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Improving Seedling Health of Bell Pepper (*Capsicum annum* L.) by Plant Growth Promoting Microorganisms

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A B S T R A C T

Organic vegetable cultivation is a present day need not only to meet the demand of export oriented produce and to reduce cost of cultivation but also to protect the environment. In the present investigation four widely studied PGPMs viz., *Azotobacter* sp. (UBAZ-1), phosphate solubilising bacteria (UBPS-9), *Trichoderma* sp. (UBT-18) and *Pseudomonas fluorescens* (VPf-1) were evaluated for their ability either individually or in consortia to induce the physical and biochemical fitness of the bell pepper (*Capsicum annum*) transplants. Uptake of nitrogen and phosporus in mature plants and available nitrogen in the soil at harvesting stage were also found significantly higher when grown with microbial consortia. Pro tray mediated seedling raising was found to be most effective. Microbial consortia showed highest level of beneficial activity in soil application along with seed bio priming to increase physical attributes at seedling transplanting stage.Vermicompost:Soil@2:3v/v as compared to other compost was found more effective but Vermicompost is costlier than FYM, so using of FYM is economically viable. In aspect of biotic stress, by using microbial consortia percentage of disease reduction was higher. This experiment can conclude that PGPM are most effective in plant growth promotion when they are applied in consortia rather than individual.

Introduction

The demand for organic food is steadily increasing with annual average growth rate of 20–25%. Worldwide, over 130 countries produce certified organic products in commercial quantities (Kortbech-Olesen, 2000). It is estimated that 18 million hectare of land is available in the North East, which can be exploited for organic production (Ramesh *et al.*, 2005).

Organic vegetable cultivation is going on in the country is basically export oriented. However, considering the demand, effort has to be given to promote vegetable cultivation

with organic cultivation practices. While production of transplants is a prime criteria in vegetable cultivation, fruitful interventions from the beginning can make the organic cultivation a success. In greenhouse studies, endophytic and epiphytic bacteria applied isolated or in mixtures, as root and substrate treatments, significantly increased the growth of micropropagated banana plantlets and controlled *Fusarium* wilt (Mariano *et al.*, 2004). According to Nowak and Shulaev (2003), the production of high-quality propagules with disease resistance may be achieved among others methods by their "*in vitro*" and "*ex vitro*" bio-priming (priming with beneficial microorganisms).

In the present investigation, the role of four different beneficial soil microbes viz.,*Trichoderma harzianum* (UBT-18) and *Pseudomonas fluorescens* (VPf-1) as bio control agent, *Azotobacter* spp. (UBAZ-1) as nitrogen facilitator and Phosphate solubilising bacteria (UBPS-9) as phosphate solubilizer was studied in seedling growth of Capsicum. Among the test bio-inoculants, *P. fluorescens*, *Azotobacter* spp. and phosphate solubilising bacteria are principally considered as Plant Growth Promoting rhizobacteria by many scientists (Glick, 1995). *Trichoderma* sp. have been used successfully in several pathogen/host systems to enhance plant growth and control disease particularly against important soil borne diseases of vegetable crops (Kapoor, 2008).

Several mechanisms have been demonstrated where biological control organisms can act as antagonists of the targeted pathogens, or by inducing resistance in the host (Cook and Baker, 1983, Papavizas, 1985). *Pseudomonas fluorescens* have been shown to enhance plant growth and protect roots from invasion by pathogens by a variety of mechanisms including production of antibiotics, hydrogen cyanide, siderophores, and induced systemic resistance (Kloepper*et al.*, 1980; Weller, 1988; Zehnder *et al.*, 2001). *Azotobacter* is generally regarded as a free-living aerobic nitrogen-fixer and reported to increase seed germination and seedling growth (Shaukat *et al*., 2006) in a plant and also help in reducing incidence of several soil borne pathogens (Smith, 2002).

