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Impact of micronutrients and organics on performance of sprouting broccoli (*Brassica oleracea*)

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ABSTRACT

An experiment was conducted during winter (*rabi*) seasons of 2019–20 and 2020–21 at the research farm of Sri Karan Narendra Agriculture University College, of Agriculture, Jobner, Rajasthan to study the effect of micronutrients and organics on performance of sprouting broccoli (*Brassica oleracea* L.). A trial having 25 treatments was conducted in Factorial Randomized Blocks Design (F-RBD) with 3 replications. The treatments grouped into categories consisting 5 micronutrients (control, borax @15 kg/ha, $Znso_4$ @25 kg/ha, $(NH_4)_2MoO$ @1.5 kg/ha and $Mnso_4$ @10 kg/ha) and another category consisted 5 organics (control, cowurine @10%, panchagavya @5%, vermiwash @10% and *azotobacter*). The results indicated that soil application of $Znso_4$ as well as foliar application of 5% panchagavya to the sprouting broccoli significantly increased most of the plant attributes i.e. plant hight (71.88 cm and 71.95 cm), no. of leaves/plant (31.38 and 31.12), leaf area (3055 cm^2 and 3068 cm^2), chl-a (2.90 mg/g and 3.09 mg/g), total curd yield per ha (28.81 Mt/ha and 29.41 Mt/ha), NR (224848 ₹/ha and 230256 ₹/ha) and BCR (3.55 and 3.60), respectively in comparison to the control. Application of $ZnSO_4$ and panchagavya contributed 24.72 and 26.49%, respectively more in total curd yield per hectare as compared to control. Thus, findings of experiment were in conclusion that application of $ZnSO_4$ @25 kg/ha in soil and application of panchagavya @5% as foliar spray have the prospective effect to enhance all attributes in sprouting broccoli not only in comparison to control but also to rest of other treatments.

Keywords: Azotobacter, Cow urine, Growth, Micronutrients, Panchagavya, Vermiwash

Broccoli (*Brassica oleracea* L. var. *italic* Plenck 2n=2x=18), belonging to the Brassicaceae family, is an important exotic vegetable and potential cole crop. It is an edible plant in the cabbage family that contains a group of immature green buds along with a stout, fleshy flower stalk that forms a head. This head is consumed as a vegetable. The curd is full with most of vitamins and minerals, and having beta-carotene, a precursor of vitamin A about 14 times higher than cabbage and cauliflower. It also contains the highest amount of protein among the cole crop. The curd also contains anti-cancerous and antioxidants compounds. As per composition its curd contains 5.5% carbohydrates, 3.3% protein, 137 mg vitamin-A, 0.05% vitamin- B_1, 0.12% vitamin-B_2, 0.80 mg calcium and 0.79 mg phosphorus (Thamburaj and Singh 2001).

The cultivation of sprouting broccoli depends mainly on organic fertilizers such as farmyard manure and vermicompost, which contain little or no micronutrients and are slow to mineralize, leaving farmers unable to achieve the desired yield and return on investment. Nowadays, foliar application of certain organic products, viz. cowurine, panchagavya and vermiwash, as well as the application of specific micronutrients (B, Zn, Mo and Mn) into the soil are cheaper, more environmentally friendly and stimulate plant growth, which increases the biological efficiency of crops compared to normal complete organic fertilizer (Choudhary *et al.* 2017). Even though micronutrients are only needed in small amounts, they are essential for healthy plant growth and profitable crop production. In addition, micronutrients are actively involved in the plant metabolic process, such as cell wall development, respiration, photosynthesis, chlorophyll, enzymes and nitrogen fixation, as they act as co-enzymes. Among micronutrients, zinc is good for the formation of chlorophyll, various enzymes and growth hormones such as auxin. However, it can deficient in alkaline and sandy soils. Crops grown with organic and various micronutrients are nutritionally and environmentally superior. In view of these facts, the present experiment was designed to study the effects of micronutrients and organic matter on growth, yield and economics of sprouting broccoli.

