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Studies on the Effect of Microbial Inoculants on Growth and Yield of Capsicum (*Capsicum annuum* L.)

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***Capsicum* is a genus of flowering plants in the nightshade family Solanaceae. Capsicum is rich in beta carotene, capsaicin, vitamin A, C and antioxidant properties. Microbial inoculants are used to improve plant nutrition and also promote plant growth by stimulating plant hormone production. In order to increase growth and yield of capsicum, an experiment was conducted under greenhouse by using different combination of microbial inoculants [*Azotobacter chroococcum* (AC) as nitrogen fixers, *Bacillus megaterium* (BM) as Phosphate solubilizer, *Glomus fasciculatum* (GF) as phosphate mobilizer] at different level of nitrogen, phosphorus and potassium (50%, 75%, 100%) along with recommended dose of farm yard manure and vermicompost. Different growth parameters and yield parameters were significantly superior in the plants treated with combination of AC + BM + 75% nitrogen and phosphorus + 100% potassium + vermicompost. This was followed by treatment combination (AC + BM + GF + 75% nitrogen and phosphorus + 100% potassium + Farm yard manure) and least growth and yield was observed in the plants treated with the combination of 75% nitrogen and phosphorus + 100% potassium. The results indicated that the combined effect of microbial inoculants and inorganic fertilizer have best effect on growth and yield of capsicum.**

Keywords: Microbial inoculants, growth and yield, capsicum.

Capsicum is one of the most important vegetable crops and is widely cultivated throughout the warm, temperate, tropical and subtropical countries. *Capsicum* is native to mexico. With the increasing demand for food production, it was imperative to use high yielding varieties, chemical fertilizers and pesticides. But with the tremendous use of these chemicals, the soil has been affected badly and the ill effects on soil properties have been noticed. To overcome this problem, it has become important to substantially increase the organic matter content of soil and to use ecofriendly plant nutrient sources like Biofertilizers. Mixed inoculants (combinations of microorganisms) interact synergistically which yields better and show quick results. Many research have evidenced that development of plant growth promoting microbial consortium, could be a feasible technology for increasing the crop productivity with savings in chemical fertilizers application to an extent of 25 to 30%. The constituent strains in the consortium not only out-compete with others for rhizospheric

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establishment but complement functionally for plant growth promotion (Pandey and Maheshwari, 2007). In the recent years, scientists have diverted their attention towards exploring the potentiality of these beneficial microorganisms for growth promotion and to obtain quality yields. In this context, this research study was initiated to study the plant growth promoting effect of biofertilizers on an important solanaceous crop like *capsicum*.

MATERIAL AND METHODS

The microbial inoculant of 24 hr old pure cultures of *Azotobacter chroococcum* and *Bacillus megaterium* were transferred aseptically into flasks containing Waksmann No. 77 broth and Sperber's broth respectively with the help of inoculation loop and incubated on a mechanical shaker for 3 days for growth and mixed with carrier material. Effectiveness of these inoculants were tested on *Capsicum* (cv. indira) crop in a replicated pot culture study under glass house conditions. Observations of plant growth parameters like plant height, number of leaves per plant, leaf area were recorded at 15, 30, 45 and 60 days after transplanting (DAT) were recorded. Shoot and root dry weight was recorded after harvest of the crop. Estimation of chlorophyll was done by the method suggested by Witham *et al.,* (1971). Observations of yield parameters were recorded after harvest of the crop. After the development of fruits, number of fruits per plant was recorded at 15 days intervals. After harvest of the fruit, number of fruits/plant, average weight and length of the fruit were recorded. The fresh weight of the fruit harvested from different treatments were weighed and average weight was recorded. The weight of matured fruits harvested from each picking was recorded till final harvest and total yield per plant was computed.

Treatments details

T_1 – *Azotobacter chroococcum(AC)* + 75%N + 100%PK + FYM
T_2 – AC + *Bacillus megaterium(BM)* + 75%NP + 100%K + FYM
T_3 – AC + BM + *Glomus fasciculatum* (GF) + 75%NP + 100%K + FYM
T_4 – *A zotobacter chroococcum(AC)* + 50%N + 100%PK + FYM
T_5 – AC + *Bacillus megaterium(BM)* + 50%NP + 100%K + FYM
T_6 – AC + BM + GF + 50%NP + 100%K + FYM
T_7 – *Azotobacter chroococcum(AC)* + 75%N + 100%PK + vermicompost(VC)
T_8 – AC + *Bacillus megaterium(BM)* + 75%NP + 100%K + VC
T_9 – AC + BM + GF + 75%NP + 100%K + VC
T_{10} – *Azotobacter chroococcum(AC)* + 50%N + 100%PK + VC
T_{11} – AC + *Bacillus megaterium(BM)* + 50%NP + 100%K + VC
T_{12} – AC + BM + GF + 50%NP + 100%K + VC
T_{13} – 75%NP + 100%K
T_{14} – 50%NP + 100%K
T_{15} – 100%NPK

