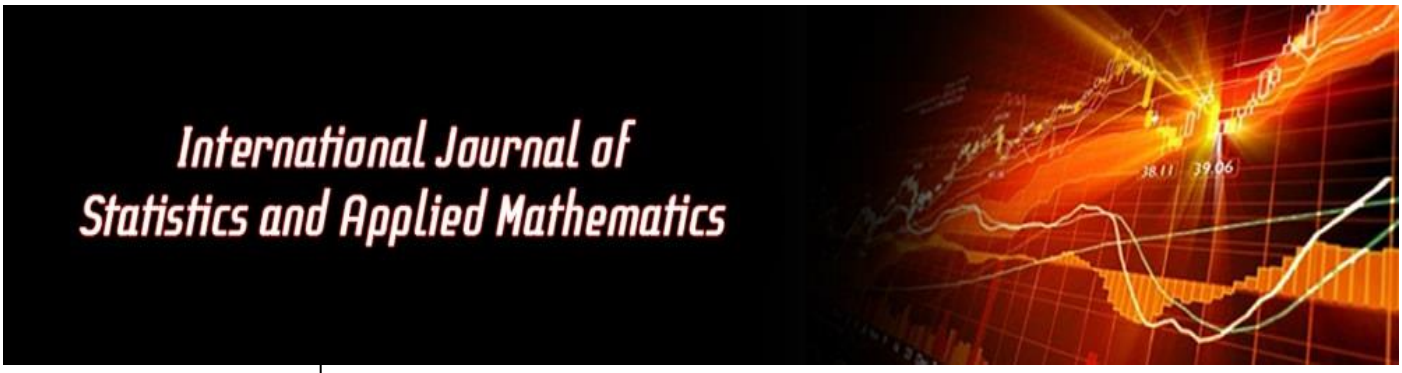

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Yield and yield attributes of cabbage as affected by foliar application of micronutrients and growth regulators in *vertisol* of central plain of C.G.

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Abstract
Micronutrient and growth regulators both play an important role in sustaining agricultural production under intensive cultivation and changing scenario of climate. Therefore, study was conducted to find out the effect of foliar application of micronutrients and growth regulators on growth and yield attributes of cabbage in a *Vertisol*. The present investigation was carried out during *Rabi* Season of the years 2017 and 2018 at Instructional Farm, IGKV Raipur (C.G.) with eighteen different combinations of foliar application of micronutrient (B + Mo + Fe + Zn) and growth regulators (GA_3 + NAA) with different micronutrient omission treatments. The present study demonstrates that combined effects of foliar application of micronutrient with growth regulators in Treatment T_{18} (B + Mo + Fe + Zn + GA + NAA) recorded maximum volume of had 90 leaf yield (22 q ha^{-1}) and head yield (455 q ha^{-1}) of cabbage. However, the micronutrients omission i.e. Fe, Mn, Cu, Zn, B and Mo was found to be significantly reduces the volume of head, diameter of head, leaf and head yield of cabbage. Large reductions in the yield of cabbage were observed with the omission of B (T_9) as compared to the other micronutrient omission treatments. This indicates that B (T_9) was the most yield limiting micronutrients followed by Fe (T_4), Zn (T_5) and Cu (T_7). However, the foliar application of micronutrient enhances the plant height, fruit diameter, leaf and head yield. Similarly, the foliar fertigation of growth regulators (GA_3 and NAA) may also significantly improve the growth and yield of cabbage. The combined effects of foliar application of micronutrient (100 ppm) with GA_3 (50 ppm) and NAA (80 ppm) in twice at 20 and 40 DAT was found to be most effective for significant increase in growth, and yield attributes of cabbage. Present work recommended that foliar fertigation of micronutrient (B + Mo + Fe + Zn) with growth regulators (GA + NAA) can enhance the growth and yield performance of cabbage and could alter an economical and simple mechanism for quality cabbage production among the farming community.