It has been shown that wheat yield increased up to 30% with *Azotobacter* inoculation (Klopper *et al.*, 1992). The use of phosphate solubilising bacteria as inoculants increases the P uptake by plants (Igual *et al.*, 2001). Phosphate Solubilising Microorganisms (PSM) in addition to providing P to plants also facilitate plant growth by other mechanisms (Saharan and Nehra, 2011). Hence, all the bio-inoculants used in the present study had specific role in seedling growth.

Materials and Methods

Mass production of bioinoculants

For mass multiplication, selected isolate of biocontrol agents and biofertilizers were first inoculated into 100 ml PDB (Potato Dextrose Broth) or NB (Nutrient Broth) orPikovskaya's Broth and incubated at 28±1 ºC for 3 to 4 days. After that mycelial mat along with the solution was blended till the mycelial mat homogenized with the solution whereas, in case of bacterial inoculants the entire culture was used per se. The homogenized culture was then mixed with pre-sterilized talc powder @ 200 ml/ kg and was left to dry overnight on trays lined with the blotting paper. The bio-inoculated talc powder was stored in a moisture-proof packaging such as aluminium laminate sachets and kept in cool place. The population of individual bio-inoculants in the formulations was determined in their respective specific medium to maintain the viable colony forming unit (cfu) at 10^8-10^9/g of the product.

Bio-priming of seed

Thirty (30) gm Bentonite clay was added into 250 ml sterilized distilled water to make bentonite solution. Fifty ml homogenized solutions of the individual bio-inoculants containing viable propagules of 10^9cfu/ml was mixed in bentonite solution and then 3% sodium alginate solution was mixed to make a slurry. Seeds were then soaked in the slurry for 15-30 min and then immediately transferred to 2.5% $CaCl_2$ solution to make bio-priming on the seed.

The bio-primed seeds were then air-dried on filter paper for 1 h in a laminar flow hood, packed into air tight container and stored in a refrigerator until required.

Microbial enrichment of growing medium

During experiment, the sterilized nursery mix consisting of soil and well rotten compost @3:1 v/v was inoculated with talc based formulation of the bio-inoculant (s) @ 5g/kg and incubated for 7 days before use.

Screening of most effective microbial consortium for production of bio-primed seedlings

Experiment was designed to examine the potentiality of the microbial consortium in improving the seedling health vegetable crop capsicum, under protected seedling development system as per following treatment schedule.

T1:	*Trichoderma harzianum* (UBT-18)
T2:	*Pseudomonas fluorescens* (Vpf-1)
T3:	Phosphate solubilizing bacteria (UBPS-9)
T4:	*Azotobacter* (UBAZ-1)
T5:	*T.harzianum* (UBT-18) + *P.fluorescens* (Vpf-1)
T6:	Phosphate solubilizing bacteria (UBPS 9)+ *Azotobacter* (UBAZ 1)
T7:	*T. harzianum*(UBT-18) + Phosphate solubilizing bacteria (UBPS-9) + *Azotobacter* (UBAZ-1)
T8:	*P.fluorescens* (Vpf -1)+ Phosphate solubilizing bacteria(UBPS-9) + Azotobacter (UBAZ-1)
T9:	*T. harzianum* (UBT-18)+ *Pseudomonas fluorescens*(Vpf-1)+ Phosphate solubilizing bacteria (UBPS-9) + *Azotobacter* (UBAZ-1)
T10:	Control

Pro-trays were used to develop the seedlings and bio-enriched soil-farm yard manure mix was used as growing medium. The growing medium was filled in holes of portrays. Seeds of the vegetable crops were first surface sterilized with 0.1% $HgCl_2$ solution then repeatedly washed in sterile distilled water and were primed according to the treatment and sown singly per hole of the pro-tray at a depth of 1-2cm depending upon the size of the seed. Controlled irrigation was given at regular interval to maintain the moisture holding capacity near 70%.