The amount of chlorophyll present per gram of leaf tissue was calculated by following formula-

(1) Chlorophyll-a mg/g of leaf = $12.7(A_{663})-2.69\ (A_{645})\times V/(1000\times w)$

(2) Chlorophyll-b mg/g of leaf = $22.9(A_{645})-4.68\ (A_{663})\times V/(1000\times w)$

(3) Total chlorophyll mg/g of leaf = $20.2(A_{645})+ 8.02\ (A_{663})\times V/(1000\times w)$

Where- A= Absorbance at specific wavelength, V= final volume of extract
w= fresh weight of leaf tissue taken

RESULTS AND DISCUSSION

Single, dual and consortium of *Azotobacter chroococcum, Bacillus megaterium,* and *Glomus fasciculatum* with different level of NPK fertilizers were tested in a glass house experiment to find out the effects of different microbial inoculants on growth parameters in *Capsicum*. The results thus obtained are discussed below.

Among different treatments, significantly maximum plant height was recorded in *Capsicum* plants inoculated with *Azotobacter chroococcum* + *Bacillus megaterium* + *Glomus fasciculatum* + 75%NP + 100%K + Vermicompost (71.46cm) and minimum was from uninoculated plants with 75% NP and 100%K (51.70cm)(Table 1).

Compared to 75% NP, the plants inoculated with microbial inoculants + 75%NP + 100%K showed significant results. This might be due to rapid multiplication of microorganisms applied to soil leading to positive effect on plant growth due to soil plant microbe interactions.

Similar results were obtained from the study conducted by Sachin and Mishra, 2009, which showed that introduction of PGPR microorganisms into the soil, indirectly prevents deleterious effects of one or more phytopathogenic microorganisms in the rhizosphere and directly help in plant growth promotion by production of IAA and by release of secondary metabolites such as plant growth

Table 1. Effect of microbial inoculants on plant height of *Capsicum* at different stages of crop growth under glass house condition

Treatments	Plant height(cm)						
	15DAT	30DAT	45DAT	60DAT	75DAT	90DAT	Mean
T1	14.80	32.26	62.53	71.53	72.80	74.33	54.71
T2	18.20	38.50	75.33	84.46	86.73	87.66	65.15
T3	19.56	42.40	80.26	89.93	92.53	93.33	69.46
T4	16.46	41.13	67.40	76.73	79.33	80.16	60.60
T5	18.60	39.53	77.40	86.40	89.66	90.16	66.96
T6	17.76	37.63	73.26	82.60	85.53	85.66	63.74
T7	15.61	33.13	64.26	73.33	76.26	77.20	56.63
T8	17.66	38.33	73.66	82.73	86.33	87.26	64.33
T9	20.26	43.53	83.46	91.86	95.13	95.66	71.46
T10	16.76	35.53	69.40	78.46	81.40	82.13	60.61
T11	18.96	40.33	78.33	87.40	84.33	85.33	65.78
T12	17.33	36.76	71.40	80.46	83.40	84.30	62.28
T13	14.33	30.33	58.33	66.73	70.33	70.45	51.70
T14	14.53	31.33	59.68	69.08	72.08	72.16	53.14
T15	15.53	33.33	64.33	72.73	75.73	76.10	56.29
SE±	0.18	0.23	0.24	0.26	0.26	0.25	0.24
CD @ 5%	0.53	0.69	0.76	0.77	0.78	0.74	0.76

Note: DAT-Days after transplanting

Table 2. Effect of microbial inoculants on number of leaves/plant of *Capsicum* at different stages of crop growth

Treatments	Number of leaves/plant					
	15DAT	30DAT	45DAT	60DAT	75DAT	Mean
T1	14.20	24.20	48.40	53.40	53.73	38.79
T2	16.40	27.33	52.80	58.06	58.40	42.60
T3	19.20	29.40	58.40	63.40	63.73	46.83
T4	15.26	25.26	50.53	54.66	55.00	40.14
T5	18.40	28.46	57.13	62.13	62.46	45.72
T6	19.13	29.20	55.66	60.66	61.33	45.20
T7	14.40	24.40	49.13	54.13	54.46	39.30
T8	16.20	26.20	52.40	57.40	57.73	41.99
T9	21.20	31.40	62.40	67.40	67.73	50.03
T10	15.40	25.40	51.13	56.13	56.46	40.90
T11	18.66	28.66	57.66	62.66	63.00	46.13
T12	18.60	28.60	57.53	62.86	63.20	46.16
T13	13.20	23.20	46.40	51.40	51.73	37.19
T14	13.40	23.40	47.13	52.13	52.46	37.70
T15	15.33	25.33	50.33	55.33	55.66	40.40
SE±	0.19	0.21	0.23	0.25	0.27	0.21
CD@5%	0.56	0.63	0..69	0.74	0.82	0.63

Note: DAT-Days after transplanting

regulators or facilitating the uptake of certain nutrients from the root environment.