Keywords: Cabbage, foliar spray, micronutrients, plant growth regulators, yield

Introduction
Cabbage (*Brassica oleraceavar. Capitata* L.), a member of the family Cruciferae, it is popular as winter season vegetable and one of the most important leafy vegetable crop and used as salad, cooked, pickling as well as dehydrated vegetable. The flavour in cabbage is due to presence of a glycoside 'SINIGRIN'. To increase the yield of cabbage application of major and micronutrients is helpful. Now a day's plant growth regulators have been tried to improve growth and ultimately yield. The cabbage head is rich source of vitamin A, B, C and protein contains minerals. It has cooling effect and helps in preventing constipation, increase appetite, speed up digestion and very useful for patients of diabetes. Since micronutrients are costly chemicals, amelioration of such deficiencies through soil application may increase the cost of cultivation whereas foliar applications may reduce the cost owing to the lesser quantities required and better absorption through the foliage. Similarly growth regulators are also becoming very popular for obtaining higher yields in vegetable crops. They help in the synthesis of metabolites as well as translocation of nutrients and assimilation in different parts, which ultimately resulted in higher yields. Plant growth regulators are effective at very low concentration when used at active growth stage i.e., vegetative growth of the crop.

Application of GA_3 with the environmental conditions play important role in modifying the growth and yield of cabbage. Gibberellic acid (GA) and Naphthalene acetic acid (NAA) exhibited beneficial effect in several crops (Thapa *et al*., 2013) [15]. Due the growth regulators, auxin causes enlargement of plant cell and Gibberellins stimulates cell division, cell enlargement or both (Nickell, 1982) [11].

Materials and Methods

The experiment was laid out at the Instructional Farm, College of Agriculture, Indira Gandhi Krishi Vishwavidhyalaya, Raipur and Chhattisgarh during the Rabi season of the years 2016-17 and 2017-18 with Randomized Complete Block Design (RCBD) with three replications. Each replication consisted of 18 unit plots. The size of each unit plot was 4.5 m x 5.2 m. The gap Between the plots was 50 cm and between the replications was 100 cm. Total of 18 treatments including the untreated control were selected in this investigation which were: T_1 = NPK + (Control), T_2 = NPK + (Water), T_3 = NPK + (All micronutrients (Fe, Mn, Zn, Cu, B and Mo), T_4 = NPK + (T_3 – Fe), T_5 = NPK + (T3 – Zn), T_6 = NPK + (T_3 – Mn), T_7 = NPK + (T_3 – Cu), T_8 = NPK + (T_3 – Mo), T_9 = NPK + (T_3 – B), T_{10} = NPK + (S), T_{11} = NPK + B + Mo, T_{12} = NPK + B + Mo + Fe, T_{13} = NPK + B + Mo + Fe + Zn, T_{14} = NPK + GA + NAA, T_{15} = NPK + B + Mo + S + GA + NAA, T_{16} = NPK + B + Mo + GA + NAA, T17 = NPK + B + Mo + Fe + GA + NAA, T_{18} = NPK + B + Mo + Zn + Fe + GA + NAA. The micronutrients were (Fe, Mn, Cu, Zn, B - 100 ppm and Mo – 50 ppm), with growth regulators (GA_3 – 50 ppm and NAA - 80 ppm) applied twice as foliar application at 20 and 40 DAT. Plants in control plots were no spray with recommended dose of fertilizers N:P:K at the rate of 130: 80: 60 kg/ha at the time of planting. The data were taken from randomly selected five plants from each plot on various characters viz., volume of head (cm^3), diameter of head (cm), leaf yield (q/ha) and head yield (q/ha). All the data analysis was carried out as per described by Gomez and Gomez (1984) [17].

