International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 1696-1700

Received: 22-05-2019
Accepted: 23-06-2019

Swetal Rana
Dept. of Vegetable Science, College of Agriculture, RVSKVV, Gwalior, Madhya Pradesh, India

Arun Kumar Barholia
Dept. of Vegetable Science, College of Agriculture, RVSKVV, Gwalior, Madhya Pradesh, India

Rahul Pippal
CSIR-Cenral Leather Research Institute, Adyar, Chennai, Tamil Nadu, India

Payal Rana
Krishi College, Jorapali, Raigarh, Chhattisgarh, India

Correspondence
Swetal Rana
Dept. of Vegetable Science, College of Agriculture, RVSKVV, Gwalior, Madhya Pradesh, India

Impact on yield potential of cabbage (*Brassica oleracea* var. *capitata* L.) cv. Pusa Drum head due to boron, molybdenum and spacing

Swetal Rana, Arun Kumar Barholia, Rahul Pippal and Payal Rana

Abstract
The aim of this study was to determine the effect of boron, molybdenum and spacing on growth and yield of cabbage in the Rabi season. The study was carried out during the rabi of 2013-14 and 2014-15. Two spacing 60 x 60 (S_1) and 60 x 45 (S_2) and three levels of each boron and molybdenum i.e. Boron @ 0%, Boron @ 0.25%, Boron @ 0.5%, and Molybdenum @ 0%, Molybdenum @ 0.25% and Molybdenum @ 0.5% were in FRBD with three replications. Higher yield 505 qha^{-1} achieved using 60 x 45 cm planting distance against 440 qha^{-1} in 60 x 60 cm planting distance. Among the boron levels 0.5% boric acid increased the yield character and maximize up to 495.18 qha^{-1} and 469.29 qha^{-1} in case of molybdenum @ 0.5%.

Keywords: Cabbage, boron, spacing, molybdenum, yield

1. Introduction

Cabbage (*Brassica oleracea* var. *capitata* L.) rich in phytonutrient antioxidants, this cool season leafy vegetable belongs to the "Brassica" family, a broad family of common plants that also include brussels sprouts, cauliflower, bok choy, kale, and broccoli. Cabbage structurally consists of clusters of thick leaves superimposed in over the other in compact layers, allowing it to take round or globular shape vegetable. Several varieties of cabbage cultivated worldwide including green, purple, red, and Savoy features loose-wrinkled leaves.

Among the leafy vegetables cabbage has a prominent place and grown as an annual crop prized for its compact green head. Cabbage is one of the nutritionally rich vegetables, liked by all classes of people and it has some medicinal values for diabetic patients. It is biennial and herbaceous in nature and is extensively grown during winter season.

Cabbage is one of the five best vegetables in the world. It is an important winter leafy vegetables grown in India.

China is the largest producer of cabbage in the world followed by India. It is commercially cultivated in U.P., Orissa, Bihar, Assam, West Bengal, Maharashtra and Karnataka states in the country. The area (in '000 Ha), production (in '000 MT) and productivity (in MT/ha) of cabbage in Madhya Pradesh are 29.0, 614.44, 21.18, in India 407.13, 8971.21, 22.0 and in the *World are 2416.88, 70644.19, 29.2, respectively (NHB, 2017 and *FAO, 2015) [12, 5].

Export of cabbage from India is approximately 385.22 MT that value of 56 lakh rupees. In order to maintain or even improve cabbage production, some factors have to be considered. Production of vigorous transplants is one such necessary factor for successful vegetable production. Again, correct cultural practices such as adequate application of fertilizers (Everaarts and Beusichem 1998) [4] and optimum plant population have to be adhered to in order to obtain good yields in cabbage production (Kumar and Rawat, 2002) [10].

Micronutrients play a significant role in plant growth and metabolic processes associated with photosynthesis, chlorophyll formation, cell wall development and respiration, water absorption, xylem permeability, resistance to plant diseases, enzyme activities involved in the synthesis of primary and secondary metabolites and nitrogen fixation and reduction.

Boron regulates the metabolism of carbohydrates in plants. It plays an important role in enhancing the translocation of carbohydrates from site of synthesis to reproductive tissue in the head. It is essential for the process by which meristem cells differentiate to form specific tissues.