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MATERIALS AND METHODS

An experiment was conducted at the Horticulture Farm of Sri Karan Narendra Agriculture University, College of Agriculture, Jobner, Rajasthan on sprouting broccoli var. Pusa KTS-1 during winter (*rabi*) season of 2019–20 and 2020–21. This region falls in agro-climatic zone IIIA, which is referred to as semi-arid eastern plains of the Indian state of Rajasthan. The soil of the experimental field was loamy sand with *p*H 8.20, organic carbon content 0.20%, available N (135.60 kg/ha), P (16.50 kg/ha), K (152.50 kg/ha), low zinc (0.46 ppm), low iron (3.95 ppm), low Mo (0.045 ppm) and medium boron (0.41 ppm). A factorial randomized block design (F-RBD) with 3 replicates was used for this experiment. Four-week-old, healthy, vigorous seedlings were planted on October 15, 2019 and October 20, 2020 with a plot size of 2.70 m × 1.80 m and a spacing of 45 cm × 45 cm.

To execute the present study treatment combinations were taken having micronutrients ($M_{0,}$ control; $M_{1,}$ borax @15 kg/ha; $M_{2,}$ $Znso_4$ @25 kg/ha; $M_{3,}$ $(NH_4)_2MoO$ @1.5 kg/ha and $M_{4,}$ $Mnso_4$ @10 kg/ha) and organics ($O_{0,}$ control (water spray); $O_{1,}$ cow urine 10%; $O_{2,}$ panchagavya 5%; $O_{3,}$ vermiwash 10% and O_4, *Azotobacter*). Treatment with micronutrients (B, Zn, Mo and Mn) was applied as soil application just before transplanting of seedlings and treatment with organics (cow urine, vermiwash and panchagavya) as foliar spray at 30 DAT (Days after transplanting) and *azotobacter* as seed treatment at the time of raising and transplanting of seedlings by root dipping. The recommended NPK dose for broccoli is 100:80:60 kg/ha, using urea, single superphosphate and potassium hydroxide. The full dose of phosphorus, potassium and half dose of nitrogen was applied at the time of transplanting, and the remaining half dose of nitrogen was applied in two equal doses 30 and 60 DAT. Recommended cultivation practices were used to successfully raise the experimental plants.

The data on various parameters, viz. plant height, no. of leaves/plant, area of leaf, optimum days to start curd formation, chl a and curd yield/ha were noted from the 5 marked plants in each plot. At harvest, plant hight, no. of leaves/plant, area of leaf were recorded. Area of leaf was recorded by leaf area meter (LICOR-3100, Lincoln, USA) and chl-a content was estimated with the method advocated by Arnon (1949). The NR of each treatment was calculated by subtracting the cost of cultivation from the GR of each treatment.

$$\text{NR (₹/ha)} = \text{GR (₹/ha)} - \text{Cultivation costs (CC) (₹/ha)}$$

$$\text{BCR} = \frac{\text{NR (₹/ha)}}{\text{CC (₹/ha)}}$$

Data obtained from two experimental years were statistically analyzed according to the procedure described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of micronutrients on growth attributes: Growth attributes of sprouting broccoli were significantly influenced by soil application of micronutrients during experiment (Table 1, 2) in both the years and in pooled mean. Significantly higher plant hight (71.88 cm), no. of leaves (31.38), area of leaf (3053 cm^2), chl-a content in leaves at 45 DAT (2.90 mg/g) and days to curd initiation (61.99) of sprouting broccoli were recorded under application of $ZnSO_4$

Table 1 Role of micronutrients and organics on plant height, leaf number and leaf area at last harvest stages of sprouting broccoli

Treatment	Plant height (cm)			No. of leaves			Leaf area (cm^2)		
	(2019–20)	(2020–21)	(Pooled)	(2019–20)	(2020–21)	(Pooled)	(2019–20)	(2020–21)	(Pooled)
Micronutrients									
M_0	57.97	57.18	57.58	22.24	20.45	21.35	2078	1853	1966
M_1	67.86	68.06	67.96	29.19	27.39	28.29	2998	2878	2938
M_2	72.59	71.16	71.88	32.12	30.63	31.38	3121	2990	3055
M_3	63.97	63.55	63.76	28.07	26.79	27.43	2778	2823	2801
M_4	62.65	61.10	61.88	26.98	25.97	26.48	2646	2568	2607
SEm±	2.41	2.11	1.60	0.91	0.44	0.50	89	52	52
CD (P=0.05)	6.86	6.00	4.50	2.58	1.25	1.41	253	149	145
Organics									
O_0	56.88	55.85	56.37	21.73	21.71	21.72	2135	1977	2056
O_1	62.22	61.69	61.96	26.47	24.29	25.38	2601	2337	2469
O_2	72.60	71.31	71.95	31.71	30.52	31.12	3117	3020	3068
O_3	68.89	68.15	68.52	30.31	29.39	29.85	2979	2916	2948
O_4	64.44	64.06	64.25	28.39	25.32	26.85	2790	2863	2826
SEm±	2.41	2.11	1.60	0.91	0.44	0.50	89	52	52
CD (P=0.05)	6.86	6.00	4.50	2.58	1.25	1.41	253	149	145