Collection of experimental data

Physical attributes of bio inoculated seedlings

The physical attributes like Germination (%) after 4-5 days after sowing, root length (cm) and shoot length on 21st days of sowing,

Vigor index {Germination (%) × (root length + shoot length)} as suggested by Abdul-Baki and Anderson (1973), average fresh shoot weight (mg) and fresh root weight (mg) taking ten normal seedling, Root and shoot dry weight (mg) after drying in butter paper bag for 72 hr in hot air oven maintained at 60°C and Chlorophyll content of leaves (21st days of sowing) by using SPAD 502 were recorded.

Biochemical attributes of bio inoculated seedlings

Biochemical studies were conducted to estimate total protein (Lowry *et al.,* (1951)), total phenol (using Folin – ciocalteau reagent by following the method of Malick and Singh (1980)), poly phenol oxidase in leaves (Mayer *et al*., 1965) and dehydrogenase activity in nursery mix (by the method described by Rossel *et al.,* (1997).

Effect of microbial consortium on nutrient uptake by bio primed vegetables and fertility status of soil

Bio-primed capsicum seedlings developed in the pro-tray were evaluated under field conditions for their nutrient uptake ability at maximum fruiting stage. Data of nutrient uptake by plants at maximum fruiting stage and fertility status of the soil was assessed after harvesting of the crops. The initial available NPK status of the experimental field was 193, 10, 62 kg ha^{-1}, respectively. A field experiment was performed in 2×4 m plots in a randomized block design with 10 treatments (9 combination of microbial consotia) including untreated check keeping three replications for each treatment. Bio-primed seedlings were transplanted in the field by making holes at desired spacing for each crop and in every holes 500 g incubated soil+compost mix was applied. Balanced fertilizer @ 20:20:20 was applied through spray @ 5g/ lit of water two times during active vegetative phase of the crop.

Nutrient uptake by plants at maximum fruiting stage

Plant samples were collected from each plot at the time of fruiting stage. The samples were oven dried and ground to fine dust which was utilized for determination of nitrogen, phosphorus and potassium content of the crop. Total nitrogen content of plant samples was analyzed by using Kjeldahl method as suggested by Jackson (1967). Total phosphorus content of plant samples was analyzed by using Vando molybdo phosphoric yellow color method with the help of flame photometer as suggested by Jackson (1967).Total potassium content of plant samples was analyzed by using the method suggested by Jackson (1967) with the help of flame photometer.

The uptake of nitrogen, phosphorus and potassium were calculated using the following formula.

Nutrient uptake = [Per cent nutrient concentration × biomass (kg/ha)]/100

Fertility status of soil after harvesting of bio-primed plants

Composite soil samples from the multiple locations of the experimental plots for all the test crops were collected after harvest of the crop from 0-30 cm depth. The samples were thoroughly dried in shade, pulverized, sieved through 0.2 mm mesh. Samples were analyzed for the determination of the available N, P and K as per following technique. Available nitrogen content in soil was estimated by modified Macro Kjeldahl method (Jackson 1967).Available phosphorus in soil was estimated by Brays Method as described by Bray and Krutz (1945).

Available potash in soil was estimated by Ammonium acetate method with the help of flame photometer (Jackson, 1967).

Effect of technological interventions on production of healthy bio-primed vegetable seedlings

Different technological interventions were examined separately where emphasis was given on to monitor the effect of production system, delivery methods of microbial consortium, compost amendments in growing medium and dose of most suitable compost on seedling health of different vegetable crops.

