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Effect of different micronutrients and their methods of application on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica*) cv. Palam Samridhi

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Abstract
A field experiment was conducted at College Farm, College of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Gujarat during the *Rabi* season of the year 2019-20 and 2020-21 to study the effect of different micronutrients and their methods of application on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica*) cv. Palam Samridhi. The experiment was laid out in Randomized Block Design with Factorial concept comprising of two factors. The first factor was micronutrients (C) with seven levels *viz.*, C1- B, C2 – Zn, C3 – Fe, C4 – B + Zn, C5 – B + Fe, C6 – Zn + Fe and C7 – B + Zn + Fe and the second factor was methods of application (M) *i.e.*, M1- soil application, M2- single spray of micronutrients at 25 DATP and M3- two sprays of micronutrients at 25 and 50 DATP. The treatments were replicated thrice. The individual effect of micronutrients and their method of application as well as their interaction effect on growth and yield of broccoli cv. Palam Samridhi was recorded. The results indicate that effect of micronutrient using B + Zn + Fe (C7) treatment was the most effective treatment in all studied traits. Method of micronutrients application (M3) two spray of micronutrients at 25 and 50 DATP was found superior for growth and yield parameters except plant height (cm) at harvest, number of leaves per plant at harvest and number of sprouts per plant at harvest. The interaction effect of micronutrients and their methods of application C7M3 *i.e.*, two spray of B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 and 50 DATP were found significant for all parameters of growth and yield, except sprout weight (g) per plant. Thus, from the present investigation it could be concluded that for successful cultivation of broccoli in North Gujarat two foliar applications of micronutrients *i.e.*, B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 and 50 DATP along with RDF (120:80:80 NPK) is beneficial for optimum growth and higher yield.

Keywords: Broccoli, micronutrients (B, Zn and Fe), foliar spray, growth, yield

Introduction
The word sprouting broccoli refers to the development of younger shoots which have been used as vegetable for long time in Italy and the name derived from Latin word "Brachium" meaning Arm of branch. It was introduced in England in the early 16th century known as Italian asparagus or sprout cauliflower (Thamburaj and Singh, 2015) [71]. Now the crop is grown in every corner of the world. The broccoli has attained the tag of commercial crop in India (Nonnecke, 1989) [43] with the growing popularity among Indian growers for the last few years due to its high nutritive value and increased tourist influx, area under broccoli is gaining momentum. It is mostly cultivated in the hilly areas of Himachal Pradesh, Uttar Pradesh, Jammu and Kashmir, Nilgiri hills and Northern plains of India. Cauliflower and broccoli are cultivated in an area of 4,58,000 hectare with an annual production of 88,40,000 tonnes and productivity of 19.30 t ha^{-1} (FAO, 2020) [20].

The primary inflorescence is characterized by higher levels of dry matter, total nitrogen, vitamin-C, chlorophylls, β-carotene, carotenoids and by lower levels of nitrates. Nutritionally, it is rich in vitamin-A (2500 I.U.), vitamin-C (113 mg), protein (3.6 g), carbohydrates (5.9 g) and minerals like calcium (103 mg), iron (1.1 mg), phosphorous (78 mg), potassium (382 mg) and sodium (15 mg) per 100 g of edible portion (Rana, 2008) [53]. After harvesting the head, its green leaves are also good source of nutritious green fodder and serves in acute shortage in winter season (Kumar *et al*., 2007) [32]. The 3, 3-di indolyl methane found in broccoli is a potent modulator of the innate immune response system with anti-viral, anti-bacterial and anti-cancer activity (Riby *et al*., 2006) [54]. It is also an excellent source of indole-3-carbinol, a chemical which boosts DNA repair in cells and appear to block the growth of cancer cells (Arthar and Richard, 2010) [8].

In India, it is being used as a fresh vegetable, whereas in USA and European countries it is used as fresh as well as in frozen form. It is usually boiled or steamed but may be eaten raw as salad and is liked in soups. The anti-cancer benefits of broccoli are greatly reduced if the vegetable is boiled. However, other preparation methods such as steaming, microwaving and frying had no significant effect on the constituent compounds (Jeffery, 2005) [26].

Mineral fertilizer is essential part of plants life and well provide for improved growth and yield of broccoli. Salwa *et al.* (2011) [55] stated that microelements are crucial substances for crop's growth; however, they are used in lower amounts compared to macronutrients, such as N, P and K. Micronutrients play a major role in cell division and development of meristematic tissues, photosynthesis, respiration and acceleration of plant maturity (Zeidan *et al*., 2010) [74].