Research Findings and Discussion

Plant height (cm) at 30, 60 DAT and at harvest

1. Volume of head (cm^3)

The response of different combinations of foliar application of micronutrient and growth regulators were significantly affected the volume of head (Table 1 and Fig 1) in different nutrient omission treatments of micronutrients in both the years (2017 & 2018). The maximum volume of head was recorded as 1640 and 1680 cm^3 in Treatment T18 (B + Mo + Fe + Zn + GA + NAA) and minimum volume of head was found as 1190 and 1150 cm^3 in Treatment T1 (Control), in both the years (2017 & 2018), respectively. Similarly the pooled mean data of volume of head was also significantly affected by foliar application of micronutrient and growth regulators in nutrient omission treatments. The pooled mean data of volume of head was found maximum (1660 cm^3) in Treatment T_{18} (B + Mo + Fe + Zn + GA + NAA), whereas, the minimum volume of head (1180 cm^3) was recorded in Treatment T_1 (Control). The omission of micronutrients namely Fe, Mn, Cu, Zn, B and Mo in treatments T4 (All Micronutrient - Fe), T_5 (All Micronutrient - Zn), T_6 (All Micronutrient - Mn), T_7 (All Micronutrient - Cu), T_8 (All Micronutrient - Mo) and T_9 (All Micronutrient - B) significantly reduced the volume of head. Therefore, results revealed that the foliar application of micronutrients and growth regulators in twice (20 and 40 DAT) was found to be more effective for significantly increased the volume of head of cabbage particularly in treatments T_3 (All Micronutrient (Fe, Mn, Zn, Cu, B, Mo), and T_{17} (B + Mo + Fe + GA + NAA) and T_{18} (B + Mo + Fe + Zn + GA + NAA). Similar type of results have also been reported by Bokade *et al*. (2004) [1] and Kotecha *et al*. (2016) [4]. The foliar application of micronutrient namely Fe led to enhance to protein and chlorophyll synthesis, catalyze the physiological process, help in cell enlargement of the plant which may lead to increase the cabbage head volume. The foliar application of Zn, accelerated and stimulated the functions of cell and tissue, synthesis of RNA and IAA, also helpful for maintaining the physiological processes namely water uptake and protein utilization. The higher protein accumulation may be one of the factors responsible for increase in cabbage volume of head. These results were in conformity with the results of Sarma *et al.* (2005) [13], Narayanamma *et al.* (2007) [10], Nandi and Nayak (2008) [9]. Cabbage volume head increased by application of boron might be attributed due to the perceptible increase in height and spread of plant may be due to an enhancement in cell multiplication and cell elongation (Meena *et al*. 2019) [7]. The exogenous applications of growth regulators (GA_3 and NAA) were enhanced and activated the enzymatic activities for various physiological process and metabolic activities viz. vegetative growth and photosynthetic area to maximize yield of the crop. These results were in accordance with the finding of Makwana (2005) [5] Landve *et al*. (2010) [18], Kotecha *et al.* (2016) [4], and Meena *et al*. (2019) [7].

2. Diameter of head (cm)

The data pertaining to diameter of head in Table 1 and fig 2 indicated that among the eighteen different treatment combinations of micronutrient and growth regulators significantly affect the diameter of head in different micronutrient omission treatments in both the years (2017 & 2018). Among the treatments, the maximum diameter of head was recorded as 16.50 and 15.83 cm^2 at in Treatment T18 (B + Mo + Fe + Zn + GA + NAA) and minimum diameter of head was registered as 12.47 and 12.17 cm in Treatment T1 (Control), in both the years (2017 & 2018), respectively. The pooled mean data of diameter of head was also significantly affected by different combinations of micronutrient and growth regulators. The pooled mean data of diameter of head was registered maximum (16.17 cm^2) in Treatment T18 (B + Mo + Fe + Zn + GA + NAA), while, minimum diameter of head was recorded in Treatment T_1 (Control) as 12.32 cm. The omission of micronutrients namely Fe, Mn, Cu, Zn, B and Mo in treatments T_4 (All Micronutrient - Fe), T_5 (All Micronutrient - Zn), T_6 (All Micronutrient - Mn), T_7 (All Micronutrient - Cu), T_8 (All Micronutrient - Mo) and T_9 (All Micronutrient - B) was significantly reduced the diameter of head. Hence, present study revealed that the foliar application of micronutrients and growth regulators in twice (20 and 40 DAT) was found to be more effective for significant increase

in diameter of head of cabbage particularly in treatments T_3 (All Micronutrient (Fe, Mn, Zn, Cu, B, Mo), T_{17} (B + Mo + Fe + GA + NAA) and T_{18} (B + Mo + Fe + Zn + GA + NAA). These views are in cognizance with the findings of Landve *et al*. (2010) [18], Kotecha *et al*. (2016) [4] and Meena *et al*. (2019) [7].

