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Foliar application of micronutrient formulations for enhanced growth and yield of cabbage

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ABSTRACT

Cabbage is a prominent leafy vegetable belonging to the cole group of vegetables. To enhance cabbage productivity, effective nutrient management, particularly through the use of micronutrients, is a crucial practice. Consequently, the present study was conducted to assess the efficacy of four laboratory-prepared micronutrient formulations (Micromix A; Mix-A, Micromix B; Mix-B, Micromix C; Mix-C and Micromix D; Mix-D) on growth and yield of cabbage. For comparison two micronutrient formulations available in the market, Arka Vegetable Special (Arka Veg-Special) and Agromin were also undertaken in this study. The results showed a significant improvement in morphological parameters like fresh stem weight, fresh root weight, root length, head weight per plant and open leaf weight per plant as a result of foliar application of micronutrient formulations in comparison to the control. Additionally, it was discovered that foliar application of Mix-A, Mix-B, Mix-C and Mix-D increased the yield of cabbage by 14.04%, 20.25%, 27.14% and 23.14%, respectively over the control. Furthermore, among different formulations, Mix-C proved to be more effective compared to the other treatments. Thus, it can be inferred that foliar application of micronutrients has great potential in improving the yield and yield characteristics of cabbage.

Key words: Micronutrient deficiency, root growth, vegetative growth, head compactness, head shape index.

INTRODUCTION

Cabbage (*Brassica oleraceae* var. *capitata* L.) is cool a season vegetable, originated in Mediterranean region and belongs to the Cruciferae family. It is widely cultivated across the temperate to tropical regions of the globe (Singh *et al*., 17). In India, the chief cabbage- producing states are Odisha, Maharashtra, Bihar, West Bengal, Gujarat and Jharkhand. Cabbage is consumed both raw and cooked, and is utilized in a wide variety of dishes such as soups, salads, slaws and stews. It serves as a good source of nutrition as it is rich in minerals, vitamins and dietary fibres content (Kumar *et al*., 7). Its consumption increases appetite, speed up the process of digestion and prevents constipation (Yadav *et al*., 20).

Horticultural crop production often encounters the problem of micronutrient deficiency (boron, iron, copper, zinc, manganese, chloride and molybdenum), which leads to limited growth and development of plants, which ultimately causes a reduction in yield and quality (Raja, 12). Micronutrients exhibit a pivotal role in chlorophyll, nucleic acid, and protein synthesis in plants. They are also engaged in various enzymatic activities like photosynthesis and respiration (Singh and Dwivedi, 18). However, micronutrient deficiency is a major problem faced by vegetable growers today. The intensive agricultural practices, imbalanced fertilizer application, and nutrient exhaustion, and lack of replenishment are the main reasons behind this deficiency. Previous studies have shown that the application of micronutrient fertilizers enhances both the yield and quality of the produce (Shoormij *et al.*, 16). Although there are numerous methods for applying micronutrients in crop production, such as soil application, seed priming, foliar application, and side dressing, foliar application is the cheapest and fastest method (Shahzad *et al*.,15). Studies have demonstrated that each crop has specific micronutrient requirements, which depend on various factors such as metabolic activities, root growth, and the presence of root-associated microorganisms (Graham *et al*., 5). Despite the wide array of benefits offered by micronutrient formulations, limited efforts have been made towards developing specific formulations for cabbage. Therefore, the present investigation was conducted to develop micronutrient formulations aimed at addressing the problem of micronutrient-deficiency and increasing the cabbage yield.

MATERIALS AND METHODS

The particular experiment was carried out at the ICAR-Indian Institute of Vegetable Research, Varanasi and ICAR-IIVR Regional Research Station,

