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RESEARCH ARTICLE

INFLUENCE OF MIXED MICROBIAL CONSORTIUM ON PLANT GROWTH AND YIELDS OF CHILLI IN VERTISOLS

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ABSTRACT

The present work demonstrated that selected growth stimulating bacterial strains with AM fungi are able to increase the growth, yields and nutrient uptake of Chilli in vertisols. Two experiments were conducted in pots as well as in field at ANGRAU, Agricultural Research Station, Amaravathi to study the response of Chilli to the inoculation of mixed microbial consortium of *Azotobacter, Azospirillum,* Phosphate solubilizing bacteria, Plant growth promoting rhizobacteria, Arbuscular mycorrhizal fungi and chemical fertilizers on AM fungal root colonization, soil microbial populations, yield attributes and yield. Inocuation of mixed microbial consortium including two diazotrophs of *Azospirillum* and *Azotobacter*(MC3 consortium) performed the best in recording AM colonization, Number of fruits per plant, Fresh and dry fruit weights per plant in pots. The highest mycorrhizal root colonization 78% and dry fruit weight 51.2 g/plant obtained by inoculation of MC3 consortium with 75%RDF in pots. The inoculation of MC3 consortium with 75% RDF enhanced the soil microbial populations under field conditions. This consortium recorded maximum per cent of nitrogen uptake(2.205%) and gave highest dry chilli yields of 3409.7 kg/ha with a saving of 25% of chemical fertilizers. Over-all the mixed microbial consortium MC3 considered being the balanced combination of different microorganisms for achieving maximum output in the cultivation of Chilli in vertisols of India.

INTRODUCTION

Chilli (*Capsicum annum* L.) is one of the most important condiments used by the people of India for its green fruits as vegetable and dry fruit as spices.

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The Chilli growing farmers of Andhra Pradesh especially in the district Guntur are known to use heavy doses of fertilizers than the actual recommendations of the crop. As we are aware that It is a world wide consensus now that sole dependence up on chemical input based crop production is not sustainable in the long run and

only integrated plant nutrient systems (IPNS) involving a combination of chemical fertilizers, organics and biofertilizers are essential to sustain crop production. Organic nutrition for chilli is especially important as they provide quality foods, which are very important for providing health security to people (Anonymous, 2008).

Microbial inoculants act as plant growth promoting rhizobacteria (PGPR) including Pseudomonas sps, fix nitrogen, solubilize soil unavailable phosphates, produce growth promoting substances and make them available to plants and also provide protection against several plant diseases (Bashan and Bashan, 2002). In India beneficial effects of *Azospirillum* and *Azotobacter* have been reported by various workers on a wide range of crops including cereals, vegetables and oil seeds etc. Applied free living nitrogen fixers (*Azotobacter* or *Azospirillum*), P-solubilizers and PGPR survive for longer period in the mycorrhizosphere of crops and often act synergistically with AMF in increasing plant growth and yield (Siva Prasad and Rai, 1990).

The effects are more profound when inoculated with two or three organisms together. Combined inoculation of phosphate solubilizing bacteria and Azospirillum on crops like sorghum, Bajra and cotton gave significant increase in dry matter and yield over single inoculation (Alaguwadi and Gaur, 1992). In order to reduce the usage of chemical fertilizers without sacrificing yield targets application of microbial inoculants are very important in chilli cultivation. In this regard there is an urgent need to develop an effective mixed microbial consortium which can support the Chilli crop to the extent possible and can reduce the chemical inputs usage. Based on the above facts the present investigation was carried out to explore capabilities of various types of plant growth promoting rhizobacterial isolates used as mixed microbial consortium through evaluation of growth and yields of Chilli.

MATERIALS AND METHODS

As per the mandate of the project based on the previous results we have developed a mixed microbial consortium by using different agriculturally important microbes like *Azospirillum* (AZS:SCH11), *Azotobacter* (AZB:AZO311), Phosphate solubilizing bacteria (PSB:AMT1003), Plant growth promoting *rhizobacteria* (PGPR:PF1) and Arbuscular mycorrhizal fungi (AMF). Efficient diazotrophic strains which exhibited high ARA and plant growth promotion abilities as evidenced by bioassay were selected for preparation of mixed consortium. The prepared mixed microbial consortia are:

MC1=AZB+PSB+PGPR+AMF,
MC2=AZS+PSB+PGPR+AMF,
MC3=AZB+AZS+PSB+PGPR+AMF.

