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EFFECT OF MICROBIAL INOCULANTS AND INORGANIC FERTILIZERS ON GROWTH AND YIELD OF HYBRID CABBAGE (*BRASSICA OLERACEA L.* VAR.*CAPITATA*)

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ABSTRACT
The present investigation was conducted to know the effect of different levels of inorganic fertilizers *viz*., F_1 = 80:40:40 Kg NPK/ha, F_2 = 120:60:60 Kg NPK/ha, F_3 = 160:80:80 Kg NPK/ha, F_4 = 200:100:100 Kg NPK/ha and F_5 = 240:120:120 Kg NPK/ha and bio-fertilizers *viz*., M_0-0, M_1-*Azotobacter*, M_2-*Azospirillum*, M_3-VAM and M_4-PSB. The experiment comprised of 25 different treatment combinations and replicated thrice. Results from the study indicated that combined application of NPK @ 200:100:100 Kg/ha along with seedling treatment with *Azospirillum* gave significantly higher plant height (30.40cm), plant spread (54.50cm), head diameter (24.32cm), head depth (21.71cm), head weight (1.878 Kg) and head yield (868.70 q/ha). However, days taken to head formation and head maturity, number of outer leaves/plant and number of inner leaves/head did not show significant interaction effects. Therefore, it may be concluded that combined application of NPK @ 200:100:100 kg/ha along with seedling treatment with *Azospirillum* was the most effective treatment combination for higher growth and yield in cabbage.

INTRODUCTION

Cabbage *(Brassica oleracea L.* var. *capitata)*, is one of the most important vegetable of the family,Brassicaceae.It is widely grown all over India and abroad for its high nutritive values, high productivity and wider adaptability. It can withstand rough handlings as well as long distance transport and thus fetch better return.However, the national productivity of cabbage is far below the global average productivity. Low productivity of cabbage may be attributed to poor management practices rather than the uncontrollable climatic factors. Continuous application of huge amount of chemical fertilizers hampers the soil health and generates pollution. Mineral nutrition does play an important role in influencing the quality of crops but it is a fact that the soil health deteriorates (Savci, 2012). The integrated nutrient management paves the way to overcome these problems, which involves conjunctive use of chemical fertilizers and organic manures to sustain crop production as well as maintenance of soil health. Systematic approach to nutrient management by tapping all possible sources of organic and inorganic nutrients in a judicious manner to maintain soil fertility and crop productivity is the essence of integrated nutrient management (INM). In addition, utilization of bio-fertilizers, which have the ability to enrich the soil with beneficial microorganisms as well as to mobilize the nutritionally important elements from non-usable to usable forms through biological processes resulting in enhanced production of fruits and vegetables offer an alternative. Among the nitrogen fixing bacteria, *Azotobacter*,not only provides nitrogen, but also synthesizes growth promoting hormones such as IAA and GA. *Azospirillum* also helps in plant growth and increases the yield of crops by improving root development, mineral uptake etc. The positive role of these bio-fertilizers has been recorded in many vegetables and spice crops by different scientists. Earlier studies have shown that plant growth-promoting rhizobacteria (PGPR) could stimulate the growth and yield of cabbage (Turan *et al.* 2014).To maintain long term soil health and productivity there is a need for integrated nutrient management through manures and bio-fertilizers apart from costly chemical fertilizers for better yield of the crop (Mondal *et al.* 2003). Use of bio-fertilizers is also needed as an alternative source to bringforth the eco-friendly methods of farming. The concept of sustainable agriculture envisages primary emphasis on manipulation and management of biological systems not only to maximize yield but also to stabilize the agro-systems and to minimize industrial input demands. In a country like India a large majority of the farmers are poor and have small holdings, the use of bio-fertilizers in combination with chemical fertilizers offers a great opportunity to increase the crop production at less cost.The extent of benefit from these microorganisms depends on their number and their efficiency which however, is governed by soil and environmental factors. When the number and activity of specific microorganism is sub-optimal, artificially multiplied bio fertilizers are used to hasten the biological activity to improve availability of plant nutrient. (Kumari *et al.* 2015).