Plants differ widely in their requirements, but the ranges of deficiency and toxicity is trace. Micronutrient deficiencies specially B, Zn and Fe are very common in cole crops. Deficiency of these elements causes many anatomical, physiological, and biological changes in broccoli plants. The deficiency of boron, zinc and iron has threatened the ever-increasing areas of broccoli production. The affected heads become irregular in shape, smaller in size, and bitter in taste, which adversely affects the market demand of the crop. The deficient plant shows the symptoms of hollow stems, browning of heads and reduced growth. Researchers observed that boron application increased growth and yield of the crops (Shelp *et al*., 1992) [58].

Boron is also an essential plant micronutrient as a constituent of cell membrane and is essential for cell division. Boron is also concerned with the precipitation of excess cation, buffer action, maintenance of conducting tissues and help in absorption of nitrogen. Its primary role is concerned with metabolism both uptake and its efficient use in plants. Boron also affect the cambial and phloem tissues of storage root or stem apical meristem and leaves, vascular cambia of fruits and other organs which are capable of meristematic activities (Singh, 1991) [63]. Among the micronutrients, boron has a direct impact on productivity of cole crops. Boron significantly improves the vegetative growth and quantitative parameters of cole crops (Singh *et al.*, 2003b) [65]. Zinc is essential component of many enzymes such as carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase and RNA polymerase *etc*. and also involved in nitrogen metabolism. It plays role in synthesis of plant growth substances and enzyme systems and is essential for promoting certain metabolic reactions. It is necessary for production of chlorophyll and carbohydrates (Cakmak, 2000) [11]. Iron is essential micronutrient required for normal growth and plant functions like photosynthesis, respiration and reduction of nitrate and sulphates in plant. Fe acts as catalyst in synthesis of chlorophyll molecules and helps in the absorption of other elements (Pandav *et al*., 2016) [45].

The requirement of micronutrients is supplied either through foliar spraying or soil application. But, from an ecological perspective, foliar fertilization is more acceptable, because the small amounts of nutrients is used for rapid use by plants (Stampar *et al*., 1999) [68] and it also paved for new approaches like nano foliar application. In perspectives, experiment was conducted to know the effect of microelement on growth, yield and quality of Palam Samridhi variety of broccoli.

Materials and Methods

The field trial was carried out in open field condition during *Rabi* season of the year, 2019-20 and 2020-21 at field of College of Horticulture, Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Gujarat, India. The experiment was laid out in Randomized Block Design with factorial concept (FRBD) keeping two factor *viz.*, first factor was micronutrients (C) with seven levels *viz.*, C1- B, C2 – Zn, C3 – Fe, C4 – B + Zn, C5 – B + Fe, C6 – Zn + Fe and C7 – B + Zn + Fe and the second factor was methods of application (M) *i.e*., M1- soil application, M2- single spray of micronutrients at 25 DATP and M3- two sprays of micronutrients at 25 and 50 DATP. For foliar application, 100 ppm solution of Boron (Boric Acid), Zn (Zinc Sulphate) and Fe (Ferrus Sulphate) was applied in combination of different micronutrient as per treatment. In single foliar application, spray was done at 25 DATP. In double foliar application, spray was done at 25 and 50 DATP. For soil application, B was applied @ 3 kg/ha, Zn @ 2 kg/ha and Fe @ 2 kg/ha. In case of combined application respective dose of each micronutrient was applied. The treatments were applied in the mode of soil application. The application of zinc, boron and iron as foliar spray of boric acid, zinc sulphate and ferrous sulphate, respectively was used and sprayed on foliage in aqueous form by using fresh solution at each spray. For preparation of 100 ppm B, 100 ppm Zn and 100 ppm Fe, 0.175 g of boric acid, 0.21 g zinc sulphate hepta hydrate, and 0.11 g ferrous sulphide, respectively were dissolved separately in one liter water. Spraying was done with micro sprayer and the leaves were wetted thoroughly with a fine mist. The variety Palam Samridhi of broccoli was taken under investigation, the seeds of this variety were procured from Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidhyalaya, Palampur, Himachal Pradesh. It was selected for the present study because it has shown better and consistent performance in the sub-tropical climatic condition than other varieties. The seedlings of broccoli cv. Palam Samridhi were transplanted after six weeks of seed sowing at 45×30 cm spacing. At the time of soil preparation 20 t/ha FYM and 50 % Nitrogen & full dose of P2O5 and K2O of RDF (120: 80: 80) *i.e*., 60 kg/ha nitrogen, 80 kg/ha phosphorus and 80 kg/ha potash were applied at basal application. Remaining 60 kg/ha nitrogen was applied as top dressing at 30 days after transplanting. The N, P and K were applied in the form of urea, SSP and MOP respectively. Sprinkler system was used to irrigate the crop for better establishment. Common cultural practices were used for the broccoli production such as irrigation, weeding, fertilization, plant protection etc., according to recommended practices for broccoli in the commercial fields. Ten randomly selected plants were tagged in each plot and used for recording the observations of growth and yield attributes.

