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Synergistic effects of micronutrients and organics on yield, quality and economics of sprouting broccoli (*Brassica oleracea*)

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ABSTRACT

An experiment was conducted during the winter (*rabi*) seasons of 2019–20 and 2020–21 at Sri Karan Narendra College of Agriculture (Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan), Jobner, Jaipur, Rajasthan to evaluate the combined effects of organics and micronutrients on sprouting broccoli [*Brassica oleracea* (L.) Planck var. *italica*)]. Along with five organic treatments (Control, 10% Cow urine, 5% *Panchagavya*, 10% Vermiwash and Azotobacter), the treatment plan also included five micronutrient applications (Control, 15 kg/ha of Borax, 25 kg/ha of Zinc sulphate, 1.5 kg/ha of Ammonium molybdate and 10 kg/ha of Manganese sulphate). Primary curd weight (409.24 g), primary curd volume (237.71 cc), diameter of primary curd (23.05 cm), number of secondary curds (12.50), ascorbic acid content (108.96 mg/100g), secondary curd weight (258.93 g), total curd yield/plant (668.17 g), yield/plot (16.04 kg), yield/ha (329.96 q), and biological yield/hectare (1743 q) were all shown to be significantly improved by the combination of zinc sulphate applied to the soil and *panchagavya* applied topically. Furthermore, the benefit-cost ratio (4.05) and net returns (₹ 2,64,573/ha) were highest for this combination of treatments. To improve the production, quality, and financial returns of sprouting broccoli in this area, the best treatment is to apply 25 kg/ha of zinc sulfate to the soil and then spray 5% *panchagavya* on the leaves.

Keywords: Ascorbic acid, Calcium, Micronutrients, Organics, *Panchagavya*

The cultivation of broccoli (*Brassica oleracea* L. var. *italica*) has garnered significant attention due to its high nutritional value and numerous health benefits. As a member of the Brassicaceae family, broccoli is renowned for its rich content of vitamins, minerals, and bioactive compounds such as glucosinolates and flavonoids, which contribute to its anti-carcinogenic and antioxidant properties. It contains 5.5% carbohydrates, 3.3% protein, and various vitamins as well as minerals like calcium, vitamin B1, vitamin B2, vitamin A, and phosphorus (Thamburaj and Singh 2001). It is noted because it contains significant amounts of ascorbic acid, calcium, and riboflavin, which are significantly higher than cauliflower. These nutrients make it beneficial for antioxidant properties and as a source of nourishment, especially for people with osteoporosis or calcium deficiency. Broccoli contains glucoraphanin and sulforaphane compounds, contributing to its anticancer properties (Kalia 1995). The indiscriminate use of straight fertilizers without incorporating sufficient organic matter can lead to a decline in soil health over time (Mal *et al.* 2015). This study investigates the integration of liquid organic manures (cow urine, *panchagavya*, vermiwash) and micronutrient applications (boron, zinc, molybdenum, manganese) to improve sprouting broccoli (Pusa KTS-1) yield and quality. Traditional bulky organic manures like farmyard and vermicompost have low nutrient content, hindering crop growth. Foliar application of liquid manures, combined with micronutrients, aims to enhance crop growth, biological efficiency, and soil fertility. Micronutrients play crucial roles in plant health, enzyme function, and photosynthesis, while organic amendments improve soil structure, nutrient availability, and microbial activity. This study explores the combined impact of organic amendments and micronutrients on the growth of broccoli. The research aims to identify optimal strategies for maximizing broccoli

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yield and quality by examining different combinations and application rates. This research explores the optimal combinations and application rates to boost broccoli growth, curd quality, and overall sustainability in production practices, offering valuable insights for farmers and horticulturists. The current experiment was conducted to investigate how organic matter, as well as micronutrients, affect the economics, growth and yield of sprouting broccoli in light of these facts.

