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Effect of integrated nutrient management on the performance of cabbage (*Brassica oleracea* var. *capitata* L.)

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Abstract
Cabbage (*Brassica oleraceae* L. var. *capitata*, 2n=18) is one of the most economically and nutritionally important crop of Brassicaceae family. The integrated nutrient management plays an important role for obtaining maximum yield and best growth characteristics of crop. This study was planned with the main objective to study the effect of integrated nutrient management on the growth and yield parameters of cabbage. In this experiment, the highest yield (39.76 t/ha) was recorded in T_1: NPK (100%) + Vermicompost + *Azospirillum*, however, it was statistically at par with T_2: NPK (75%) + Vermicompost + *Azospirillum* with a recorded yield of 38.20 t/ha. Similar trend for this treatment combination (T_2) were observed for other parameters such as plant height (25.48 cm), plant spread (50.71 cm), leaf length (26.28 cm), leaf breadth (19.42 cm), polar diameter of head (13.65 cm), equatorial diameter of head (14.96 cm) and yield per plot (7.79 kg) which showed no significant difference when the RDF was reduced by 25 per cent. Therefore, it can be concluded that supplying the cabbage crop with NPK (75%) + Vermicompost + *Azospirillum* proves efficient in increasing the yield of cabbage besides reducing 20-25 per cent of inorganic fertilizers which will eventually reduce the cost of production and harmful effects of inorganic fertilizers on soil health and environment.

Keywords: cabbage, organic, biofertilizer, growth and yield

Introduction
Cabbage (*Brassica oleraceae* L. var. *capitata*, 2n=18) is one of the most economically and nutritionally important crop of Brassicaceae family. It is cultivated in 90 countries. It is also a vital part of fast food in Indian –cuisine due to wider adaptability, economical and all year availability. It has important values because of its nutrient values like vitamins and protein. It is also a source of sulforaphane which reduces the risk of prostate cancer in human beings.

Cabbage is a heavy feeder crop, it removes various important nutrients from the soil. The indiscriminate and continuous use of chemical fertilizers adversely affects the soil quality, along with the reduction in the productivity of crop. Ultimately, it has laden the farmers with extra cost of chemical fertilizers which leads to reduction in the cost-benefit ratio of the crop. On the other hand, integration with organic manures and biofertilizers not only improves the physical and chemical properties of soil, but also maintains the quality of environment and plant produce (Maheshwarappa *et al.*, 1999) [5]. Organic manure also increases the biological reaction in soil which helps the plant to uptake the nutrients from the soil, but this process is slow.

Further, the use of organic manure along with the integrated use of bio-fertilizers and chemical fertilizer is known to increase biological and socio-physiological condition of the crop. The reduced recommended dose of nitrogen could be supplemented by biofertilizers like *Azospirillum*, *Rhizobium* and *Acetobacter*. Biofertilizers are very important in organic farming. The biofertilizers can save around 25 per cent of phosphorus and nitrogen by converting the nutrient in usable form with the biological process (Chattoo *et al.*, 2003) [2]. The experiment was laid out to study the effect of integrated nutrient management on the growth and yield parameters of cabbage.

Materials and Methods
The present investigation was carried out during 2017-18 in Agricultural Research Field of Lovely Professional University, Phagwara, Punjab. The soil of the experimental site was alkaline in nature with pH of 7.4 and organic carbon of 1.6 per cent. Twelve different treatment combinations of organic manure, biofertilizer and inorganic fertilizers along with one control were imposed on cabbage in Randomized Block Design with three replications. In experiment,

materials used were- Chemical fertilizers such as MOP, SSP and Urea for the nutrition requirement of the crop, organic materials like- vermicompost, neem cake, FYM and *Azospirillum* as biofertilizer. The treatments were T_1: NPK (100%) + Vermicompost + *Azospirillum*, T_2: NPK (75%) + Vermicompost + *Azospirillum*, T_3: NPK (50%) + Vermicompost + *Azospirillum*, T_4: NPK (100%) + FYM (Compost) + *Azospirillum*, T_5: NPK (75%) + FYM (Compost) + *Azospirillum*, T_6: NPK (50%) + FYM (Compost) + *Azospirillum*, T_7: NPK (100%) + Neem Cake + *Azospirillum*, T_8: NPK (75%) + Neem Cake + *Azospirillum*, T_9: NPK (50%) + Neem Cake + *Azospirillum*, T_{10}: NPK (100%), T_{11}: NPK (75%), T_{12}: NPK (50%) and T_{13}: Control.

