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Effect of Microbial Inoculants on the Nutrient Uptake and Yield of Beetroot (*Beta vulgaris L.*)

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ABSTRACT

Comparative performance of *Azotobacter chroococcum, Glucanobacter diazotrophicus* tested both at 50 per cent and 75 percent recommended N showed that *Glucanobacter diazotrophicus* was more effective than *Azotobacter chroococcum* in improving the tuber yield and nutrient uptake. The total tuber yield per plot (8.53 kg), per hectare (38.61 tons) and nutrient uptake in plants (135.14-N, 28.96-P, 49.04-K, kg/ha) was maximum in combined inoculation of microbial inoculants viz., *Azotobacter chroococcum, Glucanobacter diazotrophicus, Bacillus megaterium* and *Trichoderma harzianum,* with 75 per cent N, P with full dose of K compared to control plants (FYM alone T_{14}). The combined effect of microbial inoculants helps in better uptake of nutrients, improved yields and also saves 25% of application of recommended dose of chemical fertilizers.

Key words: Beetroot, Nutrient uptake, Yield, Microbial inoculants, Nutrient management, Beneficial microorganisms.

INTRODUCTION

Nutrient management is most important in Beetroot to obtain good growth and higher yield of root crops. The crop benefiting microbial inoculants generally called as biofertilizers, help in augmenting the crop productivity through effective mobilization of major plant nutrients like N, P and K and other minor nutrients needed by the crop. These beneficial microorganisms are also known to secrete plant growth promoting substances like IAA, GA, cytokinins, vitamins for the improvement of crop growth, yield and for quality produce.

India is the leading vegetable producing country in the world. Presently vegetable cultivation occupies an area of 6.09 million hectares with an annual production of 84.8 million tons accounting to a productivity of 13.90 tons per hectare (The Hindu Survey of Indian Agriculture 2004). India being blessed with the unique gift of nature with diverse climates and distinct seasons, it makes it possible to grow an array of vegetables whose number exceeds more than hundred types.

Beetroot or garden beet (*Beta vulgaris* L.) is an important root vegetable crop (root modification) belonging to the botanical family Chenopodiaceae. It is indigenous to Southern Europe (Campbell, 1979). The chromosome number of cultivated beetroot types is 2n=2x=18. It is a popular root vegetable grown mainly for its fleshy enlarged roots in almost all the states of India but not as common as radish, carrot and turnip. The garden beet is eaten boiled or as salad, cooked with other vegetables and it is also used in pickles, chutneys and in canned food products. The garden beet is rich in proteins, carbohydrates, calcium, phosphorous, iron and vitamin C (Aykroyd, 1963). The beet tops are also rich in iron, vitamin A, vitamin C and protein. Apart from these, it also contains traces of minerals, fat, potassium, vitamin B_1 and B_2. The red colour of

beetroot is due to â-cyanin, a nitrogen containing compound, with chemical properties similar to anthocyanin. Beetroot also contains a yellow pigment *viz.*, â- xanthin. The ratio of these two pigments varies with cultivation and changes during the growth and environmental conditions (Nilsson, 1973).

The area under beetroot in India is about 5000 ha with an annual production of 90,000 tons (Annonymous, 2001). It is essentially a cool weather crop. It grows best in winter with bit warm climate in the plains of India. Good quality roots, rich in sugar and intense red colour are obtained always in cool weather with a temperature range between 18.3^0 C to 21.1^{0}C. At a temperature range below 10^{0}C, plants start wilting before attaining marketable root size (Sadhu, 1986; Nath *et al.,* 1987). Under warm condition, beetroot shows alternate white and colour circles when sliced called zoning.

Beetroot grows best on fairly deep, friable loam, moist and well drained soils. Heavy yields are obtained from deep rich alluvial or silt loams. It is sensitive to soil acidity and yields are adversely affected as the soil pH goes below 5.8. But it thrives well in alkaline soils with a pH as high as 9.0 to 10.0. Soil with a pH of 6.0-7.0 is considered as ideal for beetroot cultivation. About 25-30 tons of roots could be expected from one hectare area (Kale and Masalkar, 1993).