MATERIALS AND METHODS

An experiment was conducted during the winter (*rabi*) seasons of 2019–20 and 2020–21 at Sri Karan Narendra College of Agriculture (Sri Karan Narendra Agriculture University, Jobner), Jobner, Jaipur, Rajasthan (26.50°N, 75.47°E at an altitude of 390 m amsl). The experiment was laid out in a randomized block design (RBD) with three replications consisting of 25 treatment combinations including five micronutrients [Control (M_0), Borax @15 kg/ha (M_1), Zinc sulphate @25 kg/ha (M_2), Ammonium molybdate at 1.5 kg/ha (M_3) and Manganese sulphate at 10 kg/ha (M_4)] and five organics [Control (O_0), Cow urine 10% (O_1), *Panchagavya* 5% (O_2), Vermiwash 10% (O_3) and Azotobacter (O_4)]. *Panchagavya* is a traditional organic formulation used in agriculture, known for its nutrient-rich composition and beneficial effects on plant growth. *Panchagavya* is composed of five cow-derived substances i.e. cow dung, cow urine, cow milk, curd and ghee. The micronutrients (B, Zn, Mo and Mn) were applied as soil application just before transplanting whereas, organics (cow urine, vermiwash and *panchagavya*) as foliar spray at 30 days after transplanting (DAT) and Azatobacter as seed treatment at the time of nursery raising and transplanting of seedling by root dipping. The appropriate dosage of inorganic fertilizers was then applied uniformly throughout the experiment area. The seedlings were transplanted at a spacing of 45 cm × 45 cm in a plot of size 2.7 × 1.8 m^2 (4.86 m^2). Soil of experimental field was loamy sand in texture, slight alkaline (EC, 1.36 dS/m and *p*H, 8.15) in reaction with poor in organic carbon (0.18%), low available nitrogen (132.5 kg/ha) and phosphorus (15.78 kg/ha) and medium in potassium content 148.98 kg/ha). The water used for irrigation is partially saline in nature and taken from underground resource. The irrigation water falls under class C3S1 to USDA Hand Book No. 60. The *p*H and EC was found to be 7.75 and 7.68; and 1.01 and 1.02 dS/m in the year 2019–20 and 2020–21, respectively. All cultural operations were followed continuously during crop growth. Additionally, the weight, diameter, quantity, and weight of primary and secondary curds, as well as the overall curd quality, curd production/hectare, and curd yield/plant attributes such as ascorbic acid were recorded. Five plants were tagged in each plot to record observations. The diameter of primary and secondary curds was taken from a digital vernier caliper. Ascorbic acid is the biochemical name for vitamin C, and Ranganna (1995) recommended using a titrimeter to measure it. Aliquots were made by grinding well-mixed curd samples with a solution of metaphosphoric acid, and they were titrated against dichlorophenol indophenol dye 2–6 until they reached the desired pink colour. The amount of vitamin C was determined using the given formula:

$$\text{Vitamin C (mg/100 g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot taken for estimation} \times \text{weight of the sample taken (g)} \times 100)}$$

$$\text{Dye factor} = \frac{0.5}{\text{2a Titre value (Standardization of dye with standard ascorbic acid)}}$$

Cultivation costs (CC) were deducted from each treatment's gross return (GR) to determine its net return (NR):

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

$$\text{BCR} = \frac{\text{NR}}{\text{CC}}$$

Where BCR, Benefit: cost ratio; NR, Net return (₹/ha); CC, Cultivation cost (₹/ha).

The F-test was utilized to interpret the results, and the critical difference at 5% was employed to determine whether there was a substantial variation between the two treatments' means (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Interactive effect of micronutrients and organics on yield parameters: Soil application of zinc sulphate @25 kg/ha along with foliar spray of *panchagavya* @5% (M_2O_2) significantly improved values for weight of primary curd (409.24 g), volume of primary curd (237.71 cc), diameter of primary curd (23.05 cm), number of secondary curds (12.50), weight of secondary curds (258.93 g), total curd yield/plant (668.17 g), yield/plot (16.04 kg), yield/ha (329.96 q), biological yield/ha (1743 q) and ascorbic acid (108.96 mg/100 g) of sprouting broccoli in pooled mean (Table 1 and 2; Fig. 1). Similarly, maximum net returns (2,64,573 ₹/ha) and B: C ratio (4.05) were also recorded with the treatment combination (M_2O_2) and found significantly superior over rest of the treatments. The soil application of zinc, particularly in the form of zinc sulphate, has been shown to improve the efficacy of added chemicals and fertilizers, enhancing nutrient availability in the soil. Zinc plays a crucial role in several physiological processes within plants, which contributes to increased yield and improved growth in sprouting broccoli. One of the primary mechanisms by which zinc influences crop yield is by promoting the rate of humification in the soil. This enhanced humification increases the availability of both native and added nutrients, making them more accessible to plants.