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Sargatia, Kushinagar during the *Rabi* seasons of the year 2019-20 and 2020-21, respectively**.** The study aimed to investigate the effect of laboratory-prepared micronutrient formulations (Micromix A; Mix-A, Micromix B; Mix-B, Micromix C; Mix-C, and Micromix D; Mix-D) on the growth and yield of cabbage. These formulations were prepared by blending essential plant micronutrients (Copper, Cu; Zinc, Zn; Iron, Fe; Manganese, Mn; Boron, B; Magnesium, Mg; Molybdenum, Mo and Potassium, K) in different proportions across all formulations (Table 1). Two commercially available micronutrient formulations, Arka Veg-Special (developed by ICAR-IIHR, Bengaluru) and Agromin (Aries Agro Ltd., Mumbai), were used for comparison. Agromin is hereinafter designated as the commercial formulation (Commercial F.). Twenty-day-old seedlings of cabbage (Ankur Manas, Hybrid) were transplanted on the ridge of the field. Four prepared micronutrient formulations (Mix-A, Mix-B, Mix-C, and Mix-D; dose @ 1.0 g/L), Arka Veg-Special (dose @ 3.0 g/L), and Agromin (dose @ 2.0 g/L) were applied four times at 10-day intervals starting 30 days after transplanting. Growth and yield parameters were then recorded. In the control plot, only water was sprayed to maintain similarity. The harvested cabbage heads from each treatment plot were weighed individually, and the yield per plot was determined and converted into quintals per hectare (q/ha). Five uniform plants were selected, randomly, in each treatment to record the open leaf weight per plant (g), head weight per plant (g), fresh stem weight (g), fresh root weight (g), and root length (cm). head compactness and head shape index were measured using the methods described by Pearson (11) and Odland and Noll (10), respectively.

Head shape index = Polar diameter of head/equatorial diameter of cabbage head

Head compactness = (Head weight × 100)/ average of the lateral and polar diameter of the head

Data was analysed using SPSS (version 27.0) software. The differences among treatments were analyzed using Duncan's Multiple Range Test (DMRT) at different levels of significance $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$.

RESULTS AND DISCUSSION

Foliar application of micronutrient formulations significantly improved head weight per plant (g), open leaf weight per plant (g), and yield (q/ha) in comparison to the control (Fig. 1). Specifically, foliar application of Mix-A, Mix-B, Mix-C, and Mix-D increased cabbage yield by 14.04, 20.25, 27.14, and 23.14%, respectively, over the control. Among the different micronutrient formulations, Mix-C proved to be the most effective in terms of yield (q/ha). Furthermore, it was observed that the efficacy of micronutrient formulations was influenced by the levels of the elements. Our findings align with previous research, which has indicated that usage of nano fertilizers increases external leaf weight (El-Henawy *et al*., 3). The foliar application of micronutrients is absorbed by the leaves, triggering vegetative growth and ultimately increasing yield. Similarly, Londhe (8) and Bahadur *et al.* (2) reported that balanced use of inorganic fertilizers, organic manures, and biofertilizers increases the head yield of cabbage.

Head compactness is an important trait from a consumer perspective when purchasing cabbage. In this study, head compactness ranged from 34.02 to 41.05 (Fig. 2a). Micronutrient treatments significantly increased head compactness compared to the control condition (Fig. 2a). Mix-D showed significantly higher head compactness than other micronutrient formulations. Additionally, Head shape index is another important characteristic from a consumer point of view, reflecting the shape of cabbage heads. A head shape index value > 0.8 denotes a flat or drumhead type, < 1.0 indicates a pointed head type, and between 0.8 and 1.0 indicates a normal (spherical) head type. In our study, head shape index values ranged between 0.8 and 1.0, indicating that all treatments produced normal (spherical) heads, which are preferred by consumers. Micronutrient treatments significantly increased the head shape index compared to the control condition (Fig. 2b), wherein Mix-B showed significantly higher head shape index than other micronutrient formulations (Fig. 2b; Fig. 3). Abdulhameed *et al*. (1) also

Table 1. Composition of different micronutrient formulations.

