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Effect of integrated nutrient management on vegetative growth of broccoli (*Brassica oleracea* L. var. *italica*) in light textured soil of western Uttar Pradesh

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Abstract
Integrated nutrient management is a promising method and practice of increasing yield with quality produce and sustaining soil and environmental health. Keeping this view in the mind, a field experiment was conducted at the Horticulture Research Center, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut during the Rabi seasons of 2016-17 and 2017-18 to ascertain the "Effect of integrated nutrient management on vegetative growth of Broccoli (*Brassica oleracea* L. var. *italica*) in light textured soil of western Uttar Pradesh". Three replications were used in the Randomized Block Design experiment. The experimental field's soil had a sandy loam texture. Different mixtures of organic and inorganic manures and biofertilizers considerably influenced all variables parameters pertaining to vegetative development in the experimental investigation. Results revealed that the maximum vegetative growth *viz*., plant height (63.01 cm), plant spread (north-south) (58.57 cm), plant spread (east-west) (55.39 cm), number of leaves plant^{-1} (18.62), leaf length (49.97 cm), width of leaf (19.04 cm), leaf area (377.83 cm^2) stalk length (23.28 cm) and stalk diameter (45.49 mm) were recorded under RDF + Vermicompost + PSB + Azospirillum. So, based on two years experimental findings, it is cleared that a judicious combination of inorganic, organic and bio-fertilizers significantly influenced vegetative growth of broccoli.

Keywords: Broccoli, fertilizer, organic manure, biofertilizer, vegetative growth, INM

Introduction
Since both cauliflower and broccoli are produced for their fragile flower stalks and clusters of unopened flower buds, they are both members of the Brassicaceae family and an important vegetable crop. Broccoli plants morphologically resemble cauliflower. Broccoli is a cool weather crop and originated from West Europe (Prashad and Kumar, 1999). In Himachal Pradesh, Jammu and Kashmir, Uttrakhand, and the Nilgiris hills in Tamil Nadu, as well as in plain areas of Uttar Pradesh, Haryana, and Maharashtra, broccoli is mostly grown. These plants are being grown in tropical and subtropical areas as well. Out of cole crops, broccoli has been gaining popularity among the vegetable growers in the present scenario due to the more demand in metro cities. In the international market, out of total produce about 40% broccoli is marketed as for consumption fresh and remaining 60% used as frozen. Broccoli is mainly used for making soups, pickles and mostly eaten as a salad and cooked for making various delicious dishes. **(**Thamburaj and Singh, 2001) [22]. Broccoli is a cool-season crop and grown successfully during the month of October–December in *Rabi* season. The word *broccoli* comes from the Latin word *brachium* and Italian word '*brocco'* meaning "arm" or "branch". Broccoli has numerous fleshy green flower heads that are grouped in the shape of trees on branches that emerge from a substantial eating stalk. Compared to other Cruciferae vegetables, it is more nutrient-dense. Compared to cauliflower and cabbage, this contains roughly 130 times more vitamin A (Singh, 2007) [20]. It contains calcium, vitamin A, vitamin B, vitamin B2, and vitamin B2 and is low in sodium and fat. (Decoteau, 2000) [4].
Plant nutrients play a vital role in the growth and development of plants with higher production. The introduction of improved agriculture technologies in vegetable growing emphasized the use of chemical fertilizers and pesticides to enhance productivity, which has no doubt succeeded in feeding the huge population. However, the excessive use of chemical fertilizers led to adverse effects on human health and resulted in land, water and air pollution.

