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Response of cabbage (*Brassica Oleracea* Var. Capitata L.) to different sources of nutrition and bio-fertilizer application

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Abstract
The experiment was conducted at the Main Horticulture Research Farm of P.G. College Ghazipur, U.P. during winter season of 2007-2008. The experiment consisting of 10 treatment combinations evaluated in RBD (Factorial) with three replications. The experimental findings revealed that the Plant height, Number of outer leaves, Dry weight of leaves, Stem diameter, Head diameter, Head volume, Number of wrapper leaves, Dry matter content of head, and yield were significantly higher while other characters, Fresh weight of leaves, Fresh weight of head and Dry weight of head were not significantly affected with the inoculation of bio-fertilizer. Treatment combination B_1S_4 (Half rec. dose N-P-K-+F.Y.M. @10 t ha^{-1} + Bio-fertilizer (P.S.B.), showed better response in respect of plant growth, yield and it's attributes. However, maximum yield 543.30 qha^{-1} was obtained with the application of Half recommended dose of N-P-K-+ F.Y.M. @ 10 t ha^{-1}+Bio-fertilizer (P.S.B.) followed by B_0S_4 Half rec. dose N-P-K-+F.Y.M. @10 t ha^{-1} while minimum yield was recorded under B_0S_3 Neem Cake@5q ha^{-1}. Based on findings it may be recommended that the combination of organic and inorganic fertilizers ensure higher growth and yield of cabbage.

Keywords: bio-fertilizer, cabbage, F.Y.M., N-P-K-, neem cake

Introduction
Cabbage (*Brassica oleracea* var. *capitata* Linn.) is one of the important leafy vegetable crops grown in winter season in many parts of India. Globally, the role of vegetable crops has been well recognized in solving problem of food and nutritional security. Since cabbage, a short duration vegetable crop, sometimes consumed raw, requires heavy doses of nutrients, needs integrated nutrient management to maintain high quality and minimize the cost of production. Integrated nutrient management practices for growing cabbage are of paramount importance for sustainable crop production. With the adoption of new technology of intensive cropping with high yielding varieties, there is a considerable demand on soil for supply of nutrients. However, the native fertility of our soils is poor and cannot sustain high crop yields [1]. Food and Agricultural Organization advocate an integrated nutrient supply system approach to crop. It is the system, which envisages the use of organic wastes, bio-fertilizers and inorganic fertilizers in judicious combinations to sustain soil productivity. It has been reportedly confirmed that continuous sole use and imbalanced use of mineral fertilizers leads to decrease in nutrient uptake efficiency of plants resulting in either yield stagnation or decrease in yield. Bio-fertilizers offer an economically attractive and ecologically sound means of reducing external inputs and improving quality and quantity of vegetable produce. They contain microorganisms which are capable of mobilizing nutrient elements from unavailable form to available form through different biological processes [2]. Since, there is need to increase the productivity of cabbage per unit area, hence, the present study was carried out to evaluate the performance of cabbage crop under varying sources of organic and inorganic fertilizer integrated with bio-fertilizer in respect of growth attributes, yield and yield attributes.

Materials and Methods
A field experiment was conducted during winter season at Main Horticultural Research Farm of Post Graduate College, Ghazipur, U.P. The soil of experimental site was sandy loam with pH 7.4, low in organic carbon (0.27%) and available nitrogen (175.50 kg ha^{-1}), high in available phosphorus (29.20 kg ha^{-1}) and low in available potassium (226.75 kg ha^{-1}). The treatments consisted of 5 sources of nutrition *viz.*, S_1 (Recommended dose of N-P-K- @ 120:60:60 kg ha^{-1}), S_2 (F.Y.M. @ 20 t ha^{-1}), S_3 (Neem Cake @ 5 q ha^{-1}), S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}), and S_5 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + Neem Cake @ 2.5 q ha^{-1}) with two

levels of bio-fertilizer (Phosphate Solubilizing Bacteria) application *viz.*, B_0 (No application of bio-fertilizer) and B_1 (Application of bio-fertilizer P.S.B.). Total ten treatment combinations were replicated thrice in randomized block design. Cabbage variety Indam-296 (F_1 Hybrid) transplanted at 45×45 cm spacing. Nitrogen was applied in three splits, whereas basal application of P and K was done as per treatments. Inoculation of bio-fertilizer (P.S.B.) was done at the time of transplanting as per treatments. Data on growth attributes *viz.*, plant height, number of outer leaves, stem diameter, fresh weight of leaves, and dry weight of leaves; and yield attributes *viz.*, diameter of head, volume of head, number of wrapper leaves, fresh weight of head, dry weight of head, dry matter content of head, and yield ha^{-1} were recorded.