In addition to improving soil nutrient availability, zinc application boosts plant processes that are essential for healthy growth. Zinc enhances seedling vigour, which is crucial for the initial stages of growth, helping plants

Table 1 Interactive effect of micronutrients and organics on volume of primary curd, diameter of primary curd, weight of primary curd, number of secondary curd and weight of secondary curd of sprouting broccoli (pooled mean of two years)

Treatment	Micronutrients (kg/ha)				
Organics	Control	B (15)	$ZnSO_4$ (25)	$(NH_4)_2$ MoO_4 (1.5)	$MnSO_4$ (10)
Volume of primary curd (cc)					
Control	111.60	134.18	143.32	134.41	108.82
Cow urine @10%	111.67	143.76	146.06	141.95	117.04
Panchagavya @5%	171.49	220.71	237.71	220.25	190.25
Vermiwash @10%	156.59	220.26	205.95	210.67	166.50
Azotobacter	119.12	144.34	189.06	150.80	127.26
SEM±	5.46				
CD (p=0.05)	15.35				
Diameter of primary curd (cm)					
Control	11.80	17.40	15.79	15.99	12.78
Cow urine @10%	12.59	18.11	16.94	17.09	14.56
Panchagavya @5%	16.37	19.82	23.05	18.85	20.08
Vermiwash @10%	15.07	19.67	21.26	17.78	18.31
Azotobacter	12.39	20.75	21.06	18.36	15.89
SEM±	0.57				
CD (p=0.05)	1.61				
Weight of primary curd (g)					
Control	239.60	320.15	308.62	271.39	290.80
Cow urine @10%	282.25	329.93	345.44	276.40	261.86
Panchagavya @5%	343.95	347.35	409.24	340.13	324.00
Vermiwash @10%	268.11	330.53	352.67	339.75	294.40
Azotobacter	279.06	323.67	328.64	309.68	291.94
SEM±	12.71				
CD (p=0.05)	35.69				
Number of secondary curd					
Control	5.78	6.90	7.46	8.36	6.04
Cow urine @10%	6.01	8.44	7.85	8.81	6.52
Panchagavya @5%	8.89	12.41	12.50	9.37	10.87
Vermiwash @10%	8.33	11.65	11.93	9.08	10.35
Azotobacter	6.97	8.85	11.12	8.96	8.35
SEM±	0.30				
CD (p=0.05)	0.86				
Weight of secondary curds (g)					
Control	153.27	195.46	232.99	180.16	161.32
Cow urine @10%	163.41	205.69	234.28	178.60	164.46
Panchagavya @5%	248.30	248.51	258.93	228.06	229.66
Vermiwash @10%	214.25	218.98	236.94	206.05	196.71
Azotobacter	146.25	219.61	208.96	227.71	222.72
SEM±	8.52				
CD (p=0.05)	23.92				

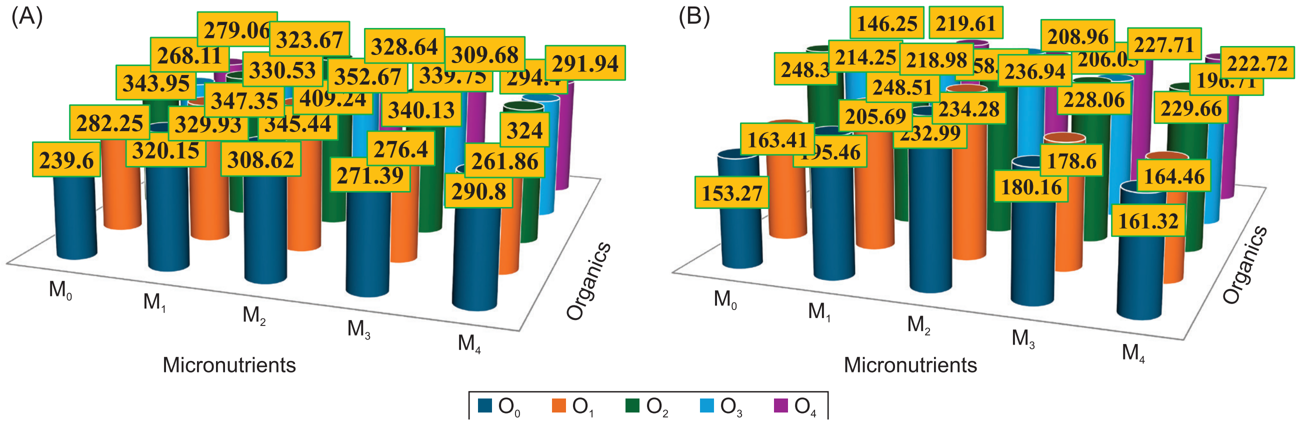

Fig. 1 Interactive effect of micronutrients and organics (A) weight of primary curd (g) and (B) weight of secondary curd (g) of sprouting broccoli.
Treatment details are given under Materials and Methods.