Hence the supply of organic manure, biofertilizer and chemical fertilizers in judicious way will be helpful to improve soil fertility and productivity. Chemical fertilizers, organic manures and biofertilizers have positive effects on soil health and crop production when used in integrated manner. Pillai *et al.*, 1985 [14] reported that a sensible mix of organic and inorganic fertilizers will preserve soil fertility over the long run and support higher levels of productivity. Chemical fertilizers are essential to full fill the requirement of macro nutrients like nitrogen, phosphorus and potassium of plants during early and later growth due to its high concentration of nutrients and fast releasing nature. However, organic manures are low in nutrient content and slow in decomposition rate, but they provide balance supply of nutrients (macro and micronutrients), improve water holding capacity of soil, decompose harmful elements, increase beneficial microorganism activity and improve soil structure for sustainability. In the case of organic manures like farmyard manures (FYM) is considered as good source slow supply of most of essential nutrients and increase availability to plants by improving soil health. Vermicompost reduces the C: N ratio, increases humic acid concentration, and gives plants nutrients including nitrate, exchangeable phosphorus, soluble potassium, calcium, and magnesium in readily available form (Talashilkar *et al.*, 1999) [21]. Similar to this, biofertilizers give the soil its usual fertility and give it life. They increase the amount of organic matter and enhance the structure and texture of the soil. They improved soil's ability to hold water even more than previously. According to many studies, biofertilizers boost yield by up to 30% because they enrich the soil with essential nutrients, particularly nitrogen and phosphorus, and make those elements more available to plants. Different micronutrients and macronutrients are also added to the soil and made more readily available by biofertilizers.

Material and Methods

The experiment was undertaken at HRC of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut during 2016-17 and 2017-18. The experimental field was laid out in a randomized complete block design with three replications. The seeds of broccoli cultivar Pusa KTS 1 were sown in the main field with all recommended package of practices. The treatments involved in the experimental study were fourteen in numbers *i.e.* T_1: Control T_2: 150 Kg N + 100 Kg P2O5 + 100 Kg K2O/ha (RDF), T_3: 75% RDF + 25% FYM, T_4: 75% RDF + 25% Vermicompost, T_5: 75% RDF + 25% FYM + PSB, T_6: 75% RDF + 25% Vermicompost + PSB, T_7: 75% RDF + 25% FYM + PSB + Azospirillum, T_8: 75% RDF + 25% Vermicompost + PSB + Azospirillum, T_9: RDF + FYM, T_{10}: RDF + Vermicompost, T_{11}: RDF + FYM + PSB, T_{12}: RDF + Vermicompost + PSB, T_{13}: RDF + FYM + PSB + Azospirillum, T_{14}: RDF + Vermicompost + PSB + Azospirillum. A few days before seedlings were transplanted, vermicompost and farmyard manure were added into the soil. Prior to three days of transplanting, PSB and azospirillum were broad cast with a mixture of finely powdered organic manure and fully infected. When transplanting broccoli seedlings, full doses of phosphorus and potassium as well as half of the nitrogen were applied. The remaining half of the nitrogen was then applied in two separate doses at 30 and 45 days later. Urea, single super phosphate, and murate of potash were the sources of N, P, and K, respectively. According to the treatment schedule, all the chemical fertilizers, organic manures, and biofertilizers were administered. The data on plant height and spread, which are aspects of vegetative growth.

Results and Discussion

The data recorded on vegetative parameters clearly indicated that the plant height, plant spread (north-south), plant spread (east-west), number of leaves plant^{-1}, leaf length, leaf width, area of leaf, length and diameter of stalk were significantly influenced by the integrated nutrient management practices. Plant height is an important vegetative trait for foliage and biomass production. In the present study, the data from table number 2 clearly shown the application of RDF + Vermicompost + PSB + Azospirillum (T_{14}) resulted in maximum average plant height 63.01 cm and 63.08 cm at final harvesting which was found statistically higher over all other treatments. However, minimum plant height 41.79 cm and 41.85 cm were observed in the control during experimentation. It is possibly because of the regular supply of the major nutrients *viz.*; NPK to the plant in the form organic, inorganic and biofertilizers. As a result, the increment of plant height with huge foliage may be due to increases the photosynthetic activity and cell elongation in the availability of nitrogenous compounds as earlier cited by Naik and Gupta (2010) [11], and Shree *et al.* (2014) [19].

