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Effect of Integrated Nutrient Management and Bio-regulators on Yield and Economics Attributes of Sprouting Broccoli {*Brassica oleracea* (L.) var. *italica*}

Arjun Lal Ola[1*], L. N. Bairwa[1], O. P. Garhwal[1] and O. P. Regar[1]

[1]Department of Horticulture, S.K.N. College of Agriculture, Jobner, Jaipur, Rajasthan, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author ALO designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors LNB and OPG managed the analyses of the study. Author OPR managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment was conducted at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Jaipur) during *Rabi* seasons of 2016-17 and 2017-18. The experiment consisted of thirty five treatment combinations including seven INM (100 per cent RDF through inorganic fertilizer, 75 per cent RDF through inorganic fertilizer + 25 per cent through FYM (5 t/ha), 50 per cent RDF through inorganic fertilizer + 50 per cent through FYM, 100 per cent RDF through FYM, 75 per cent RDF through inorganic fertilizer + 25 per cent through VC, 50 per cent RDF through inorganic fertilizer + 50 per cent through VC and 100 per cent RDF through vermicompost and five bio-regulator levels [Control, Brassinoids @ 5 ppm, Brassinoids @ 10 ppm, Salicylic acid @ 100 ppm and Salicylic acid @ 150 ppm] were under taken in Split plot design with three replications. The results showed that the maximum weight of primary curd (222.51 g), number of secondary curds per plant (6.58), weight of secondary curd (154.05 g), yield per plant (384.56 g), yield per plot (7.69 kg), yield per ha

**Corresponding author: E-mail: arjunola11@gmail.com;*

(189.90 q), biological yield per ha (1081.85 q) and net returns (₹ 304019/ha) were recorded with the application of 50 per cent RDF through inorganic fertilizer and 3.5 t/ha vermicompost (F_5) in sprouting broccoli. Whereas, the maximum B:C ratio (4.39:1) was recorded under 75 per cent RDF supplied through inorganic fertilizer and 1.75 t/ha vermicompost. Harvesting index was found non significant. In the case of bio-regulators maximum weight of primary curd (213.17 g), number of secondary curds per plant (6.20), weight of secondary curd (147 g), yield per plant (362.57 g), yield per plot (7.42 kg), yield per ha (183.19 q), biological yield per ha (1002.18 q), net returns (₹ 287563 / ha) and B:C ratio (3.99:1) were recorded significant by superior over control with foliar application of 5 ppm brassinoids. While harvesting index was found non significant to broccoli.

Keywords: Economics; yield; organic; inorganic; bio-regulators; brassinoids; vermicompost; sprouting broccoli and salicylic acid.

1. INTRODUCTION

Sprouting broccoli (*Brassica oleracea* var. *italica*) has originated in the mediterranean region and commonly known as *Hari gobhi* in Hindi and a member of cole group, belongs to the family brassicaceae. While the broccoli derived its name from the Latin word *Branchium* meaning an arm or branch. It is used as curries, soups, pickles, eaten as a salad and cooked as a single or mixed vegetable with potato (Thamburaj and Singh, 2001). Sprouting broccoli is high value exotic vegetable with a kind of terminal head consisting of green buds and thick fleshy flower stalks morphologically resembles the cauliflower except secondary heads, which develop in the axil of leaves and may contribute up to 50 per cent of the total yield.

Organic manures play direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization and improving physical and chemical properties of soils [1]. The advantages of integrated use of inorganic and organic sources of fertilizers generally superior over use of each component separately. Integration of chemical fertilizers with organic manures had maintained long time fertility and sustains higher productivity [2]. Use of organic manures is not only perfect way for obtaining fairly high productivity with suitable fertilizers economy but also a concept of ecological soundness leading to sustainable agriculture. Therefore, it is hypothesized that growth and yield of broccoli can be enhanced to a great extent by application of organic and inorganic fertilizers with integration of farm yard Manure, vermicompost and chemical fertilizers.

Brassinosteroids are a new group of plant hormones with growth promoting activity [3]. Brassinosteroids are considered as plant hormones with pleiotropic effects as they influence wide array of developmental processes such as growth, seed germination, rhizogenesis flowering, senescence, abscission and maturation [4]. Brassinosteroids improve the resistance of plants against environmental stresses such as water stress, salinity stress, low temperature stress and high temperature stress [5]. Brassinosteroids also enhances the crop productivity [6]. Brassinostroids being an eco-friendly chemical, has a potential application in agriculture to increase yield by regulating defense system under field condition in *Brassica juncea* L. Sirhindi et al. [7]. Mitchell et al. [8] reported about promotion in stem elongation and cell division by the treatment of organic extracts of rapeseed pollen.