MATERIALS AND METHODS

A study on the effect of microbial inoculants on the growth and yield of Beetroot (*Beta vulgaris*) was carried out in the Biofertilizer Scheme of the Department of Agricultural Microbiology, with a field experiment at the Olericulture Section of the Department of Horticulture, University of Agricultural Sciences, GKVK, Bangalore, during *Rabi* season 2005-2006. The details of the experiment are presented below.

Mass production of microbial inoculants:

The microbial cultures used in the experiment were obtained from the Biofertilizer scheme of the Department of Agricultural Microbiology, University of Agricultural Sciences, GKVK, Bangalore.

The microbial inoculants used in the study are as follows:

N fixing microbial inoculants

Glucanobacter diazotrophicus

It was grown on *Glucanobacter diazotrophicus* broth for 8-10 days and after attaining sufficient microbial population, it was mixed in presterilized lignite powder neutralized with $CaCO_3$. The final product had a population of 9×10^7 cfu. g^{-1} carrier and was applied to the field at the rate of 10 kg/ha.

Azotobacter chroococcum

It was grown on Ashby's broth for 8-10 days and after attaining the desired population the culture was mixed aseptically in presterilized lignite powder neutralized with calcium carbonate. The final product had a population of 8×10^7 cfu. g^{-1} carrier and was applied as soil application at the rate of 10 kg/ha.

P solubilizers:

Bacillus megaterium

Bacillus megaterium was mass multiplied on Pikovaskaya's broth for 8-10 days and after attaining sufficient microbial population, it was mixed in presterilized lignite powder neutralized with $CaCO_3$. The final product had a population of 8×10^8 cfu. g^{-1} carrier and was applied to the field at the rate of 10 kg/ha.

Trichoderma harzianum

It was grown on Trichoderma specific broth for 10 days on a mechanical shaker with frequent agitation. After sufficient growth, the mycelial mat formed at the scum was macerated along with the broth using a homogenizer. Fully grown broth culture was mixed with presterilized lignite powder earlier neutralized with $CaCO_3$. The final product had a population of 4×10^6 cfu. g^{-1} and the inoculum was added at the rate of 5 kg/ha.

Details of the field experiment

Location of the field experimental site

The field experiment was conducted during the *rabi* season of 2005-2006 in the month of Nov-Dec at the Horticulture research station, University of Agricultural Sciences, GKVK, Bangalore under protective irrigated conditions. The study site was located at 12^0 58^1 north latitude and 77^0 35^1 east

longitude with an elevation of 930m above the mean sea level.

Land Preparation

The experimental area was ploughed and harrowed to bring to a fine tilth. The experimental plot was divided in to plots of size 1.7m × 1.3m with 20 cm bunds between the plots.

Weather parameters

Weather data prevailed during the cropping season (Nov-Dec) *viz*., temperature, rainfall, mean relative humidity are given in appendix É

The weather data was collected from the Meteorological observatory of the University of Agricultural Sciences, G.K.V.K., Bangalore.

Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD), with 14 treatments and three replications.

1. Gross plot size: 92.82 square meters
2. Net plot size: 1.7m × 1.3m
3. Beetroot variety used: Ruby Queen
4. Recommended seed rate: 7.5 kg/ha
5. Recommended FYM: 25 tons/ha
6. Recommended fertilizer dose: 100: 50: 70 kg NPK/ha
7. Spacing followed: 30cm × 22.5cm

Treatments details of the field experiment

Fig. 1: General View of the Experimental Plot

T_1: 50% NP + 100% K + *Azotobacter chroococcum*

T_2: 50% NP + 100% K + *Glucanobacter diazotrophicus*

T_3: 50% NP + 100% K + *Azotobacter chroococcum* + *Gluconobacter diazotrophicus*

T_4: 50% NP + 100% K + *Azotobacter chroococcum* + *Gluconobacter diazotrophicus* + *Bacillus megaterium* (PSB).