A 100 g edible portion of cabbage contains the following described below:

Principle	Nutrient Value
Energy	25 kcal
Carbohydrates	5.8 g
Protein	1.3 g
Total Fat	0.1 g
Cholesterol	0 mg
Dietary Fiber	2.50 mg
Vitamins	
Folates	53 µg
Niacin	0.234 mg
Pantothenic acid	0.212 mg
Pyridoxine	0.124 mg
Riboflavin	0.040 mg
Thiamin	0.061 mg
Vitamin A	98 IU
Vitamin C	36.6 mg
Vitamin K	76 µg
Electrolytes	
Sodium	18 mg
Potassium	170 mg
Minerals	
Calcium	40 mg
Iron	0.47 mg
Magnesium	12 mg
Manganese	0.160 mg
Phosphorus	26 mg
Zinc	0.18 mg
Phyto-nutrients	
Carotene-α	33 µg
Carotene-ß	42 µg
Lutein-zeaxanthin	30 µg

(**Source:** USDA National Nutrient data base)

In case of boron deficiency, plant cells may continue to divide, but structural components are not differentiated. Boron is important for stabilization of plant tissues and improved plant and crop strength, working together with Ca, reducing effects of nutritional disorders such as tip burn and hollow heart, probably minimizing club root and increased crop quality and yield Molybdenum is taken up by plants as molybdate ions. It is one of the essential micronutrients. It is only required in small amounts for normal plant development. However, it plays a crucial part in the regulation of various plant functions. Like any nutrient deficiency or toxicity, it needs to be corrected before there is a negative impact on crop growth and quality.

Molybdenum is an essential component in two enzymes that convert nitrate into nitrite (a toxic form of nitrogen) and then into ammonia before it is used to synthesize amino acids within the plant. It also needed by symbiotic nitrogen fixing bacteria in legumes to fix atmospheric nitrogen. Plants also use molybdenum to convert inorganic phosphorus into organic forms in the plant.

Plant density for cabbage is an important criteria for attaining maximum yield. Densely planted crop obstruct the proper growth and development with hampering the basic requirement of plant growth. On the other hand wider spacing ensure the basic requirements but decrease the total number of plants as well as total yield.

2. Material and Methods

Cabbage (*Brassica oleracea* var. *capitata* L.). cv. Pusa Drum Head" was used to explore its yield potential by different boron levels and spacing. The present investigation was conducted in nursery area, Dept. of Horticulture, College of Agriculture, Gwalior during rabi of 2013-14 and 2014-15. For the different treatment combinations, three levels of boron i.e. B_{1-} (Boron @ 0%), B_{2-} (Boron @ 0.25%), B_{3-} (Boron @ 0.5%), three levels of molybdenum i.e. M_{1-} (Molybdenum @ 0%), M_{2-} (Molybdenum @ 0.25%), M_{3-} (Molybdenum @ 0.5%) and two spacing 60 cm x 60 cm (S_1) and 60 cm x 45cm (S_2) were used, thus in the present investigation a total of 18 treatment combinations were made in Factorial Randomized Block Design with three replications. Foliar spray of boron and molybdenum was done at 30 and 50 days after transplanting and all other cultivation practices were adopted as per recommendations. The plot size was 3.2 m x 3.2 m. Three raised nursery beds of 2 x 1 x 0.15 m size were prepared by mixing well rotten farm yard manure in soil @ 15 kg per square meter. Seeds of cabbage cv. Pusa Drum Head were sown on 22nd October 2013 in the first trial and on 25th October 2014 in second year trial @ 10 g seed per bed after treating with 0.3% thiram to check the infection of damping off and seed borne diseases. Five weeks old healthy and uniform sized seedlings were transplanted in the experimental plots on 25th November 2013 in first year trial and on 27th November 2014 in second year trial. Seed beds were watered in the morning before uprooting the seedlings in the afternoon of the same day to avoid damage to the roots. During transplanting a spacing of 60 cm × 60 cm and 60 cm x 45 cm were maintained, thus unit plot accommodated 25 and 40 seedlings respectively where the treatment was allocated at random. Two days before transplanting each plot was fertilized with a basal dose of NPKS. The recommended dose of nitrogen (120 kg/ha), phosphorus (80 kg/ha), potassium (60 kg/ha) and sulphur (20 kg/ha) were applied through urea, SSP, MOP and Gypsum, respectively. Half of the total quantity of nitrogen was applied as a basal dose. One-fourth of the total nitrogen was applied after 20 days of transplanting and remaining one-fourth at the time of head formation. Boron and Molybdenum was applied as foliar spray (at 30 and 50 DAP). Boric acid and Ammonium molybdate was used as source of boron and molybdenum.