Treatment details are given under Materials and Methods.

Table 2 Role of micronutrients and organics on Chl-a (Chlorophyll. A) content of leaves, days to curd initiation and curd of sprouting broccoli

Treament	Chl-a content (mg/g)			Days to curd initiation			Total curd (yield/ha) (Mt)		
	(2019–20)	(2020–21)	(Pooled)	(2019–20)	(2020–21)	(Pooled)	(2019–20)	(2020–21)	(Pooled)
Micronutrients									
M_0	2.24	2.40	2.32	75.24	69.45	72.35	23.33	22.86	23.10
M_1	2.83	2.75	2.79	67.19	65.79	66.49	27.32	26.80	27.06
M_2	2.95	2.85	2.90	64.34	59.63	61.99	29.45	28.16	28.81
M_3	2.67	2.60	2.64	69.07	67.16	68.12	25.82	24.71	25.26
M_4	2.45	2.58	2.52	71.36	67.97	69.67	24.50	23.65	24.08
SEm±	0.08	0.04	0.05	2.32	1.33	1.33	0.78	0.45	0.45
CD (P=0.05)	0.24	0.12	0.13	6.58	3.77	3.75	2.23	1.27	1.27
Organics									
O_0	2.06	2.16	2.11	75.48	72.62	74.05	23.63	22.86	23.25
O_1	2.51	2.27	2.39	70.20	67.10	68.65	24.52	23.72	24.12
O_2	3.10	3.07	3.09	65.63	61.59	63.61	29.96	28.86	29.41
O_3	2.93	2.99	2.96	66.93	62.54	64.74	26.69	25.82	26.26
O_4	2.53	2.69	2.61	68.96	66.14	67.55	25.62	24.91	25.27
SEm±	0.08	0.04	0.05	2.32	1.33	1.33	0.78	0.45	0.45
CD (P=0.05)	0.24	0.12	0.13	6.58	3.77	3.75	2.23	1.27	1.27

Treatment details are given under Materials and Methods.

at 25 kg/ha (M_2) over rest of treatments in pooled mean analysis. However, application of borax at 15 kg/ha (M_1) was found statistically at par with respect to plant height, area of leaf and chl a. This could be due to the stimulating effect of zinc and boron in cell division and cell elongation. Zinc is effective for the synthesis of plant hormones such as auxin and carbohydrate formation (Pankaj *et al.* 2018). The improvement in plant growth parameters could be due to the role of zinc in chlorophyll synthesis, which affects cell division and morphological activity of plant tissues, as well as cell wall formation through active synthesis of the aromatic amino acid tryptophan, which is the primary precursor of auxin and stimulates plant tissue growth through cell elongation and cell division (Basavarajeshwari *et al.* 2008). Zinc can improve the growth of vegetables due to its role in photosynthesis. Zinc is a critical component of the enzyme carbonic anhydrase, which is involved in the conversion of carbon dioxide to bicarbonate, a critical step in photosynthesis (Abedi *et al.* 2014). This process leads to increased production of glucose and other sugars, which are used to fuel plant growth and development. Zinc deficiency can limit the activity of carbonic anhydrase, reducing the efficiency of photosynthesis and limiting plant growth (Alloway 2008).