Statistical Analysis

The data recorded for various parameters during the course of investigation were statistically analysed by a procedure of FRBD described by Panse and Sukhatme (1978) [48].

Results and Discussion

Growth Parameters

Plant height (cm) at harvest

Effect of micronutrients and their method of application on plant height (cm) at harvest Effect of micronutrients: Data presented in Table 1 revealed that plant height at harvest was significantly influenced by different micronutrients. Among the various micronutrients the maximum plant height at harvest was recorded in treatment (C7) *i.e.*, B + Zn + Fe. This increase could be attributed to the role of zinc and boron closely associated with development of cell wall and cell differentiation that help in root and shoot growth of plants (Basavaraeswari *et al*., 2008) [10]. According to Chopde *et al.* (2015) [17], iron applied with proper concentration acts as an important catalyst in the enzymatic reaction of metabolism. This ultimately would have helped in larger biosynthesis of photoassymilates, thereby enhanced vegetative growth of plant. These results are in line with the results obtained by Azeem and Ahmed (2011) [9], Ali *et al*., (2013) [6] and Zarghamnead *et al.*, (2015) [73] in tomato, Adhikary *et al.* (2004) [2] and Patel (2002) [49] in cauliflower, Kanujia *et al.* (2006) [28], Kotecha *et al*. (2011) [30] in cabbage and Ain *et al.* (2016) [4] and Singh *et al*. (2018) [67] in broccoli.

Effect of method of application: Values in Table 1 showed that methods of application of micronutrients was statistically non significant in pooled analysis.

Interaction effect: Data on interaction effect of micronutrients and their method of application of micronutrients presented in Table 1, revealed that interaction effect was statistically significant. Significantly maximum plant height at harvest was recorded in treatment C7M3 (Two spray of B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 & 50 DATP). Which was at par with treatment C7M1 (Soil application of B @ 3 kg/ha + Zinc @ 2 kg/ha + Fe @ 2 kg/ha), C6M3 (Two spray of Zinc @ 100 ppm + Fe 100 ppm at 25 & 50 DATP), C5M1 (Soil application of B @ 3 kg/ha + Zn @ 2 kg/ha), C3M2 (Single spray of Fe @ 100 ppm at 25 DATP), C2M3 (Two spray of Zinc @ 100 ppm at 25 & 50 DATP), C2M2 (Single spray of Zinc @ 100 ppm at 25 DATP) during pooled analysis. It could be due to, the combined foliar application of different micronutrients which might have accelerated the rate of metabolic activities in the plant system that might have resulted in increasing height of the plant. The similar results were also reported through foliar sprays by Jamre and Verma (2010) [25] and Chaudhari *et al.* (2017a) [14] in cauliflower, Nandi and Nayak (2008) [41], Naher *et al*. (2014) [40] and Swiatikiewies and Sandy (2015) [69] in cabbage and Singh *et al.* (2015) [60], Singh *et al*. (2017) [61] and Pankaj *et al.* (2018) [47] in broccoli.

Number of leaves per plant at harvest

Effect of micronutrients and their method of application on number of leaves per plant at harvest

Effect of micronutrients: Data in table 1 showed that number of leaves per plant at harvest was significantly influenced by different micronutrients. Among the various micronutrients, the maximum number of leaves per plant at harvest was recorded in treatment C7 *i.e*., application of B + Zn + Fe. Increase in number of leaves may be due to the availability of required quantity of essential plant nutrients at various growth stages leading to hastening the metabolic processes of plant that might have resulted in production of more number of leaves. Similar results were also reported by Patel (2002) [49] and Kumar *et al.* (2012) [31] in cauliflower, Kotecha *et al.* (2011) [30] in cabbage and Ain *et al*. (2016) in broccoli.

Effect of method of application: The data (Table 1) showed that the method of application of micronutrients was statistically non significant.