Observations recorded on diameter of head, weight of untrimmed head, weight of trimmed head, yield kgplot^{-1} and qha^{-1}.

3. Results

3.1 Diameter of head

3.1.1 Effect of Spacing: The size of head in terms of diameter was measured at harvest. It is elucidated with the data presented in Table 1, that spacing S_1 (60 cm x 60 cm) exhibited significantly higher diameter of head as compared to S_2 (60 x 45 cm). The magnitude of increase in diameter of head observed 16.33 cm, 17.66 cm and 17.00 cm during first year, second year and in pooled data, respectively under the wider spacing S_1 (60 cm X 60 cm), while the spacing S_2 (60 x 45 cm) recorded 12.64, 13.64 cm and 13.14 cm diameter of head during first year, second year and in pooled data, respectively.

3.1.2 Effect of Boron: As a result B_3 (Boron @ 0.5%) exhibited the highest diameter of head 15.59 cm, 16.63 cm and 16.11 cm during first year, second year and in pooled data, respectively followed by 14.48 cm, 15.87 cm and 15.17 cm in B_2 (Boron @ 0.25%) and minimum diameter of head in case of boron application was found in B_1 (Boron @ 0%) *i.e.* 13.38 cm, 14.46 cm and 13.92 cm during first year, second year and in pooled data, respectively. All the levels *i.e.* B_1, B_2

and B_3 were found significant to each other during the entire experimental period.

3.1.3 Foliar spray of molybdenum: Data further indicated that application of M_3 (Molybdenum @ 0.5%) significantly increased the diameter of head upto 14.71 cm, 15.83 cm and 15.27 cm during first year, second year and in pooled data, respectively. It was followed by 14.82 cm, 16.12 cm and 15.47 cm under M_2 (Molybdenum @ 0.25%) and the minimum diameter of head *i.e.* 13.93 cm, 15.0 cm and 14.46 cm during first year, second year and in pooled data, respectively, was noted in M_1 (Molybdenum @ 0%). However, M_2 and M_3 were at par to each other during both the years of experimentation as well as in pooled data.

3.2 Weight of untrimmed head

3.2.1 Effect of Spacing: There was significant increase in weight of untrimmed head with wider spacing S_1 (60 cm x 60 cm) as compared to the other spacing *i.e.*S_2 (60 cm x 45 cm). Maximum weight of untrimmed head 2.41 kg, 2.50 kg and 2.45 kg was found during first year, second year and in pooled data under S_1 (60 cm x 60 cm) and 2.10 kg, 2.17 kg and 2.13 kg during first year, second year and in pooled data, respectively under S_2 (60 cm x 45 cm).

3.2.2 Foliar spray of boron: Among the boron levels, application of B_3 (Boron @ 0.5%) exhibited the highest weight of untrimmed head *i.e.* 2.41 kg, 2.46 kg and 2.43 kg during first year, second year and in pooled data, respectively followed by 2.26 kg, 2.34 kg and 2.30 kg under B_2 (Boron @ 0.25%) and the minimum weight of untrimmed head was recorded in B_1 (Boron @ 0%) which was 2.10 kg, 2.20 kg and 2.15 kg during first year, second year and in pooled data, respectively. All the levels of B_1, B_2 and B_3 were found significant to each other during the entire experimental period.

3.2.3 Foliar spray of molybdenum: With increasing dose of molybdenum, there was corresponding increase in weight of untrimmed head. Maximum weight of untrimmed head was found under M_2 (Molybdenum @ 0.25%) *i.e* 2.30 kg, 2.38 kg and 2.34 kg, however M_3 (Molybdenum @ 0.5%) was also found equal to M_2 in the first year. The trend was found M_2> M_3 >M_1 during first year, second year and in pooled data, respectively. However M_2 and M_3 were at par to each other during both the years of experimentation as well as in pooled data.