Effect of production system for raising healthy bio-primed vegetable seedlings

T1: non solarized seed bed
T2: solarized seed bed
T3: Soil with poly thene tarping
T4: Pro-tray

Effect of delivery system of the microbial consortium for production of bio-primed vegetable seedling

T1: Soil application
T2: Seed dressing
T3: Seed encapsulation/priming solid matrix priming
T4: T1+T2
T5: T1+T3
T6: Control

Evaluation of different composts on seedling health of vegetable crops

T1 : Vermicompost + Soil (1:3 v/v)
T2 : Water hyacinth compost + Soil (1:3 v/v)
T3 : FYM +Soil (1:3 v/v)
T4 : Mushroom compost + soil (1:3 v/v)
T5 : Soil

Effect of compost dose on seedling health of vegetable crops

T1: Compost + soil @ 0:1 v/v
T2: Compost + soil @ 1:0 v/v
T3: Compost + soil @ 2:3 v/v
T4: Compost + soil @ 1:3 v/v

Integrated production system of bio-primed vegetables under field condition

T1:	Seed bed (soil + FYM @ 1:3 v/v) and effective microbial consortium un-inoculated (Farmers practice).
T2:	Effective microbial consortium inoculated in non-solarized seed bed (soil + FYM @ 1:3 v/v).
T3:	Non-solarized seed bed (soil + most effective compost amendment at most appropriate dose) with microbial consortium.
T4:	Effective microbial consortium inoculated in non-sterilized soil + FYM @1:3 v/v in pro-trays.
T5:	Non sterilized soil + most effective compost amendment at most appropriate dose) with microbial consortium in pro-trays.
T6:	Effective microbial consortium inoculated in solarized seed beed (soil + FYM @ 1:3 v/v).
T7:	Solarized seed bed (soil + most effective compost amendment at most appropriate dose) with microbial consortium.
T8:	Effective microbial consortium inoculated sterilized soil + FYM @ 1:3 in pro-trays.
T9:	Sterilized soil + most effective compost amendment at most appropriate dose in pro-trays with effective microbial consortium.

Disease assessment

The incidence of damping off (both pre emergence and post emergence) was recorded as the number of non-germinated seed vs germinated seeds those developed in pro-trays. Bacterial wilt incidence was calculated as the number of typical wilt infected plants relative to the total number of transplanted seedlings.

Statistical analysis

Calculation of raw data was made with the help of Microsoft excel (MS office, Windows XP) software package and statistical analysis was done using INDOSTAT (7.1 version) software according to Gomez and Gomez (1984).

Results and Discussion

Effect of microbial consortia on physical attributes of capsicum seedlings at transplanting stage

The physical attributes of bio-primed capsicum seedlings raised by application of different microbial consortia was evaluated at transplanting stage and the results have been presented in Table 1.

The results revealed that bio-inoculant consortia irrespective of combination increased the germination, chlorophyll, shoot and root length, shoot and root biomass as compared to non-inoculated seedlings.

UBT-18, UBPS-9 and UBAZ-1 in integration were found to increase significantly the physical parameters like chlorophyll, shoot length; fresh and dry shoot weight (SPAD value of 42.00, 5.98 cm, 1238.29 mg and 119.88 mg, respectively). It was statistically at par with consorted inoculation of VPf-1, UBPS-9 and UBAZ-1. Germination was significantly higher in UBT-18 and VPf-1 (65.67%) and it was statistically at par in combined application of Vpf-1, UBPS-9 and UBAZ-1 (64.43%) followed by combination of UBT-18, VPf-1, UBPS-9 and UBAZ-1 (63.00%).

Root length, fresh and dry root weight were significantly higher in consorted inoculation of all test bio-inoculants (7.93 cm, 809.17 mg and 97.58 mg, respectively). The corresponding vigour index as the indicator of seedling health was determined to be significantly higher with consorted inoculation of UBT-18, UBPS-9 and UBAZ-1 (1080.55) which was closely followed by combination of VPf-1, UBPS-9 and UBAZ-1 (1076.02) (Fig. 1).

Effect of microbial consortia on biochemical attributes of capsicum seedlings at transplanting stage

Biochemical analysis of the bio-primed capsicum seedlings revealed that protein and phenol content were maximum in UBT-18, UBPS-9 and UBAZ-1 (Fig. 2, 3, 4 and 5). Poly phenol oxidase activity was found to be significantly high in the seedlings raised by using combination of UBT-18, VPf-1, UBPS-9 and UBAZ-1 (Fig. 3). The highest dehydrogenase activity of the nursery mixes at transplanting stage was measured in consorted inoculation of UBT-18, UBPS-9 and UBAZ-1.

