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Effect of micronutrients (Boron and Molybdenum) on yield and quality traits of Broccoli (*Brassica oleracea* var. *italica*) under polyhouse

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Abstract
The present investigation was formulated to find out the efficiency of micronutrients (boron and molybdenum) in improving the yield and quality traits of broccoli. The whole study was carried out for two consecutive of *Rabi* season during year 2018-19 and 2019- 20 in poly house conditions at the Department of Plant Physiology, Agricultural Biochemistry, Medicinal and Aromatic Plants, College of Agriculture, Raipur, Chhattisgarh. The study was conducted in complete randomized block design (RBD) with three replications and experimental material comprised Shishir F_1 hybrid of broccoli. Various combinations of micronutrients *viz*., boron and molybdenum (0.25%, 0.50%, 0.75%, 1.00%, and 1.25%) were used along with control during the study. The treatments were given as foliar application to the crop. Different quality traits such as protein content, total sugar, ascorbic acid content, total soluble solids, starch content and final curd yield plant^{-1} were recorded during the Study. The results revealed that the combined application of all both micronutrients at any concentration significantly improved the quality traits as well as yield of the plants compared to control. The most promising results were obtained when crop received a combined treatment of B and Mo at 0.75% with basal dosage of N, P, and K followed by a combined application of B and Mo at 1.0% with 100% RDF compared to control and rest of treatments. Therefore from the present study, it can be inferred that application of boron and molybdenum (0.75%) in combination along with basal dosage (100%) was highly effective in improving the both quality and quantity traits of broccoli.

Keywords: Broccoli, micronutrients, boron, molybdenum, quality and quantity traits

1. Introduction
Producing vegetables is one of man's fundamental skills. The name "broccoli" (*Brassica oleracea* L. var. *italica*) is derived from the Italian word "broccolo," which means "the flowering crest of cabbage," which implies "tiny nail" or "a sprout." Broccoli, a member of the Brassicaceae family (2n=18), is a dicotyledonous biennial herbaceous and is regarded as an annual plant when used for seed production (Yamayuchi, 1983) [28]. According to Sermenli (2011) [20], broccoli is a "cole crop" that originated in the Mediterranean region. It is a cool-weather crop that thrives when daily average temperatures range from 18 to 23 °C (Baloch, 1994) [6], and due to this, the crop is suitable for cultivation in regions with mild weather.
The crop has a high vitamin C content, which lowers the risk of cardiovascular disease (Du *et al*., 2012) [10]. In addition, it contains a small amount of goitrogens, which are naturally occurring compounds that can be helpful in the normal functioning of the thyroid gland. As a source of vitamins, antioxidants, glucosinolates, and other anti-carcinogenic components, broccoli is regarded as a useful vegetable crop (Parente *et al*., 2013) [16].
China is the largest producer worldwide of broccoli followed by India, the United States, Spain, Italy, France, Mexico, Poland, Pakistan, and the United Kingdom (FAO statistics, 2017) [11]. Broccoli is underutilized in India and mostly grown in small regions, particularly near major cities.
Despite growing soil nutrient deficiencies, modern agriculture heavily relies on chemical pesticides, fungicides, and fertilisers. According to Bukvić *et al.* (2003) [8], this condition confirms the notion that about 60% of the world's arable land is unsuitable for crop production due to deficiencies of one or more of the nutrients necessary for growing healthy plants. Moreover, human activities, erosion, soil acidity, alkalinity, and salinity may further result in a deficiency of macro- and micronutrients, thus contributing to soil degradation.
To improve the productivity and quality of broccoli, nutrient management strategies including fertilising with nitrogen and other macronutrients are critical. In addition to macronutrients, micronutrients are also necessary, albeit in very small amounts, for optimal crop growth and a

good yield (Salwa *et al.* 2011) [19]. Micronutrients are essential for photosynthesis, respiration, meristematic tissue growth, cell division, and the quickening of plant maturity (Zeidan *et al*., 2010) [29]. Application of fertiliser/amendments to the soil or foliar spray could make up for the lack of soil nutrients, particularly micronutrients.

