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Effect of biofertilizers and micronutrients on growth and quality attributes of cabbage (*Brassica oleracea* var. *capitata* L.)

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Abstract

The present field experiment was conducted during Rabi season of 2016-17 and 2017-18 at the Experimental Farm, Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, (HP). The experiment was laid out in Randomized Complete Block Design (RCBD) Factorial with three replications comprising of fourteen treatment combinations having two levels of biofertilizers i.e. B₀= No biofertilizers & B₁= Biofertilizers (*Azotobacter* + PSB + KSB) and seven levels of micronutrients viz., M₀= No micronutrient, M₁= Boric acid @ 0.5%, M₂= Zinc sulphate @ 0.5%, M₃= Ferrous sulphate @ 0.5%, M₄= Manganese sulphate @ 0.5%, M₅= Ammonium molybdate @ 0.5%, M₆= Multiplex @ 0.5%. The results revealed that growth attributes and quality status of cabbage were found significantly increased with the application of biofertilizers and micronutrients. The minimum number of days to 50 per cent head maturity (67.50) was recorded in treatment combination B₁M₁ (Biofertilizers + Boric acid 0.5%). The significantly maximum polar diameter (13.75 cm) and maximum equatorial diameter (13.36 cm) was recorded in treatment combination B₁M₃ (Biofertilizers + Ferrous sulphate 0.5%). Maximum TSS (5.72 °Brix) was observed in treatment combination B₁M₁ (Biofertilizers + Boric acid 0.5%). However, maximum Vitamin C content (59.97 mg/100 g) was recorded in treatment combination B₁M₂ (Biofertilizers + Zinc sulphate 0.5%).

Keywords: Biofertilizers, cabbage, growth, quality, micronutrients, multiplex

Introduction

Cabbage (*Brassica oleracea* var. *capitata* L.) is one of the most important member of genus *Brassica*. The word "Cabbage" is derived from the French word "coboche" means head. It is a popular vegetable around the world in respect of area, production and availability, almost round the year. It has been originated from a single wild ancestor *Brassica oleracea* L. var. *oleracea* (Syn. *sylvestris*) commonly known as wild cabbage, cliff cabbage or 'Colewart', through mutation and introgression from wild species, human selection and adaptation.

It occupies the pride place among cole crops due to its pleasant taste, delicious flavour, nutritive value and very low fat and calories content. It is grown for heads which are used as vegetable, eaten raw and frequently preserved as sauerkraut or pickle. Cabbage is an excellent source of vitamin C, potassium and calcium (Hasan and Solaiman, 2012) [6]. It has cooling effect and helps in preventing constipation, increase appetite, speed up digestion and very useful for the patients of diabetes (Yadav *et al.*, 2000) [23].

The injudicious use of chemical fertilizers has simultaneously resulted in many problems like degradation of soil productivity, environmental pollution, depletion of non-renewable source of energy etc. Application of biofertilizers in vegetable crops has been found very effective to get rid of this problem. Bio-fertilizers are agriculturally beneficial microorganisms, which have the ability to mobilize the nutritionally important elements from non-usable form to usable form through biological processes. (Kumar *et al.*, 2001) [13]. They are eco-friendly, less expensive and are based on renewable energy sources and provide sustainability to the farming system. Due to the intensive cultivation practices and injudicious use of macronutrients, soils are becoming deficient in secondary micronutrients. In addition to macronutrients, micronutrients have been found to be beneficial for cabbage production (Hara and Sonoda, 1981) [5].

Micronutrients are used in smaller quantities than other essential nutrients and are very important for proper plant nutrition. Now days, it is realized that foliar spray of micronutrients (Fe, Zn, Mn, B, Mo) has proved beneficial to increase yield, quality and improving shelf life of cabbage (Kotecha *et al.*, 2011)^[9]. Foliar application of micronutrients can be considered one of the easier and effective methods, to deliver the needed nutrients to plants in adequate concentrations. The balanced supply of these micronutrients and application of biofertilizers have a potential to increase the growth characteristics and quality of the crop to match the national and international standards. Thus, keeping in view all these factors, the present investigations have therefore, been undertaken to study the effect of biofertilizers and micronutrients on growth and quality attributes of cabbage.