T_5: 50% NP + 100% K + *Azotobacter chroococcum* + *Glucanobacter diazotrophicus* + *Bacillus megaterium* + *Trichoderma harzianum*

T_6: 75% NP + 100% K + *Azotobacter chroococcum*

T_7: 75% NP + 100% K + *Glucanobacter diazotrophicus*

T_8: 75% NP + 100% K + *Azotobacter chroococcum* + *Glucanobacter diazotrophicus*

T_9: 75% NP + 100% K + *Azotobacter chroococcum* + *Glucanobacter diazotrophicu* + *Bacillus megaterium*

T_{10}: 75% NP + 100% K + *Azotobacter chroococcum* + *Glucanobacter diazotrophicus* + *Bacillus megaterium* + *Trichoderma harzianum*

T_{11}: 50% NP + 100% K

T_{12}: 75% NP + 100% K

T_{13}: 100% NPK (Reccommended dose)

T_{14}: FYM alone

NOTE: (FYM is common to all the treatments)

Cultural operations

Seeds and Sowing

Beetroot variety ruby queen seeds were sown directly on main experimental plot at the rate of 7.5 kg/ha, at a spacing of 22.5 cm between plants and 30 cm between rows.

Fertilizer Application

The recommended dose of fertilizer 100 kg nitrogen, 50 kg phosphorous and 70 kg potassium per hectare (UAS package of practice for vegetable cultivation) was applied in the form of urea, single super phosphate and muriate of potash respectively as per the treatments requirement. Half of the nitrogen and entire dosage of P and K were applied as basal dose while the remaining half of the nitrogen was applied 30 days after sowing. FYM was applied uniformly to all the treatments at the rate 25 tons/ha, 15 days prior to seed sowing and mixed well with the soil.

Weeding and irrigation

Periodic hand weeding was done to keep the plots free from weeds. Irrigation was given at an interval of 3 to 4 days depending on the soil moisture condition.

Yield parameters

Yield of tuber per plant (g)

Fresh tuber weight per plant was recorded at harvest and expressed in grams.

Yield of beetroot (kg/plot)

The plants were uprooted from each plot at harvest and fresh weight of tubers were recorded after cleaning the adhering soil and expressed as kg per plot.

Yield tons/ha

Root yield per hectare was computed from the net plot yield and expressed as tons per hectare.

Statistical analysis

The experimental data obtained were subjected to statistical analysis as per Fischer's method of variance as given by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The results pertaining to the field study "Effect of microbial inoculants on growth and yield of Beetroot. (*Beta vulgaris*)" conducted during Rabi season 2005-06 are presented below.

Yield parameters

Yield of tuber per plant (g)

Fresh tuber weight per plant was recorded at harvest (Table 3). The highest tuber yield per plant (302 g/plant) was recorded in the treatment of 75 per cent N, P plus full dose of K with *Azotobacter chroococcum, Glucanobacter diazotrophicus, Bacillus megaterium* and *Trichoderma harzianum.*

Table 1: Influence of microbial inoculants on nutrient uptake in Beetroot:

Treatments	Nutrient uptake (kg/ha)		
	N	P	K
T_1 – *A. chroococcum* + 50% N, P	36.96	7.90	14.02
T_2 – *G. diazotrophicus* + 50% N, P	45.93	9.80	17.15
T_3 – *A. chroococcum* + *G. diazotrophicus* + 50% N, P	49.32	10.83	18.58
T_4 – *A. chroococcum* + *G. diazotrophicus* + *B. megaterrium* + 50% N, P	77.94	16.79	29.02
T_5 – *A. chroococcum* + *G. diazotrophicus* + *B. megaterium* + *T. harzianum* + 50% N, P	85.78	18.74	32.46
T_6 – *A. chroococcum* + 75% N, P	57.04	12.70	21.71
T_7 – *G. diazotrophicus* + 75% N, P	64.61	13.98	24.41
T_8 – *A . chroococcum* + *G. diazotrophicus* + 75% N, P	69.98	15.31	26.02
T_9 – *A. chroococcum* + *G. diazotrophicus* + *B. megaterium* + 75% N, P	96.00	20.63	35.53
T_{10} – *A. chroococcum* + *G. diazotrophicus* + *B. megaterium* + *T. harzianum* + 75% N, P	135.14	28.96	49.04
T_{11} - 50% N, P	28.83	6.81	12.16
T_{12} - 75% N, P	54.94	11.87	20.73
T_{13} - 100% N, P	106.41	22.85	39.12
T_{14} - FYM alone	20.63	5.07	9.29
F-test	*	*	*
SEm ±	3.55	0.77	1.31
CD @ 5%	10.76	2.32	3.97

Note: Recommended K is common to all the treatments except $T_{14.}$; FYM is common to all the treatments at recommended dose.