Interaction effect: The data (Table 1) revealed that interaction effect was statistically significant in pooled analysis. significantly maximum number of leaves per plant in pooled basis at harvest was recorded in treatment C7M3 (Two spray of B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 & 50 DATP). It was statistically at par with treatment C2M3, C3M1, C5M1, C5M2, C6M3 and C7M2 in pooled analysis. The significant of interaction effect of micronutrient application through foliar spray might be due to the significant effect of both the main effects. Present results are in agreement with those of Tahir *et al.* (2020) [70] in rose, Kumar *et al*. (2010a) [33] in cauliflower and Ain *et al*. (2016) [4] in broccoli.

Table 1: Effect of micronutrients and their methods of application on plant height, number of leaves and plant spread

	Plant height at harvest (cm)				Number of leaves per plant at harvest				Plant spread (N-S) (cm) at harvest			
	Pooled				Pooled				Pooled			
Treatment	**M1**	**M2**	**M3**	**Mean (C)**	**M1**	**M2**	**M3**	**Mean (C)**	**M1**	**M2**	**M3**	**Mean (C)**
C1	50.87	49.50	48.27	49.54	14.00	14.63	14.13	14.26	56.27	57.17	63.88	59.10
C2	51.90	62.17	62.93	59.00	16.33	14.97	17.30	16.20	62.03	68.22	66.65	65.63
C3	55.20	64.27	55.70	58.39	17.10	15.40	15.57	16.02	59.57	63.85	66.12	63.18
C4	60.20	52.77	56.27	56.41	14.57	16.73	15.80	15.70	67.52	71.42	74.00	70.98
C5	61.47	60.50	58.03	60.00	16.87	16.97	15.63	16.49	67.03	68.00	73.00	69.34
C6	57.20	58.73	64.57	60.17	16.07	15.87	17.63	16.52	69.49	74.98	75.40	73.29
C7	66.77	59.40	67.03	64.40	16.27	17.83	18.60	17.57	75.77	78.88	80.97	78.54
Mean (M)	57.66	58.19	58.97	58.27	15.89	16.06	16.38	16.11	65.38	68.93	71.43	68.58
	C	M	C x M		C	M	C x M		C	M	C x M	
S.E.M. ±	1.36	0.75	1.97		0.34	0.23	0.61		1.41	0.92	2.42	
C.D. (P=0.05)	3.96	NS	5.59		0.98	NS	1.73		4.10	2.59	NS	
CV %	8.30				9.30							
	C X Y	M X Y	C X M X Y		C X Y	M X Y	C X M X Y		C X Y	M X Y	C X M X Y	
S.E.M. ±	1.92	1.05	2.79		0.48	0.33	0.87		1.99	1.29	3.43	
C.D. (P=0.05)	NS	NS	NS		NS	NS	NS		NS	NS	NS	
CV %	8.30				9.30				8.65			

Plant Spread (N-S and E-W) (cm) at harvest

Effect of micronutrients and their method of application on plant Spread (N-S and E-W) (cm) at harvest

Effect of micronutrients: The data presented in Table 1 and 2 pertaining to the effect of micronutrients on plant spread showed that plant spread was significantly influenced by different micronutrients. Treatment C7 *i.e*., B + Zn + Fe micronutrients found significantly superior and recorded the

maximum plant spread in North – South and East - West in pooled analysis. Increase in plant spread can be ascribed to the role of zinc in chlorophyll formation, which also influenced cell division, meristematic activity of plant tissues and expansion of cell and formation of cell wall by active synthesis of aromatic amino acid *i.e*., tryptophan, which is precursor of IAA and it is responsible to stimulate plant spread by cell elongation and cell division (Choudhary and Mukherjee, 1999) [18], Iron plays an important role in promoting growth character, being a component of ferredoxin, an electron transport protein and is associated with chloroplast. It helps in photosynthesis which might have helped in better vegetative growth (Hazra *et al.* 1987) [22]. Present results are in conformity with those of Kanujia *et al*. (2006) [28] and Lashkari *et al.* (2007) [35] in cauliflower, Singh *et al.* (2015), Sharma *et al*. (2005) [56] in cabbage and Pankaj *et al.* (2018) [47] in broccoli.

Effect of method of application: The significantly maximum plant spread in North – South and East – West in pooled was found in treatment M3 (Two spray of micronutrients), which was statistically at par with treatment M2 (Single spray of micronutrients) in East – West. Increase in plant spread may be due to foliar application of Zn, B and Fe that accelerate photosynthesis process and enhances translocation of metabolites and development as well as elongation of new cells. These findings are in accordance with earlier findings reported by Patel (2002) [49] and Chaudhari *et al.* (2017a) [14] in cauliflower and Kotecha *et al.* (2011) [30] in cabbage.