Material and methods

The present investigation was conducted at Vegetable Research Farm of the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan HP during Rabi season of 2016-17 and 2017-18. The experiment was laid out in Randomized Complete Block Design (RCBD) Factorial with three replications comprising of fourteen treatment combinations having two levels of biofertilizers i.e. B₀= No biofertilizers & B₁= Biofertilizers (*Azotobacter* + PSB + KSB) and seven levels of micronutrients viz., M₀= No micronutrient, M₁= Boric acid @ 0.5%, M₂= Zinc sulphate @ 0.5%, M₃= Ferrous sulphate @ 0.5%, M₄= Manganese sulphate @ 0.5%, M₅= Ammonium molybdate @ 0.5%, M₆= Multiplex @ 0.5%. The seedling of cabbage cv. 'Golden Acre' was transplanted on 7th October, 2016 and 8th October 2017. The plot size was 2.25 m × 1.80 m and a spacing of 45 cm × 30 cm was followed. Two method of application was followed in case of biofertilizers where (*Azotobacter* + PSB + KSB) @ 100 g/lit was used for seedling root dip and same biofertilizers @ 5 kg/ha was used for soil application. Foliar applications of micronutrients were given three times at a concentration of 0.5 per cent (5 g/l of water) every 20 days interval starting from 20 days after transplanting to harvesting. All micronutrients were soluble in water.

Days to 50 per cent head maturity was recorded as number of days taken from date of transplanting to date when 50 per cent heads showing marketable size in a plot/treatment and were harvested. Polar diameter and Equatorial diameter in centimeter was measured longitudinally and transversally respectively with the help of vernier caliper. TSS content of the head was worked out by crushing and extracting juice from mature head through a muslin cloth and the liquid extract obtained was used to record total soluble solids (°Brix) with the help of ERMA hand refractrometer. Ascorbic acid content was determined as per the method given by Ranganna (2009)^[19] using 2-6 dichlorophenolindophenol dye.

Results and discussion

Days to 50 per cent head maturity

Days to head maturity is an important character as it indicates the earliness of the crop. Early maturity is desirable since it fetches good returns to the vegetable growers. It is apparent from the data presented in Table 1 that both biofertilizers and micronutrients and their interaction exhibited significant results for the number of days to 50 per cent head maturity in cabbage during both the years of study. Application of biofertilizers B₁ took minimum number of days to 50 per cent head maturity (72.02) than B₀ (76.43) without biofertilizer

application. Among micronutrients, minimum number of days to 50 per cent head maturity (69.75) was recorded in M₁ (Boric acid 0.5%) which was followed by M₂ (Zinc sulphate 0.5%) which took 71.75 days to 50 per cent head maturity, whereas, maximum number of days to 50 per cent head maturity (78.49) was found in the treatment M₀ (No Micronutrients). Combined effect of biofertilizers and micronutrients (B×M) exhibited a significant response in number of days to 50 per cent head maturity. The minimum number of days to 50 per cent head maturity (67.50) was recorded in treatment combination B₁M₁ (Biofertilizers+ Boric acid 0.5%) which was followed by B₁M₂ (Biofertilizers + Zinc sulphate 0.5%), taking 69.50 days to 50 per cent head maturity whereas, maximum number of days to 50 per cent head maturity (80.98) was recorded in B₀M₀ (No Biofertilizers + No Micronutrients)

It has been reported that the treatments with the application of biofertilizers (*Azotobacter*+PSB+KSB) took minimum number of days to 50 per cent head maturity. This might be attributed to increased and better availability of nutrients (i.e. nitrogen, phosphorus and potassium) because of the action of added biofertilizers which acts as an important constituent of chlorophyll and protein, which ultimately resulted in early growth and development of heads. The findings are in agreement with Kachri (2007)^[8] in cauliflower, Negi *et al.* (2017)^[17], Meena *et al.* (2017)^[15] and Sharma *et al.* (2018)^[20] in broccoli. Boric acid @ 0.5% took minimum number of days to 50 per cent head maturity this might be due to the function of boron which resulted into the precipitation of excess cation, buffer action and enhancement of conducting tissues which ultimately resulted into absorption of other essential nutrients. In this way, boron treatment brought about rapid vegetative growth, which subsequently helped in early formation and maturity of heads. The findings are in agreement with Sharma (2012)^[21] in broccoli and Naher *et al.* (2014)^[16] in cabbage.