Treatment	Element							
	Zinc (%)	Iron (%)	Manganese (%)	Copper (%)	Boron (%)	Molybdenum (%)	Magnesium (%)	Potassium (%)
Micromix- A	2	2	1	0.5	2	2	1	1.25
Micromix- B	3	3	1.5	0.5	3	3	1.5	1.25
Micromix- C	4	5	2	1	4	4	2	2
Micromix- D	3.5	4	3	1	3.5	3.5	3	1.5

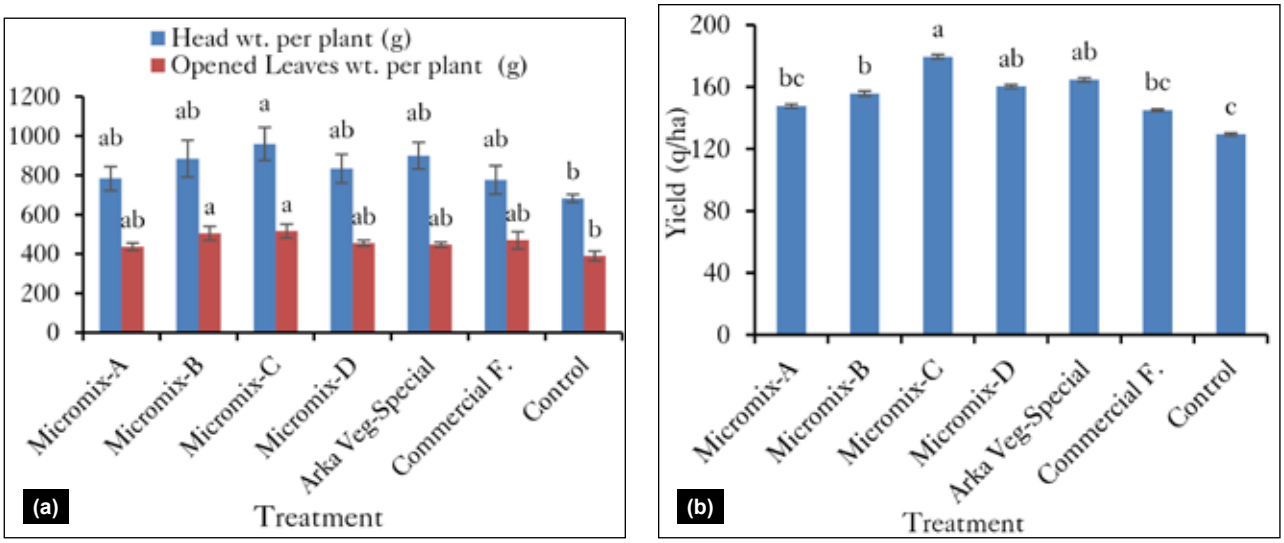


Fig. 1. Effect of micronutrient formulations on (a) head weight per plant (g) and (b) yield (q/ha) of cabbage.