Plants receiving microbial inoculants containing *Azotobacter chroococcum* + *Bacillus megaterium* + *Glomus fasciculatum* + 75%NP + 100%K + Vermicompost recorded highest number of branches/plant (15.37), number of leaves/plant (50.03) and leaf area (73.82cm). The least number was observed in uninoculated plants (10.66 no. of branch/pl., 37.19 no. of leaves/pl. , 56.25cm leaf

Table 3. Effect of microbial inoculants on leaf area of *Capsicum* at different stages of crop growth under glass house condition

Treatments	Leaf area(cm)					
	15DAT	30DAT	45DAT	60DAT	75DAT	Mean
T1	32.53	42.53	74.40	76.33	76.67	60.49
T2	35.26	45.20	80.53	82.33	82.33	65.13
T3	39.33	49.33	87.40	89.33	89.67	71.01
T4	31.60	41.53	73.53	75.20	75.53	59.48
T5	34.40	44.33	79.33	81.06	81.40	64.10
T6	39.20	49.00	87.33	88.60	88.93	70.61
T7	30.34	40.33	71.33	73.60	73.93	57.91
T8	35.33	45.07	80.33	81.40	82.06	64.84
T9	40.21	50.21	91.33	93.33	94.00	73.82
T10	33.46	43.06	76.13	78.46	78.46	61.91
T11	38.40	48.61	86.06	88.33	88.66	70.01
T12	39.00	46.40	87.00	88.80	89.46	70.13
T13	29.00	39.40	69.33	71.13	71.46	56.25
T14	29.60	39.73	71.33	73.46	73.46	57.33
T15	35.33	45.06	81.33	82.60	83.93	65.65
SE±	0.25	0.26	0.27	0.46	0.49	0.40
CD@5%	0.76	0.78	0.81	1.38	1.46	1.20

Note: DAT-Days after transplanting

Table 4. Effect of microbial inoculants on Chlorophyll-a, Chlorophyll-b and total Chlorophyll content of the plant at flowering stage

Treatments	Chlorophyll (mg/g of plant)		
	Chlorophyll-a	Chlorophyll-b	Total Chlorophyll
T1	1.48	0.82	2.33
T2	1.82	0.86	2.63
T3	2.07	1.09	3.16
T4	1.53	0.84	2.34
T5	1.84	0.90	2.74
T6	1.94	0.95	2.89
T7	1.52	0.81	2.61
T8	1.83	0.83	2.63
T9	2.22	1.20	3.42
T10	1.56	0.77	2.33
T11	2.01	0.89	2.90
T12	1.96	0.80	2.76
T13	1.33	0.68	1.98
T14	1.35	0.72	2.03
T15	1.46	0.82	2.28
SE±	0.11	0.09	0.10
CD@5%	0.34	0.27	0.31

area) receiving only inorganic fertilizers (Table 2 and 3).

These results might be due to co-inoculation of different microbial inoculants and synergestic interaction among them. The number of branches and leaves per plant might have increased due to increased availability of nutrients (nitrogen, phosphorus) and by production of growth promoting substances by microbial inoculants. Similar result was obtained by Gholani *et al*. (2009)

Table 5. Effect of microbial inoculants on fruit yield and other parameters of fruit at different stages of crop growth under glass house condition

Treatments	No. of fruits/pl. 60DAT	75DAT	90DAT	Mean	Average fruit wt. /pt.(gm)	Average Diameter of fruit(cm)	Average Fruit length(cm)
T1	5.33	3.67	4.33	4.44	50.60	19.20	5.66
T2	5.33	4.67	4.33	4.78	62.86	21.40	6.33
T3	7.80	5.40	5.33	6.11	75.73	22.33	7.73
T4	5.33	4.45	4.33	4.11	51.76	18.53	5.80
T5	5.33	3.67	4.33	4.43	60.93	20.13	6.13
T6	7.13	5.67	4.33	5.78	70.46	21.20	6.60
T7	4.33	3.67	3.33	3.78	53.46	19.06	6.06
T8	5.33	5.17	4.33	5.11	63.73	21.60	6.46
T9	8.33	5.67	5.50	6.44	80.66	23.33	8.40
T10	3.33	3.67	3.33	4.54	52.60	18.13	5.60
T11	5.33	3.67	4.33	4.44	61.66	20.33	6.20
T12	7.33	4.67	4.33	5.44	71.53	20.73	7.33
T13	4.33	3.40	2.33	3.40	41.60	18.33	4.66
T14	4.60	3.67	3.33	3.44	50.46	17.00	5.73
T15	6.33	3.70	3.33	4.44	51.73	20.60	4.33
SE±	0.32	0.33	0.32	0.32	0.18	0.21	0.21
CD@5%	0.97	0.98	0.96	0.96	0.53	0.64	0.63