The lowest tuber yield per hectare was recorded in the treatment of un inoculated control (100.33 g/ plant).

Tuber yield per plot (kg)

Treatments differed significantly with respect to tuber yield per plot and the results are presented in Table 3. Maximum tuber yield was in the treatment of 75 per cent N, P plus full dose of K with *Azotobacter chroococcum, Glucanobacter diazotrophicus Bacillus megaterium* and *Trichoderma harzianum* (8.53 kg/plot). The lowest tuber yield per plot (1.90 kg/plot) was recorded in uninoculated control treatment.

Tuber yield per hectare

Based on tuber yield per plot, the tuber yield per hectare was computed Table 3 and Fig. 2. The highest tuber yield per hectare (38.61 t/ha) was recorded in the treatment of 75 per cent N, P plus full dose of K with *Azotobacter chroococcum, Glucanobacter diazotrophicus, Bacillus megaterium* and *Trichoderma harzianum.* The lowest tuber yield per hectare was recorded in the treatment of uninoculated control (8.60 t/ha).

Nitrogen uptake

The total nitrogen uptake by beetroot plants was maximum in the treatment combination of 75 per cent N, P plus full dose of K with *Azotobacter chroococcum*, *Glucanobacter diazotrophicus, Bacillus megaterium* and *Trichoderma harzianum* (135.14 kg ha^{-1}). Minimum 'N' uptake was recorded in plants treated with FYM alone (20.63 kg ha^{-1}).

Phosphorous uptake

Phosphorous uptake in beetroot plants was maximum in the treatment combination of 75

Table 2: Influence of microbial inoculants on yield of Beetroot

Treatments (g)	Tuber yield/plant (kg)	Tuber yield/plot (t/ha)	Tuber yield
T_{1} – *A. chroococcum* + 50% N, P	122.67	2.82	12.74
T_{2} – *G. diazotrophicus* + 50% N, P	128.33	3.38	15.31
T_{3} – *A. chroococcum* + *G. diazotrophicus* + 50% N, P	139.00	3.63	16.44
T_{4} – *A. chroococcum* + *G. diazotrophicus* + *B. megaterrium* + 50% N, P	180.67	5.30	23.98
T_{5} – *A. chroococcum* + *G. diazotrophicus* + *B. megaterium* + *T. harzianum* + 50% N, P	194.00	5.83	26.39
T_{6} – *A. chroococcum* + 75% N, P	150.67	4.07	18.40
T_{7} – *G. diazotrophicus* + 75% N, P	163.00	4.53	20.51
T_{8} – *A . chroococcum* + *G. diazotrophicus* + 75% N, P	174.33	4.83	21.87
T_{9} – *A. chroococcum* + *G. diazotrophicus* + *B. megaterium* + 75% N, P	205.67	6.33	28.66
T_{10} – *A. chroococcum* + *G. diazotrophicus* + *B. megaterium* + *T. harzianum* + 75% N, P	302.00	8.53	38.61
T_{11} - 50% N, P	114.33	2.47	11.16
T_{12} - 75% N, P	143.00	3.92	17.72
T_{13} - 100% N, P	215.00	6.92	31.30
T_{14} - FYM alone	100.33	1.90	8.60
F-test	*	*	*
SEm ±	9.47	0.23	1.05
CD @ 5%	30.03	0.70	3.19

Note: Recommended K is common to all the treatments except $T_{14.}$; FYM is common to all the treatments at recommended dose.

per cent N, P plus full dose of K with *Azotobacter chroococcum*, *Glucanobacter diazotrophicus, Bacillus megaterium* and *Trichoderma harzianum* (28.96 kg ha^{-1}).Minimum uptake was recorded in plants treated with FYM alone (5.07 kg ha^{-1}).