Results

Growth Attributes

Plant Height

Plant height is one of the important growth contributing characters for cabbage plant. The plant height of cabbage at 30, 45 and 60 days after transplanting (DAP) was significantly influenced by different sources of nutrients (Table 1). Data pertaining to plant height showed that the application of Bio-fertilizer significantly increased the plant height of cabbage at all the levels and maximum plant height was recorded with the application of Bio-fertilizer. The interactive effect of different sources of nutrition and Bio-fertilizer application was found to be non-significant. However, maximum and minimum plant height was recorded under B_1S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}+ Bio-fertilizer) and S_3 (Neem Cake @ 5 q ha^{-1}), respectively at all the stages of plant growth.

Number of outer leaves

Number of outer leaves of cabbage varied significantly with the different sources of nutrients and Bio-fertilizer application but their interactive effect was found statistically non-significant (Table 1). It is quite clear from the data that the number of outer leaves at 30 days after transplanting was maximum under B_1S_1 (NPK Full dose + Bio-fertilizer) but at 45 and 60 days after transplanting it was maximum under B_1S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}+ Bio-fertilizer).

Stem Diameter

It is evident from the table-1 that the sources of nutrition and Bio-fertilizer application had very significant influence on the stem diameter of cabbage at all stages of the plant growth. The interaction of sources of nutrition and Bio-fertilizer application was found to be highly significant at 30 and 60 days after transplanting but not at 45 days after transplanting. However, the maximum and minimum thickness of stem was recorded with B_1S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}+ Bio-fertilizer) and S_1 (N-P-K- full dose).

Fresh weight of leaves

Significant effect was observed on fresh weight of leaves of sources of nutrition and Bio-fertilizer application solely but their interactive effect was found to be non-significant. In general, all the sources of nutrition with Bio-fertilizer application inoculation expressed higher value of this parameter as compare to no application of Bio-fertilizer.

Dry weight of leaves

Different sources of nutrition and Bio-fertilizer application affected dry weight of leaves significantly. The data also indicated that the interactions of Bio-fertilizer and different sources of nutrition had significant effect on dry weight of leaves. However, the maximum (3.58 g) and minimum (2.24 g) dry weight of leaves was recorded with B_1S_2 (FYM 20 t ha^{-1}) and S_1 (NPK full dose), respectively.

Yield and Yield attributes

Head Diameter

Head diameter of cabbage is significantly influenced by different sources of nutrition and bio-fertilizer application and their interactions. A critical interpretation of the data revealed that there was much difference between the size of head under B_1S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}+ Bio-fertilizer) and B_1S_3 (Bio-fertilizer + Neem cake full dose). However, among all the treatment combinations the maximum (189.43 mm) and minimum (92.87 mm) diameter of head was noted under B_1S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}+ Bio-fertilizer) and S_3 (Neem Cake @ 5 q ha^{-1}), respectively.

Volume of Head

Data pertaining to volume of head revealed that the different sources of nutrition influenced the volume of head significantly. It is also observed that the application of bio-fertilizer proved to be statistically significant in respect to volume of head and exerted better response. Interactions of different sources of nutrition and bio-fertilizer application had wide and significant effect on volume of head. However, the maximum (2701 cc) and minimum (1649.67 cc) volume of head was recorded under B_1S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}+ Bio-fertilizer) and S_3 (Neem Cake @ 5 q ha^{-1}), respectively.

Number of wrapper leaves

Number of wrapper leaves was significantly influenced by the different sources of nutrition and bio-fertilizer application. However, bio-fertilizer application brought a remarkable edge over the application of the different sources of nutrition alone. The interaction effect of bio-fertilizer and different sources of nutrition proved to be significantly effective for the number of wrapper leaves. However, among all the treatment combinations the highest (51.07) and minimum (31.40) number of wrapper leaves was noted under B_1S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}+ Bio-fertilizer) and S_3 (Neem Cake @ 5 q ha^{-1}), respectively.

Fresh and dry head weight

Various sources of nutrition had significant influence on the fresh and dry head weight. The efficacy of the bio-fertilizer with respect to both the characters was found to be highly significant and maximum fresh and dry head weight was recorded with application of bio-fertilizer. Interactions of sources of nutrition and bio-fertilizer application were found to be non-significant in case of fresh and dry head weight. It is also clear from the table that all the sources of nutrition expressed heavier heads (fresh and dried) in combination with bio-fertilizer than they were applied alone.

Dry matter content of head

Dry matter content of head was significantly influenced by the different sources of nutrition. Among all sources of nutrition S_3 (Neem Cake @ 5 q ha^{-1}) and S_1 (NPK full dose) were found to be most superior and inferior and exerted the highest and lowest dry matter content of head. Inoculation of bio-fertilizer was also found to be significantly effective with respect to the dry matter content of heads. The efficacy of interaction on dry matter content of head was found to be highly significant.