Similarly, Salicylic acid (SA) also a plant hormone plays an important role in induction of plant defense against a variety of biotic and abiotic stresses through morphological, physiological and biochemical mechanisms [9]. Salicylic acid not only improved the growth and yield in no-stress condition but also for adjusting the drought stress especially at vegetative stress is recommended in bean (*Phaseolus vulgaris* L.) Sepehri et al. [10]. Salicylic acid (SA) is classified as phenolic growth regulator, a non- enzymatic antioxidant, messenger molecule in plants to induce responses of plants to environmental stressess. It is found in plant which play vital role in plant growth and development, photosynthesis, transpiration, ion uptake and transport. It also involved in the systemic acquired resistance (SAR) in which a pathogenic attack on one part of the plant includes resistance in other parts. SA also plays an important role in the regulation of some physiological processes in plants. It has been found that SA positively affects growth and development, ion uptake and transport, and membrane permeability [11].

2. MATERIALS AND METHODS

The field experiment was conducted at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Jaipur) during *Rabi* seasons of 2016-17 and 2017-18. The experiment consisted of thirty five treatment combinations including seven INM (F_0 - 100 per cent RDF through inorganic fertilizer, F_1 - 75 per cent RDF through inorganic fertilizer + 25 per cent through FYM (5 t/ha), F_2 - 50 per cent RDF through inorganic fertilizer + 50 per cent through FYM, F_3 - 100 per cent RDF through FYM, F_4 - 75 per cent RDF through inorganic fertilizer + 25 per cent through VC, F_5 - 50 per cent RDF through inorganic fertilizer + 50 per cent through VC and F_6 - 100 per cent RDF through vermicompost and five bio-regulator levels [B_0 - Control, B_1 - Brassinoids @ 5 ppm, B_2 - Brassinoids @ 10 ppm, B_3 - Salicylic acid @ 100 ppm and B_4 - Salicylic acid @ 150 ppm] were under taken in Split plot design with three replications. Each plot measured 2.25 × 1.8 m^2 area. The variety was sowed at the spacing between plants to plant as well as row to row was kept at 45 x 45 cm. Before sowing the seed were treated with Azotobactor and PSB inoculums, which was added with 5 g jiggery in 50 ml of boiled water and made in to a sticky paste. The seeds were treated for half an hour and then dried in shade for 30 minutes and then sown in the experimental plots immediately. These healthy seedling & with uniform shape and size were selected and transplanted in well prepared field. All the cultural operations were followed which were necessary to raise the good crop. Five plants were randomly selected and tagged before flowering from each plot to record the data on the following attributes. The observations were recorded on weight of primary curd, Number of secondary curds, weight of secondary curd, curd yield per plant, curd yield per plot and curd yield per hectare on the basis of the total curd yield per plot. However Biological yield was calculated on the basis of total weight of plant at last harvest and harvest index were calculated on the ratio of the economic yield to the biological yield produced. It was calculated by the formula suggested by Singh and Stoskoff, [12].

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

The net return of each treatment was calculated by deducting the cost of cultivation from the gross return of individual treatment. Benefit – cost ratio was calculated also =

$$\frac{\text{Net return}}{\text{Cost of cultivation}}$$

All the parameters were collected from five randomly selected plants of each treatment. Least significant difference at 5% level was used for finding the significant differences among the treatment means. The data obtained from selected plants were subjected to analysis of variance [13].

3. RESULTS AND DISCUSSION

3.1 Effect of Integrated Nutrient Management on Yield Attributes

Data mentioned in Tables 1 and 2 clearly revealed that integrated nutrient management significantly influenced the tied and economics parameters of sprouting broccoli. Pooled results showed that F_5 treatment (50% RDF through inorganic fertilizer + 3.5 t/ha vermicompost) produced the maximum weight of primary curd (222.51 g/plant), number of secondary curds per plant (6.58), weight of secondary curds per plant (154.05 g) and curd yield per plant (384.56 g), curd yield per plot (7.69 kg), curd yield per ha (189.90 q) and biological yield (1081.85 q/ha) which were significantly higher over rest of the treatments except F_4, which was remained at par to it. The significant improvement in yield and yield attributing parameters on account of integrated form using in organic and vermicompost might have attributed to the translocation of nutrients from soil, particularly when sink was able to synthesize the enhanced amount of carbohydrates assimilated by the enhanced rate of photosynthesis. Further, increased vegetative growth might have provided more sites for translocations of photosynthesis. This ultimately resulted in increased yield. The beneficial effect of yield and yield attributees might be due to increased supply of all the essential nutrients by different organic and inorganic sources. Which might have resulted in higher manufacture of photosynthesis and it's subsequent partitioning to sink. The findings of present investigation are supported by Dalal et al. [14] in cabbage who reported that the maximum yield with 50 per cent nitrogen supplied through urea and 50 per cent through vermicompost. Similar results have also been reported by Kumar et al. [15] in cauliflower, Chatterjee et al. [16] in cabbage and Mohanta et al. [17] in broccoli.