The treatment combination T_{14} (RDF + Vermicompost + PSB + Azospirillum) resulted in maximum plant spread i.e., 58.12 and 59.02 cm (N-S) and 54.43 and 56.36 cm (E-W), whereas minimum East West plant spread and North South were measured under T_1 (control) during both the years of investigation. This may be possibly due to the cell elongation and secondary growth of plant by optimum level of nitrogen, phosphorous and potassium make readily available in soil with the help of PSB and Azospirillum, resulting in an increase the plant spread was noticed. Similar by Chatterjee *et al.*, 2005 [1], Pandey *et al.* (2008) [13] and Mohanta *et al.* (2018) [9].

Data from table 2 shown significant increment was observed number of leaves plant^{-1} with various INM treatments during both the years. The maximum number of leaves plant$^{\mathbf{-1}}$ (18.65 and 18.59) was recorded in treatment T_{14} (RDF + Vermicompost + PSB + Azospirillum) and minimum number of leaf (11.41 and 11.46) noticed with treatment T_1 (control) during 2016-17 and 2017-18, respectively. However, the minimum numbers of leaf plant^{-1} were noted under control treatment. This increment in the number of leaves plant^{-1} may be due to the effect of combined applications of inorganic, organic and biofertilizers in optimum level. The optimum availability of nutrients from root zone may be possible to higher accumulation of carbohydrate, which improve the metabolic activities and increase the photosynthesis process in leaves of plants. Results of the investigation are also in agreement with Raghav and Shashi (2007) [15], Ewees *et al.* (2008) [5], Maurya *et al.* (2008) [10] and Choudhary *et al.* (2018) [3].

The maximum leaf length (49.93 cm and 50.01 cm) and leaf width (19.01 cm and 19.08 cm) were reported with treatment T_{14} (RDF + Vermicompost + PSB + Azospirillum) over all other treatments. Minimum leaf length (32.28 and 35.32 cm) and leaf width (12.40 cm and 12.43 cm) were measured with treatment T_1 (control) during both the seasons of experimentation. This might be due to the presence of azospirillum to proliferate the atmospheric nitrogen and facilitate nitrogen ability to plants. Similarly, PSB also plays an important role to increase the optimum amount of phosphorus to unavailable form to available form. The improvement in leaf length and width seen with the application of organic manures, biofertilizers, and inorganic fertilizers may be due to long-term, continuous nutrition availability throughout the whole growth period. These findings are in line with Navale and Wani (2004) [12], Kachari and Korla (2009) [7] and Sharma *et al.* (2018) [18].

It is cleared in table 3 that leaf area at the final harvest was affected significantly due to various INM treatment combinations. On full maturity stage of growth, the maximum leaf area i.e., 367.42 to 388.24 cm^2 was recorded with T_{14} (RDF + Vermicompost + PSB + Azospirillum) and the minimum leaf area (227.15 and 230.18 cm^2) was measured with treatment T_1 (control) during both the years of investigation. The reason for the better growth was the organic manure as one of the components of treatments and it might provide better soil structure and fertilizer efficiency which might improve the growing environment. The effect of farmyard manure and vermicompost in vegetative production has been proven to be beneficial, it has also been reported by Shalini *et al.* (2002) [17] Kumar and Sharma (2004) [8] and Chattoo *et al.* (1997) [2].

The data obtained from the experimental field revealed that the stalk length was significantly influenced by the various INM treatments of inorganic fertilizers, organic manures and biofertilizers (table 3). Among various treatment combinations, higher stalk length (23.25 cm and 23.31 cm) and stalk diameter (45.45 mm and 45.53 mm) were reported under RDF + Vermicompost + PSB + Azospirillum, while minimum stalk length (15.16 and 15.19 cm) and stalk diameter (31.22 mm and 32.08 mm) were observed in control during both of the experimental years. This increment in stalk length may be because of the cell elongation by the presence of nitrogenous compounds (Chaterjee *et al*., 2005). Similar results were recorded by Reddy and Reddy (2005) [16], Maurya *et al.* (2008) [10] and Ewees *et al.* (2008) [5].