Polar diameter (cm)

The size of heads formed and their shape are an important cultivar trait in cabbage determined by genetics, but these traits can be influenced by cultivation practices. Pooled data enumerated in Table 1 varied significantly for biofertilizers, micronutrients and their interaction in respect to polar diameter (cm) and equatorial diameter (cm) of cabbage for both the years. The treatment without application of biofertilizers B₀ recorded significantly more polar diameter (12.61 cm) as comparison to the treatment with the application of biofertilizers B₁ (12.54 cm). Among micronutrients, treatment M₃ (Ferrous sulphate 0.5%) recorded maximum polar diameter (13.27 cm) which was followed by treatment M₆ (Multiplex 0.5%) which recorded 13.20 cm polar diameter, whereas, minimum polar diameter (11.94 cm) was recorded in M₀ (No Micronutrients). Combined effect of biofertilizers and micronutrients (B×M) had significant influence on polar diameter. The significantly maximum polar diameter (13.75 cm) was recorded in treatment combination B₁M₃ (Biofertilizers + Ferrous sulphate 0.5%) which was followed by treatment combination B₀M₆ (No Biofertilizers + Multiplex 0.5%) recorded (13.53 cm) polar diameter, whereas, significantly minimum polar diameter (11.68 cm) was recorded in treatment combination B₁M₅ (Biofertilizers + Ammonium molybdate).

Application of biofertilizers individually does not resulted into significant effect on polar diameter but in combined effect with micronutrients it influenced the polar diameter

significantly. This might be due to additional supply of nutrients which increased the synthesis of chlorophyll and amino acid, which in turn enhanced the head size. However, micronutrients individually exhibited significant response for polar diameter. Ferrous sulphate @ 0.5% recorded maximum polar diameter. It might be due to the reason that iron act as an important catalyst in the enzymatic reactions of plant metabolism would have helped in the larger biosynthesis of photo assimilates thereby improving diameter of head. The results are in line with the findings of Lashkari *et al.* (2008)^[14] in cauliflower, Naher *et al.* (2014)^[16] in cabbage and Chaudhari *et al.* (2017)^[2] in cabbage.

Equatorial diameter (cm)

On the basis of pooled data of both the years, the treatment without application of biofertilizers B₀ recorded significantly more equatorial diameter (12.43 cm) as comparison to the treatment with the application of biofertilizers B₁ (12.38 cm). Among micronutrients, treatment M₃ (Ferrous sulphate 0.5%) recorded maximum equatorial diameter (13.08 cm) which was

followed by M₆ (Multiplex 0.5%) which recorded 12.91 cm equatorial diameter, whereas, minimum (11.69 cm) was recorded in M₀ (No Micronutrients). Combined effect of biofertilizers and micronutrients (B×M) significantly influenced the equatorial diameter. Maximum equatorial diameter (13.36 cm) was recorded in treatment combination B₁M₃ (Biofertilizers + Ferrous sulphate 0.5%) which was followed by treatment combination B₀M₆ (No Biofertilizers + Multiplex 0.5%) recorded (13.22 cm) equatorial diameter, whereas, significantly minimum equatorial diameter (11.31 cm) was recorded in treatment combination B₁M₅ (Biofertilizers + Ammonium molybdate 0.5%).