Table 1. Effect of INM and bio-regulators on yield and economics attributes of sprouting broccoli

Treatments	Weight of primary curd (g)	Number of secondary curds	Weight of secondary curds	Yield per plant (g)
INM				
F_{0-}100% RDF (100:80:60 kg NPK/ha) through inorganic fertilizer	188.89	5.88	136.92	325.80
F_1- 75% RDF through inorganic fertilizer + 25% through FYM (5 t/ha)	177.80	5.38	126.35	304.15
F_2 -50% RDF through inorganic fertilizer + 50% through FYM (10 t/ha)	209.44	6.04	141.88	353.32
F_3 -100% RDF through FYM (20 t/ha)	172.83	4.92	110.91	283.73
F_4-75%RDF through inorganic fertilizer + 25% through VC (1.75 t/ha)	219.07	6.40	148.23	373.80
F_5 -50% RDF through inorganic fertilizer + 50% through VC (3.5 t/ha)	222.51	6.58	154.05	384.56
F_6 -100% RDF through VC (7 t/ha)	186.01	5.63	131.33	317.34
SEm±	3.45	0.10	2.41	5.78
CD (P=0.05)	10.08	0.30	7.02	16.87
Bio-regulators				
B_0 -Control (water spray)	174.92	5.12	117.95	295.98
B_1-Brassinoids (5 ppm)	213.17	6.20	147.36	362.57
B_2 -Brassinoids (10 ppm)	209.33	6.10	144.25	357.79
B_3 -Salicylic acid (100 ppm)	197.35	5.88	136.17	333.13
B_4 -Salicylic acid (150 ppm)	188.48	5.84	132.58	323.87
SEm±	2.33	0.07	1.62	3.95
CD (P=0.05)	6.54	0.20	4.53	11.07

Table 2. Effect of INM and bio-regulators on yield and economics attributes of sprouting broccoli

Treatments	Yield per plot (kg)	Yield (q/ha)	Biological yield (q/ha)	Harvest index	Net returns (Rs/ha)	B:C ratio
INM						
F_{0-}100% RDF (100:80:60 kg NPK/ha) through inorganic fertilizer	6.52	160.89	936.62	17.18	259964	4.20
F_1- 75% RDF through inorganic fertilizer + 25% through FYM (5 t/ha)	6.08	150.20	856.60	17.53	236339	3.69
F_2 -50% RDF through inorganic fertilizer + 50% through FYM (10 t/ha)	7.07	174.48	978.84	17.83	282670	4.26
F_3 -100% RDF through FYM (20 t/ha)	5.67	140.11	818.98	17.11	209465	2.96
F_4-75%RDF through inorganic fertilizer + 25% through VC (1.75 t/ha)	7.48	184.59	1052.10	17.55	300379	4.36
F_5 -50% RDF through inorganic fertilizer + 50% through VC (3.5 t/ha)	7.69	189.90	1081.85	17.55	304019	4.01
F_6 -100% RDF through VC (7 t/ha)	6.35	156.71	868.83	18.04	223655	2.49
SEm±	0.13	3.33	16.46	0.31	5132	0.06
CD (P=0.05)	0.39	9.72	48.06	NS	14981	0.18
Bio-regulators						
B_0 -Control (water spray)	5.48	135.35	847.89	17.09	212271	3.28
B_1-Brassinoids (5 ppm)	7.42	183.19	1002.18	18.19	287563	3.99
B_2 -Brassinoids (10 ppm)	7.30	180.14	982.54	17.68	283064	3.87
B_3 -Salicylic acid (100 ppm)	6.72	165.89	948.13	17.38	260416	3.71
B_4 -Salicylic acid (150 ppm)	6.55	161.77	929.12	17.36	254181	3.72
SEm±	0.07	1.72	11.34	0.21	2711.64	0.05
CD (P=0.05)	0.20	4.83	31.76	NS	7598.25	0.13

The maximum net returns (₹ 304019 /ha) was recorded under F_5 treatment *i.e.* 50 per cent RDF supplied through inorganic fertilizer and 3.5 t/ha vermicompost. This treatment was significantly higher over rest of the treatment but statistically at par in F_4 treatment. Similar results have been reported by Khan *et al.* (2009) and Mohanta (2015) in broccoli. Pooled results showed that F_4 treatment *i.e.* 75 per cent RDF supplied through inorganic fertilizer and 1.75 t/ha vermicompost recorded the highest B: C ratio of 4.39:1. This treatment was significantly higher over rest of the treatment but statistically at par with F_2 treatment. The increase in benefit cost ratio and other parameters might be due to the increase in yield which fetches more prices in the market having less expenditure.Similar results have also been reported by Sharma et al. [18] in broccoli.