3.3 Weight of trimmed head

3.3.1 Effect of Spacing: It is evident from Table 1 that spacing S_1 (60 cm x 60 cm) significantly influenced weight of trimmed head as compared to spacing S_2 (60 cm x 45 cm). The maximum weight of trimmed head was found under S_1 (60 cm x 60 cm) which was 1.76 kg, 1.84 kg and 1.80 kg during first year, second year and in pooled data, respectively whereas 1.44 kg, 1.52 kg and 1.48 kg weight of trimmed head was found in relatively narrow spacing *i.e.* S_2 (60 cm x 45 cm) during first year, second year and in pooled data, respectively.

Table 1: Effect of spacing, boron and molybdenum on yield parameters of cabbage

Treatments	Diameter of head (cm)			Weight of untrimmed head (kg)			Weight of trimmed head (kg)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
S_1	16.33	17.66	17.00	2.41	2.50	2.45	1.76	1.84	1.80
S_2	12.64	13.64	13.14	2.10	2.17	2.13	1.44	1.52	1.48
SEm+	0.141	0.168	0.103	0.023	0.027	0.016	0.023	0.016	0.013
CD(0.05)	0.405	0.481	0.290	0.065	0.076	0.046	0.067	0.046	0.035
B_1	13.38	14.46	13.92	2.10	2.20	2.15	1.46	1.54	1.50
B_2	14.48	15.87	15.17	2.26	2.34	2.30	1.61	1.69	1.65
B_3	15.59	16.63	16.11	2.41	2.46	2.43	1.74	1.81	1.78
SEm+	0.173	0.205	0.126	0.028	0.033	0.020	0.029	0.019	0.015
CD(0.05)	0.496	0.590	0.356	0.079	0.093	0.056	0.082	0.056	0.043
M_1	13.93	15.00	14.46	2.16	2.27	2.22	1.46	1.54	1.50
M_2	14.82	16.12	15.47	2.30	2.38	2.34	1.74	1.81	1.78
M_3	14.71	15.83	15.27	2.30	2.35	2.33	1.61	1.69	1.65
SEm+	0.173	0.205	0.126	0.028	0.033	0.020	0.029	0.019	0.015
CD(0.05)	0.496	0.590	0.356	0.079	0.093	0.056	0.082	0.056	0.043

3.3.2 Foliar spray of boron: Further examination of data showed that application of B_3 (Boron @ 0.5%) exhibited the highest weight of trimmed head 1.74 kg, 1.81 kg and 1.78 kg during first year, second year and in pooled data, respectively followed by 1.61 kg, 1.69 kg and 1.65 kg in B_2 (Boron @ 0.25%) and the minimum weight of trimmed head *i.e.* 1.46 kg, 1.54 kg and 1.50 kg was found in B_1 (Boron @ 0%). However, B_1, B_2 and B_3 were found significant to each other during the entire experimental period.

3.3.3 Foliar spray of molybdenum: The data presented in Table 1 further indicated that with the increasing levels of molybdenum, there was corresponding increase in weight of trimmed head. As a result maximum weight of trimmed head was found under M_2 (Molybdenum @ 0.25%) *i.e* 1.74 kg, 1.81 kg and 1.65 kg followed by1.61 kg, 1.69 kg and 1.65 kg under M_3 (Molybdenum @ 0.5%) and minimum weight of trimmed head was found under M_1 (Molybdenum @ 0%) which was 1.46 kg, 1.54 kg and 1.50 kg during first year, second year and i pooled data, respectively. However, M_2 and M_3 were at par to each other during both the years of experimentation as well as in pooled data.

3.4 Yield per plot

3.4.1 Effect of Spacing: A quick glance of the data presented in Table 2 brought out that spacing S_2 (60 cm x 45 cm) gained significantly more yield per plot. It was noted 50.48 kg/plot, 53.08 kg/plot and 51.78 kg/plot during first year, second year and in pooled data. In the spacing S_1 (60 cm x 60 cm) the yield per plot was found inferior to S_2 (60 cm x 45 cm). In this spacing yield were noted 40.58 kg/plot, 42.40 kg/plot and 41.49 kg/plot during first year, second year and in pooled data.