First year application of biofertilizers individually does not resulted into much significant effect on equatorial diameter but second year application of biofertilizers resulted in enhanced head diameter. This might be due to additional supply of NPK which increased the synthesis of chlorophyll, photosynthesis and amino acid which ultimately lead to increased head size. Micronutrients on the other hand resulted in significant response for equatorial diameter. This

Table 1: Effect of biofertilizers and micronutrients on growth attributes of cabbage (pooled data of two years)

Biofertilizers Micronutrients	Days to 50 per cent head maturity Pooled			Polar diameter (cm) Pooled			Equatorial diameter (cm) Pooled		
	B ₀ No Biofertilizer	B ₁ (Azotobacter+PSB+KSB)	Mean	B ₀ No Biofertilizer	B ₁ (Azotobacter+PSB+KSB)	Mean	B ₀ No Biofertilizer	B ₁ (Azotobacter+PSB+KSB)	Mean
M ₀ (No micronutrients)	80.98	76.00	78.49	11.78	12.10	11.94	11.67	11.72	11.69
M ₁ (Boric acid @ 0.5%)	72.00	67.50	69.75	11.83	12.13	11.98	11.61	12.25	11.93
M ₂ (Zinc sulphate @ 0.5%)	74.00	69.50	71.75	12.99	12.21	12.60	12.60	12.83	12.72
M ₃ (Ferrous sulphate @ 0.5%)	77.52	73.00	75.26	12.78	13.75	13.27	12.80	13.36	13.08
M ₄ (Manganese sulphate @ 0.5%)	78.50	74.90	76.70	12.90	13.05	12.98	12.82	12.56	12.69
M ₅ (Ammonium molybdate @ 0.5%)	76.50	72.42	74.46	12.45	11.68	12.07	12.29	11.31	11.80
M ₆ (Multiplex @ 0.5%)	75.50	70.85	73.18	13.53	12.88	13.20	13.22	12.61	12.91
Mean	76.43	72.02		12.61	12.54		12.43	12.38	
B (Biofertilizers)		0.20			0.03			0.04	
M (Micronutrients)		0.38			0.06			0.07	
B×M		0.53			0.08			0.09	

Could be due to the application of micronutrient induced the synthesis of chlorophyll which in turn resulted in higher vegetative growth. The results are in line with the findings of Lashkari *et al.* (2008)^[14] cauliflower, Naher *et al.* (2014)^[16] in cabbage and Chaudhari *et al.* (2017)^[2] in cabbage.

TSS (°Brix)

TSS is important parameter which reflects the quality of head. An introspection of data in Table 2 revealed that both biofertilizers and micronutrients and their interaction had significant effect on TSS (°Brix) of cabbage during both the years of study. On the basis of pooled data of both the years, significantly more TSS (5.43 °Brix) was observed in the treatment B₁ as compared to the treatment B₀ (5.30 °Brix). Among micronutrients, highest TSS (5.64 °Brix) was recorded in M₁ (Boric acid 0.5%) which was followed by M₅ (Ammonium molybdate 0.5%) having 5.55 °Brix of TSS, whereas, lowest TSS (5.08 °Brix) was found in the treatment M₀ (No Micronutrients). Combined effect of biofertilizers and micronutrients (B×M) exhibited a significant response in total soluble solids (TSS in °Brix). Highest TSS (5.72 °Brix) was recorded in treatment combination B₁M₁ (Biofertilizers + Boric acid 0.5%) which was followed by B₁M₅ (Biofertilizers + Ammonium molybdate 0.5%) having TSS of 5.63 °Brix, whereas, lowest TSS (4.98 °Brix) was recorded in B₀M₀ (No Biofertilizers + No Micronutrients).

This increase in TSS content with the application of biofertilizers may be attributed to greater movement and availability of essential nutrients that might have accelerated the breakdown of complex polysaccharides into simple sugars and directs their accumulation in developing heads. These findings are in agreement with Chatterjee *et al.* (2012)^[1] and Jha *et al.* (2017)^[7] in cabbage. Boric acid @ 0.5% produced significantly increased TSS content in cabbage head, the enhancement in TSS content, could be due to the catalytic action of boron particularly at higher concentration. Hence, the foliar application of boron quickly increased the uptake of macronutrients in the tissues and organs of the cabbage that ultimately decreased the nutritional deficiencies and improved the head quality. These results are in accordance with the findings of Sharma (2012)^[21] and Singh *et al.* (2018)^[22] in broccoli.