The seeds of cabbage cv. 'Green Flash' were sown in nursery in September. The plot size adopted was 2 m x 1 m and planting was done with spacing of 45 cm x 45 cm in the main field. The observations were recorded on plant height, plant spread, leaf length, leaf breadth, polar head diameter, equatorial head diameter and yield parameters for all the treatments.

Land was prepared by ploughing and beds of size 2 m length and 1 m breadth were prepared. Proper irrigation was provided during transplanting. The fertilizer applications were followed as per the treatment details viz., For 100% NPK, Urea- 55 g/bed; SSP- 77.5 g/bed; MOP- 5 g/bed, for 75% NPK, Urea- 41 g/bed; SSP- 58 g/bed; MOP- 3.7 g/bed and for 50% NPK, Urea- 27 g/bed; SSP- 39 g/bed; MOP-2.5 g/bed and vermicompost was added @ 400 g/bed and farm yard manure @ 4 kg/bed.

Cabbage was harvested when its head reached desired size and firm after 90 to 95 days. Each head was cut with the sharp knife at the base. Then outer leaves and roots were removed. Data collection was carried out at 90 days after transplanting and harvesting of cabbage heads was done at maturity. Six plants were tagged and assessed on each bed for the purpose of recording data.

Results and Discussion

The statistical analysis showed significant results among all treatments for the growth and yield parameters (Table 1).

The highest plant height (26.33 cm), plant spread East-West (52.53 cm), spread North-South (53.82 cm), leaf length (27.38 cm), leaf breadth (20.26 cm), polar head diameter (14.93 cm), equatorial head diameter (15.68 cm) and yield per plot (7.95 kg) was observed in T_1 (NPK 100% + vermicompost + *Azospirillum*) followed by T_7 with plant height (26.10 cm), plant spread East-West (52.11 cm), plant spread North-South (53.30 cm), leaf length (27.10 cm), leaf breadth (19.87 cm), polar head diameter (14.31 cm), equatorial head diameter (15.53 cm) and yield per plot (7.91 kg) and T_4 with plant height (25.80 cm), plant spread East-West (51.25 cm), plant spread North-South (52.54 cm), leaf length (26.52 cm), leaf breadth (19.70 cm), polar head diameter (14.12 cm), equatorial head diameter (15.21 cm) and yield per plot (7.80 kg) compared to the lowest in control T_{13} with plant height (19.45 cm), plant spread East-West (38.31 cm), plant spread North-South (37.55 cm), leaf length (17.08 cm), leaf breadth (13.00 cm), polar head diameter (7.55 cm), equatorial head diameter (8.93 cm) and yield per plot (3.47 kg).

However, it has been observed that for plant height T_1 (26.33 cm) was statistically at par with T_2 - NPK 75%, vermicompost and *Azospirillum* with a plant height of 25.48 cm, similarly, T_4 (25.80 cm) was statistically at par with the T_5 - NPK 75%, FYM and *Azospirillum* with a plant height of 25.04 cm and also T_7 (26.10 cm) was statistically at par with T_8 - NPK 75%, Neem cake and *Azospirillum* with a plant height of 25.15 cm.

For plant spread East-West as well, it has been observed that T_1 (52.53 cm) was statistically at par with T_2 - NPK 75%, vermicompost and *Azospirillum* with a plant spread of 50.71 cm, similarly, T_4 (51.25 cm) was statistically at par with T_5 - NPK 75%, FYM and *Azospirillum* with a plant spread of 49.94 cm. For plant spread North-South also showed that T_1 (53.82 cm) was statistically at par with T_2 - NPK 75%, vermicompost and *Azospirillum* with a plant spread (N-S) of 51.41 cm, similarly, T_4 (52.54 cm) was statistically at par with T_5 – NPK 75%, FYM and *Azospirillum* with a plant spread (N-S) of 49.37 cm.