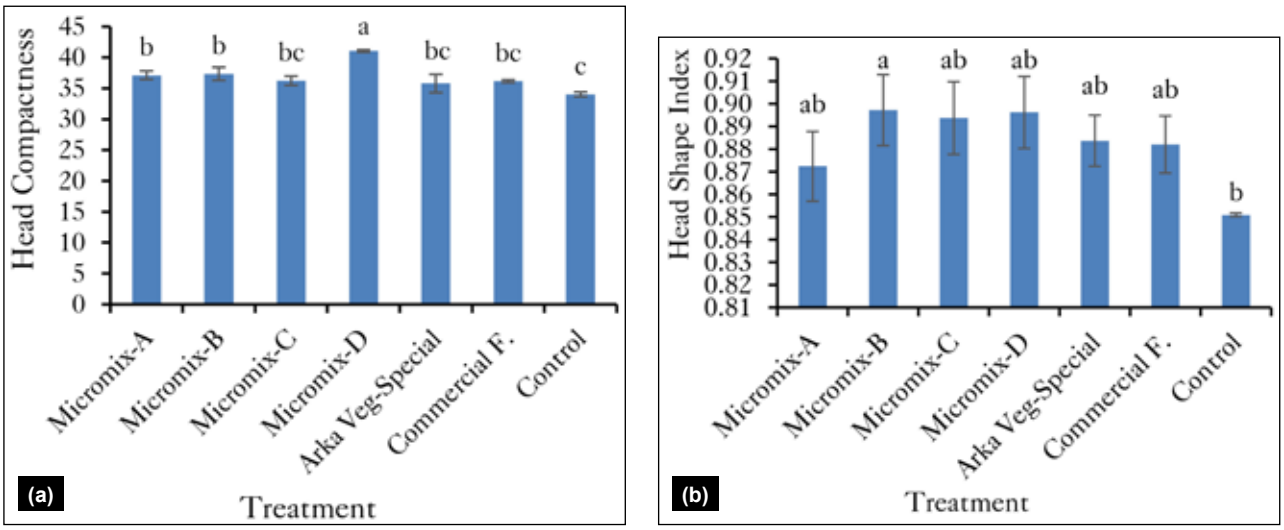
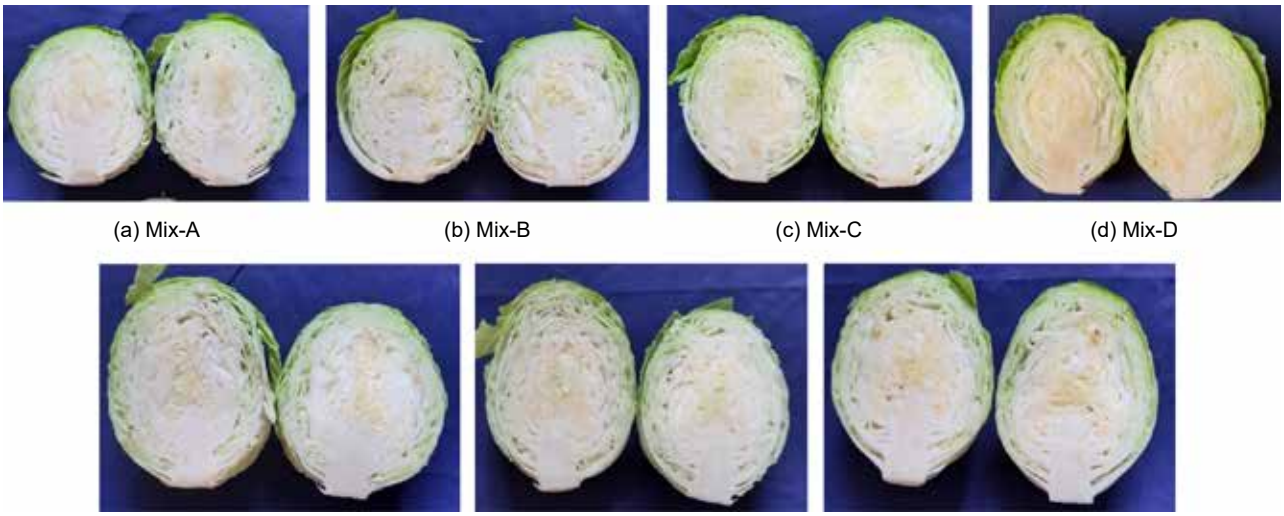


Fig. 2. Effect of micronutrient formulations on (a) head compactness and (b) head shape index of cabbage.

observed that NPK + Fe nano-fertilizer application increases head circumference in cabbage. This phenomenon is due to iron's contribution to raising plant hormone levels, such as auxin and gibberellin, which promotes greater cell division and growth (Rico *et al*., 13).

Furthermore, a significant difference was observed between the control and the micronutrient-treated plants for root length, fresh shoot and fresh root weight (Fig. 4a), whereas there was no significant difference in parameters like stem length and stem diameter (Fig. 4b) among the treatments. The micronutrient-treated cabbage plants have better developed root system as compared to control condition **(**Fig. 5) that may help them for affluent uptake of minerals and water through the roots which facilitate their growth and development (Aftab and Hakeem, 19).

The correlation analysis was conducted among head weight per plant, yield, head compactness, head shape index, stem length, stem diameter, stem weight, root length, root weight, and open leaf weight per plant (Table 2). Yield exhibited a significant positive correlation ($p < 0.01$) with stem length ($r = 0.77$), stem weight ($r = 0.81$), and open leaf weight per plant ($r = 0.77$). Additionally, the head shape index was significantly positively correlated ($p < 0.01$) with stem weight ($r = 0.77$), root weight ($r = 0.79$), and open leaf weight per plant ($r = 0.81$).



(a) Mix-A (b) Mix-B (c) Mix-C (d) Mix-D

(e) Arka Veg-Special (f) Commercial F. (g) Control

Fig. 3. Cabbage head under different treatment conditions (a) Mix-A, (b) Mix-B, (c) Mix-C, (d) Mix-D, (e) Arka Veg-Special, (f) Commercial F, and (g) Control.

