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Interactive effect of integrated nutrient management and bio-regulators on yield and economics attributes of sprouting broccoli (*Brassica oleracea* (L.) var. *italica* Plenck)

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Abstract
The field experiment was conducted at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Jaipur) during *Rabi* season 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 + 5 t/ha FYM, 50 per cent RDF through inorganic fertilizer + 10 t/ha FYM, 100 per cent RDF through FYM (20 t/ha), 75 per cent RDF through inorganic fertilizer + 1.75 t/ha VC, 50 per cent RDF through inorganic fertilizer + 3.5 t/ha VC and 100 per cent RDF through vermicompost (7 t/ha) and five bio-regulators 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 combined application of 50 per cent RDF through inorganic fertilizer and 3.5 t/ha vermicompost along with brassinoids @ 5 ppm proved to be most superior treatment combination weight of primary curd (266.45 g) weight of secondary curd (180.60 g) yield per plant (444.19 g), yield per plot (9.11 kg) yield per ha (224.94 q) and net returns (₹ 360074/ha) and at par with F_4B_2.However, the maximum B:C ratio (4.77:1) was noticed in F_4B_1 treatment combination.

Keywords: Bio-regulators, interactive, yield, organic, inorganic, vermicompost and sprouting broccoli

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) [13]. 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. It is one of the most nutritious cole crop and contains vitamin A (130 times and 22 times higher than cauliflower and cabbage, respectively), thiamin, riboflavin, niacin, vitamin C and minerals like Ca, P, K and Fe (Hazra and Som, 1999) [3]. It contains carbohydrates (5.5%), protein (3.3%), vitamin-A (3500 IU), vitamin-C (137 mg), vitamin-B-$_1$ (0.05 mg), vitamin-B_2 (0.12 mg), calcium (0.80 mg) and phosphorus (0.79 mg). Broccoli has 4.0, 2.5 and 2.0 times more riboflavin, calcium and ascorbic acid contents, respectively as compared to cauliflower (Thamburaj and Singh, 2001) [13]. It is also a rich source of sulphoraphane, a compound associated with reducing the risk of cancer (Thamburaj and Singh, 2001) [13].

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 (Chaterjee *et al.*, 2005) [2]. 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 (Bhardwaj *et al.* 2000) [1]. 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 (Mandava, 1988) [5]. 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 (Sasse, 1999) [9]. Brassinosteroids improve the resistance of plants against environmental stresses such as water stress, salinity stress, low temperature stress and high temperature stress (Rao *et al.*, 2002) [8]. Brassinosteroids also enhances the crop productivity (Vardhani *et al.*, 2006) [14]. 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.* (2009) [12]. Mitchell *et al.* (1970) [6] 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 (War *et al.* 2011) [15]. 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.* (2015) [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. SA is a monohydroxy benzoic acid, a type of phenolic acid and a beta hydroxy acid. SA is a phenolic phytohormons and is found in plant which play vital role in plant growth and development, photosynthesis, transpiration, ion uptake and transport. SA also induces specific change in leaf anatomy and chloroplast structure. SA 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 (Simaei *et al*., 2012) [11].

Materials and Methods

The field experiment was conducted at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Jaipur) during *Rabi* season 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 + 5 t/ha FYM, 50 per cent RDF through inorganic fertilizer + 10 t/ha FYM, 100 per cent RDF through FYM (20 t/ha), 75 per cent RDF through inorganic fertilizer + 1.75 t/ha VC, 50 per cent RDF through inorganic fertilizer + 3.5 t/ha VC and 100 per cent RDF through vermicompost (7 t/ha) and five bio-regulators 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 seed were treats for half an hour and then dried in shade for 30 minutes and then sown the experimental plot immediately. These healthy seedling uniform shape and size were selected and transplanting 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 line 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, volume of curd, diameter of curd, curd yield per plant, curd yield per plot and curd yield per hectare in quintals was calculated on the basis of the total curd yield per plot. 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 as follows: Benefit:

$$\text{Cost ratio} = \frac{\text{Net return}}{\text{Costof cultivation}}$$

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 Panse and Sukhamate (1961) [7].