Interaction effect: Interaction effect between different micronutrients and their method of application was found non significant on plant spread in (North – South) and (East – West).

Days taken for curd initiation

Effect of micronutrients and their method of application on days taken for curd initiation Effect of micronutrient: Data regarding effect of different micronutrients on days taken for curd initiation are presented in Table 2 were found statistically significant during pooled analysis. The treatment C7 (B + Zn + Fe) was significantly superior and recorded the minimum days for curd initiation, which was statistically at par with treatment C4 (B + Zn). Earliness in curd initiation might due to physiological role of micronutrients and rapid translocation of photosynthates towards the curd which might have developed advance curd (Moklikar *et al*. 2018) [39]. This result is in conformity with the finding of Makhan *et al.* (2003) in tomato, Lashkari *et al.* (2007) [35] in cauliflower and Singh *et al.* (2013) [62] in broccoli.

Effect of method of application: Data (Table-2) showed that days taken for curd initiation were significantly influenced by method of application. Minimum days taken to curd initiation was recorded in treatment M3 (Two spray of micronutrients). The reason for early flowering might be due to rapid initial plant growth because of favourable environment and due to proper and appropriate concentration of micronutrients. This result is in conformity with the finding of Karuppaiah (2005) [29] and Dong (1995) [19] in tomato, Chandni *et al*. (2020a) [12] in cauliflower, Patel *et al*., (2021) [50] in cabbage and Singh *et al*. (2018) [67] in broccoli.

Table 2: Effect of micronutrients and their methods of application on plant spread, days taken for curd initiation and curd harvesting

Plant spread (E-W) (cm) at harvest					Days taken for curd initiation				Days taken for curd harvesting			
Pooled					Pooled				Pooled			
Treatment	**M1**	**M2**	**M3**	**Mean (C)**	**M1**	**M2**	**M3**	**Mean (C)**	**M1**	**M2**	**M3**	**Mean (C)**
C1	56.20	58.84	65.93	60.32	54.18	45.10	44.77	48.02	69.43	66.07	63.73	66.41
C2	63.60	67.84	67.40	66.28	52.20	49.28	43.80	48.43	69.88	68.70	65.10	67.89
C3	60.00	65.20	67.17	64.12	48.55	49.85	44.97	47.79	69.23	68.65	63.98	67.29
C4	72.31	74.67	76.50	74.49	44.90	43.90	43.15	43.98	63.27	63.37	63.48	63.37
C5	67.87	69.46	74.20	70.51	45.52	44.50	44.27	44.76	62.93	64.00	63.30	63.41
C6	68.14	71.46	74.87	71.49	55.22	55.37	44.10	51.56	74.07	72.80	63.25	70.04
C7	77.57	80.36	80.40	79.44	43.83	43.07	43.06	43.32	61.00	57.40	52.42	56.94
Mean (M)	66.53	69.69	72.35	69.52	49.20	47.30	44.02	46.84	67.12	65.85	62.18	65.05
	C	M	CXM		C	M	CxM		C	M	C I M	
S.Em. *	1.17	0.81	2.15		0.55	0.33	0.88		0.57	0.27	0.71	
C.D. (P-0.05)	3.42	2.30	NS		1.61	0.95	2.50		1.68	0.76	2.00	
CV %	7.66				4.62				4.66			
	CXY	MXY	CXMXY		CXY	MXY	CXMXY		CXY	MXY	CXMXY	
S.Em. #	2.02	1.23	3.26		0.78	0.47	1.25		0.81	0.38	1.00	
C.D. (P=0.05)	NS	NS	NS		2.27	NS	3.54		2.37	NS	2.83	
CV %	7.66				4.62				4.66			

Interaction effect: The significant minimum days taken for curd initiation was recorded in treatment C7M3 (Two spray of micronutrients at 25 & 50 DATP), which was at par with treatment C2M3, C4M2, C4M3, C5M2, C5M3, C6M3, C7M1 and C7M2 in pooled analysis. The probable reason for early curd initiation and curd maturity might be due to foliar application of boron, zinc and ferrous sulphate (Moklikar *et al.*, 2018) [39]. This result is in accordance with those of Lashkari *et al*. (2007) [35] and Chaudhari *et al.* (2017a) [14] in cauliflower and Kumar (2010) [33] and Singh *et al*. (2018) [67] in broccoli.