Thus, it makes it imperative to make a concerted efforts to bridge the gap between potential yield and actual yield harvested by the farmers to make cabbage cultivation more remunerative through the better management of inputs like

inorganic nutrients and microbial inoculants for better exploitation of yield potentialities.Therefore, this study was carried out to investigate the effect of different levels of inorganic fertilizers and microbial inoculants on growth and yield of cabbage.

MATERIALS AND METHODS

The present investigation was conducted in the *Rabi* season at Bihar Agricultural College, Sabour. The design of experiment was RBD (Factorial), replicated thrice and a popular Mahyco hybrid cabbage No-139 was used for the study.Seeds were sown and covered with thin layer of soil mixed with FYM. There after the bed was covered with paddy straws. Twenty five days old seedlings were used for transplanting in the main field.

Microbial inoculants were used as seedling inoculation and twenty five days seedlings were transplanted in the main field at the spacing of 45 × 45 cm.The soil and the weather condition prevailing during the period of investigation was close to normal for the place and could be termed congenial for growth and development of cabbage.

The treatment comprised of four microbial inoculants(M_0-0, and M_1-*Azotobacter,* M_2-*Azospirillum,*M_3-VAM, M_4-PSB) and five different fertility levels (F_1=80:40:40 : : N:P:K kg/ha, F_2=120:60:60 : : N:P:K kg/ha, F_3=160:80:80 : :N:P:K kg/ha, F_4=200:100:100 N:P:K kg/ha and F_5=240:120:120 N:P:K kg/ha) in different combinations. Treatment wise different microbial inoculants in @ 10g/litre of water were mixed and required quantity of solution was prepared. The roots of uprooted seedlings were dipped in this solution for20 minutes before transplantation. Half dose of nitrogen as urea with full dose of phosphorus (P_2O_5) as single super phosphate and potash (K_2O) as murate of potash were applied before planting of seedling as basal dressing as per the treatments specification. The desired quantity of fertilizers as per treatments were mixed thoroughly and the mixture was placed and incorporated in the top 6-8 layer of soil on the point marked for transplanting of each seedlings. After placement and incorporation of the fertilizer mixtures, seedlings were transplanted. The remaining half amount of nitrogen was top dressed in two equal split doses at 25 days and 50 days after transplanting. Five plants in each treatment combination and in each replication were randomly selected and tagged properly for recording various observations. The observation recorded for the aforesaid five plants were worked out to give mean in respect of all the characters, *viz.* plant height (cm), plant spread (cm), number of outer leaves/plant,number of inner leaves/plant,number of days taken to head initiation after transplanting, number of days to head maturity after transplanting diameter of head (cm), weight of head (kg), yield/plot (kg), yield (q/ha). The statistical analysis of the data recorded in all observations was carried out by the method of "Analysis of the variance prescribed by Fisher and Yates (1963). Comparison of treatment was made with the help of critical differences (C.D.).

RESULTS AND DISCUSSION

The maximum plant height (28.0cm), number of outer leaves (22.72) and plant spread(49.78cm) were obtained with the treatment, M_2(*Azospirillum*)and were significantly superior to other bio-fertilizers. The possible reason for this could be some growth promoting substances secreted by the bio-fertilizers,

Table 1: Effect of bio-fertilizers and inorganic fertilizers on plant height (cm), plant spread (cm) and number of outer leaves/plant of cabbage (Pooled results of two years)