Result and Discursion

Interaction effect of INM and bio-regulators on weight of primary curds and secondary curd

The interactive effect of various sources of INM and bio-regulators had significant influence on weight of primary curd per plant and weight of secondary curd. The data on pooled mean basis (Table 1 and 2) revealed that the maximum weight of primary curd (266.45 g/plant) and weight of secondary curd (180.60 g per plant) were recorded under treatment F_5B_1 (50% RDF through inorganic fertilizer + 3.5 t/ha VC with brassinoids @ 5 ppm). These were found statistically at par with F_4B_2 treatment combination but significantly superior to other treatment combinations. The minimum weight of primary curd (150.56 g/ plant) and weight of secondary curds (89.46 g/ plant) were recorded in treatment combination F_3B_0. The enhancement of weight of curd of sprouting broccoli may be due to light induction and supplementary effect of different inorganic sources, vermicompost and brassinoids. The beneficial effect on yield and yield attributes may also be due to increased supply of all the essential nutrients by vermicompost and fertilizers simultaneously supplementary effect of bio-regulators *i.e.* brassinoids which enhanced physiological and bio-chemical process of curd function in sprouting broccoli.

Table 1: Interactive effect of INM and bio-regulators on weight of primary curd (g) of sprouting broccoli (pooled mean of two years)

Treatments	INM						
bio-regulators	F_0	F_1	F_2	F_3	F_4	F_5	F_6
B_0	156.60	158.54	185.18	150.56	197.37	197.63	178.55
B_1	200.84	197.77	217.33	187.97	220.63	266.45	201.18
B_2	184.26	177.80	226.84	183.18	252.59	241.29	199.34

B_3	191.20	179.99	212.10	170.90	216.43	222.51	188.30
B_4	211.53	174.89	205.75	171.52	208.34	184.67	162.69
For B at same levels of F							
S.Em+							6.18
CD (P=0.05)							17.30
For F at same or different levels of B							
S.Em+							6.38
CD (P=0.05)							18.57

Table 2: Interactive effect of INM and bio-regulators on weight of secondary curd (g) of sprouting broccoli in (pooled mean of two years)

Treatments	**INM**						
bio-regulators	**F_0**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**
B_0	113.45	108.85	125.96	89.46	127.86	130.94	129.17
B_1	146.90	138.99	150.81	119.18	152.97	180.60	142.08
B_2	138.30	127.59	160.13	113.12	170.05	159.79	140.78
B_3	138.60	127.96	143.68	109.64	148.26	152.11	132.95
B_4	147.33	128.37	128.82	123.12	141.99	146.79	111.65
For B at same levels of F							
S.Em+							4.28
CD (P=0.05)							12.00
For F at same or different levels of B							
S.Em+							4.79
CD (P=0.05)							13.44

Interaction effect of INM and bio-regulators on yield

Table 3, 4 and Fig 5 showed that application of organic and inorganic source of RDF with bio-regulators had significant effect on curd yield of sprouting broccoli. The treatment combination F_5B_1 (50% RDF through inorganic fertilizer + 3.5 t/ha VC with brassinoids @ 5 ppm) recorded maximum and significantly yield of sprouting broccoli (444.19 g/plant), (9.11 kg/ plot) and (224.94 q/ha) over other treatments except F_4B_2 which was found at par to it, while the minimum curd yield (232.65 / plant), (4.51 kg/plot) and (111.39 q/ha) was observed in F_3B_0 treatment combination. The enhancement of weight of curd, number of secondary curd and yield of sprouting broccoli may be due to light induction and supplementary effect of different inorganic sources, vermicompost and brassinoids. The beneficial effect on yield and yield attributes may also be due to increased supply of all the essential nutrients by vermicompost and fertilizers simultaneously supplementary effect of bio-regulators *i.e.* brassinoids which enhanced physiological and bio-chemical process of curd function in sprouting broccoli. The above findings are in close agreement with finding of Kumar *et al.* (2013) [4] in cauliflower.