Boron (B) and molybdenum (Mo) are critical micronutrients, as both nutrients act as catalysts for numerous enzymes and other physiologically active molecules that are needed for regular growth and to increase production (Alloway and Brain, 2008) [4]. It was observed that boron accelerated crop growth and yield since it promotes the growth of pollen tubes, cell walls, and other plant tissues. However, deficiency of boron and molybdenum is frequently observed in soils. The affected curds are malformed in shape, size, flavour (they are bitter), and productivity, which declines the market price. On the other hand, molybdenum (Mo), a component of the meta-protein nitrogenase, aids in N_2 fixation (Gupta and Vyas, 1994) [12]. Hollow stems, browning of the heads and whiptail are common disorders caused by a deficiency of these nutrients (Shelp *et al*., 1992) [21].

The effects of boron and molybdenum on broccoli are not well understood despite broccoli being a highly valued vegetable crop globally. Hence, considering these perspectives in the account, the present study was carried out with an objective to find out the effect of foliar application of micronutrients (boron and molybdenum) on quality and quantity aspects of broccoli.

2. Material and Methods

The study was carried out for two consecutive of Rabi season during year 2018-19 and 2019- 20 in poly house conditions at the Department of Plant Physiology, Agricultural Biochemistry, Medicinal and Aromatic Plants, College of Agriculture, Raipur, Chhattisgarh. The experiment was laid out in complete randomized block design with three replications and experimental material comprised Shishir F_1 hybrid of broccoli. The quality traits, *viz*., protein content, total sugar, ascorbic acid content, total soluble solids, starch content and final curd yield plant^{-1} were recorded after the foliar application of micronutrients. The micronutrients were applied as foliar spray two times i.e., at 20 and 40 days after transplanting (prior to flowering stage). The different treatments, i.e., T_0- control−Recommended Dose of Fertilizers (RDF), T_1- RDF + (MO + B at 0.25%), T_2- RDF + (MO + B at 0.50%), T_3- RDF + (MO + B at 0.75%), T_4- RDF + (MO + B at 1.0%), T_5- RDF + (MO + B at 1.25%) were given to the crop. The seedlings were irrigated at regular interval and need based plant protection measures were taken up as and when necessary. The seedlings were ready for transplanting within three weeks.

3. Results and Discussion

The data recorded on various quality traits and revealed significant differences. The mean performances under each treatment are presented in table 1 and 2.

Table 1: The effect of micronutrients (boron and molybdenum) on TSS, final curd yield and protein content without leaves of broccoli cultivar Shishir F_1 hybrid in Rabi season during year 2018-19 and 2019-20

Treatments	Total Soluble Solids (^{0}Brix)			Final curd yield (g)			Protein content (%)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
T_0(Control)	6.60	7.40	7.00	263.38	329.47	296.40	4.81	5.60	5.21
T_1 RDF + (Mo + B 0.25%)	7.50	7.70	7.60	326.67	326.69	326.67	5.95	6.39	6.17
T_2 RDF + (Mo + B 0.50%)	7.19	7.28	7.24	303.33	370.00	303.33	5.69	6.04	5.87
T_3 RDF + (Mo + B 0.75%)	8.33	8.43	8.38	382.00	466.87	424.43	6.13	7.35	6.74
T_4 RDF + (Mo + B 1.0%)	8.10	8.27	8.19	368.29	405.66	387.83	5.78	6.74	6.26
T_5 RDF + (Mo + B 1.25%)	7.89	8.01	7.95	356.70	303.33	384.17	5.87	6.21	6.04
C.V.	3.68	2.68	2.46	5.39	8.15	4.63	6.13	7.62	6.74
SE(m)	0.17	0.12	0.11	10.38	17.60	9.45	0.20	0.28	0.23
C.D.	0.53	0.39	0.36	33.14	56.18	30.17	0.64	0.90	0.75

Table 2: The effect of micronutrients (boron and molybdenum) on vitamin C, starch content and total sugar content without leaves of broccoli cultivar SHISHIR F1 HYBRID in Rabi season during year 2018-19 and 2019-20