Days taken for curd harvesting

Effect of micronutrients and their method of application on days taken for curd harvesting

Effect of micronutrient: The treatment C7 *i.e.*, B + Zn + Fe was significantly superior and recorded the minimum days to curd harvesting in pooled basis. This might be due to the better absorption of nutrients resulting in efficient physiological activities in plant, which was governed by beneficial effect of micronutrient (Lashkari *et al*., 2007) [35]. This is in accordance with the findings of Moklikar *et al.* (2018) [39] in cauliflower.

Effect of method of application: The minimum days taken for curd harvesting was recorded in treatment M3 (Two spray of micronutrients). These results are correlated with Kumar *et al.* (2012) [31], Ali *et al.* (2013) [6] and Chaudhari *et al.* (2017a) [14] in cauliflower.

Interaction effect: The significant minimum days taken for curd harvesting in pooled was recorded in treatment C7M3 (Two spray B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 & 50 DATP). Similar tread of results was reported by Chaudhari *et al.* (2017a) [14] and Moklikar *et al.* (2018) [39] in cauliflower and Mehraj *et al.*, (2015) [38] in okra.

Yield Parameters: Fresh weight of curd (g)

Effect of micronutrients and their method of application on fresh weight of curd (g) Effect of micronutrient: Data (Table 3) revealed that fresh weight of curd was significantly influenced by different micronutrients. Treatment C7 *i.e.*, B + Zn + Fe was found significantly superior and it recorded the highest fresh weight of curd. According to Reddy (2004) [53] micronutrients help in chlorophyll formation, nucleic acid, protein synthesis and play an active role in several enzymatic activities which ultimately improve the yield attributes. These results are closely related with Kant *et al.* (2013) [27] and Chandni *et al.* (2020b) [13] in cauliflower, Patel *et al.*, (2021) [50], Alam (2007) [5], Narayanamma *et al.* (2007) [42] and Ahmed *et al.* (2011) [3] in cabbage and Singh *et al.* (2017) in broccoli.

Method of application: Significantly maximum fresh weight of curd was recorded in treatment M3 (Two spray of micronutrients). Though it was statistically at par with treatment M2 (Single spray of micronutrients). This result is in conformity with the finding of Singh *et al.* (2018) [67] in cauliflower and Abd *et al.* (2018) [1] in broccoli.

Interaction effect: The maximum fresh weight of curd was recorded in treatment C7M3 (Two spray of B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 & 50 DADP) and it was statistically at par with treatment C7M2. The superiority of combined effect lies in the results of main effect and due to synergistic role of both the factors. Earlier, Sharma (1995) [57] recorded similar results in tomato.

Sprout weight (g) per plant

Effect of micronutrients and their method of application on sprout weight (g) per plant Effect of micronutrient: Data represented in Table 3 showed that sprout weight per plant (g) was significantly affected by different micronutrients. Treatment C7 (B + Zn + Fe) recorded maximum sprout weight per in pooled analysis.

Effect of method of application: The maximum sprout weight per plant in pooled analysis was recorded with treatment M3 (Two spray of micronutrient at 25 and 50 DATP).

Interaction effect: Data presented in Table 3 showed that interaction effect between different micronutrients and their method of application was found statistically non significant.

Table 3: Effect of micronutrients and their methods of application on plant spread, days taken for curd initiation and curd harvesting