The quantity of individual inoculants we have used for preparing the mixer is 1.5 kg Azospirillum/Azotobacter, 1.0 kg PSB, 1.0 kg PGPR and 5.0 kg of AMF. Wherever we have used both the diazotrophs care has been taken to mix 50% share of for each diazotrophs. The entire mixer was used as a standard dose for one acre. At the time of application these mixers were added to 200 kg vermicompost (per acre) for easy distribution.

Two experiments (one pot and one field) were performed at Agricultural Research Station, Amaravathi, AP, India during 2006-07 on Chilli in vertisol soils. The pots were filled with 23kg of sieved natural vertisol soil. The treatments evaluated are mixed microbial consortia of MC1, MC2, and MC3 in integration with 50% RDF, and 75% RDF in both the experiments and were replicated four times in a split plot arrangement in a randomized block design. The Chilli variety LCA334 was used in this study. In the field experiment, plots were prepared with 8 m length by 6 m wide. Mixed microbial consortium doses were applied based on the weight of the soil in case of pot experiment and area in case of field experiment for maintaining the uniformity in both the experiments. Wherever we have not applied microbial consortium we supplemented quantity with vermicompost. The plant root samples were collected from one set of pots and processed for assessing mycorrhizal colonization by using binocular stereomicroscope (Koske and Gemma, 1989). Soil samples were processed for AM propagules by using MPN technique. We have monitored the changes in soil microflora by

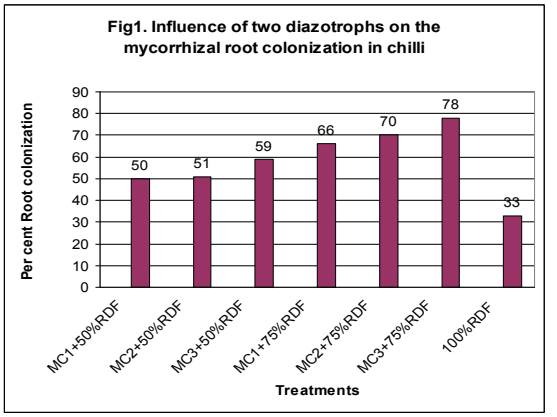
measuring the population of various types of microorganisms by following standard procedures (Alef and Nannipieri,1995). Plants were harvested and recorded the dry fruit yields. Data were subjected to analysis of variance and means were separated using Fisher's least significant difference (LSD) test (P=0.05).

RESULTS AND DISCUSSION

We have experienced by several ways of applying of different microbial inoculants in the crop rhizosphere for obtaining better yields when crops raised in different agro-climatic situations. Several researchers proved dual application of biofertilizer organisms are much better than single inoculant for growth and yields of many crop plants (Kundu and Tauro,1987; Okon and Labandera,1994). In the recent agriculture technology it has become a common practice of using a nitrogen fixing organism in combination of other plant growth promoting microbial inoculants. In the present experiments we have studied the influence of prepared mixed microbial consortia in combination with fertilizer doses in Chilli crop.

Pot trial

The application of Azospirillum and Azotobacter together in the mixed consortium gave significantly higher values than others in case of mycorrhizal root colonization. This may be due to the synergistic effect of these two diazotrophs on AM fungi colonization at 70 Days after sowing (Fig 1). These two diazotrophs might have showed influence in triggering number of genes controlling AM colonization in Chilli. The strain of Azospirillum (SCH 11) which has the endophytic colonization ability on Chilli might have facilitated the AM fungi for more colonization. Similarly, Sakamoto and Tsukui (2005) reported that AM colonization was high in the presence of hyper modulating Rhizobium mutant compared to wild type in soybean because of their control on auto regulatory system of Soybean. The results indicated that there is a positive correlation of fertilizers application for Chilli on the mycorrhizal colonization to the extent of 75% RDF. Significantly higher per cent mycorrhizal root



Note MC1: AZB+PSB+PGPR+AMF, MC2: AZS+PSB+PGPR+AMF, MC3: AZB+AZS+PSB+PGPR+AMF

Table 1. Influence of mixed microbial consortium on the yields of Chilli in pots

Treatment	No. of fruits/pl	Fresh fruit wt. (g/pl)	Dry fruit wt. (g/pl)
MC1+50%RDF	117	101.75	38.00
MC2+50%RDF	127	105.75	44.25
MC3+50%RDF	138	104.75	43.75
MC1+75%RDF	153	120.25	47.25
MC2+75%RDF	167	127.50	50.50
MC3+75%RDF	179	129.50	51.25
100%RDF	152	118.00	43.00
CD at 5%	7.396	11.361	5.611