Nutrient uptake by bio-primed capsicum plants and fertility status of soil

Nutrient uptake by bio-primed capsicum plants and fertility status of soil was calculated and presented in Table 2. Uptake of nitrogen by bio-primed capsicum plants was found to be highest in consorted

application of VPf-1, UBPS-9 and UBAZ-1 (61.39 kg/ha) while it was significantly at par with consortium of UBT-18, UBPS-9 and UBAZ-1 (58.49 kg/ha). The phosphorus and potassium uptake were significantly higher in the capsicum plants enriched with consortium of UBT-18, UBPS-9 and UBAZ-1 (17.76 and 58.05 kg/ha, respectively).

Fertility status of the soil after harvesting of the bio-primed capsicum plants revealed that available nitrogen was significantly high whenever UBAZ-1 was included in the consortium and even application of the same as sole bio-inoculant. The available nitrogen in the treatments varied between 229.33 to 233.00 kg/ha (Table 2).

No significant variation in available phosphorus was detected among the treatments where consortia were applied irrespective of combination of bio-fertlizer and bio-control agents. Available potassium was also almost on par in the treatments where bio-inoculant consortia were applied (106.67 – 117.00 kg/ha).

Evaluation of different production system for bio-primed capsicum seedlings

Pro-tray mediated seedling raising technology was proved to be the most effective method of bio-primed capsicum seedling production (Table 3) (Fig. 6 and 7).

Influence of delivery system of microbial consortia on physical health of capsicum seedlings

The physical attributes of the bio-primed capsicum seedlings at transplanting stage were significantly influenced by the delivery system of the bio-inoculants (Table 4).

Effect of composts on seedling health of capsicum transplants

Significant variation in physical attributes of the bio-primed capsicum seedlings was observed with different kind of composts as one of the component of nursery mix with soil. Vermicompost was found more effective than other (Table 5).

Determination of compost dose in nursery mix for production of bio-primed capsicum seedlings

Significant variation in physical attributes of the bio-primed capsicum seedlings at transplanting stage was observed upon application of different doses of vermicompost. Compost : soil @2:3 v/v was found more effective (Table 6).

Incidence of damping off and bacterial wilt in capsicum under organic production system

Substantially low incidence of damping off and bacterial wilt was noticed in capsicum when the bio-primed seeds were sown in pro-trays filled with microbial consortium inoculated nursery mix composed of Vermicompost and sterilized soil @ 2:3 v/v (T9) followed by the production systems viz., sowing of bio-primed seed in pro-trays containing (Table 7).

Economic analysis of the production system of capsicum

Though Vermicompost was found more effective for physical and other plant attributes, it was more costly than FYM, So use of FYM was more cost effective than others. B:C ratio was highest i.e. 1.53. (Table 8).

Table.1 Effect of microbial consortia on seedling health of capsicum at transplanting stage

Treatment	Chlorophyll (SPAD Value)	Germination (%)	Shoot length (cm)	Root length (cm)	Fresh shoot wt (mg)	Fresh Root wt (mg)	Dry shoot wt (mg)	Dry Root wt (mg)	Vigor index
T1	39.17	74.00 (59.35) *	5.16	6.06	1066.60	618.12	103.20	74.54	830.21
T2	35.00	72.33 (58.29)	5.02	5.82	1038.64	593.97	100.73	71.59	784.07
T3	34.87	70.33 (57.01)	4.69	5.78	967.72	590.03	94.53	71.14	736.66
T4	36.00	71.00 (57.44)	4.75	5.82	982.78	593.31	95.19	71.55	749.98
T5	38.57	**83.00 (65.67)**	5.47	7.06	1131.39	720.45	109.33	86.84	1039.67
T6	35.79	78.00 (62.08)	5.28	6.97	1093.79	710.94	105.93	85.73	955.48
T7	**42.00**	79.33 (63.00)	**5.98**	7.82	**1238.29**	797.45	**119.88**	96.15	**1094.85**
T8	39.67	81.33 (64.43)	5.82	7.47	1203.51	761.53	116.33	91.84	1080.55
T9	39.33	79.33 (63.00)	5.63	**7.93**	1164.85	**809.17**	112.60	**97.58**	1076.02
T10	31.33	62.67 (52.34)	4.11	5.22	850.34	532.10	82.13	64.17	584.30
SEm±	1.02	0.67	0.07	0.03	15.27	3.23	1.49	0.40	12.70
LSD (P=0.05)	3.02	1.98	0.22	0.10	45.36	9.60	4.42	1.18	37.74

