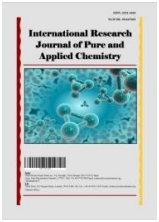

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Impact of Integrated Nutrient Management (INM) for Sustainable Production of Sprouting Broccoli (*Brassica oleracea* L. var. *italica* Planck)

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Authors' contributions

This work was carried out in collaboration among all authors. Author BL designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AKD and INS managed the analyses of the study. Authors SD, MKY, VPS and SK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The investigation was conducted at Vegetable Research Station, Kalyanpur, C. S. A. University of Agriculture and Technology, Kanpur, Uttar Pradesh during 2018-19 and 2019-20 to find out the effect of different levels of inorganic and organic fertilizers with the combination of biofertilizers on the sustainable production of sprouting broccoli. The experiment was laid out in a Randomized Block Design (RBD) with three replications. Results revealed that application of Vermicompost @ 5 t ha^{-1} + Azotobacter gave a significant effect on yield and yield attributing characters *viz*., days to first curd initiation, days to 50% curd initiation, stalk diameter, stalk length, curd diameter, curd length, curd width, days to curd maturity, weight of curd with guard leaves, weight of curd without guard leaves, weight of curd after 24 hours at room storage and curd yield as compared to other treatments.

Keywords: INM; sprouting broccoli; sustainable; curd yield.

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1. INTRODUCTION

Sprouting broccoli (*Brassica oleracea* var. *italica*) is an important Cole crop after cabbage and cauliflower [1], and belonging to the Brassicaceae family that is consumed as a vegetable throughout the world. Broccoli is very highly nutritious and rich source of health promoting phytochemicals [2]. Therefore, it is recognized as anti-cancerous food by the American Cancer Society. In the last decades, the consumption of broccoli increased by several fold and this increased consumption is due to awareness about its high content of polyphenols, flavonoids, vitamins, minerals, fibers and it being low in calories [3]. Therefore, this vegetable is balanced and full sufficient source of nutrients for the better development of the human diet [4].

Nutrient management is one of the most important practices for profitable cultivation of any vegetable crop. Recommendations on fertilizer application in broccoli have also been made from different parts of the country with varying doses of different nutrients depending upon the soil fertility status under different regions [5]. 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 [6]. 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 [7]. INM refers to the integration of organic, inorganic and biological components to increase crop productivity and maintenance of soil fertility for future use. This is all done without any deleterious effect on the physico-chemical and biological properties of the soil on a long-term basis [8]. However, integrated applications having the judicious combination of mineral fertilizer with organic and biological sources of nutrients are not only complementary but also synergistic as organic inputs have beneficial effects [9]. 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 and yield of broccoli (*Brassica oleracea L.* var. *italica*).

2. MATERIALS AND METHODS

The experiment was carried out during the winter season of two consecutive years *i.e*., 2018-19 and 2019-20 at Vegetable Research Station, C. S. A. University of Agriculture and Technology, Kanpur, (U. P.). The soil of the experimental field was Gangetic alluvial with sandy clay loam texture, good water holding capacity, well-drained with moderate soil fertility status and soil pH of 7.5.

The experiment consisted of twelve treatments laid out in a Randomized Block Design with three replications (Table 1). The hybrid variety of Green Magic was used in both years of the experiment. One month old healthy seedlings with uniform vigour were transplanted in plots that measured 2.40 x 1.35 m at the spacing of 60 x 45 cm. Biofertilizers (Azotobactor) were inoculated as a seedling root dip for 30 minutes @ 5 kg ha^{-1} each. The full dose of organic manures was applied before one week of transplanting. NPK was supplied through Urea, DAP and MOP. Half dose of N and a full dose of P and K were applied at the time of transplanting and the remaining half dose of N was given in two equal splits at 30 and 60 days after transplanting. Recommended cultural and plant protection practices were followed equally in all the plots as and when required.

The observations were taken on different reproductive and yield attributing characters like days to first curd initiation, days to 50% curd initiation, stalk diameter, stalk length, curd diameter, curd length, curd width, days to curd maturity, weight of curd with guard leaves, weight of curd without guard leaves, weight of curd (g) after 24 hrs. Storage, curd yield (kg $plot^{-1}$) and curd yield (q ha^{-1}).

3. RESULTS AND DISCUSSION

The presented data of INM on different yield and yield attributes characters were significantly affected by various treatments (Table 2). The pooled data indicated that minimum days of first curd initiation (51.15 days) were found with the application of vermicompost @ 5 t ha^{-1} + Azotobacter (T_8) which was at par with T_1, T_2, T_9, T_{10} and T_{11}. The maximum days of first curd initiation (57 days) were recorded as in case of control (T_0). Similar results have also been reported by Chaubey et al. [10] in their study on cabbage.