Note MC1: AZB+PSB+PGPR+AMF, MC2: AZS+PSB+PGPR+AMF, MC3: AZB+AZS+PSB+PGPR+AMF

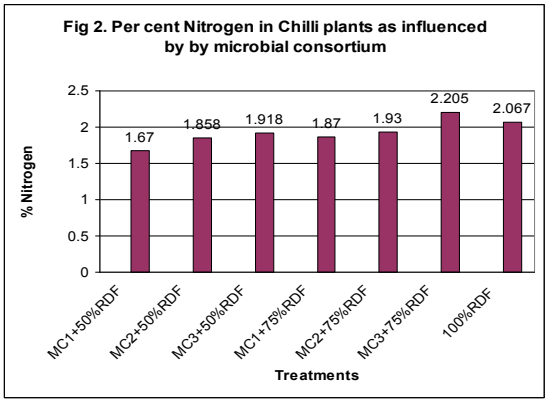
colonization (78%) was recorded with the inoculation of MC3 with 75% dose of recommended fertilizers over other treatments at 70 days after sowing. This indicates that application of 75% of N or P doses has no inhibitory action on AM mycorrhizal root colonization.

The number of fruits per plant was recorded highest in the treatment of MC3+75%RDF at 110 days after sowing in pots and it was significantly higher than other treatments. Mixed microbial consortium of Azoto+Azosp+PSB+PGPR+AM (MC3) along with 75%RDF gave significantly high fresh and dry fruit yields in pots (Table 1) over other treatments. In MC3 mixer the presence of two diazotrophs might have stimulated the PGPR action of fluorescent pseudomonads to increase ACC deaminase activity or suppression of phytopathogens and that might have contributed to the enhancement of growth, yield and nutrient uptake (Pal and Dey, 2005). The results indicated

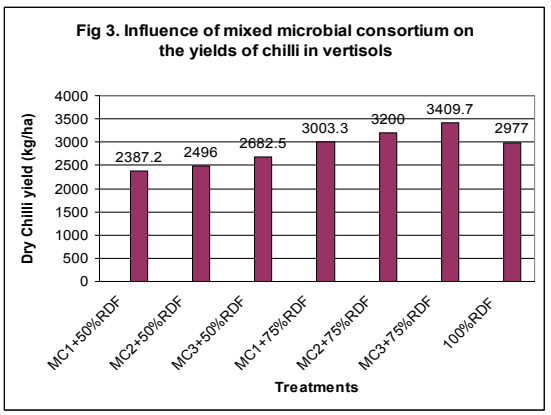
Table 2.Inflenuence of inoculation of mixed microbial consortia on native microbial population (CFU/g soil) in Chilli field after 70 DAT.

Treatments	AZS $X10^4$	AZB $X10^4$	PSB $X10^4$	TBC $X10^7$	TF $X10^3$	AMF propagules /10 g soil
MC1+50%RDF	35	48	40	53	31	420
MC2+50%RDF	50	35	48	57	43	510
MC3+50%RDF	56	54	45	72	44	520
MC1+75%RDF	42	58	44	66	48	470
MC2+75%RDF	61	38	52	69	53	610
MC3+75%RDF	57	56	58	73	57	670
100%RDF	31	34	34	39	62	230
Initial Population	14	15	21	24	12	120

Note MC1: AZB+PSB+PGPR+AMF, MC2: AZS+PSB+PGPR+AMF, MC3: AZB+AZS+PSB+PGPR+AMF



Note MC1: AZB+PSB+PGPR+AMF, MC2: AZS+PSB+PGPR+AMF, MC3: AZB+AZS+PSB+PGPR+AMF



that among asymbiotic nitrogen fixers Azospirillum (SCH18) is much better than Azotobacter(AZO 311) as a plant growth promoter in Chilli rhizosphere. Even though the strain of Azotobacter (AZO 311) had an extra ability of P-solubilization the mixed microbial consortia prepared with Azospirillum performed better than Azotobacter. Similar kind of observations was reported by Okon and Labandera (1994) in several crops. This may be because of non-availability of energy sources in the prsent vertisol soil which are essential factors for Azotobacter activities or may be due to its poor competitiveness to establish its population in the Chilli rhizosphere.