Bio-fertilizers	Levels of inorganic fertilizers					
	F_1-$N_{80}P_{40}K_{40}$	F_2-$N_{120}P_{60}K_{60}$	F_3-$N_{160}P_{80}K_{80}$	F_4-$N_{200}P_{100}K_{100}$	F_5-$N_{240}P_{120}K_{120}$	Mean
Plant height (cm)						
M_0-0	16.86	23.91	24.91	25.70	26.36	23.55
M_1-Azotob.	23.24	25.61	27.29	29.77	28.07	26.79
M_2-Azosp.	24.43	27.86	29.09	30.40	28.37	28.03
M_3-VAM	22.87	25.20	26.79	28.95	27.42	26.24
M_4-PSB	23.06	25.44	27.68	29.44	27.80	26.68
Mean	22.09	25.60	27.15	28.85	27.60	
Plant spread (cm)						
M_0-0	28.00	42.36	44.13	45.53	48.20	41.64
M_1-Azotob.	41.16	45.36	48.35	52.74	49.71	47.46
M_2-Azosp.	43.29	49.35	51.53	54.50	50.25	49.78
M_3-VAM	40.51	44.64	47.46	51.27	48.68	46.51
M_4-PSB	40.85	45.05	49.04	52.15	49.25	47.27
Mean	38.76	45.35	48.10	51.23	49.22	
Number of outer leaves/plant						
M_0-0	18.40	20.30	21.10	21.70	22.10	20.72
M_1-Azotob.	20.60	21.80	22.60	23.20	22.60	22.16
M_2-Azosp.	20.90	22.70	23.30	23.80	22.90	22.72
M_3-VAM	19.70	21.40	22.10	22.70	22.00	21.58
M_4-PSB	19.90	21.80	22.70	23.10	22.40	21.98
Mean	19.90	21.60	22.36	22.90	22.40	
C.D. at 5%		Microbial inoculants (M)		Inorganic Fertilizer (F)		M × F
Plant height		0.77		0.77		1.63
Plant spread		1.36		1.36		2.89
Number of outer leaves/plant		0.70		0.70		NS

Table 2: Effect of bio-fertilizers and inorganic fertilizers on number of days to head initiation after transplanting and number of days to head maturity after transplanting of cabbage (Pooled results of two years)

Bio-fertilizers	Levels of inorganic fertilizers					
	F_1-$N_{80}P_{40}K_{40}$	F_2-$N_{120}P_{60}K_{60}$	F_3-$N_{160}P_{80}K_{80}$	F_4-$N_{200}P_{100}K_{100}$	F_5-$N_{240}P_{120}K_{120}$	Mean
Number of days to head initiation after transplanting						
M_0-0	56.70	54.50	53.80	53.10	52.40	54.10
M_1-Azotob.	55.00	52.50	52.10	52.00	51.10	52.54
M_2-Azosp.	54.00	51.40	51.40	51.20	50.00	51.60
M_3-VAM	56.10	53.80	53.00	52.70	51.90	53.50
M_4-PSB	55.40	52.80	52.50	52.50	51.50	52.94
Mean	55.44	53.00	52.56	52.30	51.38	
Number of days to head maturity after transplanting						
M_0-0	88.70	85.50	84.30	83.60	82.70	84.96
M_1-Azotob.	86.80	83.40	82.60	81.90	81.80	83.30
M_2-Azosp.	85.90	82.70	82.00	81.10	81.10	82.56
M_3-VAM	88.10	84.60	83.60	82.60	82.40	84.26
M_4-PSB	87.00	84.00	83.20	82.60	82.20	83.80
Mean	87.30	84.04	83.14	82.36	82.04	
C.D. at 5%		Microbial inoculants (M)		Inorganic Fertilizer (F)		M × F
Number of days to head formation after transplanting		NS		1.74		NS
Number of days to head maturity after transplanting		NS		2.74		NS

Table 3: Effect of bio-fertilizers and inorganic fertilizers on diameter of head (cm) and weight of head (Kg) of cabbage (Pooled results of two years)