The minimum days taken for 50% curd initiation (55.16 days) were found with the application of Vermicompost @ 5 t ha^{-1} + azotobacter (T_8) which was at par with T_4, T_6, T_7, T_9, T_{10} and T_{11}. The maximum days taken for 50% curd initiation

after transplanting (68 days) was recorded as in case of control (T_0). Similar results have also been reported by Chaubey et al. [10] in their study on cabbage. The finding has also been observed by Mohanta et al. [1] Singh et al. [11], Meena et al. [12], Pawar and Barkule [13] and Merentola et al. [14] in broccoli.

At harvesting stage pooled data indicated that maximum stalk diameter (3.52 cm) was found with the application of Vermicompost @ 5 t ha^{-1} + Azotobacter (T_8), which was at par with T_4, T_6 and T_9. The minimum stalk diameter (1.75 cm) was recorded as the harvesting stage in case of control (T_0). These findings have also been observed by Atal et al. [15], Mal et al. [16].

The maximum stalk length at the harvesting stage (21.39 cm), found with the application of Vermicompost @ 5 t ha^{-1} + Azotobacter (T_8), which was at par with T_9, T_{10} and T_{11}. The minimum stalk length at the harvesting stage (13.99 cm) was recorded as in case of control (T_0). These findings have also been observed by Sharma et al. [17].

The maximum curd diameter at harvesting stage (12.62 cm), found with application of Vermicompost @ 5t ha^{-1} + azotobacter (T_8) which was at par with T_7, T_9 and T_{10}. The minimum curd diameter at the harvesting stage (9.03 cm) was recorded as in case of control (T_0). These findings have also been observed by Mohanta et al. [1] Atal et al. [15], Manivannan and Singh [18], Jigme et al. [19], Akbar et al. [20] in cabbage and Kumar et al. [21] in cauliflower.

The maximum curd length at the harvesting stage (7.25 cm) was found with application of Vermicompost @ 5 t ha^{-1} + Azotobacter (T_8). Which was at par with T_9 and T_{10}. The minimum curd length at the harvesting stage (3.50 cm) was recorded as in case of control (T_0). These findings have also been observed by Akbar et al. [20] in cabbage and Das et al. [22].

The pooled data of curd width was found indicated that maximum (12.89 cm) with the application of Vermicompost @ 5 t ha^{-1} + Azotobacter (T_8) which was at par with T_6, T_7, T_9, T_{10} and T_{11}. The minimum curd width at the harvesting stage (8.62cm) was recorded as in case of control (T_0). These findings have also been reported by Das et al. [22] and Yadav et al. [23].

The minimum days (72.11 days) taken for curd maturity for harvesting was found with the application of Vermicompost @ 5 t ha^{-1} + azotobacter (T_8) which was at par with T_7, T_9 and T_{10}. The maximum days to taken curd maturity for harvesting (78.16 days) were recorded as in case of control (T_0). These findings have also been observed by Sharma et al. [17], Pawar and Barkule [13], Singh et al. [11] and Meena et al. [24] in broccoli combined application with bio-fertilizers and vermicompost.

Table No-3 indicate that maximum weight of curd with guard leaves (1283.20 g) was found with the application of Vermicompost @ 5 t ha^{-1} + Azotobacter (T_8) which was at par with T_9, T_{10} and T_{11}. The minimum weight of curd with guard leaves (718.50 g) was recorded as in case of control (T_0). The increase in weight of curd with guard leaves might be due to the more photosynthesis from a larger area of the leaves and the translocation of photosynthates to the sink which is ultimately the curd. The increase in the weight of curd with guard leaves at this level might also be due to the increase in the length and width of the leaves and plant spread. These findings have also been observed by Kumar et al. [25], Atal et al. [15], Manivannan and Singh [18], Kumawat [26] and Kumar et al. [21] in cauliflower.

Similarly, the maximum weight of curd without guard leaves (510.88 g) was found with the application of Vermicompost @ 5 t ha^{-1} + Azotobacter (T_8) which was at par with T_9, T_{10} and T_{11}. The minimum weight of curd without guard leaves (349.78 g) was recorded as in case of control (T_0). The increase in the weight of curd without guard leaves at this level might also be due to the increase in the length and width of the leaves and plant spread cited by these findings have also been observed by Kumar et al. [24] in broccoli, Yadav et al. [23], Kumar et al. [25], Acharya et al. [27] and Kumar et al. [21].

The weight of curd (g) after 24 hrs. at room, storage significantly influenced by different treatments. The minimum weight of curd (441.43 g) was recorded in T_8 (Vermicompost @ 5 t ha^{-1} + Azotobacter) which was at par with T_9, and T_{10}. The maximum weight of curd (319.22) was recorded in 100% RDF (120: 80: 60 N P K kg ha^{-1}). These findings have also been observed by Chatterjee et al. [28].

The significantly maximum curd yield (6.21 kg $plot^{-1}$) at harvesting time was found with the application of Vermicompost @ 5 t ha^{-1} + Azotobacter (T_8) which was at par with T_7, T_9,

and T_{10}. The minimum curd yield (3.47 kg plot^{-1}) was recorded as in case of control (T_0). The beneficial role of bio-fertilizers and vermicompost in improving the plants growth and also resulted in higher values for yield contributing parameters. These findings have also been reported by Acharya et al. [27], Kumar et al. [24] and Kumawat [26].