Zinc is required for the synthesis of several plant growth-regulating hormones such as auxins, cytokinins, and gibberellins (Siddiqui *et al.* 2018). These hormones are responsible for various plant growth and development processes, including cell division, elongation and differentiation, leading to improved plant growth. Additionally, zinc is involved in the activation of several enzymes required for plant growth and development, including superoxide dismutase, peroxidase and catalase (Hassan *et al.* 2019). These enzymes play a vital role in plant defense against stress and help in the detoxification of harmful reactive oxygen species, leading to improved plant growth and health. Duman *et al.* (2021) also reported that the application of zinc significantly improved the growth of lettuce plants, including plant height, fresh weight and dry weight. The study also reported an increase in the yield of lettuce. The availability of auxin in zinc treatments to the plant may have increased the length between nodes, associated with greater apical dominance, which could ultimately contribute to greater plant spread. The results of the experiments are consistent with the previous study results of Singh *et al.* (2018) in broccoli and Jat (2020) in okra.

Effect of micronutrients on yield: A significant effect was noticed on total curd yield per hectare during both the years by the application of micronutrients (Table 2). The maximum values for most parameters affecting curd yield were recorded in broccoli with 25 kg/ha ZnSO4 (M_2) as soil application compared to other treatments in both the years and in the pooled mean analysis, borax at 15 kg/ha (M_1) as soil application recorded statistically at par values to it for diameter of primary curd in pooled mean analysis. This could be due to the fact that increased supply of zinc through soil application in zinc deficient soils improves the availability of zinc in the plant along with other plant nutritional elements plays a role in regulating auxin concentration in plants. In addition, zinc also improves the absorption of essential elements by increasing the cation exchange capacity (CEC) of roots, which may have improved the effectiveness of added chemicals and fertilizers in the soil and increased the rate of humification, which in turn increased the availability of both native and added nutrients in the soil and thus may have improved the yield and yield-related parameters of sprouting broccoli (Pandav *et al.* 2016). Zinc might have also helped to accumulate more of photosynthates in plant to ensure significantly better curd weight and diameter. The main function of zinc in a plant is to activate enzymes like dehydrogenase, proteinase, nitrate reductase and peptidases (Prasad *et al.* 2010). Of these enzymes, some are involved with carbohydrate and nitrogen metabolism to improve N uptake and regulate the many physiological processes of plants, so zinc supports the utilization of phosphorus and nitrogen by plants, resulting in improved yield characteristics and ultimately yield. Moreover, zinc is also involved in the synthesis of proteins and enzymes that are essential for plant growth and development. These proteins and enzymes are responsible for several processes, including cell division, elongation, and differentiation, which ultimately lead to increased yield (Tewari and Tripathi 2018). These results of the experiment are consistent with Singh *et al.* (2018) on sprouting broccoli and Jat (2020) in okra.

Effect of micronutrients on economic returns: The significantly higher NR (231308, 218389 and 224848 ₹/ha) and BCR (3.65, 3.45 and 3.55) were obtained in treatment M_2 ($ZnSO_4$-25 kg/ha) during 2019–20 and 2020–21 and pooled mean analysis (Table 3). Results clearly shows that soil application of zinc in deficient soils maintained its superiority over all other treatments and proved to have suitable relationship with growth, yield attributes, yield and economic profitability in growing broccoli.

Effect of organics on growth parameters: Foliar application of panchagavya at 5% significantly improved the plant height (71.95 cm), leaf no. (31.12), leaf area (3068 cm^2), total chl-a content in leaves (3.09 mg/g) and days to curd initiation (63.61) of sprouting broccoli over rest of the treatments (Table 1, 2) in pooled mean analysis. Application of organics like, panchagavya might have contributed to increase in the beneficial microbial population which improved plant growth (plant height) by improving the availability of nitrogen, phosphorus, potassium, zinc, copper and plant growth hormones. Additionally, panchgavya has been reported to enhance soil microbial activity and improve soil structure (Patel *et al.* 2021). The beneficial microorganisms in panchgavya can help decompose organic matter in the soil, making nutrients more available to plants. The improvement in soil structure can enhance water and nutrient uptake by plant roots, leading to improved plant growth. Study conducted by Verma *et al.* (2021) reported that the application of panchgavya significantly improved the growth of brinjal plants, including plant height, leaf area, and stem girth. The study also reported an increase in the yield of brinjal. Rakesh *et al.* (2017) noted an increase in plant height in capsicum due to panchagavya where sufficient macro and micro nutrients as well as growth hormones were observed. Such trend was, also noted by Kumar *et al.* (2018) in cabbage and Choudhary (2020) in mothbean.