Leaf yield (q ha^{-1})

The effects of different combinations of foliar application of micronutrient and growth regulators were significantly affected the leaf yield (Table 2 and Fig 3) in different micronutrient omission treatments in both the years (2017 & 2018). The leaf yield was recorded maximum as 210 and 232 q ha^{-1} in Treatment T_{18} (B + Mo + Fe + Zn + GA + NAA) and minimum leaf yield was registered as 168 and 185 q ha^{-1} in Treatment T_1 (Control), in both the years (2017 & 2018), respectively. Similarly the pooled mean data of leaf yield was also significantly affected by foliar application of micronutrient and growth regulators. The pooled mean data of leaf yield was registered maximum (221 q ha^{-1}) in Treatment T_{18} (B + Mo + Fe + Zn + GA + NAA), whereas, the minimum leaf yields (176 q ha^{-1}) was recorded in Treatment T_1 (Control). The omission of micronutrients namely Fe, Mn, Cu, Zn, B and Mo in treatments T_4 (All Micronutrient - Fe), T_5 (All Micronutrient - Zn), T_6 (All Micronutrient - Mn), T_7 (All Micronutrient - Cu), T_8 (All Micronutrient - Mo) and T_9 (All Micronutrient - B) was found to be significantly reducing the leaf yield of cabbage. Large reductions in the leaf yield were observed with the omission of B (T_9) as compared to the other nutrient omission treatments. The yield reductions were more pronounced with B omission. This indicates that B was the most yield limiting micronutrients followed by Fe, Zn and Cu for cabbage yield. Micronutrients are not applied by farmers as basal dressing. Therefore, the soils are low in available B and Fe than that of other nutrients. Hence, the study revealed that the foliar application of micronutrients along with growth regulators in twice (20 and 40 DAT) was found to be more effective for significant increase in leaf yield of cabbage particularly in treatments T_3 (NPK + all micronutrient (Fe, Mn, Zn, Cu, B and Mo), T_{17} (B + Mo + Fe + GA + NAA) and T_{18} (B + Mo + Fe + Zn + GA + NAA). The increased in leave yield might be due to the combine effect of micronutrient and plant growth regulator application in improving the crop growth than that of micronutrients omission (Lashkari *et al*. 2007; Singh *et al*. 2014) [5, 14]. The application of micronutrients in optimum level responsible for higher photosynthesis which may increase carbohydrate and sugar accumulation, higher N fixation by Fe and Mo enhance the protein synthesis of cabbage. (Moklikar *et al*. 2018 and Meena *et al*. 2019) [7, 8]. The increase in leave yield with application of growth regulators GA3 and NAA may be due to enhance the activity of apical meristem resulting in more nucleo - protein and carbohydrate synthesis responsible for increasing leaf initiation (Dhengle and Bhosale 2007) [2].

Head yield (q ha^{-1})