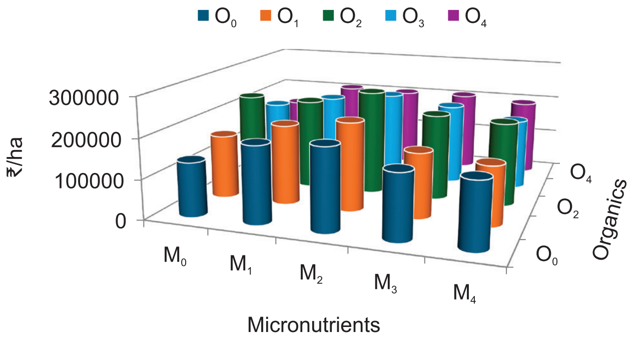

Fig. 2 Interactive effect of micronutrients and organics on net returns (₹//ha) of sprouting broccoli.
Treatment details are given under Materials and Methods.

establish strong root systems and robust shoots. It also aids in starch formation, an essential process for energy storage in plants, contributing to better growth and development. Furthermore, zinc is important for chlorophyll production, the green pigment responsible for photosynthesis. With more chlorophyll, plants can efficiently capture sunlight, convert it into energy, and produce photosynthates, which are critical for overall plant development and yield.

Zinc also accelerates various enzymatic activities in plants, including those involved in sulphur and nitrogen metabolism. These two elements are vital for protein synthesis, growth, and overall plant health. By improving the efficiency of nitrogen and sulfur utilization, zinc ensures that plants can make the most of available nutrients, further enhancing the yield and quality of sprouting broccoli. Thus, the soil application of zinc sulfate significantly contributes to increased broccoli productivity through improved nutrient use, enhanced physiological processes, and better overall plant health (Pandav *et al.* 2016). Application of zinc could have improved the availability of zinc itself in the plant together with other nutrients as well as the absorption of essential elements via increasing the cation exchange capacity (CEC) of their roots. Zinc also helps to accumulate more of photosynthates in plant to ensure significantly higher curd weight and diameter. Application of zinc also plays a role to increase the activity of nitrate reductase enzyme and enhance synthesis of certain amino acids and protein. The main function of zinc in a plant is to activate enzymes like dehydrogenase, proteinase and peptidases (Prasad *et al.* 2010). Among these enzymes, some of are concerned with carbohydrate and nitrogen metabolism to enhance N uptake and for regulating many physiological processes of plants and thus zinc is assisted in the utilization of phosphorus and nitrogen by the plants (Marschner 1995). Soil application of zinc due to its catalytic or stimulatory effect in plants on most of the physiological processes like biosynthesis of indole acetic acid (IAA) as well as its role in ignition of primordia for reproductive parts and partitioning of photosynthates towards them, result into improvement in yield attributes and finally yield. It plays a vital role in sulphur and nitrogen metabolism. These results were in accordance with the findings of Chaudhari *et al.* (2018) in cabbage, Singh *et al.* (2018) in sprouting broccoli and Jat (2020) in okra. Organic manures serve as a nutrient reservoir that gradually releases absorbed ions throughout the entire crop growth period, resulting in enhanced crop yield (Raza *et al.* 2022).

Application of organic sources like *panchagavya* might have ameliorated the biochemical properties of the plant and enhanced the activities of beneficial micro-organisms such as *Azospirillum, Azotobacter*, Phosphobacteria and *Pseudomonas* besides *Lactobacillus* resulting in production of growth promoting substances. It might have also improved nutrient availability for longer period and thus, exerted favourable effects on yield attributes and yield of broccoli. Moreover, enhanced activities of growth regulatory elements such as indole acetic acid, gibberellic acid, cytokinin and essential plant nutrients have also been observed in *panchagavya*. Thus, it may carry overall improvement in plant growth which reflected into better source-sink relationship by increasing the yield attributes. Yield of a crop is modification of plant anatomy and morphology in the growing plants due to physiological processes and