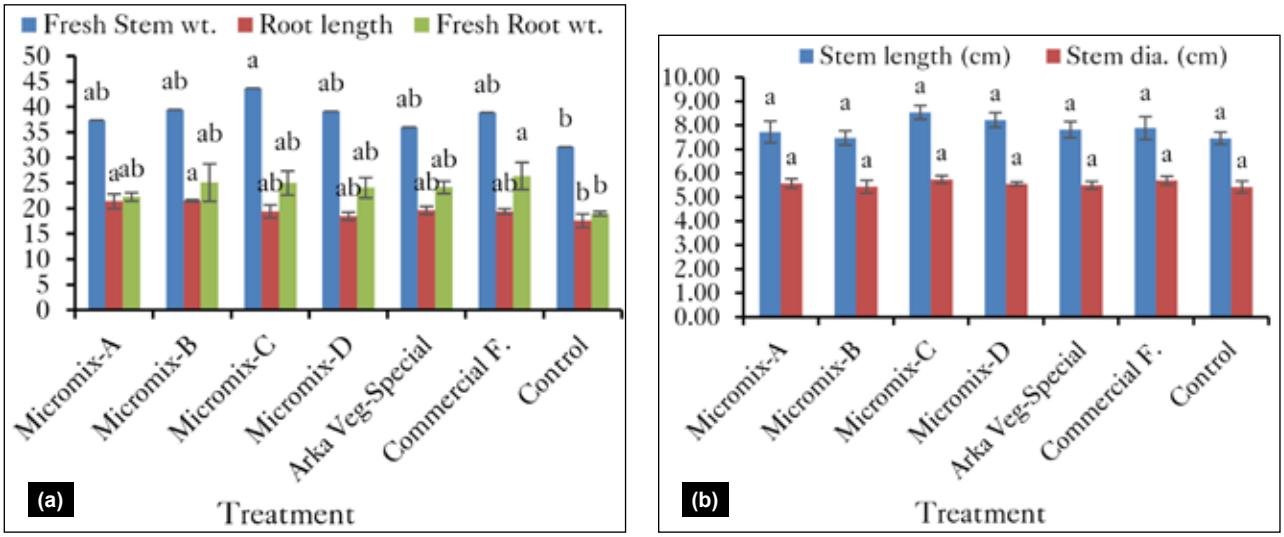
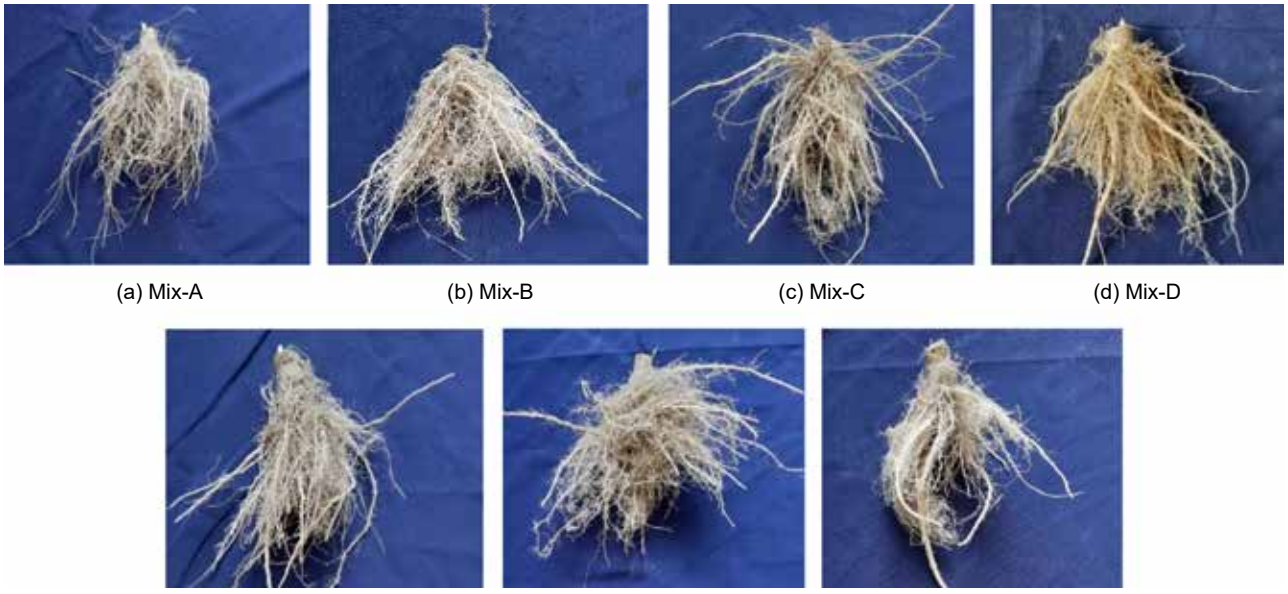