	Fresh weight of curd (g)				Sprout weight (g) per plant				Number of sprouts per plant			
	Pooled				Pooled				Pooled			
Treatment	**M1**	**M2**	**M3**	**Mean (C)**	**M1**	**M2**	**M3**	**Mean (C)**	**M1**	**M2**	**M3**	**Mean (C)**
C1	166.32	207.74	238.46	204.17	77.27	87.88	107.58	90.91	11.07	11.00	10.41	10.82
C2	215.76	239.32	239.15	231.41	103.45	123.17	128.09	118.24	12.80	12.55	12.47	12.60
C3	213.52	229.71	230.44	224.56	97.83	112.43	110.62	106.96	11.53	12.42	12.06	12.00
C4	237.30	249.48	257.56	248.11	101.59	131.54	146.33	126.49	11.73	13.32	13.84	12.96
C5	244.21	246.47	253.42	248.03	121.07	124.58	127.64	124.43	12.64	11.74	12.44	12.27
C6	248.39	247.74	268.59	254.90	132.28	136.12	147.09	138.50	12.97	13.07	13.38	13.14
C7	270.18	288.27	292.92	283.79	140.53	147.91	174.23	154.23	12.97	13.27	14.47	13.57
Mean (M)	227.95	244.10	254.36	242.14	110.57	123.38	134.51	122.82	12.24	12.48	12.72	12.48
	C	M	C x M		C	M	C x M		C	M	C x M	
S.Em. ±	5.67	2.96	7.82		4.40	2.57	6.81		0.21	0.14	0.36	
C.D. (P=0.05)	16.54	8.38	22.16		12.84	7.30	NS		0.63	NS	1.03	
CV %	7.91				13.58				7.11			
	C X Y	M X Y	C X M X Y		C X Y	M X Y	C X M X Y		C X Y	M X Y	C X M X Y	
S.Em. ±	8.01	4.18	11.06		6.22	3.64	9.63		0.30	0.19	0.51	
C.D. (P=0.05)	NS	NS	NS		NS	NS	NS		NS	NS	NS	
CV %	7.91				13.58				7.11			

Number sprouts per plant

Effect of micronutrients and their method of application on number of sprouts per plant Effect of micronutrient: Treatment C_7 (B + Zn + Fe) found significantly and recorded maximum number of sprouts per plant in pooled analysis, it was at par with treatment C_6 (Zn + Fe) and C4 (B + Zn). It is due to the role of micronutrients in growth and development of plant and curd. These results are in line with these reported by Zarghamnead *et al.* (2015) [73] in tomato and Mehraj *et al.* (2015) [38] in okra.

Effect of method of application: Data regarding effect of method of application of micronutrients represented in Table 3 revealed that it was statistically non significant. Interaction effect: The significantly maximum numbers of sprouts per plant in pooled analysis was recorded in treatment C7M3 (Two spray of B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 & 50 DATP), which was at par with treatment C4M3 (Two spray of B @ 100 ppm + Zn @ 100 ppm at 25 & 50 DATP). It is due to the role of micronutrients and method of application. These results concur with the findings of Ain *et al.* (2016) [4] in broccoli.

Yield per plot (kg)

Effect of micronutrients and their method of application on yield per plot (kg)

Effect of micronutrient: Data presented in Table 4 showed that yield per plot (kg) was significantly affected by different micronutrients. Treatment C7 *i.e.*, B + Zn + Fe recorded maximum yield per plot with 3.95 kg in pooled analysis. Increase in the yield per plot was due to the combined

application of boron, zinc and iron which helped to increase the uptake of boron, zinc, iron, manganese and copper in vegetable crops. Micronutrients improve photosynthesis and facilitate transportation of assimilated source to sinks and finally increases yield. Our results correlated with Mallick and Muthukrishan (1980) [37], Singh and Thakur (1991) [59], Chaudhari *et al*. (2017b) [15] and Chandni *et al*. (2020b) [13] in cauliflower and Patel *et al*. (2021) [50] in cabbage.

Effect of method of application: Data regarding effect of method of application of micronutrient on yield per plot are presented in Table 4, which showed significant influence. The maximum yield per plot 3.64 kg in pooled analysis was recorded with treatment M3 (Two spray of micronutrients). Foliar spray of micronutrients improves photosynthesis, yield and assimilates transportation to sink and finally increase yield (Alvarez *et al.*, 2003) [7]. This might be due to the fact that, micronutrients activate several enzymes and involves in synthesis and activity of chlorophylls, thereby it increases the photosynthesis. Ability to photosynthesize and produce more food increase the generative power and thereby upscaled the yield. Rafique *et al.* (2004) [51] who have also reported that foliar feeding of micronutrients increased the yield. The present results are collaborating the finding of Kanujia *et al.* (2006) [28], Nandi and Nayak (2008) [41] and Patel *et al.* (2021) [50] in cabbage, Moklikar *et al.* (2018) [39] and Chandni *et al.* (2020b) [13] in cauliflower.

Interaction effect: It is seen from the data (Table 4) that in pooled analysis of yield per plot (kg) was significantly influenced by different micronutrients and method of application. Maximum yield per plot 4.19 kg was significantly recorded by treatment C7M3 (Two spray of B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 and 50 DATP), which was statistically at par with treatment C7M2 (Single spray of B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 DATP). The superiority of interaction effect of micronutrients and method of application is due to beneficial effect of both the main factor. The results are close accordance with Singh *et al*. (2018) [67] in broccoli.