Table 2 Interactive effect of micronutrients and organics on number of yield/ha and biological yield in sprouting broccoli (pooled mean of two years)

Treatment	Micronutrients (kg/ha)				
Organics	Control	B (15)	$ZnSo_4$ (25)	$(NH_4)_2$ MoO_4 (1.5)	$MnSo_4$ (10)
Yield/ha (q)					
Control	194.01	254.62	267.46	222.99	223.27
Cow urine @10%	220.08	264.50	286.28	224.69	210.53
Panchagavya @5%	292.47	294.25	329.96	280.59	273.41
Vermiwash @10%	238.20	271.36	291.17	269.53	242.53
Azotobacter	210.03	268.29	265.48	265.38	254.15
SEM±	10.08				
CD (p=0.05)	28.30				
Biological yield (q)					
Control	790	1107	1246	1129	1011
Cow urine @10%	968	1202	1330	1198	1051
Panchagavya @5%	1555	1583	1743	1440	1485
Vermiwash @10%	1315	1440	1632	1364	1314
Azotobacter	1182	1293	1399	1269	1121
SEM±	51				
CD (p=0.05)	144				

biochemical activities. The findings of present experiment were in accordance as reported by Prabhu (2020). Foliar application of *panchagavya* at flowering, 15 DAS and after flowering significantly produced higher yield of green gram (Shariff and Sajjan 2017). Similarly, Gunasekar *et al.* (2018) also opined that *panchagavya* spray at 25, 35 and 45 DAS registered high yield attributes with black gram. Application of *panchagavya* might have led to better photosynthetic activity in the plant which resulted in development of extensive root system to extract more of nutrient from the soil and thus, improved yield attributes and increased the yield of green gram. The results were in support with those of Maheswari *et al.* (2016) in dolichos lablab, Kumar *et al.* (2018) in cauliflower, Gajjela and Chatterjee (2019) and Varshini and Jayanthi (2020) in bitter gourd who recorded that spray of liquid organic manures may led translocation of more amount of carbohydrates to developing fruits and better utilization of nutrients resulting an increase in fruit weight. According to Sardar *et al.* (2022), the application of zinc (Zn) and boron (B) plays a significant role in enhancing both the quantity and quality of broccoli heads. Their research delves into the importance of micronutrient supplementation in crop production, specifically focusing on how these elements impact broccoli, a widely consumed vegetable known for its health benefits. This investigation provides valuable insights for farmers, horticulturists, and agricultural researchers looking to optimize broccoli yield and quality in diverse growing conditions.

Interactive effect of micronutrients and organics on quality parameters: The data presented in Table 3 clearly demonstrates that the soil application of zinc sulphate at 25 kg/ha, combined with a foliar spray of *panchagavya* at 5% (M_2O_2), significantly improved the ascorbic acid content in the curd of sprouting broccoli. The ascorbic acid content was recorded at 108.96 mg/100 g, which is notably higher across both years of study as well as in the pooled mean analysis. This improvement in ascorbic acid levels can be attributed to the combined effects of zinc and *panchagavya* on plant metabolism and physiological processes.

Zinc plays a crucial role in enhancing various metabolic activities within plants. One of its key functions is in nitrogen metabolism, where it helps plants efficiently utilize nitrogen, which is a vital element for protein synthesis and overall growth. By improving nitrogen use efficiency, zinc contributes to better plant health, leading to increased nutrient content, including ascorbic acid. Moreover, zinc promotes chlorophyll formation, which is essential for photosynthesis. A higher chlorophyll content leads to more efficient energy capture, allowing the plant to produce more photosynthates, further enhancing the nutritional value of the broccoli curd.

Zinc also influences the concentration of auxins, which are plant hormones that regulate various aspects of growth, including cell elongation and division. By increasing auxin levels, zinc encourages better plant development, leading to healthier and more robust broccoli plants, which can synthesize more nutrients, including ascorbic acid.

Furthermore, the application of zinc stimulates the activity of the nitrate reductase enzyme, which is essential for converting nitrate into usable nitrogen. This enhanced enzyme activity not only improves nitrogen assimilation but also supports the synthesis of amino acids and proteins. These proteins are crucial for maintaining plant health and further contribute to the overall quality of the broccoli curd, including its ascorbic acid content.