Treatments	Vitamin C (mg/100g)			Starch content (%)			Total sugar content (%)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
T_0(Control)	1.58	1.67	1.63	3.62	3.70	3.66	3.07	2.88	2.98
T_1 RDF + (Mo + B 0.25%)	1.82	1.76	1.79	3.76	3.81	3.79	3.21	3.14	3.18
T_2 RDF + (Mo + B 0.50%)	1.88	1.92	1.90	3.98	4.24	4.11	3.04	3.17	3.11
T_3 RDF + (Mo + B 0.75%)	2.01	2.05	2.03	4.12	4.41	4.26	3.56	3.47	3.52
T_4 RDF + (Mo + B 1.0%)	2.29	2.24	2.27	3.87	4.08	3.98	3.38	3.28	3.33
T_5 RDF + (Mo + B 1.25%)	2.20	2.44	2.32	3.98	3.92	3.95	3.19	3.13	3.16
C.V.	3.82	3.66	3.11	2.95	2.23	1.73	8.35	2.52	4.36
SE(m)	0.04	0.04	0.04	0.07	0.05	0.04	0.16	0.05	0.08
C.D.	0.14	0.14	0.11	0.21	0.17	0.12	0.14	0.15	0.13

3.1 Protein content

The protein content was recorded and analysis of variance showed significant variations. The mean performance under each treatment is depicted in presented in Table 1.

The protein content ranged from 4.81 to 6.13% with an average of 5.71%, from 5.60 to 7.35% with a mean of 6.39% during first and second year respectively. The *per se* performance showed that the highest protein content was recorded when plants were treated with a combined application of B and Mo at 0.75% along with a basal dose of N, P, and K at 100% (T_3) followed by treatment T_4 (B and Mo at 1.0% in combination with 100% RDF) compared to the control and the rest of the treatments during both the seasons.

The experimental results indicated that various treatments of

micronutrients (B and Mo) significantly affect the protein content in curd and it was found to increase due to foliar application of B and Mo compared to control. These obtained results are in good agreement with the findings of Saha *et al.* (2010) [18], Tudu *et al.* (2020) [26], and Netwal *et al.* (2021) [14] in broccoli. Molybdenum (Mo) is an important constituent of the meta-protein nitrogenase, and aids in N_2 fixation (Gupta and Vyas, 1994) [12]. The micronutrient involves in the absorption of nitrogen and nitrogen metabolism, which leads to higher protein content in broccoli heads (Weisany *et al.* 2013) [27].

3.2 Total soluble solids

The recorded data on total soluble solids (T.S.S.) were recorded and were found to be significant during both seasons. During the first year, the range of variation for T.S.S. was from 6.60 to 8.33 brix, with a mean of 7.60 brix. Similarly, in second year T.S.S. ranged from 7.28 to 8.43 brix, with a mean of 7.85 brix. Among the various treatments, foliar spray of B and Mo at 0.75% in combination with RDF at 100% (T_3) was found most promising and resulted in maximum TSS, followed by foliar application of B and Mo at 0.1% in combination with RDF at 100% (T_4) compared to the rest of the treatments and control during both the years.

The present findings indicated that foliar application of micronutrients (B and Mo) when given in any combination results in an improvement in TSS, and these results are in good accordance with the reports of Singh *et al.* (2018) [23], Tudu *et al*. (2020) [26], and Netwal *et al.* (2021) [14] in broccoli. The improvement in the TSS content of broccoli heads with the application of micronutrients might be attributed to increased metabolic activities associated with the production of total soluble solids, such as carbohydrates, organic acids, amino acids, and other inorganic elements (Acharya *et al.* 2015) [1]. This might be due to the increased carbohydrate production during the process of photosynthesis and the photosynthetic activity of plants.

3.3 Total sugar content

The data on total sugar content was recorded and found significant during both seasons. The performance revealed that total sugar content varied from 3.04 to 3.56% with a mean of 3.24% during the first year; whereas from 2.88 to 3.47% with a mean of 3.18% during the second year. It was observed that the application of micronutrients (B and Mo) significantly increased the total sugar in curd of broccoli. The maximum total sugar was recorded with a combined application of B and Mo at 0.75% in combination with 100% RDF (T_3) followed by B and Mo at 1.0% with 100% RDF (T_4) during both seasons compared to the rest of treatments and control.

The mean performance indicates that total sugar content (reducing and non-reducing sugars) significantly increased due to the foliar application of B and Mo compared to the control. These results conform to the results obtained by Thapa *et al.* (2013) [25] and Singh *et al.* (2018) [23]. The previous reports indicated that Mo enhanced the sugar content in broccoli.

In addition, the role of B in the translocation of sugars, carbohydrate transportation, and metabolism is also well documented (Ain *et al.* 2016) [2]. These findings suggested that both B and Mo are promising in enhancing the total sugar content in broccoli.