Potassium uptake

Potassium uptake in beetroot plants was maximum in the treatment combination of 75 per cent N, P plus full dose of K with *Azotobacter chroococcum*, *Glucanobacter diazotrophicus, Bacillus megaterium* and *Trichoderma harzianum* (49.04 kg ha^{-1}). Minimum uptake was recorded in plants treated with FYM alone (9.29 kg ha^{-1}).

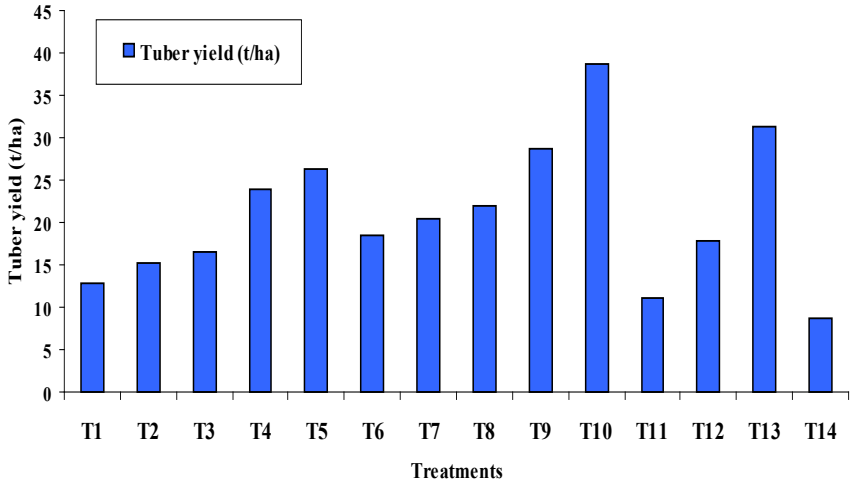
DISCUSSION

Nutrient content in plants

Increased nutrient uptake in plants was recorded in biofertilizer treated plants. However significant difference in nutrient uptake was noticed among the treatments. The combined inoculation of *Azotobacter chroococcum, Glucanobacter diazotrophicus, Bacillus megaterium* and *Trichoderma harzianum* along with 75 per cent N, P plus full dose of K recorded highest N (135.14 kg/ha) and P (28.96 kg/ha) while it was lowest in control plants which were supplemented only with FYM (N, P). Higher nutrient uptake in plants could be attributed to effective translocation of nutrients due to better biological nitrogen fixation and P solubilization by the introduced microbial inoculants which are in conformity with the findings of Mohandas (1987).

Effect of microbial inoculants on yield parameters of beetroot

The tuber yield per plot and per hectare was significantly influenced due to biofertilizers application in conjunction with different levels of nitrogen and phosphorous. Maximum tuber yield per