The response of different combinations of foliar application of micronutrient and growth regulators were significantly affected the head yield of cabbage (Table 2 and Fig 4) in different micronutrient omission treatments in both the years (2017 & 2018). The maximum head yield was recorded as 462 and 449 q ha^{-1} in Treatment T_{18} (B + Mo + Fe + Zn + GA + NAA) and minimum head yield was registered as 357 and 339 q ha^{-1} in Treatment T_1 (Control), in both the years (2017 & 2018), respectively. Similarly the pooled mean data of head yield was also significantly affected by foliar application of micronutrient and growth regulators. The pooled mean data of head yield was registered maximum (455 q ha^{-1}) in Treatment T_{18} (B + Mo + Fe + Zn + GA + NAA), whereas, the minimum head yield (348 q ha^{-1}) recorded in Treatment T_1 (Control). The omission of micronutrients i.e. Fe, Mn, Cu, Zn, B and Mo in treatments T_4 (All Micronutrient - Fe), T_5 (All Micronutrient - Zn), T_6 (All Micronutrient - Mn), T_7 (All Micronutrient - Cu), T_8 (All Micronutrient - Mo) and T_9 (All Micronutrient - B) was found to be significantly reduces the head yield of cabbage. The yield reductions were more pronounced with B omission. This indicates that B was the most yield limiting micronutrients followed by Fe, Zn and Cu for cabbage yield. Micronutrients are not applied by farmers as basal dressing. Therefore, the soils are low in available B and Fe than that of other nutrients. Hence, the study revealed that the foliar application of micronutrients along with growth regulators in twice (20 and 40 DAT) was found to be more effective for significant increase in head yield of cabbage (Patel *et al*. 2018 and Moklikar *et al*. 2018) [12, 8]. The increase in yield and yield attributing characters might be due to the synergistic effect of micronutrient and growth regulator on cabbage (Kotecha *et al*. 2016) [4] than that of micronutrient omission plot. The enhancement of yield of cabbage due to micronutrient application may be attributed to the fact that micronutrients play a vital role in plant nutrition uptake and use, and influence various physiological processes like photosynthesis, protein and chlorophyll synthesis, reduce incidence of diseases etc. GA_3 application decreased number of days taken for head initiation. It might be due to the more cell division and elongation with increase in photosynthetic activity that could be attributed to better crop yield (Yadav *et al*. 2000) [16]. NAA application causes the improvement in physiological and other metabolic activity which led to an increase in various plant metabolites responsible for actively cell division and elongation results improvement in yield and yield attributes of cabbage (Singh *et al*. 2014 and Patel *et al*. (2018) [12, 14].

Table 1: Effect of foliar application of micronutrient and growth regulator on volume of head and diameter of head of cabbage

Treatment	Volume of Head (cm^3)			Diameter of Head (cm)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
T_1 Control (No Spray)	1190 e	1150 e	1180 e	12.47 d	12.17 d	12.32 d
T_2 (Water Spray)	1200 de	1150 e	1180 e	13.33 cd	13.17 cd	13.25 cd
T_3 (All Micronutrient (Fe, Mn, Zn, Cu, B, Mo)	1460 abc	1480 abc	1470 abc	15.50 ab	14.50 abc	15.00 ab
T_4 (All Micronutrient - Fe)	1450 abcd	1440 abcd	1440 bcd	14.17 bcd	13.83 bc	14.00 bc

T_5 (All Micronutrient - Zn)	1380 bcde	1400 bcde	1390 bcd	14.17 bcd	13.67 cd	13.92 bc
T_6 (All Micronutrient - Mn)	1360 bcde	1340 bcde	1350 cde	14.00 bcd	13.83 bc	13.92 bc
T_7 (All Micronutrient - Cu)	1290 cde	1220 cde	1250 de	13.83 bcd	14.00 bc	13.92 bc
T_8 (All Micronutrient - Mo)	1260 cde	1290 cde	1280 cde	14.50 abcd	13.83 bc	14.17 bc
T_9 (All Micronutrient - B)	1310 bcde	1270 cde	1290 cde	14.17 bcd	14.33 abc	14.25 bc
T_{10} (S)	1390 abcde	1390 bcde	1390 bcd	14.00 bcd	13.33 cd	13.67 bcd
T_{11} (B+Mo)	1350 bcde	1350 bcde	1350 cde	13.83 bcd	14.33 abc	14.08 bc
T_{12} (B+Mo+Fe)	1360 bcde	1390 bcde	1370 cde	14.17 bcd	13.67 cd	13.92 bc
T_{13} (B+Mo+Fe+Zn)	1280 cde	1280 cde	1280 cde	13.50 bcd	13.83 bc	13.67 bcd
T_{14} (GA+NAA)	1260 cde	1230 cde	1250 de	13.67 bcd	13.83 bc	13.75 bc
T_{15} (B+Mo+S+GA+NAA)	1330 bcde	1200 de	1260 de	15.17 abc	14.50 abc	14.83 ab
T_{16} (B+Mo+GA+NAA)	1230 cde	1220 cde	1230 de	15.17 abc	14.67 abc	14.92 ab
T_{17} (B+Mo+Fe+GA+NAA)	1560 ab	1590 ab	1580 ab	16.33 a	15.33 ab	15.83 a
T_{18} (B+Mo+Fe+Zn+GA+NAA)	1640 a	1680 a	1660 a	16.50 a	15.83 a	16.17 a
S Em (±)	86	91	67	0.72	0.57	0.47
CD (%)	248	262	193	2.06	1.64	1.35