3.2 Effect of Bio-regulators on Yield of Sprouting Broccoli

It is evident from the data (Tables 1 and 2) that application of different bio-regulators also had significant influence on the yield parameters of sprouting broccoli. The maximum weight of primary curd per plant (213.17 g), number of secondary curds (5.12), weight of secondary curds(147.36 g/plant) curd yield per plant (362.57 g), curd yield (7.42 kg/plot), curd yield (183.19 q/ha) were recorded in B_1 treatment (Brassinoids @ 5 ppm). This treatment remained at par with B_2 (Brassinoids @ 10 ppm) but proved significantly superior over rest of the treatments. Application of B_1 treatment registered by 22.50, 11.94 and 8.84 per cent higher curd yield per plant over B_0, B_4 and B_3 treatments respectively. The maximum biological yield of 1002.18 q/ha was also recorded with the application of Brassinoids @ 5 ppm (B_1), However, the minimum (847.89 q/ha) under control (B_0). The treatment B_2 found statistically at par with B_1. The increase in biological yield under B_1 was registered as 18.20 per cent higher over control. The results showed that application of Brassinoids 5 ppm and Brassinoids 10 ppm significantly enhanced all the above yield parameters over control. The yield of sprouting broccoli was found to be strongly influenced by the application of brassiniods thus indicating the importance of brassinoids in increasing the yield potential through their effect of various physiological and biochemical trands. This could be attributed to the stimulatory effect of brassinoids on cell division and elongation. From the findings it is evident that increase in curd formation and development of sprouting broccoli there by providing more sources for the better development of sinks. The increase in yield and yield attributes with the application of brassinoids might be because of better utilization of resources in the plants received by plant growth regulators. Yield is the consequence of various physiological processes and bio-regulators play an important role in reproduction of plants. These findings are in accordance with the results of Netwal [19] who reported that brassinoids 1.0 ppm increased number of green pods per plant, green pod yield per plant and per ha (74.11 q /ha) in Indian bean. Brassiniods increased the total biomass and then might have resulted in an increase in assimilate transport from source to sink and their ultimate conversion into final reserved food by Dhall and Singh [20] in cucumber.

3.3 Effect of Bio-regulators on Economics of Sprouting Broccoli

A perusal of data (Table 2) revealed that application of different bio-regulators had significant increasing in the net returns and B:C ratio of sprouting broccoli. The maximum net returns ₹ 287563 per ha was recorded with 5 ppm brassinoids (B_1) and treatment B_2 (Brassinoids @ 10 ppm) remained statistically at par with B_1. The maximum B:C ratio of (3.99:1) was recorded in B_1 treatment (Brassinoids @ 5 ppm) It was probably due to the magnificent role played by application of bio-regulators *i.e.* brassinoids in improvement of growth, yield and quality attributes of sprouting broccoli therefore, the proportional increase in yield led to ultimately resulted in significantly higher net returns and B:C ratio. Similar results have also been reported by Netwal [19] who reported maximum net returns at 1 ppm of brassiniods in Indian bean.

4. CONCLUSION

On the basis of results obtained in present investigation, it may be concluded that application of 50 per cent RDF through inorganic fertilizer and vermicompost @ 3.5 tonnes/ha as a source of INM was found significantly most suitable in terms of weight of primary curd (222.51 g), number of secondary curds per plant (6.58), weight of secondary curd (154.05 g), yield per plant (384.56 g), yield per plot (7.69 kg), yield per ha (189.90 q), biological yield per ha (1081.85 q) and net returns (₹ 304019/ha). Similarly, foliar application of 5 ppm brassinoids significantly increased the weight of primary curd

(213.17 g), number of secondary curds per plant (6.20), weight of secondary curd (147 g), yield per plant (362.57 g), yield per plot (7.42 kg), yield per ha (183.19 q), biological yield per ha (1002.18 q), net returns (₹ 287563 /ha) and B:C ratio (3.99:1).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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