Head Yield ha^{-1}

Effect of different sources of nutrition, bio-fertilizer application and their interactions was found to be highly significant on the yield ha^{-1}. Among all the treatment combinations B_1S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}+ Bio-fertilizer) was expressed the maximum yield ha^{-1} (543.3 q) while S_3 Neem Cake @ 5 q ha^{-1}) proved to be most inferior and expressed 245.27 q ha^{-1}.

Discussion

Cabbage (*Brassica oleracea* L.) is a leafy green or purple biennial plant, grown as an annual vegetable crop for its dense-leaved heads. Plants perform best when grown in well-drained soil in a location that receives maximum radiation. Different varieties prefer different soil types, ranging from lighter sand to heavier clay, but all prefer fertile ground with a pH between 6.0 and 6.8. Though cabbage is a shallow rooted plant even its growth influenced (and in many cases is limited) by the soil profile. Hard pans, clay pans and compact soil generally restrict root growth. This, in turn, reduces nutrient and water uptake, limits plant growth and reduces yields [3]. The highest values for plant height, Number of folded leaves per head, Fresh weight of cabbage leaves at harvest, were recorded in integrated plant nutrition System with the treatment B_1S_4 (Half recommended dose of N-P-K- @ 120:60:60 kg ha^{-1} + F.Y.M. @ 10 t ha^{-1}+ Bio-fertilizer). This might be due to the fact that organic manures and inorganic fertilizers supplied adequate available plant nutrients for proper vegetative growth of cabbage plants and the PSB increased the availability of the phosphorus to the plant. All these actions ultimately influenced the plant height. Farmyard manure offers better water holding capacity, supply of micro-nutrient and availability of major nutrients due to favourable soil conditions [4]. The present findings are in line with the results in broccoli [5] and [6]. Application of bio-fertilizers help in secretion of growth promoting substances, which lead to better root development, transportation of water, uptake and decomposition of nutrients [7]. As outer leaves of cabbage mainly take part in photosynthesis, their number as well as fresh weight of the leaves is the most important physio-morphological character, which has a great contribution on cabbage yield. The phenomena of increase in number of outer leaves in later stage might be due to the better nourishment of plant in combination with organic and mineral fertilizer. These findings are in conformity with the earlier findings [8] and [9] whereas contrary to this obtained more number of outer leaves with mineral fertilizers than organically grown plants [10]. The integration of organic and inorganic fertilizers coupled with Bio-fertilizer application significantly influenced the head yield of cabbage. Increased yield due to N-P-K- Fertilization in conjunction with FYM and Bio-fertilizer added supplementary nutrition to the crop. It is probably due to the fact that bio-fertilizers in combination with organic fertilizers help in better root proliferation, which facilitate more uptakes of nutrients and water, higher leaf number and more area responsible for effective photosynthesis and enhanced food accumulation. The correlated findings are also reported by [11-15].

Table 1: Plant height of cabbage as influenced by different sources of nutrition and Bio-fertilizer application

Days	Bio-fertilizer Application	Sources of Nutrition					Mean	CD@5%		
		S_1	S_2	S_3	S_4	S_5		B	S	BS
30 DAP	B_0	15.33	14.90	12.90	15.87	13.93	14.59	0.224	0.335	NS
	B_1	15.80	15.33	13.13	16.40	14.17	14.97			
	Mean	15.57	15.12	13.02	16.13	14.05	14.78			
45 DAP	B_0	25.20	26.87	22.53	29.27	23.06	25.39	0.322	0.509	NS
	B_1	27.16	28.67	23.43	30.00	24.93	26.76			
	Mean	26.18	27.77	22.98	29.63	23.80	26.07			
60 DAP	B_0	30.00	31.80	24.87	36.53	26.00	29.84	0.500	0.790	NS
	B_1	33.40	37.27	29.27	37.20	31.33	33.65			
	Mean	31.70	34.53	27.07	36.87	28.57	31.75			

Table 2: Number of outer leaves of cabbage as influenced by different sources of nutrition and Bio-fertilizer application

Days	Bio-fertilizer Application	Sources of Nutrition					Mean	CD@5%		
		S_1	S_2	S_3	S_4	S_5		B	S	BS
30 DAP	B_0	12.87	12.33	11.20	11.33	11.80	11.91	0.055	0.086	0.122
	B_1	13.13	12.60	12.00	11.73	12.33	12.36			
	Mean	13.00	12.46	11.60	11.53	12.07	12.13			
45 DAP	B_0	17.76	19.27	15.33	19.50	17.00	17.77	0.137	0.216	0.103
	B_1	18.46	19.47	15.47	19.33	17.67	18.20			
	Mean	18.12	19.37	15.40	19.72	17.33	17.98			
60 DAP	B_0	20.67	21.47	19.53	23.47	20.40	21.10	0.262	0.414	NS
	B_1	21.07	22.07	19.87	24.20	20.73	21.59			
	Mean	20.87	21.77	19.70	23.83	20.57	21.34			