Vitamin C content (mg/100 g)

Ascorbic acid content (Vitamin C) is one of the major quality components in cabbage as it improves the nutrition quality of head. The observation of data in Table 2 showed that both biofertilizers and micronutrients and their interaction had significant effect on vitamin C content (mg/100 g) of cabbage during both the years of study. Between biofertilizers, maximum vitamin C content (53.32 mg/100 g) was observed in the treatment B₁ as comparison to the treatment B₀ (44.90

mg/100 g). While among micronutrients, M₂ (Zinc sulphate 0.5%) recorded maximum vitamin C content 55.51 mg/100 g) which was followed by M₃ (Ferrous sulphate 0.5%) having 52.60 mg/100 g of vitamin C content, whereas, minimum

vitamin C content (41.32 mg/100 g) was found in the treatment M₀ (No Micronutrients). Combined effect of biofertilizers and micronutrients (B×M) exhibited a significant response on vitamin C content (mg/100 g).

Table 2: Effect of biofertilizers and micronutrients on quality attributes of cabbage head (pooled data of two years)

Biofertilizers Micronutrients	(TSS °Brix) Pooled			Vitamin C content (mg/100 g) Pooled		
	B ₀ (No Biofertilizer)	B ₁ (<i>Azotobacter</i> + PSB + KSB)	Mean	B ₀ (No Biofertilizer)	B ₁ (<i>Azotobacter</i> + PSB + KSB)	Mean
M ₀ (No micronutrients)	4.98	5.18	5.08	37.78	44.85	41.32
M ₁ (Boric acid @ 0.5%)	5.56	5.72	5.64	44.49	53.43	48.96
M ₂ (Zinc sulphate @ 0.5%)	5.35	5.45	5.40	51.05	59.97	55.51
M ₃ (Ferrous sulphate @ 0.5%)	5.30	5.39	5.34	48.32	56.88	52.60
M ₄ (Manganese sulphate @ 0.5%)	5.18	5.31	5.24	42.37	50.38	46.38
M ₅ (Ammonium molybdate @ 0.5%)	5.48	5.63	5.55	44.55	52.52	48.53
M ₆ (Multiplex @ 0.5%)	5.28	5.35	5.31	45.73	55.22	50.48
Mean	5.30	5.43		44.90	53.32	
CD _(0.05)						
B (Biofertilizers)	0.02			0.36		
M (Micronutrients)	0.04			0.68		
B×M	0.05			0.96		

The maximum vitamin C content (59.97 mg/100 g) was recorded in treatment combination B₁M₂ (Biofertilizers + Zinc sulphate 0.5%) which was followed by B₁M₃ (Biofertilizers + Ferrous sulphate 0.5%) having 56.88 mg/100 g vitamin C content, whereas, minimum (37.78 mg/100 g) was recorded in B₀M₀ (No Biofertilizers + No Micronutrients).

The increase in Vitamin-C content could be due to the increased efficiency of microbial inoculants to fix atmospheric nitrogen and secrete growth promoting substances which accelerates the physiological processes like synthesis of carbohydrates, better nutrient uptake, excellent biochemical activity and in turn synthesis of ascorbic acid. These findings are in agreement with Chatterjee *et al.* (2012)^[1], Kumar *et al.* (2015)^[12] and Devi *et al.* (2017)^[4] in cabbage. Application of Zinc sulphate @ 0.5% recorded maximum vitamin C content in cabbage head followed by Ferrous sulphate @ 0.5%. This increase in vitamin C content might be due to application of zinc and iron, both working as active carrier to enzymatic activities and enzymes catalyzing numerous biochemical reactions, including those neutralizing the effects of reactive oxygen species and various pathways of ascorbate synthesis in plants and resulted in to higher vitamin C content in cabbage head. Similar findings of increased vitamin C contents were reported by Kotecha *et al.* (2016)^[10] in cabbage and Singh *et al.* (2018)^[22] in broccoli.

Conclusion

From the present studies it can be concluded that conjoint application of biofertilizers and micronutrients increases the growth and quality attributes of cabbage. Therefore, from economic point of view, seedling root dip @ 1 kg/ha and soil application @ 5kg/ha of (*Azotobacter* + PSB + KSB) with three foliar spray of @ 0.5% Multiplex at 20 days interval from days of transplanting can be recommended for commercial cabbage cultivation in Himachal Pradesh.

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