Table 2: Effect of foliar application of micronutrient and growth regulator on yield of leaf and head of cabbage

Treatment	Leaf Yield (q ha^{-1})			Head Yield (q ha^{-1})		
	2017	2018	Pooled	2017	2018	Pooled
T_1 Control (No Spray)	168 d	185 d	176 f	357 e	339 e	348 g
T_2 (Water Spray)	181 cd	199 cd	190 ef	372 de	367 de	370 fg
T_3 (All Micronutrient (Fe, Mn, Zn, Cu, B, Mo)	205 ab	230 ab	218 a	441 ab	434 ab	437 ab
T_4 (All Micronutrient - Fe)	192 abc	219 abc	205 abcde	419 abcd	397 abcd	408 bcde
T_5 (All Micronutrient - Zn)	189 abcd	209 bc	199 bcde	417 abcd	400 abcd	409 bcde
T_6 (All Micronutrient - Mn)	196 abc	216 abc	206 abcde	436 abc	417 abcd	427 abc
T_7 (All Micronutrient - Cu)	200 abc	214 abc	207 abcde	402 bcde	415 abcd	408 bcde
T_8 (All Micronutrient - Mo)	203 abc	220 abc	212 ab	438 ab	423 abc	431 abc
T_9 (All Micronutrient - B)	182 bcd	202 cd	192 def	390 cde	369 de	380 efg
T_{10} (S)	183 bcd	198 cd	190 ef	408 bcd	384 bcde	396 cdef
T_{11} (B+Mo)	209 a	206 cd	207 abcde	422 abc	429 ab	426 abc
T_{12} (B+Mo+Fe)	182 bcd	201 cd	192 def	429 abc	407 abcd	418 bcd
T_{13} (B+Mo+Fe+Zn)	181 cd	205 cd	193 cdef	397 bcde	372 cde	384 def
T_{14} (GA+NAA)	208 a	210 abc	209 abcd	418 abcd	406 abcd	412 bcde
T_{15} (B+Mo+S+GA+NAA)	200 abc	220 abc	210 abc	432 abc	408 abcd	420 bc
T_{16} (B+Mo+GA+NAA)	203 abc	216 abc	209 abcd	426 abc	403 abcd	415 bcd
T_{17} (B+Mo+Fe+GA+NAA)	209 a	232 ab	221 a	442 ab	437 ab	440 ab
T_{18} (B+Mo+Fe+Zn+GA+NAA)	210 a	232 ab	221 a	462 a	449 a	455 a
S Em (±)	8.16	7.95	6.03	16.43	18.60	12.20
CD (%)	23.45	22.86	17.35	47.23	53.46	35.05