Table 1: Effect of integrated nutrient management on plant height and plant spread (N-S and E-W) of broccoli (*Brassica oleracea* L. var. *italica*) in light textured soil of western Uttar Pradesh.

Treatment details	Notation	Plant height (cm)			Plant spread (North-South), (cm)			Plant spread (East-West), (cm)		
		2016-17	2016-17	2016-17	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Control	T_1	41.79	41.85	41.82	41.60	41.71	41.66	37.99	38.95	38.47
150 Kg N + 100 Kg P_2O_5 + 100 Kg K_2O/ha (RDF)	T_2	50.51	50.58	50.54	49.90	50.15	50.02	46.19	47.5	46.84
75% RDF + 25% FYM	T_3	51.18	51.24	51.21	50.63	51.16	50.89	46.91	48.5	47.70
75% RDF + 25% Vermicompost	T_4	52.05	52.11	52.08	51.98	52.02	52.00	48.26	49.37	48.81
75% RDF + 25% FYM + PSB	T_5	53.68	53.75	53.71	53.01	53.18	53.09	49.28	50.53	49.90
75% RDF + 25% Vermicompost + PSB	T_6	55.48	55.54	55.51	53.67	54.18	53.92	49.95	51.53	50.74
75% RDF + 25% FYM + PSB + Azospirillum	T_7	60.00	60.07	60.03	56.11	57.12	56.61	52.39	54.47	53.43
75% RDF + 25% Vermicompost + PSB + Azospirillum	T_8	60.28	62.35	61.31	56.87	57.77	57.32	53.15	55.11	54.13
RDF + FYM	T_9	51.54	51.61	51.57	51.71	52.21	51.96	47.99	49.56	48.77
RDF + Vermicompost	T_{10}	53.29	53.34	53.31	52.12	58.83	55.47	48.41	56.17	52.29
RDF + FYM + PSB	T_{11}	57.28	57.37	57.32	54.50	55.00	54.75	50.78	52.38	51.58
RDF + Vermicompost + PSB	T_{12}	58.94	58.98	58.96	55.56	56.03	55.79	51.86	53.38	52.62
RDF + FYM + PSB + Azospirillum	T_{13}	61.89	61.95	61.92	57.27	58.12	57.69	53.55	55.47	54.51
RDF + Vermicompost + PSB + Azospirillum	T_{14}	63.01	63.08	63.04	58.12	59.02	58.57	54.43	56.36	55.39
C.D. at 5.0%		1.07	1.06		0.61	0.86		0.61	0.56	
SEm(±)		0.36	0.36		0.21	0.29		0.21	0.19	

Table 2: Effect of integrated nutrient management on number of leaves $plant^{-1}$, leaf length and leaf width of broccoli (*Brassica oleracea* L. var. *italica*) in light textured soil of western Uttar Pradesh