*Figures in parenthesis are arcsine transformed prior to the analysis.

T1= Seed bio priming with UBT-18 ,T2= Seed bio priming with VPf 1 ,T3= Seed bio priming with UBPS-9 ,T4= Seed bio priming with UBAZ-1, T5= Seed bio priming with UBT-18+VPf-1 ,T6 = Seed bio priming with UBPS-9+UBAZ-1 ,T7= Seed bio priming with UBT-18+UBPS-9+UBAZ-1 ,T8= Seed bio priming with VPf-1+UBPS-9+UBAZ-1 , T9= Seed bio priming with UBT-18+VPf-1+UBPS-9+UBAZ-1, T10= Control

Table.2 Effect of microbial consortia on NPK uptake by bioprimed capsicum plants and subsequent fertility status of soil

Treatment	Plant uptake			Soil fertility status		
	N (kg/ha)	P (kg/ha)	K (kg/ha)	available N (kg/ha)	available P (kg/ha)	available K (kg/ha)
T1	45.33	8.88	33.27	219.00	20.00	101.00
T2	42.63	8.56	33.50	223.00	19.33	101.67
T3	42.94	13.16	34.42	219.00	20.33	107.67
T4	50.82	8.47	38.39	229.33	20.33	104.67
T5	47.92	9.95	45.29	219.00	24.00	113.33
T6	53.83	14.74	49.37	230.33	23.67	106.67
T7	58.49	**17.76**	**58.05**	**233.00**	**25.67**	113.67
T8	**61.39**	14.90	49.95	231.33	24.33	**117.00**
T9	49.39	14.05	45.83	232.33	24.67	113.33
T10	29.41	5.48	23.32	219.00	15.67	78.33
SEm±	1.89	0.71	2.50	1.25	0.84	4.20
LSD(P=0.05)	5.63	2.12	7.42	3.72	2.49	12.47

T1= Seed bio priming with UBT-18 ,T2= Seed bio priming with VPf 1 ,T3= Seed bio priming with UBPS-9, T4= Seed bio priming with UBAZ-1, T5= Seed bio priming with UBT-18+VPf-1 ,T6 = Seed bio priming with UBPS-9+UBAZ-1 ,T7=Seed bio priming with UBT-18+UBPS-9+UBAZ-1, T8= Seed bio priming with VPf-1+UBPS-9+UBAZ-1, T9= Seed bio priming with UBT-18+VPf-1+UBPS-9+UBAZ-1, T10= Control

Table.3 Effect of production technology on seedling health at transplanting stage

Treatment	Germination (%)	Shoot length (cm)	Root length (cm)	Fresh shoot wt (mg)	Fresh Root wt (mg)	Dry shoot wt (mg)	Dry Root wt (mg)	Vigor index
T1	60.40 (51.00)*	4.08	4.97	798.90	467.37	61.14	49.72	546.43
T2	72.80 (58.58)	5.25	5.79	1029.78	544.64	78.81	57.94	810.33
T3	70.80 (57.30)	5.23	5.62	1024.69	528.66	78.42	56.24	768.26
T4	**78.80 (62.61)**	**5.34**	**6.13**	**1045.86**	**575.84**	**80.04**	**61.26**	**896.66**
SEm±	0.43	0.02	0.04	4.20	3.42	0.32	0.36	6.75
LSD(P=0.05)	1.33	0.06	0.11	12.94	10.55	0.99	1.12	20.80