Table 3: Interactive effect of INM and bio-regulators on yield per plant (g) of sprouting broccoli (pooled mean of two years)

Treatments	**INM**						
bio-regulators	**F_0**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**
B_0	276.16	255.87	342.22	232.65	345.90	332.07	286.99
B_1	350.67	349.77	357.65	305.01	387.41	444.19	343.27
B_2	337.12	310.23	396.76	303.59	417.99	398.77	340.11
B_3	329.80	307.94	357.82	280.54	373.95	360.60	321.25
B_4	335.25	296.91	312.15	296.86	343.72	387.14	295.05
For B at same levels of F							
S.Em+							10.45
CD (P=0.05)							29.29
For F at same or different levels of B							
S.Em+							11.09
CD (P=0.05)							32.28

Table 4: Interactive effect of INM and bio-regulators on yield per plot (kg) of sprouting broccoli (pooled mean of two years)

Treatments	**INM**						
bio-regulators	**F_0**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**
B_0	4.92	4.94	5.87	4.51	6.17	6.26	5.70
B_1	7.20	6.95	7.45	6.27	7.93	9.11	7.03
B_2	6.60	6.30	8.34	6.00	8.71	8.29	6.83
B_3	6.60	6.16	7.07	5.61	7.48	7.61	6.51
B_4	7.27	6.07	6.60	5.98	7.09	7.19	5.66
For B at same levels of F							
S.Em+							0.19
CD (P=0.05)							0.52
For F at same or different levels of B							
S.Em+							0.29
CD (P=0.05)							0.76

Table 5: Interactive effect of INM and bio-regulators on yield per ha (q) of sprouting broccoli (pooled mean of two years)

Treatments	INM						
bio-regulators	**F_0**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**
B_0	121.37	122.04	144.92	111.39	152.44	154.49	140.82
B_1	177.80	171.60	184.01	154.82	195.70	224.94	173.49
B_2	162.86	155.45	205.90	148.17	215.17	204.64	168.75
B_3	162.86	152.07	174.48	138.54	184.67	187.97	160.63
B_4	179.56	149.82	163.09	147.65	174.97	177.47	139.86
For B at same levels of F							
S.Em+							4.56
CD (P=0.05)							12.77
For F at same or different levels of B							
S.Em+							4.71
CD (P=0.05)							13.59

Interaction effect of INM and bio-regulators on net return

The interactive effect of INM and bio-regulators on net returns was significantly influenced. The data (Table 6 and Fig 1) revealed that the maximum net returns (₹ 360074/ha) was recorded under treatment combination F_5B_1 *i.e.* 50 per cent RDF supplied through inorganic fertilizer and 3.5 t/ha vermicompost with brassinoids @ 5 ppm. This treatment was statistically at par with F_4B_2 where 75 per cent RDF supplied through inorganic fertilizers and 1.75 t/ha vermicompost with brassinoids @ 10 ppm. Whereas the minimum net returns (₹ 166523/ha) was recorded under F_3B_0 treatment.

Interaction effect of INM and bio-regulators on B:C ratio

The interactive effect of INM and bio-regulators on B:C ratio was significantly influenced. The data (Table 7 and Fig 2) revealed that the maximum B:C ratio (4.77:1) was recorded under treatment combination F_4B_1 *i.e.* 75 per cent RDF supplied through inorganic fertilizer and 1.75 t/ha VC with brassinoids @ 5 ppm followed by F_2B_1 where 50 per cent RDF supplied through inorganic fertilizer and 10 t/ha FYM with brassinoids @ 5 ppm. The treatment F_4B_1 registered an increase of 174.14 per cent higher over F_6B_0 treatment combination, whereas the minimum B:C ratio1.74:1 was recorded.