Yield per hectare (q)

Effect of micronutrients and their method of application on yield per plot (kg)

Effect of micronutrient: Treatment C7 *i.e.*, B + Zn + Fe was found statistically superior and recorded the maximum yield per hectare 243.90 q in pooled analysis. Boron, zinc and iron application increased dry matter production of fruits may be due to greater accumulation of photosynthates by vegetative parts and it subsequent translocation to the sink. Also, role of these micronutrients which enhance the movement of sugar from the leaves to the fruit and ultimately increase the yield according to results given by Singh *et al*. (2003a) [64]. Increase yield in response to micronutrients is also reported by Mallick and Muthukrishan (1980) [37], Singh and Verma (1991) [66] and Hussein *et al*. (2012) [24] in tomato, Hatwar *et al*. (2003) [21] in chilli, Choudhary and Mukherjee (1999) [18] and Lashkari *et al*. (2007) [35] in cauliflower and Singh *et al*. (2017) [61] in broccoli.

Effect of method of application: The maximum significant yield per hectare 224.59 q in pooled was recorded in treatment M3 (Two spray of micronutrients). It was at par with treatment M2 (Single spray of micronutrients) in pooled. Yield and yield producing attributes were found the best in two foliar sprays than single and soil application. It may be due to getting the sufficient amount of these nutrients which stimulated enzymatic activities (Oostherhuits and Weir, 2010) [44], leading to an improvement in biochemical process like photosynthesis, respiration and protein synthesis (Cheniae and Martin, 1970) [16]. Inadequate level of micronutrients may be responsible for less plant growth and yield and for that reason two times foliar application made the plants adequate absorption and utilization of these nutrients that accelerated plant growth and registered a higher yield. The results of the present studies are in consonance with those of Mehraj *et al.* (2015) [38] in okra, Chandni *et al*. (2020b) [13] in cauliflower and Patel *et al*. (2021) [50] in cabbage and Singh *et al*. (2017) [61] in broccoli.

Interaction effect: The maximum yield per hectare 258.44 q was recorded in treatment C7M3 (Two spray of B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 & 50 DATP) which was statistically at par with treatment C7M2 (Single spray of B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm at 25 DATP). These results are in close accordance with Pandita *et al.* (1976) [46], Hooda *et al.* (1984) [23] and Kumbhar and Deshmukh (1993) [34] in tomato, Singh *et al*. (2017) [61] and Chandni *et al*. (2020b) [13] in cauliflower, Patel *et al*. (2021) [50] in cabbage and Yilmaz *et al*. (2013) [72] in broccoli.

Table 4: Effect of micronutrients and their methods of application on yield per plot and yield per hectare

	Yield per plot (kg)				Yield per hectare (q)			
	Pooled				Pooled			
Treatment	**M1**	**M2**	**M3**	**Mean (C)**	**M1**	**M2**	**M3**	**Mean (C)**
C1	2.63	2.67	3.30	2.86	162.04	164.51	203.50	176.68
C2	2.71	3.34	3.34	3.13	167.49	206.07	206.28	193.28
C3	2.89	2.95	3.23	3.02	178.50	181.79	199.07	186.45
C4	3.24	3.79	3.87	3.63	199.90	233.64	238.89	224.14
C5	3.23	3.81	3.81	3.62	199.59	235.29	235.19	223.35
C6	3.40	3.73	3.74	3.62	209.88	230.25	230.76	223.63
C7	3.75	3.92	4.19	3.95	231.48	241.77	258.44	243.90
Mean (M)	3.12	3.46	3.64	3.41	192.70	213.33	224.59	210.20
	C	M	C x M		C	M	C x M	
S.Em. ±	0.10	0.04	0.11		6.02	2.55	6.75	
C.D. (P=0.05)	0.28	0.12	0.31		17.59	7.23	19.14	
CV %	7.87				7.87			
	C X Y	M X Y	C X M X Y		C X Y	M X Y	C X M X Y	
S.Em. ±	0.14	0.06	0.15		8.52	3.61	9.55	
C.D. (P=0.05)	NS	NS	NS		NS	NS	NS	
CV %	7.87				7.87			

Conclusions

Based on the results of two years study, it can be inferred that under the North Gujarat condition maximum yield and profitable income from broccoli cultivation during *Rabi* season can be harvested with the combined application of micronutrient *i.e.*, B @ 100 ppm + Zn @ 100 ppm + Fe @ 100 ppm through two foliar spray at 25 and 50 DATP along with RDF.

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