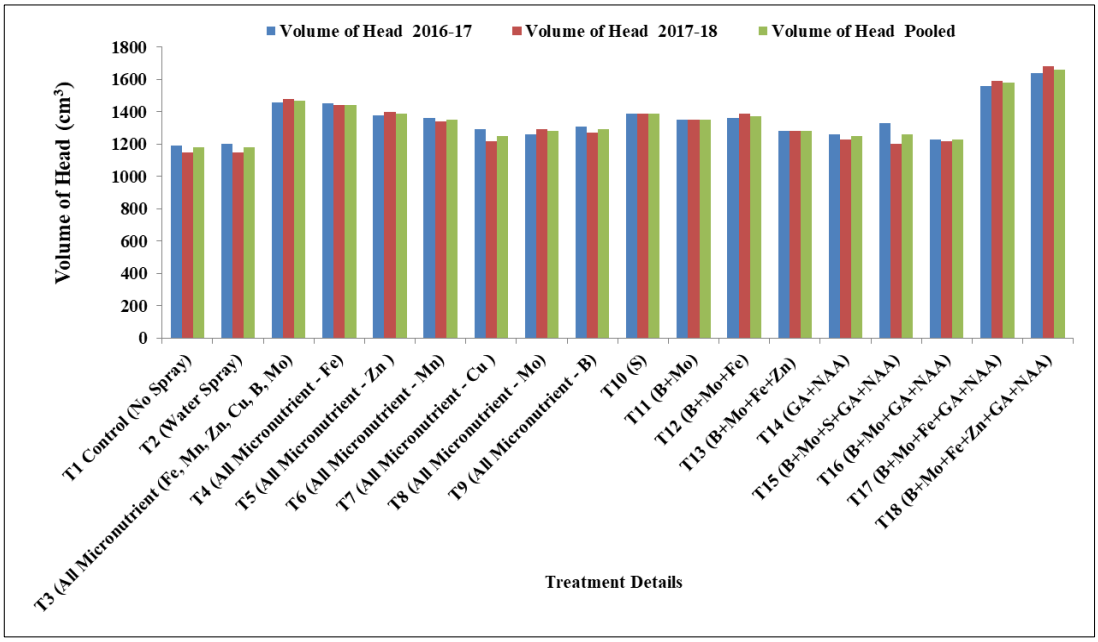

Fig 1: Effect of micronutrient and growth regulator on volume of head of cabbage

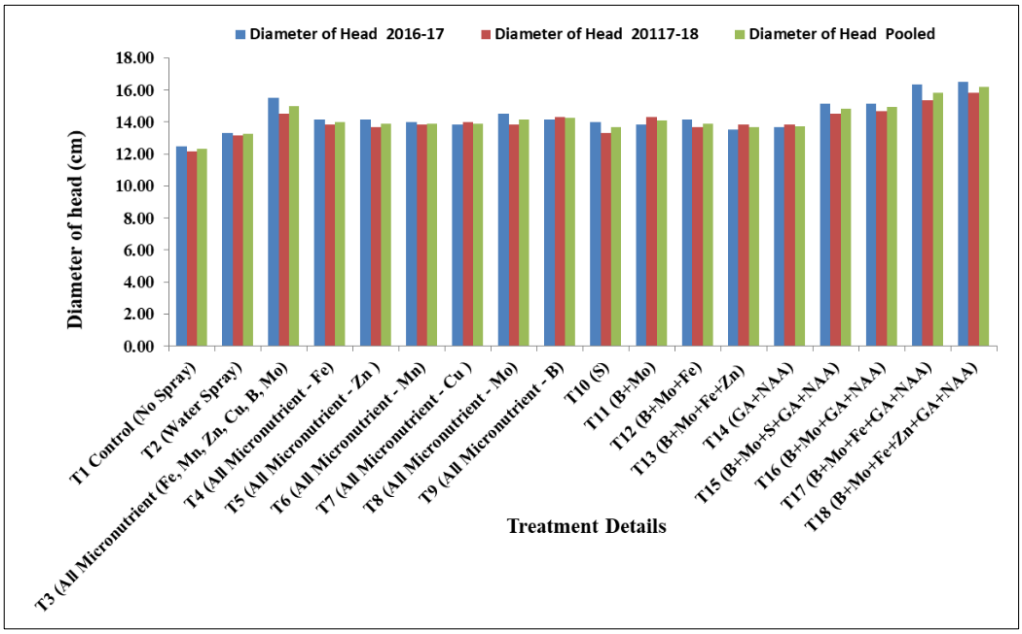

Fig 2: Effect of micronutrient and growth regulator on diameter of head of cabbage