In conclusion, the synergistic effect of zinc sulfate

Table 3 Interactive effect of micronutrients and organics on biological ascorbic acid in curd, net returns and B: C ratio of sprouting broccoli (pooled mean of two years)

Treatment	Micronutrients (kg/ha)				
Organics	Control	B (15)	$ZnSO_4$ (25)	$(NH_4)_2$ MoO_4 (1.5)	$MnSO_4$ (10)
Ascorbic acid (mg/100 g)					
Control	77.73	84.53	88.30	86.94	71.31
Cow urine @10%	77.83	86.46	89.44	86.99	76.07
Panchagavya @5%	89.07	96.61	108.96	87.66	91.48
Vermiwash @10%	88.13	96.69	97.55	87.55	96.05
Azotobacter	83.92	91.28	86.56	88.21	93.26
SEM±	3.41				
CD (p=0.05)	9.58				
Net returns (₹/ha)					
Control	136368	193456	206121	163534	163705
Cow urine @10%	160889	201788	223391	163688	149417
Panchagavya @5%	230778	229041	264573	217084	209801
Vermiwash @10%	177012	206651	226279	206528	179413
Azotobacter	152123	206860	203878	205660	194323
SEM±	10083				
CD (p=0.05)	28305				
B: C ratio					
Control	2.37	3.16	3.36	2.75	2.75
Cow urine @10%	2.72	3.22	3.55	2.68	2.44
Panchagavya @5%	3.74	3.51	4.05	3.42	3.30
Vermiwash @10%	2.89	3.19	3.49	3.28	2.84
Azotobacter	2.63	3.37	3.31	3.44	3.25
SEM±	0.16				
CD (p=0.05)	0.46				

and *panchagavya* application has a significant positive impact on the ascorbic acid content of sprouting broccoli curd, likely due to improvements in nitrogen metabolism, chlorophyll formation, auxin concentration, and enhanced enzyme activity. These findings suggest that the combined use of zinc and *panchagavya* can be an effective strategy to increase the nutritional quality of broccoli (Ramesh *et al.* 2006). This result agrees with those obtained by Singh *et al.* (2018) in sprouting broccoli. Chemolithotrops and autotropic nitrifiers (ammonifers and nitrifers) present in *panchagavya* which colonize in the leaves and increase the ammonia uptake and total N supply help in increased nutrient and protein content in curd of sprouting broccoli. Foliar application of *panchagavya* may also offer more macro and micronutrients alongwith growth regulators like auxins and gibberellin which aid in producing more biomass and improved recovery of N, P, K, B, Zn, Mo and Mn in plant. Beaulah (2002) found that the secondary and micronutrients (Ca, S and Fe) and macronutrient (NPK) content of leaves and pods of annual moringa were superior under poultry manure + neem cake + *panchagavya* treatment. *Panchagavya* contains urea and other nutrients that can be absorbed rapidly through the cuticle of leaves, enhancing nutrient availability for the plant. *Panchagavya* may stimulate phytohormones, such as enhancing nitrate reductase activity or protein synthesis in functional leaves, thereby affecting fundamental processes like translation. This positive impact on nutrient content and quality parameters aligns with previous findings in other crops, as referenced by Gajjela and Chatterjee (2019) and Varshini and Jayanthi (2020), particularly in bitter gourd. These findings suggest that foliar application of *panchagavya* at 5% concentration is a promising approach to enhance the nutritional quality of sprouting broccoli under semi-arid conditions.

Interactive effect of micronutrients and organics on economics: The result of the present investigation given in Table 3 and Fig. 2 showed that, soil application of zinc sulphate-25 kg/ha along with foliar spray of *panchagavya* @5% (M_2O_2) significantly recorded maximum values for net returns (2,64,573 ₹/ha) and B:C ratio (4.05) and found significantly superior over rest of the treatments. Results clearly demonstrated that soil application of zinc in deficient soils is superior to all other treatments, significantly enhancing growth, yield attributes, and economic profitability in broccoli cultivation.

Based on the study's findings over two years of experimentation, it is recommended that the soil application of zinc sulphate @25 kg/ha alongwith foliar spray of *panchagavya* @5% (M_2O_2) provided maximum curd yield and fetched maximum net returns and B: C ratio in sprouting broccoli crop and it was found significantly superior to other treatment combinations. Thus, soil application of zinc sulphate @25 kg/ha in combination with foliar spray of *panchagavya* @5% is hereby recommended for sprouting broccoli growers of semi-arid region of Rajasthan under loamy sand soil conditions.

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