3.4 Ascorbic acid content

The recorded data on vitamin C (ascorbic acid) content was recorded and it was found significant during both seasons. During the first year, the vitamin C content significantly varied from 91.60 to 83.29 mg/100g with a mean of 88.03 mg/100g; whereas during second year it ranged from 89.95 to 82.18 mg/100g with a mean of 87.23 mg/100g. The results indicated that the highest vitamin C content was obtained when plants were treated with foliar application of B and Mo at 0.75% in addition to RDF at 100% (T_3) followed by foliar application of B and Mo at 0.1% in combination with addition with RDF at 100% (T_4) compared to rest of treatments and control during both the years.

It was noticed from the present findings that vitamin C (ascorbic acid content significantly higher due to the application of boron and molybdenum. Similar results were also obtained by Pankaj *et al.* (2018) [15], and Patel *et al.* (2017) [17] in broccoli. The boron and molybdenum meet up need-based essential nutrients in plants and may create the synergistic effects to enhance the photosynthetic rate for greater development and growth of broccoli which finally mobilize the ascorbic acid biosynthesis to accumulate vitamin C in broccoli heads. These results are consistent with the results of broccoli (Tarafder *et al.* 2023) [24].

3.5 Starch content

The results about starch content were recorded during both seasons and found significant. In the first year, the starch content ranged from 4.12 to 3.62 mg/100g with a mean value of 3.89 mg/100g; while from 4.41 to 3.70% with an average of 4.03 mg/100g during second year. The maximum starch content in curd was recorded when plants received a combined treatment of B and Mo at 0.75% + RDF at 100% (T_3) followed by a combined treatment of B and Mo at 0.1% + RDF at 100% (T_4) compared to rest of treatments and control during both the years.

The present findings indicated that a foliar spray of micronutrients (boron and molybdenum) at any concentration increased the starch content. Boron is unique among the essential mineral micronutrients because it is the only element that is normally present in soil solution as a non-ionized molecule over the pH range suitable for plant growth. Boron is involved in the transformation of sugar and starch formation. It also influences cell development and elongation. Boron affects carbohydrate metabolisms and starch formation and synthesis.

Similarly, the promotive role of Mo in increasing the starch content was observed by Li *et al.* (2017) [30]. It was reported that Mo enhances due to the higher photosynthetic capacity of leaves and also the activity of starch phosphorylase activity, leading to a higher starch and sugar content in mature fruits.

3.6 Final curd yield plant^{-1}

The data on the final curd yield of plant-1 was recorded and found to be significant during both the seasons. In the first season, it varied from 263.38 to 382.00 g, with an average curd yield of 333.68 g; whereas from 329.47 to 466.87 g with a mean of 382.28 g in second year. The maximum curd yield was noticed under a combined application of B and Mo at 0.75% as a foliar spray in addition to a basal dose of N, P, and K at 100% (T_3), followed by B and Mo at 1.0% in combination with RDF at 100% (T_4) compared to the control and rest of the treatments.

The experimental results indicated that due to the application of different treatments, the curd yield significantly varied, and it was found to be highest with the combined application of micronutrients B and Mo. This increase in the curd yield by the application of micronutrients may be attributed to their role in enhancing the translocation of carbohydrates from the site of their synthesis to the storage tissue in the curd, and our interpretation is in close conformity with the findings of Singh *et al.* (2018) [23], and Tudu *et al.* (2020) [26].

Various researchers reported that the yield of broccoli is affected by cultivars, nitrogen doses, seedling age, planting time, and plant density. Boron plays an important role in many biochemical processes in plants, like carbohydrate metabolism and the transport of sugar through membranes, tissue development, and cell division (Thapa *et al*., 2013) [25]. Pizetta *et al.* (2005) [31], in their studies with broccoli, cabbage, and cauliflower, obtained positive results in growth, development, and yield due to the increase in boron dose, thus showing the positive relationship between boron application and the increase in yield of Brassicaceae species.

4. Conclusion

The qualitative and quantitative parameters were recorded under the polyhouse conditions and found to increase due to application of micronutrients (boron and molybdenum). The experimental findings indicated among the different concentrations given to the crop, the most promising results were obtained with the application of combined application of B and Mo at 0.75% as a foliar spray in addition to a basal dose of N, P, and K at 100% (T_3), followed by B and Mo at 1.0% in combination with RDF at 100% (T_4) compared to the control and rest of the treatments. In conclusion, both micronutrients when applied in combination were highly effective in improving the qualitative and quantitative parameters in broccoli.

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