Highest leaf length in T_1 (27.38 cm) was also statistically at par with T_2 - NPK 75%, vermicompost and *Azospirillum* with leaf length recorded at 26.28 cm, similarly, T_4 (26.52 cm) was statistically at par with T_5 - NPK 75%, FYM and *Azospirillum* with a leaf length of 25.87 cm and also T_7 (27.10 cm) was statistically at par with T8 - NPK 75%, Neem cake and *Azospirillum* with a leaf length of 26.14 cm. Highest leaf breadth in T_1 (20.26 cm) was also statistically at par with T_2 - NPK 75%, vermicompost and *Azospirillum* with a leaf breadth of 19.42 cm, similarly, T_4 (19.70 cm) was statistically at par with T_5 - NPK 75%, FYM and *Azospirillum* with a leaf breadth of 18.83 cm and also T_7 (19.87 cm) was statistically at par with T_8 - NPK 75%, Neem cake and *Azospirillum* with a leaf breadth of 19.19 cm.

Higher polar head diameter (14.93 cm) in T_1 - NPK 100%, vermicompost and *Azospirillum* was statistically at par with T_2 - NPK 75%, vermicompost and *Azospirillum*, similarly, T_4 - NPK 100%, FYM and *Azospirillum* was statistically at par with T_5 – NPK 75%, FYM and *Azospirillum* and T_7 - NPK 100%, Neem cake and *Azospirillum* was also statistically at par with T_8 - NPK 75%, Neem cake and *Azospirillum*. Higher equatorial head diameter (15.68 cm) in T_1 - NPK 100%, vermicompost and *Azospirillum* was statistically at par with T_2 - NPK 75%, vermicompost and *Azospirillum*, similarly T_4 - NPK 100%, FYM and *Azospirillum* was statistically at par with the T_5 – NPK 75%, FYM and *Azospirillum* and T_7 – NPK 100%, Neem cake and *Azospirillum* was also statistically at par with T_8 - NPK 75%, Neem cake and *Azospirillum*.

Higher yield per plot (7.95 kg) observed in T_1 was also statistically at par with T_2 (NPK 75%, vermicompost and *Azospirillum*) with 7.79 kg per plot, similarly, T_4 (7.80 kg) was statistically at par with T_5 (NPK 75%, FYM and *Azospirillum*) with 7.40 kg per plot and also T_7 (7.91 kg) was statistically at par with T_8 (NPK 75%, Neem cake and *Azospirillum*) with 7.54 kg/ha.

Considering the projected yield per hectare, highest yield (39.76 t) was recorded in T_1 where a combination of NPK 100%, vermicompost and *Azospirillum* was applied followed by T_7 (39.55 t) with a combination of NPK 100%, Neem cake and *Azospirillum* and T_4 (39.02 t) with a combination of NPK 100%, FYM and *Azospirillum* compared to the lowest yield in control (17.34 t) without any treatment.

However, the results clearly indicated that T_1 - NPK 100%, vermicompost and *Azospirillum* with a recorded highest yield per hectare (39.76 t) was statistically at par with T_2 (NPK 75%, vermicompost and *Azospirillum*) with an yield of 38.94 tonnes per hectare; similarly T_4 (39.02 t) was also statistically at par with T_5 (NPK 75%, FYM and *Azospirillum*) with an yield of 36.98 tonnes per hectare and also T_7 (39.55 t) was statistically at par with T8 (NPK 75%, Neem cake and

Azospirillum) with a recorded yield of 37.68 tonnes per hectare.

Application of organic manures increased the physical and chemical properties of the soil thereby helping the crop to produce good vegetative growth. This investigation revealed that integrated application of nutrients by adding organic manures helps in increasing the growth of the crop as well as contributing to soil health properties. The results are similar with the findings of Gupta and Samnotra (2004) [3], Yadav *et al*. (2012) [9] and Singh and Singh (2005) [8] in cabbage where up to 25 per cent inorganic fertilizers can be saved without affecting the yield of the crop while at the same time reduced the harmful effects of chemical fertilizers on soil health. Khandait (1996) [4] also reported the increased growth of crops when biofertilizers such as *Azospirillum and Azotobacter* were integrated in the nutrient application.

The experimental results clearly indicated that application of organic manures, biofertilizers viz. *Azospirillum* along with inorganic fertilizers proved to be effective in increasing the yield of cabbage. Among the different treatments, the best performance in almost all parameters was observed in T_1 (NPK (100%) + Vermicompost + *Azospirillum*), however, T_2 (NPK 75% + Vermicompost + *Azospirillum*) recorded statistically at par values with T_1 for different growth parameters such as plant height (25.48 cm), leaf length (26.28 cm), leaf breadth (19.42 cm), plant spread north-south (51.41 cm) and plant spread east-west (50.71 cm). Also, this treatment combination (T_2) showed similar trend for polar head diameter (13.65 cm), equatorial head diameter (14.96 cm), yield per plot (7.79 kg) and yield per hectare (38.94 t).