Note: DAT-Days after transplanting

Table 6. Effect of microbial inoculants on total biomass of *Capsicum* plant under glass house condition after harvest of the crops

Treatments	Shoot dry weight (g/pl.)	Root dry weight (g/pl.)	Total biomass (g/pl.)
T1	4.75	2.45	7.23
T2	5.63	2.55	8.15
T3	6.33	3.45	9.75
T4	4.65	2.30	6.95
T5	5.45	2.60	8.05
T6	6.03	3.25	9.25
T7	4.95	2.05	7.03
T8	5.83	2.65	8.45
T9	6.95	3.53	10.45
T10	5.03	2.13	7.13
T11	6.13	3.13	9.23
T12	5.95	3.35	8.96
T13	4.25	2.03	6.73
T14	4.53	2.23	6.35
T15	4.80	2.33	7.13
SE±	0.23	0.20	0.32
CD@5%	0.68	0.61	0.97

which showed that the phosphobacteria solubilizes and increase the availability of phosphorus to the plants and its greater uptake. These results are in confirmation with the findings of Suthar *et al*. (2005) in brinjal.

Highest chlorophyll content was found in *Capsicum* (*capsicum annum)* inoculated with *Azotobacter chroococcum* + *Bacillus megaterium* + *Glomus fasciculatum* + 75%NP + 100%K + Vermicompost(3.42mg/g of pl.) compared to uninoculated control (1.98mg/g of pl.) with different doses of inorganic fertilizers (Table 4). Highest number of fruits per plant was observed in plants inoculated with *Azotobacter chroococcum* + *Bacillus megaterium* + *Glomus fasciculatum* + 75%NP + 100%K + Vermicompost (6.44 fruits/pl.) compared to uninoculated control (3.40 fruits/pl.) with different doses of inorganic fertilizers resulting in good fruit yield (Table 5).

Root dry weight, shoot dry weight and total dry weight of *Capsicum* plant increased significantly due to the inoculation of *A. chroococcum, B. megaterium* and *Glomus fasciculatum* (Table 6). The treatment which received *Azotobacter chroococcum* + *Bacillus megaterium* + *Glomus fasciculatum* + 75%NP + 100%K + Vermicompost (T_9) (10.45g/pl.) recorded higher dry weight compared to uninoculated plants(6.35g/pl.) with different levels of NPK fertilizers .

This could be due to the beneficial properties of vermicompost such as high nitrogen, phosphorus, potassium and micronutrients *etc.* Since the vermicompost is having high nutrient value which may influence on the higher dry weight of plant compared to FYM. It may be due to inoculation of crop plants with certain strains of PGPR microorganisms at an early stage which might have improved biomass production though their direct effects on root and shoot growth.

Similar results were earlier reported by Datta *et al*, (2011) and Gandhi and Sivakumar (2010). Generally the plant dry matter content increased by the influence of bioinoculants (Adhikari *et al*., 2001).

CONCLUSIONS

Effect of microbial inoculants on growth and yield of capsicum revealed that, different growth parameters like plant height, number of branches, number of leaves, leaf area and yield parameters like number of fruits per plant, average fruit weight, fruit length and diameter significantly increased at different stages of crop growth in the treatment which received three different microbial inoculants *viz., Azotobacter chroococcum*, *Bacillus megaterium* and *Glomus fasciculatum* with 75% of nitrogen, phosphorus and 100% potassium along with vermicompost. Highest chlorophyll content (3.42mg/g of pl.) was recorded with the treatment receiving three different microbial inoculants (*Azotobacter chroococcum*, *Bacillus megaterium* and *Glomus fasciculatum* with 75% of nitrogen, phosphorus and 100% potassium along with vermicompost. The population of *Azotobacter chroococcum*, *Bacillus megaterium* and *Glomus fasciculatum* was enhanced wherever they were inoculated and synergistically enhanced the availability of nutrients to plants for improved plant growth. It is also found from the results that consortial application of microbial inoculants was found more advantageous than the individual inoculation in terms of improving crop growth and yield of *Capsicum.*

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