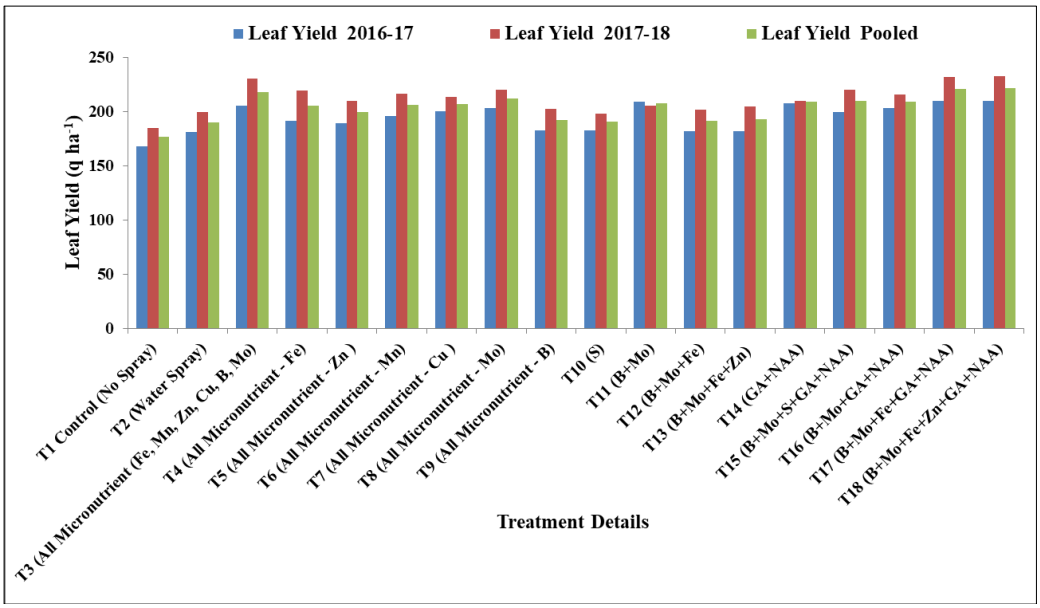

Fig 3: Effect of foliar application of micronutrient and growth regulator on yield of leaf of cabbage

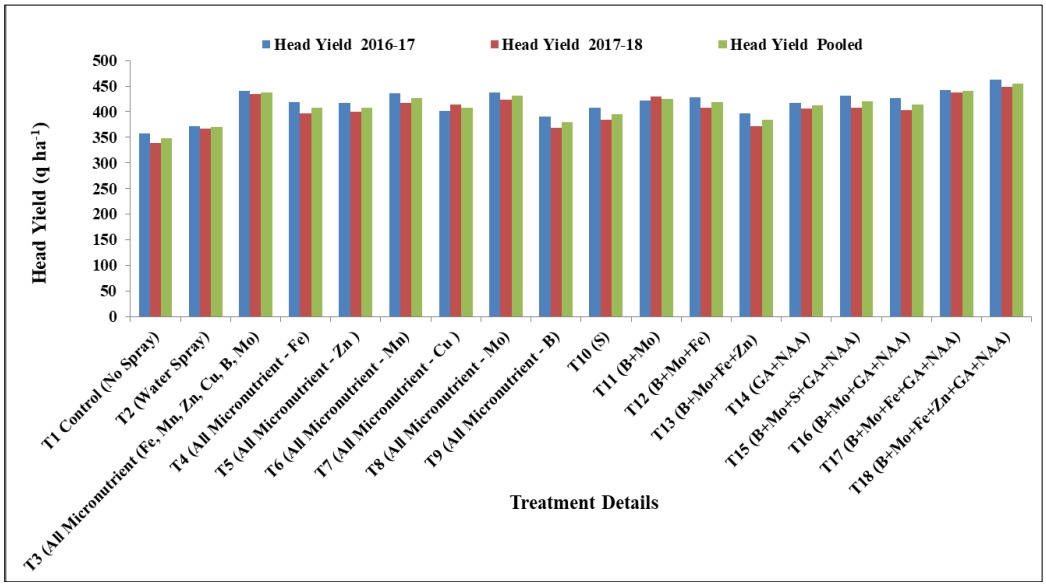

Fig 4: Effect of foliar application of micronutrient and growth regulator on yield of head of cabbage

Conclusion

The present study demonstrate that omission of micronutrients namely Fe, Mn, Cu, Zn, B and Mo significantly reduces the volume of head, diameter of head, leaf and head yield of cabbage. Hence, the combined effects of foliar application of micronutrient with growth regulators twice at 20 and 40 DAT were found to be most effective for significant maximum increased in yield and yield attributes of cabbage. This work recommended that foliar fertigation of micronutrient (B + Mo + Fe + Zn) with growth regulators (GA_3 + NAA) can enhance the growth and yield performance of cabbage and could alter an economical and simple mechanism for quality cabbage production among the farming community.

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