Curd yield of broccoli differed significantly due to the application of different levels of inorganic and organic fertilizer. Among the treatments the maximum curd yield at harvesting time (183.99 q ha^{-1}) was found with the application of Vermicompost @ 5 t ha^{-1} + Azotobacter which was at par with T_9 and T_{10}. The minimum curd yield (123.88 q ha^{-1}) was recorded as in case of control (T_0). Various yield parameters have been significantly influenced when organic manures are applied, which signifies the role of vermicompost in combination with bio-fertilizers for enhancing yield parameters in sprouting broccoli. These findings have also been observed by Atal et al. [15], Akbar et al. [20] in cabbage, Khan et al. [29], Kumar et al. [21] in cauliflower and Chatterjee et al. [30] in cabbage.

Table 1. Treatments details

S. no.	Symbols	Treatment combinations
1.	T_0	Control
2.	T_1	100% RDF (120: 80: 60 N P K ha^{-1})
3.	T_2	FYM @ 25t ha^{-1}
4.	T_3	Vermicompost @ 5t ha^{-1}
5.	T_4	Azotobacter
6.	T_5	100%RDF + FYM@ 25t ha^{-1}
7.	T_6	100%RDF + Vermicompost@ 5t ha^{-1}
8.	T_7	100% RDF + Azotobacter
9.	T_8	Vermicompost @ 5t ha^{-1} + Azotobacter
10.	T_9	100% RDF + FYM @ 25t ha^{-1} + Azotobacter
11.	T_{10}	100% RDF + Vermicompost @ 5 t ha^{-1} + Azotobacter
12.	T_{11}	100% RDF+FYM@12.5t ha^{-1}+Vermicompost@2.5tha^{-1} + Azotobacter

Table 2. Effect of integrated nutrient management on yield and yield attributing parameters of sprouting broccoli (Pooled data)

Treatments	Days to first curd initiation	Days to 50 % curd initiation	Stalk diameter (cm)	Stalk length (cm)	Curd diameter (cm)	Curd length (cm)	Curd width (cm)	Days to curd maturity
T_0	57.00	68.00	1.75	13.99	9.03	3.50	8.62	78.16
T_1	52.30	58.00	3.14	15.61	9.76	4.77	10.59	75.83
T_2	52.66	58.16	3.11	16.21	10.18	5.54	10.46	77.00
T_3	52.46	58.00	3.20	17.68	10.49	6.13	10.30	76.83
T_4	53.16	57.66	3.27	19.55	10.30	6.18	10.62	77.16
T_5	53.46	58.33	3.01	18.16	11.15	5.55	12.04	76.16
T_6	53.13	57.83	3.28	18.83	11.36	5.94	12.21	74.83
T_7	53.15	57.66	3.22	19.57	11.83	5.26	12.37	72.50
T_8	51.15	55.16	3.52	21.39	12.62	7.25	12.89	72.11
T_9	52.46	57.33	3.28	20.63	11.50	6.40	12.07	74.61
T_{10}	52.48	57.00	3.08	19.65	11.63	6.42	12.20	74.99
T_{11}	51.83	56.66	3.14	19.74	11.00	6.01	12.25	75.44
SE (m) ±	0.325	0.456	0.093	0.301	0.299	0.182	0.236	0.267
CD @ 5%	0.925	1.295	0.265	0.855	0.851	0.518	0.672	1.861

Table 3. Effect of integrated nutrient management on yield and yield attributing parameters of sprouting broccoli (Pooled data)

Treatments	Weight of curd with guard leaves (g)	Weight of curd without guard leaves (g)	Weight of curd after 24 hours storage (g)	Curd yield (kg plot^{-1})	Curd yield (q ha^{-1})
T_0	718.50	349.78	321.33	3.47	123.88
T_1	888.10	378.71	319.22	4.61	132.85
T_2	951.40	373.74	326.63	4.56	131.43
T_3	871.30	385.49	360.66	4.51	132.68
T_4	927.63	368.03	353.33	4.60	134.16
T_5	893.63	366.58	323.34	4.48	131.65
T_6	1010.76	415.22	363.89	5.15	154.62
T_7	891.21	435.51	391.45	5.50	166.21
T_8	1283.20	510.88	441.43	6.21	183.99
T_9	1178.98	490.83	434.16	5.94	172.39
T_{10}	1232.93	489.59	419.50	5.70	171.30
T_{11}	1237.66	456.26	390.61	5.48	153.29
SE (m) ±	45.922	11.311	9.229	0.199	4.194
CD @ 5%	130.581	32.162	26.243	0.568	11.925

4. CONCLUSION

The above study revealed that the integration of organic manures and bio-fertilizers had shown an effect in enhancing yields as well as productivity of sprouting broccoli. The application of Vermicompost @ 5 t ha^{-1} + Azotobacter (T_8) gave a significant effect on yield and yield attributing characters resulting higher curd yield per unit area and it can be recommended for higher production of broccoli under Central U.P. Conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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