Treatment details	Notation	Number of leaves $plant^{-1}$			Leaf length (cm)			Leaf width (cm)		
		2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Control	T_1	11.41	11.46	11.43	32.28	35.32	33.80	12.40	12.43	12.41
150 Kg N + 100 Kg P_2O_5 + 100 Kg K_2O/ha (RDF)	T_2	14.65	14.69	14.67	39.40	39.43	39.41	15.00	15.04	15.02
75% RDF + 25% FYM	T_3	14.84	14.90	14.87	39.92	39.96	39.94	15.20	15.25	15.22
75% RDF + 25% Vermicompost	T_4	15.09	15.12	15.10	40.60	40.64	40.62	15.46	15.49	15.47
75% RDF + 25% FYM + PSB	T_5	15.57	15.61	15.59	41.87	41.90	41.88	15.94	15.98	15.96
75% RDF + 25% Vermicompost + PSB	T_6	16.09	16.13	16.11	43.27	43.31	43.29	16.48	16.51	16.49
75% RDF + 25% FYM + PSB + Azospirillum	T_7	17.40	17.45	17.42	46.80	46.85	46.82	17.82	17.89	17.85
75% RDF + 25% Vermicompost + PSB + Azospirillum	T_8	17.48	17.51	17.49	47.02	47.07	47.04	17.90	17.94	17.92
RDF + FYM	T_9	14.95	14.98	14.96	40.20	40.24	40.22	15.31	15.36	15.33
RDF + Vermicompost	T_{10}	15.45	15.48	15.46	41.57	41.61	41.59	15.83	15.88	15.85
RDF + FYM + PSB	T_{11}	16.61	16.72	16.66	44.68	44.72	44.7	17.01	17.08	17.04
RDF + Vermicompost + PSB	T_{12}	17.09	17.13	17.11	45.98	46.01	45.99	17.51	17.57	17.54
RDF + FYM + PSB + Azospirillum	T_{13}	18.00	17.99	17.99	48.27	48.34	48.30	18.38	18.43	18.40
RDF + Vermicompost + PSB + Azospirillum	T_{14}	18.65	18.59	18.62	49.93	50.01	49.97	19.01	19.08	19.04
C.D. at 5.0%		0.61	0.55		1.38	1.36		0.59	0.55	
SEm(±)		0.21	0.19		0.47	0.46		0.20	0.19	

Table 3: Effect of integrated nutrient management on leaf area, stalk length and stalk diameter of broccoli (*Brassica oleracea* L. var. *italica*) in light textured soil of western Uttar Pradesh

Treatment details	Notation	Leaf area (cm^2)			Stalk length (cm)			Stalk diameter (mm)		
		2016-17	2017-18	Mean	2016-17	2017-18	Mean	2016-17	2017-18	Mean
Control	T_1	227.15	230.18	228.66	15.16	15.19	15.17	31.22	32.83	31.65
150 Kg N + 100 Kg P_2O_5 + 100 Kg K_2O/ha (RDF)	T_2	289.93	290.05	289.99	18.34	18.41	18.37	35.86	35.71	35.78
75% RDF + 25% FYM	T_3	293.77	294.12	293.94	18.58	18.62	18.60	36.34	36.38	36.36
75% RDF + 25% Vermicompost	T_4	298.77	299.67	299.22	18.89	18.93	18.91	36.96	36.98	36.97
75% RDF + 25% FYM + PSB	T_5	308.12	309.35	308.73	19.49	19.50	19.49	38.11	38.15	38.13
75% RDF + 25% Vermicompost + PSB	T_6	318.46	320.65	319.55	20.14	20.19	20.16	39.39	40.43	39.91
75% RDF + 25% FYM + PSB + Azospirillum	T_7	344.40	345.48	344.94	21.78	21.82	21.8	42.60	42.63	42.61
75% RDF + 25% Vermicompost + PSB + Azospirillum	T_8	346.01	346.85	346.43	21.88	21.91	21.89	42.80	42.85	42.82
RDF + FYM	T_9	295.84	296.91	296.37	18.71	18.73	18.72	36.59	36.63	36.61
RDF + Vermicompost	T_{10}	305.88	306.65	306.26	19.34	19.39	19.36	37.84	37.91	37.87
RDF + FYM + PSB	T_{11}	328.79	330.45	329.62	20.79	20.85	20.82	40.67	40.71	40.69
RDF + Vermicompost + PSB	T_{12}	338.32	339.17	338.74	21.40	21.46	21.43	41.85	41.89	41.87
RDF + FYM + PSB + Azospirillum	T_{13}	355.25	356.38	355.81	22.47	22.52	22.49	43.94	44.01	43.97
RDF + Vermicompost + PSB + Azospirillum	T_{14}	367.42	388.24	377.83	23.25	23.31	23.28	45.45	45.53	45.49
C.D. at 5.0%		11.52	27.45		0.61	0.55		1.36	1.44	
S.Em(±)		3.94	9.39		0.21	0.19		0.46	0.49	

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