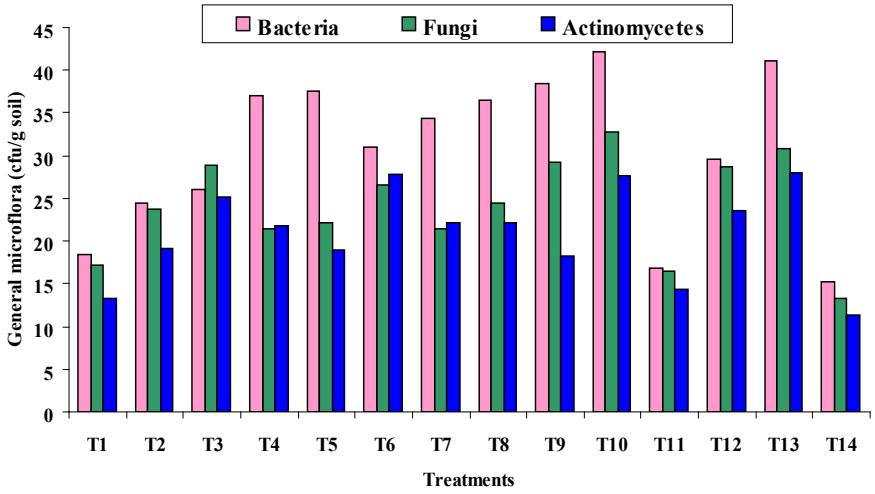


Treatment details

T_1 - 50% N,P + *A.c*	**T_2 - 50% N,P + *G. d***
T_3 - 50% N,P + *A.c* + *G.d*	**T_4 - 50% N,P + *A. c* + *G. + B. m***
T_5 - 50% N,P + *A.c* + *G. d* + *B.m* + *T. h*	**T_6 - 75% N,P + *A. c***
T_7 - 75% N,P + *G. d*	**T_8 - 75% N,P + *A. c* + *G. d***
T_9 - 75% N,P + *A.c* + *G.d* + *B.m*	**T_{10} - 75% N,P+ *A.c* + *G.d* + *B.m* + *T.h***
T_{11} - 50% N,P	**T_{12} - 75% N,P**
T_{13} - 100% N,P (Reccommended dose)	**T_{14} - FYM alone**

Note : K is common to all the treatments at rcommended dose
DAS : Days after sowing
A.c=*Azotobacter chroococcum* **G.d= *Glucanobacter diazotrophicus***
B.m= *Bacillus megaterium* **T.h= *Trichoderma harzianum***

Fig. 2: Influence of microbial inoculants on yield of Beetroot



Treatment details

T_1 - 50% N,P + *A.c*	**T_2 - 50% N,P + *G. d***
T_3 - 50% N,P + *A.c* + *G.d*	**T_4 - 50% N,P + *A. c* + *G.* + *B. m***
T_5 - 50% N,P + *A.c* + *G. d* + *B.m* + *T. h*	**T_6 - 75% N,P + *A. c***
T_7 - 75% N,P + *G. d*	**T_8 - 75% N,P + *A. c* + *G. d***
T_9 - 75% N,P + *A.c* + *G.d* + *B.m*	**T_{10} - 75% N,P+ *A.c* + *G.d* + *B.m* + *T.h***
T_{11} - 50% N,P	**T_{12} - 75% N,P**
T_{13} - 100% N,P (Reccommended dose)	**T_{14} - FYM alone**

Note : K is common to all the treatments at rcommended dose
DAS : Days after sowing
A.c=*Azotobacter chroococcum* **G.d= *Glucanobacter diazotrophicus***
B.m= *Bacillus megaterium* **T.h= *Trichoderma harzianum***

Fig. 3: General microbial population in soil of beetroot after harvest of the crop

plot and per hectare was recorded in the plots treated with 75 per cent N, P plus full dose of K. Similar findings of improvement in yield of potato due to triple inoculation of *Azospirillum brasilense, Bacillus megaterium,* and *Glomus fasciculatum* was earlier reported by Thamiz vendan and Nanjan (1998). Maximum yield of sugar in beetroot was recorded due to inoculation of *Azotobacter chroococcum,* plus *Glucanobacter diazotrophicus* with 75 kg N per hectare (Jambukar and Wange, 2005).

Basavaraju (1999) observed significant increase in fresh weight and dry weight of radish due to inoculation of *Azotobacter.* Similarly Wange (1995) reported maximum bulb yield in garlic due to inoculation of *Azotobacter.*

Similarly maximum yield of sugarcane with increase in sugar recovery from 0.5 to 1% was recorded due to inoculation of *Glucanobacter diazotrophicus* with 50 per cent saving in the application of chemical nitrogen fertilizers was reported by Muthukumara samy *et al.* (1994).

CONCLUSION

The treatment combinationed application of *Azotobacter chroococcum, Glucanobacter diazotrophicus, Bacillus megaterium* and *Trichoderma harzianum* with 75 per cent N, P and recommended dose of K was found most remunerative by considering the yield, quality and benefit: cost ratio, and highest monetary returns. This treatment also

showed a possible saving of 25 per cent N and P chemical fertilizers with maximum yield compare to that of 100 % recommended NPK.

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