Table 6: Interactive effect of INM and bio-regulators on net returns (₹/ha) of sprouting broccoli (pooled mean of two years)

Treatments	INM						
bio-regulators	**F_0**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**
B_0	196214	192035	234823	166523	248128	247309	200862
B_1	287288	270019	298079	231457	318465	360074	247559
B_2	263141	244606	333585	221511	350194	327628	240785
B_3	263141	239291	282670	207108	300537	300916	229247
B_4	290032	235745	264193	220728	284573	284170	199824
For B at same levels of F							
S.Em+							7174
CD (P=0.05)							20103
For F at same or different levels of B							
S.Em+							7203
CD (P=0.05)							20245

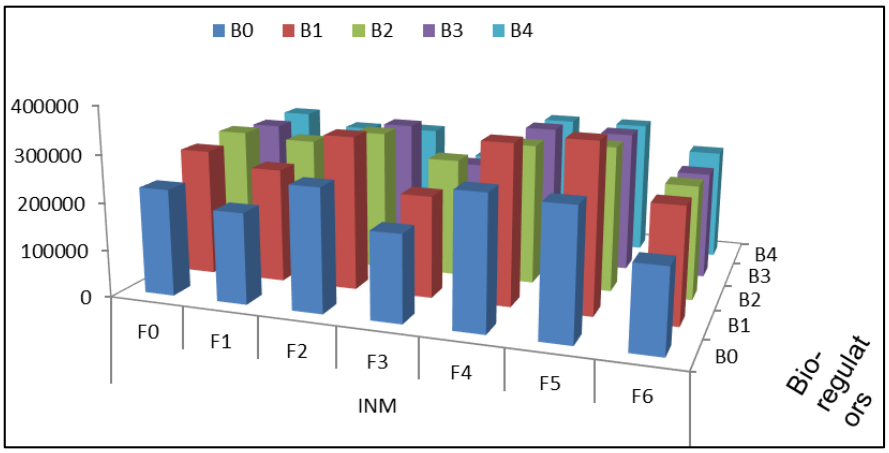

Fig 1: Interactive effects of INM and bio-regulators on net returns of sprouting broccoli (pooled mean of two years).

Table 7: Interactive effect of INM and bio-regulators on B:C ratio of sprouting broccoli (pooled mean of two years)

Treatments	INM						
bio-regulators	**F_0**	**F_1**	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**
B_0	3.89	3.18	3.91	2.61	4.10	3.51	1.74
B_1	4.42	3.69	4.73	3.18	4.77	4.38	2.74
B_2	4.16	4.13	4.22	3.17	4.34	4.19	2.86
B_3	4.26	3.73	4.11	2.93	4.26	4.01	2.64
B_4	4.31	3.71	4.34	2.91	4.37	3.96	2.47
For B at same levels of F							
S.Em+							0.10
CD (P=0.05)							0.29
For F at same or different levels of B							
S.Em+							0.12
CD (P=0.05)							0.34

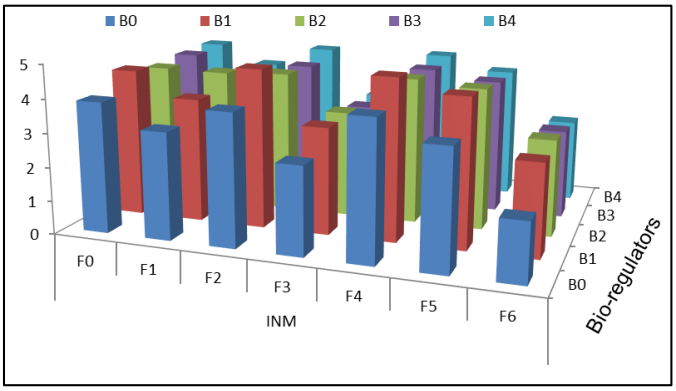

Fig 2: Interactive effects of INM and bio-regulators on B: C ratio in sprouting broccoli (pooled mean of two years).

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