3.4.2 Foliar spray of boron: The application of different levels of boron also significantly influenced the yield per/

plot. The maximum yield achieved by plots which was sprayed with B_3 (Boron @ 0.5%). It was recorded 49.73 kg/plot, 51.69 kg/plot and 50.71 kg/plot during first year, second year and in pooled data, respectively followed by 45.68 kg/plot, 48.11 kg/plot and 46.90 kg/plot under B_2 (Boron @ 0.25%) and minimum yield/plot was recorded 41.18 kg/plot, 43.41 kg/plot and 42.29 kg/plot with B_1 (Boron @ 0%) during first year, second year and in pooled data, respectively. All the levels of B_1, B_2 and B_3 were found significant to each other during the entire experimental period.

3.4.3 Foliar spray of molybdenum: A further reference to data in Table 2 revealed that application of M_2 (Molybdenum @ 0.25%) recorded the maximum yield which was 46.84 kg/plot, 49.27kg/plot and 48.06 kg/plot during first year, second year and pooled data, respectively followed by 46.57 kg/plot, 48.55 kg/plot and 47.56 kg/plot under M_3 (Molybdenum @ 0.5%) and the minimum yield per plot was observed as 43.18 kg/plot, 45.40 kg/plot and 44.29 kg/plot in M_1 (Molybdenum @ 0%). However M_2 and M_3 were at par to each other during both the years of experimentation as well as in pooled data.

Table 2: Effect of spacing, boron and molybdenum on yield of cabbage

Treatments	Yield per plot			Yield qha^{-1}		
	2013	2014	Pooled	2013	2014	Pooled
S_1	40.58	42.40	41.49	396.29	414.00	405.14
S_2	50.48	53.08	51.78	492.92	518.36	505.64
SEm+	0.82	0.54	0.44	7.97	5.32	4.28
CD(0.05)	2.35	1.56	1.23	22.91	15.28	12.02
B_1	41.18	43.41	42.29	402.12	423.90	413.01
B_2	45.68	48.11	46.90	446.12	469.84	457.98
B_3	49.72	51.69	50.71	485.56	504.80	495.18
SEm+	1.00	0.67	0.54	9.76	6.51	5.24
CD(0.05)	2.87	1.92	1.51	28.06	18.72	14.73
M_1	43.18	45.40	44.29	421.64	443.30	432.47
M_2	46.84	49.27	48.06	457.43	481.15	469.29
M_3	46.57	48.55	47.56	454.73	474.09	464.41
SEm+	1.00	0.67	0.54	9.76	6.51	5.24
CD(0.05)	2.87	1.92	1.51	28.06	18.72	14.73

3.5 Yield per hectare (q)

3.5.1 Effect of Spacing: It is clear from data represented in Table 2 that spacing S_2 (60 cm x 45 cm) achieved significantly more yield per hectare. It was recorded 492.92 q/ha, 518.36 q/ha and 505.64 q/ha during first year, second year and in pooled data, respectively. In the Spacing S_1 (60 cm x 60 cm), it was noted 396.29 q/ha, 414.00 q/ha and 405.14 q/ha during first year, second year and in pooled data, respectively.

3.5.2 Foliar spray of boron: Data shown in Table 2 indicated that head yield was increased due to application of boron. As a result, B_3 (Boron @ 0.5%) gave yield of head 485.56 q/ha., 504.80 q/ha. and 495.18 q/ha during first year, second year and pooled data, respectively followed by 446.12 q/ha, 469.84 q/ha and 457.98 q/ha in B_2 (Boron @ 0.25%) and minimum yield/ha was recorded with B_1 (Boron @ 0%) *i.e.* 402.12 q/ha, 423.90 q/ha and 413.01 q/ha during first year, second year and in pooled data, respectively. All the levels of B_1, B_2 and B_3 were found significant to each other during the entire experimental period.

3.5.3 Foliar spray of molybdenum: An insight look of figures clearly showed that the application of M_2 (Molybdenum @ 0.25%) recorded the maximum yield which was 457.43 q/ha, 481.15 q/ha and 469.29 q/ha during first year, second year and in pooled data, respectively followed by 454.73 q/ha, 474.09 q/ha and 464.41 q/ha under M_3 (Molybdenum @ 0.5%) and the minimum yield per hectare was recorded under M_1 (Molybdenum @ 0%) which was 421.64 q/ha, 443.30 q/ha and 432.47 q/ha during first year, second year and in pooled data, respectively. However M_2 and M_3 were at par to each other during both the years of experimentation as well as in pooled data.