Among the organic manures, the combinations where vermicompost was applied produced better performance and higher yield than neem cake and compost. The findings are in good agreement with the observations of earlier workers in cabbage (Akhter *et al.*, 2013; Sarangthem *et al*., 2011 and Merentola *et al.*, 2012) [1, 7, 6]. Use of vermicompost promotes soil aggregation and stabilizes soil structure. This improves the air-water relationship of soil, thus increasing the water retention capacity and encourages extensive development of root system of plants. The mineralization of nutrients was observed to be enhanced, which results in boosting up of crop productivity.

Table 1: Effect of Integrated nutrient management on the performance of cabbage

Treat-ments	Plant height (cm)	Plant Spread East-West (cm)	Plant Spread North-South (cm)	Leaf Length (cm)	Leaf Breadth (cm)	Polar Head Diameter (cm)	Head Equatorial Diameter (cm)	Yield /plot (kg)	Yield/ hectare (t)
T_1	26.33	52.53	53.82	27.38	20.26	14.93	15.68	7.95	39.76
T_2	25.48	50.71	51.41	26.28	19.42	13.65	14.96	7.79	38.94
T_3	23.09	45	45.61	21.61	15.73	9.43	11.41	4.71	23.56
T_4	25.8	51.25	52.54	26.52	19.7	14.12	15.21	7.80	39.02
T_5	25.04	49.94	49.37	25.87	18.83	13.11	14.55	7.40	36.98
T_6	22.46	45.48	47.03	22.2	15.04	10.19	11.91	5.00	25.01
T_7	26.1	52.11	53.3	27.1	19.87	14.31	15.53	7.91	39.55
T_8	25.15	50.48	49.67	26.14	19.19	13.29	14.72	7.54	37.68
T_9	23.18	44.97	44.97	20.98	15.55	10.52	10.44	4.98	24.91
T_{10}	25.61	50.93	51.73	26.37	19.58	14.07	15.09	6.09	30.46
T_{11}	24.72	49.79	48.95	25.75	18.62	12.85	14.21	5.72	28.58
T_{12}	22.27	43.78	43.42	20.67	15.34	10.09	10.41	4.05	20.25
T_{13}	19.45	38.31	37.55	17.08	13	7.55	8.93	3.47	17.34
SEm±	0.473	0.526	1.197	0.502	0.411	0.47	0.436	0.338	1.692
CD @5%	1.38	1.54	3.49	1.47	1.2	1.37	1.27	0.99	4.94

T_1: NPK (100%) + Vermicompost + *Azospirillum*, T_2: NPK (75%) + Vermicompost + *Azospirillum*
T_3: NPK (50%) + Vermicompost + *Azospirillum*, T_4: NPK (100%) + FYM (Compost) + *Azospirillum*
T_5: NPK (75%) + FYM (Compost) + *Azospirillum*, T_6: NPK (50%) + FYM (Compost) + *Azospirillum*
T_7: NPK (100%) + Neem Cake + *Azospirillum*, T_8: NPK (75%) + Neem Cake + *Azospirillum*
T_9: NPK (50%) + Neem Cake + *Azospirillum*, T_{10}: NPK (100%)
T_{11}: NPK (75%), T_{12}: NPK (50%)
T_{13}: Control

Conclusion

The results from the present investigation revealed that nutrients from organic sources can be used to supplement the nutrition requirement of cabbage, hence, the amount of inorganic chemical fertilizers can be reduced. In the present investigation, after comparing all treatments, the treatment combination of NPK 75%, Vermicompost and *Azospirillum* (T_2) revealed promising performance as it showed at par results statistically with the best treatment i.e., T_1 (NPK 100%, Vermicompost and *Azospirillum*) in almost all growth and yield parameters.

Therefore, it can be concluded that supplying the cabbage crop with NPK 75% along with vermicompost and *Azospirillum* can help to reduce the costly inorganic fertilizers by up to 20-25 per cent and supplementing the remaining nutrients from organic sources without affecting the yield of cabbage and at the same time contribute to the reduction of harmful effects of chemical fertilizers on soil health and environment.

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