Table 3: Stem diameter of cabbage as influenced by different sources of nutrition and Bio-fertilizer application

Days	Bio-fertilizer Application	Sources of Nutrition					Mean	CD@5%		
		S_1	S_2	S_3	S_4	S_5		B	S	BS
30 DAP	B_0	0.56	0.69	0.59	0.76	0.65	0.65	0.008	0.013	0.180
	B_1	0.58	0.72	0.64	0.83	0.67	0.69			
	Mean	0.57	0.71	0.61	0.80	0.66	0.67			
45 DAP	B_0	0.91	1.09	1.00	1.21	1.05	1.05	0.025	0.039	NS
	B_1	0.95	1.14	1.03	1.30	1.11	1.11			
	Mean	0.93	1.12	1.02	1.26	1.08	1.08			
60 DAP	B_0	0.93	1.17	1.03	1.38	1.12	1.13	0.012	0.018	0.026
	B_1	1.01	1.24	1.09	1.50	1.13	1.20			
	Mean	0.97	1.21	1.06	1.44	1.13	1.16			

Table 4: Fresh weight (g) and dry weight (g) of leaves of cabbage as influenced by different sources of nutrition and Bio-fertilizer application

	Bio-fertilizer Application	Sources of Nutrition					Mean	CD@5%		
		S_1	S_2	S_3	S_4	S_5		B	S	BS
Fresh weight of leaves (g)	B_0	28.82	29.62	20.07	36.16	21.03	27.14	1.942	3.070	NS
	B_1	29.97	35.90	23.38	35.05	27.24	30.31			
	Mean	29.39	32.76	21.72	35.60	24.13	28.72			
Dry weight of leaves	B_0	2.24	2.78	3.29	2.90	2.58	2.76	0.157	0.248	0.350
	B_1	3.08	3.58	3.43	2.80	3.11	3.40			
	Mean	2.66	3.18	3.36	3.35	2.84	3.08			

Table 6: Head diameter, volume of head and number of wrapper leaves of cabbage as influenced by different sources of nutrition and Bio-fertilizer application

Yield Attributes	Bio-fertilizer Application	Sources of Nutrition					Mean	CD@5%		
		S_1	S_2	S_3	S_4	S_5		B	S	BS
Head diameter	B_0	152.40	131.33	92.87	175.80	122.80	135.04	1.361	2.152	3.043
	B_1	170.70	141.00	105.73	189.43	128.80	147.13			
	Mean	161.55	136.17	99.30	182.62	125.80				
Volume of head	B_0	2254.00	2066.33	1476.00	2451.33	1901.00	2029.73	17.737	28.045	39.661
	B_1	2381.66	2212.33	1649.67	2701.00	1922.33	2173.40			
	Mean	2317.83	2139.33	1562.83	2576.17	1911.67				
Number of wrapper leaves	B_0	33.80	39.13	29.73	44.80	40.20	37.53	1.081	1.710	2.418
	B_1	39.73	47.20	31.40	51.07	41.80	42.24			
	Mean	36.77	43.17	30.57	47.93	41.00				

Table 7: Fresh head weight, dry head weight, dry matter content and yield (q ha^{-1}) of cabbage as influenced by different sources of nutrition and Bio-fertilizer application

Yield attributes	Bio-fertilizer Application	Sources of Nutrition					Mean	CD@5%		
		S_1	S_2	S_3	S_4	S_5		B	S	BS
Fresh head weight	B_0	2260.67	2438.33	1467.00	2407.33	1472.33	2009.13	61.629	97.443	NS
	B_1	2389.67	2511.67	1506.33	2716.33	1631.67	2151.13			
	Mean	2325.17	2475.00	1486.67	2561.83	1552.00				
Dry head weight	B_0	158.63	189.61	132.30	205.14	132.06	163.55	2,275	3.597	NS
	B_1	167.06	195.26	134.62	210.05	133,55	168.11			
	Mean	162.84	192.44	133.46	207.60	132.81				
Dry matter content	B_0	7.02	7.80	9.03	8.53	8.97	8.27	0.153	0.241	0.341
	B_1	6.99	7.78	8.95	7.74	8.19	7.93			
	Mean	7.00	7.79	8.99	8.14	8.58				
Yield (q ha^{-1})	B_0	342.93	413.97	245.27	464.80	279.93	349.38	2.007	3.173	4.487

Conclusion

Finally on the basis of experimental evidences the following specific conclusion in general adopted for commercial cultivation of cabbage:

1. The application of half rec. dose of N-P-K- +10 t FYM ha^{-1} in order to secure higher growth and yield of cabbage.
2. Head yield was uniformly enhanced by application of bio-fertilizer during present investigation. Thus, bio-fertilizer may be used for better realization of head yield in cultivation.

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