4. Discussion

4.1 Effect of Spacing

The various yield traits i.e. diameter of head (cm), weight of untrimmed head (g), weight of trimmed head (g), yield per plot (kg) and yield (qha^{-1}) were studied. The data presented denoted that both the plant spacing significant influenced the various yield traits. Values were found to be maximum at wider spacing i.e. S_1 (60 x 60 cm) for diameter of head (cm), weight of untrimmed head (kg), weight of trimmed head (kg) in both years followed by S_2 (60 cm x 40 cm). There was a linear increase in spacing S_1 (60 cm x 60 cm) it was found better than spacing S_2. The plants grown under wider spacing received more nutrients, light and moisture around compared to plants of closer spacing, which was probably the cause of better performance in yield attributes and yield of individual cabbage head (Khatun *et al*., 2011) [9]. The total marketable head yield of cabbage per plot and per hectare grown in closer {S_2 (60 cm x 45 cm)} spacing resulted in significantly higher yields in both the years than those of wider spacing {S_1 (60 cm x 60 cm)}. In wider spacing the plant population decreased and failed to compensate the loss of increase of due to lesser plant population, though large number of best quality head was obtained. Consequently the yield of head qha^{-1} was more in closer spacing as compared to wider spacing. (Khatiwada, 2001) [8].

4.2 Effect of boron

The various yield traits i.e. diameter of head (cm), weight of untrimmed head (g), weight of trimmed head (g), yield per plot (kg) and yield (qha^{-1}) were studied. The data presented in the chapter results denoted that different boron levels significant influenced the various yield traits. Values were found to be maximum under B_3 i.e. (Boron @ 0.5%) for diameter of head (cm), weight of untrimmed head (kg), weight of trimmed head (kg) in both years followed by B_2 (Boron @ 0.25%) and minimum values for these parameters were found under B_1 (Boron @ 0%). The increase in the head weight by Boron application may be due to its role in enhancing the translocation of carbohydrates from the site of its synthesis to the storage tissue in the head as Boron is known to play beneficial role in the translocation of carbohydrates which helps in better seed or fruit set (Kumar *et al*., 2011 and Alam, 2007) [11, 2]. The total marketable head yield of cabbage per plot and per hectare sprayed by B_3 i.e. (Boron @ 0.5%) resulted in significantly higher yields in both the years followed by B_2 (Boron @ 0.25%) and minimum values for these parameters were found under B_1 (Boron @ 0%).

4.3 Effect of molybdenum

The data presented in Table 1 and 2 denoted that molybdenum also significant influenced the various yield traits. Values were found to be maximum under M_2 i.e. (Molybdenum @ 0.25%) for diameter of head (cm), weight of untrimmed head (kg), weight of trimmed head (kg) in both years followed by M_3 (Molybdenum @ 0.5%) and minimum values for these parameters were found under M_1 (Molybdenum @ 0%). Mo plays a vital role in photosynthesis which decides the yield of crops as observed by Ahmed *et al*., 2013 [1] and Chattopadhyay and Mukhopadhyay, 2003 [3]. Molybdenum affects plant metabolism at many different levels. The responses are strongly linked to the requirement of molybdenum for the various types of molybdoenzymes present in plants. Plant molybdoenzymes can be broken down to those involved in nitrogen reduction and assimilation, nitrogenase, purine catabolism, abscisic acid (ABA) and indole-3 acetic acid (IAA) synthesis and sulfur metabolism. Since molybdenum is involved in a number of different enzymatic processes, a defined plant response to molybdenum deficiency can be complex and thus difficult to assign causally to specific enzyme systems. This is particularly evident in molybdoenzymes involved in nitrogen metabolism where overall reductions in plant growth and health can alter plant development, susceptibility to pest damage, and fruit development (Kanujia *et al*., 2006) [7].

5. Conclusion

It is judicial to use different micronutrients with recommended dose of NPKS fertilizer. Application of micronutrients is one of the important management practices to improve soil productivity. Crop yield and profit are both important to a farmer. Soil health is also very important for sustainable production. Higher yield may also be achieved using higher plant population. Furthermore, the present results on cabbage conclude that a different treatment significantly increases the yield attributing characters and yield. B_3 (Boron @ 0.5%) and M_2 (Molybdenum @ 0.25%) proved in increasing the characters which were studied.

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