*Figures in parenthesis are arc sine transformed values
T1= Non Solarized seed bed, T2=Solarized seed bed, T3=Soil with polythene tarping, T4= Pro-tray

Table.4 Effect of delivery system of microbial consortium on seedling health at transplanting stage

Treatment	Germination (%)	Shoot length (cm)	Root length (cm)	Fresh shoot wt (mg)	Fresh Root wt (mg)	Dry shoot wt (mg)	Dry Root wt (mg)	Vigor index
T1	71.25 (57.59)*	5.12	5.30	1126.95	530.00	87.08	63.60	742.63
T2	73.00 (58.71)	5.27	5.55	1158.85	555.25	89.55	66.63	789.83
T3	77.50 (61.70)	5.33	5.64	1172.60	563.75	90.61	67.65	850.02
T4	74.50 (59.68)	**5.39**	5.83	**1185.80**	583.25	**91.63**	69.99	836.26
T5	**79.75 (63.29)**	5.28	**6.08**	1161.05	**607.50**	89.72	**72.90**	**905.15**
T6	61.50 (51.65)	4.10	5.06	902.55	506.00	69.74	60.72	563.38
SEm±	0.65	0.03	0.04	7.02	3.75	0.54	0.45	11.29
LSD(P=0.05)	1.96	0.10	0.11	21.17	11.30	1.64	1.36	34.03

*Figures in parentheses are arc sine transformed values
T1 =Soil application, T2 =Seed dressing, T3 =Seed bio priming, T4=T1+T2, T5=T1+T3, T6 =Control

Table.5 Effect of microbial consortium enriched composts on seedling health at transplanting stage

Treatment	Germination (%) .	Shoot length (cm)	Root length (cm)	Fresh shoot wt (mg)	Fresh Root wt (mg)	Dry shoot wt (mg)	Dry Root wt (mg)	Vigor index
T1	**81.00 (64.21)***	5.28	**6.07**	1160.50	**607.00**	68.58	**54.63**	918.68
T2	76.25 (60.88)	5.58	5.79	1227.60	578.50	72.54	52.07	866.38
T3	75.75 (60.51)	**5.94**	5.80	**1306.25**	580.25	**77.19**	52.22	889.54
T4	79.75 (63.31)	5.78	5.76	1272.15	576.25	75.17	51.86	**920.56**
T5	64.00 (53.14)	4.11	5.22	903.10	521.50	53.37	46.94	596.63
SEm±	0.69	0.06	0.04	13.60	3.60	0.80	0.32	12.61
LSD(P=0.05)	2.13	0.19	0.11	41.90	11.11	2.48	1.00	38.85

*Figures in parentheses are arc sine transformed values; T1= Vermicompost+soil , T2= Water hyacinth compost +soil, T3= FYM+soil; T4= Mushroom compost +soil , T5=Soil

Table.6 Effect of dose of vermicompost on seedling health at transplanting stage

Treatment	Germination (%)	Shoot length (cm)	Root length (cm)	Fresh shoot wt (mg)	Fresh Root wt (mg)	Dry shoot wt (mg)	Dry Root wt (mg)	Vigor index
T1	60.80 (51.26)	4.09	5.03	801.25	487.72	61.32	50.28	554.42
T2	73.00 (58.71)	5.32	5.65	**1041.94**	547.66	79.74	56.46	800.17
T3	**79.20 (62.90)**	5.27	**6.10**	1033.70	**591.31**	79.11	**60.96**	**900.31**
T4	74.40 (59.62)	**5.36**	5.82	1050.56	564.54	**80.40**	58.20	831.95
SEm±	0.70	0.03	0.04	5.76	3.58	0.44	0.37	11.28
LSD(P=0.05)	2.14	0.09	0.11	17.75	11.02	1.36	1.14	34.77

