertilizer + Vermicompost). However, minimum (8.93 °Brix) was recorded in T_0 (Control). The possible increase depicted in the TSS content with the integrated application of nutrients may be due to the action of specific soil nutrients which may be made more readily available into the soil for plant absorption which in turn may activate specific enzymes (Chumei *et al*. 2013) [4].

Table 3: Effect of integrated nutrient management on quality contributing traits of broccoli

Treatment	Dry matter (%)	Ascorbic acid (mg 100 g^{-1})	TSS (°Brix)
T_0	6.51	68.24	8.93
T_1	6.53	72.33	9.20
T_2	7.32	75.53	10.40
T_3	7.12	74.67	9.73
T_4	8.52	78.81	12.50
T_5	7.35	78.35	10.60
T_6	9.69	79.31	11.70
T_7	8.48	83.00	12
T_8	9.88	80.15	10.00
T_9	9.83	84.17	14.76
SE(m)±	0.24	0.53	0.23
$CD_{0.05}$	0.74	1.57	0.69

Soil Chemical Attributes

Maximum (7.94) pH values was recorded under treatment T_2 (Biofertilizers) presented in table 4. Integrated nutrient management did not influence the pH of soil. The net increase in pH may be due to increased microbial activities in the root zone which decomposed organic manures and also fixed unavailable form of mineral nutrients into available forms in soil thereby substantiated crop requirements and stabilized soil pH (Chumei *et al.* 2013) [4].

Maximum amount of available nitrogen (259.10 kg) was observed in the treatment T_8 (100% RDF + Biofertilizer + Vermicompost). However, minimum (196 kg) amount of available nitrogen was obtained in T_0 (Control). The increase in available nitrogen might be due to direct addition of nitrogen through inorganic sources and fixation of nitrogen by *Azotobacter* and greater multiplication of soil microbes that could convert organically bound nitrogen to inorganic form (Sharma. 2000) [15].

The maximum (35.03 kg) available phosphorus was observed in T_8 (100% RDF + Biofertilizer + Vermicompost). However, minimum available phosphorus content (16.86 kg) was recorded in T_0 (Control). The release of organic acid during microbial decomposition of organic matter might have helped in solubility of native phosphorus and hence resulted in increased phosphorus content in soil (Feller and Fink, 2005) [5].

The maximum (139.63 kg) available potassium was observed in T_8 (100% RDF + Biofertilizer + Vermicompost). However, minimum amount of potassium (98.3 kg ha^{-1}) was found in T_0 (Control). This might be due to interaction of organic matter with clay soil besides addition of potassium to the available potassium pool of the soil (Kachari and Korla, 2012) [8].

Examination of the data revealed that maximum net returns per hectare (₹ 2,29,029.00) was obtained in treatment T_8 (100% RDF + Biofertilizer + Vermicompost) with the benefit cost ratio of 3.26:1. The minimum ratio of 2.19:1 was obtained in control. The reason for increased profit and benefit: cost ratio is due to maximum marketable yield due to healthy and better curd size and higher net returns as compared to other treatments. Economics was also calculated by Singh *et al.* (2009) [17].

Table 4: Effect of integrated nutrient management on soil characteristics after harvesting of broccoli.

Treatment	pH	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})
T_0	7.68	196	16.86	98.3
T_1	7.80	201.13	19.33	101.50
T_2	7.94	241.37	25.90	124.13
T_3	7.70	228.17	24.27	119.20
T_4	7.82	248.23	33.27	132.33
T_5	7.73	241.03	29.27	127.13
T_6	7.80	256.50	30.23	137.90
T_7	7.70	247.37	27.17	131.13
T_8	7.80	259.10	35.03	139.63
T_9	7.70	251.17	31.13	134.17
SE(m)±	0.07	1.30	0.64	1.13
$CD_{0.05}$	0.21	3.86	1.91	3.36

Conclusion

Integrated approach of biofertilizer, vermicompost and 100 per cent recommended dose of NPK performed better with respect to growth characters (plant height, plant spread, leaf length, leaf width, stalk length, days to curd initiation), yield and yield contributing characters curd diameter, averagecurd diameter, average curd weight, curd yield, and dry matter content. It also improved the soil characters like pH with minimum deterioration of already available nutrient content of soil. Whereas, quality characters (TSS, ascorbic acid content) performed better with 75 per cent RDF + Biofertilizers (*Azotobacter*) + Vermicompost and net returns with highest benefit: cost ratio (3.26:1) performed better with biofertilizer, vermicompost and 100 per cent NPK. Therefore, application of biofertilizer with vermicompost and 100 per cent recommended dose of NPK may trail be suggested after on-farm testing in trail for commercial cultivation of broccoli for getting higher fruit yield with maximum net returns per unit area in broccoli.

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