The strains of Azospirillum and Azotobacter used in the present study might be highly synergistic and compatible with other microbial inoculants used in the mixer. These two diazotrophs might be not only acted as nitrogen fixers but also produced plant growth substances which ultimately enhanced the number of fruits, fresh fruit weights and dry fruit weights per plant. The endophytic character of Azospirillum might have contributed further to increase the availability of nutrients as well as growth hormones to the Chilli plants (Prabhu *et al.,* 2000). The results showed that there is an increase of 19% in the dry fruit yield in the treatment of MC3+75%RDF over 100% RDF in pot trial with an additional benefit of saving 25% chemical fertilizers in Chilli cultivation.

Field Trial

In the field we have monitored the microbial populations of different groups and found that inoculation has enhanced the levels of several microorganisms at 70 days after transplantation (Table 2) in all treatments. It was found that there is an increase in the soil microbial parameters like population of Azospirillum, Azotobacter, Phosphate solubilising bacteria, Total bacteria, total fungi and AM fungi at 70 DAT in all the treatments over initial populations (Table 2).The number of AM propagules were recorded maximum in the treatment of MC3+75% RDF and the trend was in agreement with the results of pot experiment. The increase in the population of various groups of soil microorganisms might be due to high compatibility of inoculated mixed microbes and suitability with Chilli rhizosphere microcosm under field conditions.

Even at higher doses of fertilizers we have recorded considerable increase in soil microbial populations. This may be due to more root surface

area and excretion of more quantities of root exudates in the rhizosphere of Chilli. Azopsirillum and Azotobacter populations were recorded maximum with 75% RDF when they were applied as individual in the mixed consortia. Whereas the synergistic effect of these two diazotrophs showed good influence with 75% RDF by enhancing the population of PSB, TBC and AM propagules at 70 days after transplantation. The introduced mixed microbial consortium might have utilized a portion of 75% RDF for their growth and establishment without any adverse effect.

The per cent Nitrogen was measured in the vegetative parts of the plant at the time of harvest and found that the highest per cent N content in the plants of MC3+75%RDF treatment(2.205) where we have applied two N_2–fixers together with PSB+PGPR+AM (Fig 2). In general Azospirillum inoculated plants tend to absorb more amounts nutrients from the soil solution. In MC3 mixer Azospirillum in combination with Azotobacter might have enhanced the uptake of nutrients of much faster rate and this might have reflected finally for getting more accumulation of N in the plant parts. Similar kinds of observations were reported by Okon (1985) where the Azospirillum inoculated plants absorbed the nutrients at faster rate than uninoculated plants. Similarly, Lazarovits and Norwak (1997) found that the inoculation of rhizobacteria on maize increased the crop yields and uptake of nutrients such as N, P and K. The nitrogen accumulation in the plant was increased with the application of two diazotrophs together in combination of other microbial inoculants at both the levels of 50% RDF and 75% RDF fertilizer doses (Fig 2). The maximum was recorded as 2.205%in the MC3+75% RDF treatment. Visual observation clearly indicated that the vigor of the plants of MC3+755 RDF treatment always better than other treatments This might be because of more hormonal release by PGPR organisms Pseudomonas fluorescence and enhanced nutrient availability by other organisms in the mixed microbial consortium.

Significantly higher dry Chilli yields were recorded with the application of MC3 mix with 75% RDF (3409.7 kg/ha) over 100 % RDF (2977 kg/ha). The applied mixed microbial consortium including AM fungi and Rhizobacteria such as Pseudomonas sp. Azopsirillum spp, Pantoea spp. increased growth and nutrient uptake of maize, wheat and legumes (Boddey and Germida, 1995). In our field experiment there is an yield increase of 14.5% by the inoculation of mixed microbial consortium of Azoto+Azosp+PSB+PGPR+AM with 75%RDF over 100%RDF treatment with an additional benefit of saving 25% of RDF for this crop.The increased nutrient uptake by Chilli plants inoculated with effective microbial consortium may be attributed to the increase in crop yields.

Conclusion

The results of both the experiments demonstrated that Chilli crop gained maximum benefit by inoculation of two diazotrophs of Azospirillum and Azotobacter together along with the mixed microbial inoculants of Phospharte solubilizing bacteria (AMT 1003) and plant growth promoting rhizobacteria (Fluorescent Pseudomonas) and Arbusuclar mycorrhizal fungi. The selected mixed microbial consortium not only increased the uptake of N but also enhanced crop yields. This mixed microbial consortium gave maximum benefit when we have applied with 75% RDF dose of Chilli crop. At this fertilizer dose we could able to increase dry Chilli yields by 19% in pots and 14.8% in the field with an extra benefit of saving 25% of fertilizers. This biological approach may decrease the usage of chemical fertilizers in Chilli production and give more healthy Chilli for human consumption.

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