Bio-fertilizers	Levels of inorganic fertilizers					
	F_1-$N_{80}P_{40}K_{40}$	F_2-$N_{120}P_{60}K_{60}$	F_3-$N_{160}P_{80}K_{80}$	F_4-$N_{200}P_{100}K_{100}$	F_5-$N_{240}P_{120}K_{120}$	Mean
Diameter of head (cm)						
M_0-0	12.23	19.13	19.93	20.56	21.09	18.58
M_1-Azotob.	18.59	20.48	21.83	23.82	22.45	21.43
M_2-Azosp.	19.55	22.28	23.27	24.32	22.69	22.42
M_3-VAM	18.29	20.16	21.43	23.15	21.98	21.00
M_4-PSB	18.45	20.34	21.77	23.55	22.24	21.27
Mean	17.42	20.48	21.64	23.08	22.09	
Weight of head (Kg)						
M_0-0	0.907	1.503	1.561	1.607	1.645	1.444
M_1-Azotob.	1.464	1.602	1.699	1.842	1.744	1.670
M_2-Azosp.	1.534	1.732	1.803	1.878	1.762	1.741
M_3-VAM	1.437	1.578	1.670	1.794	1.710	1.637
M_4-PSB	1.454	1.591	1.694	1.823	1.729	1.658
Mean	1.359	1.601	1.685	1.789	1.718	
C.D. at 5%		Microbial inoculants (M)		Inorganic Fertilizer (F)		M × F
Diameter of head		0.58		0.58		1.23
Depth of head		0.57		0.57		1.20
Weight of head		0.052		0.052		0.111

leading to better root development, better transportation of water and more uptake and deposition of nutrients. These finding are in close agreement with those reported by Bhagavantagoudra and Rokhade (2001) and Sharma (2002) in cabbage and Bhardwaj *et al.*, (2007) in broccoli. The maximum growth of plant in terms of height (30.40cm), number of outer leaves/plant (22.90) and plant spread (51.23) was at fertility level F_4($N_{200}P_{100}K_{100}$). The adequate supply of the three major nutrients NPK is expected to regulate plant physiological functions and morphological responses favorably. These results are in close proximity with the findings of Patil *et al.* (2003) in knolkhol and Bhardwaj *et al.* (2007) in broccoli. Plant height and plant spread were influenced significantly due to interaction effect of chemical and bio-fertilizers, being maximum (30.40 cm and 54.50 cm respectively) at with M_2 F_4. This might be due to fact that higher fertility levels increase photosynthetic capacity and auxin levels in the plant. The increase in plant growth induced by NPK may result in more assimilation of carbohydrates. Higher vegetative growth of plant in case of bio-fertilizers application might be due to better growth and elongation of leaves. These results are closely in consonance with the findings reported earlier by Devi *et al.* (2003) in cabbage and Chaudhury *et al.* (2004) in cauliflower.

The various levels of microbial inoculants showed non-significant effect on head formation and head maturity after transplanting. The plants grown under the higher level of inorganic fertilizers F_5, ($N_{240}P_{120}K_{120}$) were earliest with respect to the days taken for initiation of head formation(30.40) and for head maturity(54.50) after transplanting. The lowest fertility

Table 4: Effect of bio-fertilizers and inorganic fertilizers on number of inner leaves/plant and head yield (q/ha) of cabbage

Bio-fertilizers	Levels of inorganic fertilizers					
	F_1-$N_{80}P_{40}K_{40}$	F_2-$N_{120}P_{60}K_{60}$	F_3-$N_{160}P_{80}K_{80}$	F_4-$N_{200}P_{100}K_{100}$	F_5-$N_{240}P_{120}K_{120}$	Mean
Number of inner leaves/plant						
M_0-0	39.40	41.00	42.00	42.50	42.70	41.52
M_1-Azotob.	41.10	42.50	43.60	45.20	44.60	43.40
M_2-Azosp.	43.70	45.00	44.90	46.40	45.00	45.00
M_3-VAM	42.20	42.60	43.10	43.90	42.80	42.92
M_4-PSB	42.80	44.00	44.10	44.60	44.20	43.94
Mean	41.84	43.02	42.54	44.52	43.86	
Head yield (q/ha)						
M_0-0	435.58	683.45	712.10	734.45	753.35	663.79
M_1-Azotob.	664.06	731.86	780.03	850.91	802.13	765.80
M_2-Azosp.	698.39	796.20	831.28	868.70	810.78	801.07
M_3-VAM	653.56	720.25	765.70	827.20	785.34	750.41
M_4-PSB	659.12	726.92	777.68	841.40	794.60	759.94
Mean	622.14	731.74	773.36	824.53	789.24	
C.D. at 5%		Microbial inoculants (M)		Inorganic Fertilizer (F)		M×F
Number of inner leaves/plant		1.44		1.44		NS
Head yield		21.00		21.00		44.36