Fig. 4. Effect of micronutrient formulations on (a) fresh stem weight, fresh root weight and root length, and (b) stem length and stem diameter of cabbage.

The growth and yield traits of cabbage exhibited a positive response to the foliar application of micronutrient formulations. The nutrient sprays improved head weight per plant, open leaf weight per plant, yield, head compactness, head shape index, fresh stem weight, root length, and fresh root weight in the present study. Research indicates that micronutrient sprays, including Zn, Fe, and B, enhance crop yield by improving the physiological and biochemical processes (Aftab and Hakeem, 19; Sardar *et al*., 14). Zinc is vital for carbohydrate, chlorophyll, and DNA synthesis, while boron aids in carbohydrate translocation (Moniruzzaman *et al*., 9). Copper and manganese are crucial for antioxidant enzyme reactions (Ghorbani *et al*., 4). These micronutrients also stimulate hormone biosynthesis, such as auxins from zinc, which influence cell elongation and root branching, and abscisic acid from molybdenum, which is vital in stress response. Micronutrients are essential for plant growth and environmental adaptation.

In conclusion, exogenous application of micronutrient formulations on cabbage increases the yield, head compactness, head shape index,



(a) Mix-A (b) Mix-B (c) Mix-C (d) Mix-D

(e) Arka Veg-Special (f) Commercial F. (g) Control

Fig. 5. Cabbage root growth under different treatment conditions (a) Mix-A, (b) Mix-B, (c) Mix-C, (d) Mix-D, (e) Arka Veg-Special, (f) Commercial F. and (g) Control.

Table 2. Pearson correlation coefficients of morphological and yield traits in cabbage.

Parameter	Head weight/ plant	Yield	Head compactness	Head Shape index	Stem length	Stem diameter	Stem weight	Root length	Root weight	Open leaves weight/plant
Head weight/plant	1.00	0.97**	0.28	0.75	0.60	0.37	0.78*	0.38	0.66	0.83*
Yield		1.00	0.36	0.71	0.77*	0.50	0.81*	0.23	0.61	0.77*
Head compactness			1.00	0.74	0.40	0.11	0.44	0.14	0.38	0.30
Head shape index				1.00	0.47	0.25	0.77*	0.37	0.79*	0.81*
Stem length					1.00	0.81*	0.75	-0.22	0.46	0.52
Stem diameter						1.00	0.73	-0.01	0.58	0.52
Stem weight							1.00	0.36	0.77*	0.93**
Root length								1.00	0.40	0.49
Root weight									1.00	0.83*
Open leaves weight/ plant										1.00

**Means significance at 1% level of significance, *Means significant at 5% level of significance.

open leaf weight per plant, fresh stem weight, root length and fresh root weight. Among different micronutrient formulations, Mix-C proved more effective in terms of yield (q/ha) as compared to the other treatments. Furthermore, the foliar application of Mix-C not only enhances cabbage yield but is also likely to improve its nutritional value, thereby addressing issues related to nutritional security.

AUTHORS' CONTRIBUTIONS

Investigation and writing- original draft (RK), writing – review & editing (HK, AB), supervision (HK), methodology, visualisation and project Administration (RBY), data recording (KKY, RKV).

DECLARATION

The authors declare that there are no conflicts of interest regarding this article.

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