Effect of organics on yield parameters: The curd yield/ha (29.41 mt) enhanced significantly in sprouting broccoli when panchagavya 5% applied. Panchagavya might have

Table 3 Role of micronutrients and organics on NR and BCR of sprouting broccoli

Treatment	NR (₹/ha)			BCR		
	(2019–20)	(2020–21)	(Pooled)	(2019–20)	(2020–21)	(Pooled)
Micronutrients						
M_0	173800	169069	171434	2.91	2.83	2.87
M_1	210125	204994	207559	3.33	3.25	3.29
M_2	231308	218389	224848	3.65	3.45	3.55
M_3	196862	185736	191299	3.21	3.02	3.11
M_4	183596	175068	179332	2.99	2.85	2.92
(SEm±)	7834	4467	4509	0.13	0.07	0.07
CD (P=0.05)	22276	12703	12658	0.36	0.21	0.20
Organics						
O_0	176495	168778	172637	2.94	2.81	2.88
O_1	183808	175862	179835	2.99	2.86	2.92
O_2	235747	224765	230256	3.69	3.52	3.60
O_3	203502	194851	199177	3.21	3.07	3.14
O_4	196138	189000	192569	3.26	3.14	3.20
(SEm±)	7834	4467	4509	0.13	0.07	0.07
CD (P=0.05)	22276	12703	12658	0.36	0.21	0.20

NR, Net returns; BCR, Benefir : Cost ratio.
Treatment details are given under Materials and Methods.

ameliorated the biochemical properties of the plant and enhanced the activities of beneficial microorganisms such as *azospirillum*, *azotobactor*, *phosphobacteria* and *pseudomonas* besides *lactobacillus* resulting production of growth promoting substances (Shivakumar 2014). It might have also improved nutrient availability for longer period and thus, exerted favourable effects on yield attributes and yield of broccoli. Moreover, IAA, GA, Cyt. and some essential plant nutrients have also been observed in panchagavya treated plants (Tharmaraj *et al.* 2011). Thus, it might have carried overall improvement in plant growth which reflected into better source-sink relationship by increasing the yield attributes. The yield of a crop is modification of plant anatomy and morphology in the growing plants due to physiological processes and biochemical activities. Moreover, panchgavya also contains beneficial microorganisms such as bacteria, fungi and yeast, which can improve soil health, and enhance nutrient uptake by plants. These microorganisms can help break down organic matter and release nutrients into the soil, making them available for plant uptake. Additionally, they can also produce plant growth-promoting substances such as hormones and enzymes, which can enhance plant growth and yield (Kumar *et al.* 2017). Panchgavya contains several essential nutrients, including nitrogen, phosphorus, potassium, and trace elements such as iron, manganese and zinc (Khan *et al.* 2017). These nutrients are essential for plant growth and development and play a crucial role in increasing yield. It also contains several plant growth-promoting hormones such as auxins, cytokinins, and gibberellins (Khan *et al.* 2017). These hormones are responsible for various plant growth and development processes, including cell division, elongation, and differentiation, leading to increased yield. Study conducted by Kumari *et al.* (2017) reported that the application of panchgavya significantly increased the yield of cucumber plants by up to 24%. The study also showed an improvement in the nutrient content of the cucumbers. Similarly, another study by Dubey *et al.* (2018) reported that the application of panchgavya increased the yield of tomato plants by up to 35%. The study also reported an improvement in the fruit quality of the tomatoes. The results of this study are also supported with those of Kumar *et al.* (2018) in cauliflower and Gajjela and Chatterjee (2019) in bitter gourd who found that spraying with liquid organics can lead to more carbohydrates entering the developing fruits and better utilization of nutrients, resulting in higher fruit weight.

Effect of organics on economics: The data indicate that the use of different organic matter significantly affects the economics of sprouting broccoli in both years and in the pooled mean analysis (Table 3). The foliar spray of panchagavya at 5% (O_2) recorded highest NR (230256 ₹/ha), BCR (3.60) which were significantly better in comparison to the other treatments in pooled mean analysis. Based on the two-year trial results, it can be concluded that the application of 25 kg/ha of $ZnSO_4$ in the soil and 5% panchagavya as foliar spray improves the growth characteristics, curd yield and NR (economics) of sprouting broccoli under semi-arid climatic conditions.

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