level F_1($N_{80}P_{40}K_{40}$) significantly delayed to head formation and head maturity. The interaction effect of microbial inoculants and levels of fertility was found to be non-significant in these respects. The probable reason for earlier heading and maturity of head is due to higher NPK and increased nutrient transport from root to the aerial parts and increased rate of photosynthesis and transport of photosynthates. Similar results have also been reported by Westerveld *et al.* (2003) and Chaubey *et al.* (2006) in cabbage.

There was a significant variation among bio-fertilizers in respect of diameter, number of inner leaves per plant, weight of head and head yield. The plants developed under application of microbial inoculants M_2, (*Azospirillum*) produced heads with maximum diameter (22.42 cm), number of inner leaves per plant (45) and maximum weight of head (1.741 kg) and yield of head (801.07 q/ha). The maximum head weight was recorded with the use of microbial inoculants M_2 which was significantly superior to *Azotobacter*. It is a well-known fact that *Azospirillum* has definite role in cell division, cell enlargement, cell elongation and physiological activities. These physiological activities give beneficial response on uptake of water and nutrients development of cambial growth, respiration, co-enzyme activity, utilization of ATP, formation of RNA and cell permeability, due to these activities application of *Azospirillum* had induced effect on weight of head. The result in respect of head weight of cabbage is in complete agreement with the findings of Manivannan and Singh (2004) in cabbage. The improvement in yield might be due to higher amount of nitrogen fixed in soil by *Azospirillum* and made available to plants, and growth promoting substances like IAA, GA, cytokinins and vitamins secreted by *Azospirillum* which have beneficial effects on crop growth. Better crop due to all these factors, which might have helped in increasing photosynthetic rate and more physiological and biochemical activities which in turn, perhaps might have increased the movement of photosynthates from source to sink. Thus, finally resulted in increasing the yield and yield components. Significant increase in yield by adopting integrated nutrient management approach has also been reported by Bhardwaj *et al.* (2007) in broccoli and Khan and Pariari (2012) in chilli and Damse *et al.*(2014) in garlic.The maximum diameter(23.55cm),number of inner leaves per plant (44.52), weight of head(1.78kg) and yield (824.53q/ha) were obtained at fertility level of F_4($N_{200}P_{100}K_{100}$). This might be due to increased vegetative growth as induced by higher dosages of NPK which might account for carbohydrates accumulation as a result of increased photosynthesis. These results are in agreement with the findings of Agrawal and Agrawal (2003) in cabbage and Sharma *et al.* (2004) in cauliflower. Higher fertility levels probably resulted in the production of larger number of leaves and increased leaf area, which ultimately contributed towards the manufacture of more carbohydrates, consequently more weight of head. The findings pertaining to head weight are in close agreement with those reported by Bhardwaj *et al.* (2007) in broccoli.

All yield contributing characters such as diameter, depth, and weight of head were favourably influenced by combined action of NPK and microbial inoculants *Azospirillum* which ultimately increased the head yield. These results are closely in consonance with the findings reported earlier by Bahadur *et al.* (2006) in cabbage.

On the basis of results and discussion made so far, it may be concluded that application of microbial inoculants basically *Azospirillum* as seedling treatment as well as application of NPK @ 200:100:100 kg/ha was the most effective treatment combination for higher growth and yield in cabbage cultivation. Hence, the use and management of natural resources in sustainable agriculture, the microbial fertilizers hold vast potential for future.

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