*Figures in parentheses are arc sine transformed values
T1=Compost: Soil @0:1 v/v, T2=Compost: soil @1:0 v/v, T3=Compost:soil @2:3 v/v T4=Compost: soil @ 1:3 v/v

Table.7 Incidence of damping off and bacterial wilt under organic production system

Treatment	Pre-emergence Damping off (%)	Disease reduction over control	Post-emergence Damping off (%)	Disease reduction over control	Bacterial wilt (%)	Disease reduction over control
T1	23.56	-	11.55	-	7.83	-
T2	14.58	38.12	6.92	40.09	5.94	24.14
T3	13.90	41.00	6.36	44.94	5.44	30.52
T4	12.53	46.82	5.83	49.52	4.97	36.53
T5	9.27	60.65	5.75	50.22	4.30	45.08
T6	11.55	50.98	6.10	47.19	5.55	29.12
T7	9.14	61.21	5.64	51.17	5.04	35.63
T8	8.56	63.67	4.94	57.23	4.19	46.49
T9	8.38	**64.43**	4.59	**60.26**	3.13	**60.03**
CV%	12.39		8.91		12.91	
SEm±	0.89		0.33		0.38	
LSD(P=0.05)	2.67		0.99		1.14	

T1: Seed bed (soil+FYM @1:3 v/v) uninoculated (Farmers' practice) T2: microbial consortium inoculated non-solarized seed bed (soil+FYM @1:3 v/v) T3: Non-solarized seed bed (soil+vermicompost @2:3 v/v) with microbial consortium T4: Microbial consortium inoculated non- sterilized soil+FYM @1:3 in pro-trays T5: Non-sterilized soil+ vermicompost @ 2:3 v/v with microbial consortium in pro-trays T6: Microbial consortium inoculated in solarized seed bed (soil+FYM @1:3 v/v), T7: Solarized seed bed (soil+vermicompost @2:3 v/v) with microbial consortium T8: Microbial consortium inoculated sterilized soil+FYM @ 1:3 v/v in pro-trays T9: Sterilized soil+vermicompost @2:3 v/v with microbial consortium in pro-trays

Table.8 Economics of organic capsicum cultivation

Treatment	Yield (ton/ha)	Gross return (Rs /ha)	Cost of cultivation (Rs /ha)	B:C ratio
T1	9.67	67690.00	32686.50	1.07
T2	10.00	70000.00	29550.00	1.37
T3	10.15	71050.00	33242.50	1.14
T4	10.22	71540.00	34511.00	1.07
T5	10.70	74900.00	34874.00	1.15
T6	10.35	72450.00	28682.50	**1.53**
T7	11.10	77700.00	33345.00	1.33
T8	11.50	80500.00	36154.00	1.23
T9	11.88	83160.00	36631.00	1.27
SEm±	**0.61**			
LSD (P=0.05)	**NS**			

T1: Seed bed (soil+FYM @1:3 v/v) uninoculated (Farmers' practice) T2: microbial consortium inoculated non-solarized seed bed (soil+FYM @1:3 v/v) T3: Non-solarized seed bed (soil+vermicompost @2:3 v/v) with microbial consortium T4: Microbial consortium inoculated non- sterilized soil+FYM @1:3 in pro-trays T5: Non-sterilized soil+ vermicompost @ 2:3 v/v with microbial consortium in pro-trays T6: Microbial consortium inoculated in solarized seed bed (soil+FYM @1:3 v/v), T7: Solarized seed bed (soil+vermicompost @2:3 v/v) with microbial consortium T8: Microbial consortium inoculated sterilized soil+FYM @ 1:3 v/v in pro-trays T9: Sterilized soil+vermicompost @2:3 v/v with microbial consortium in pro-trays

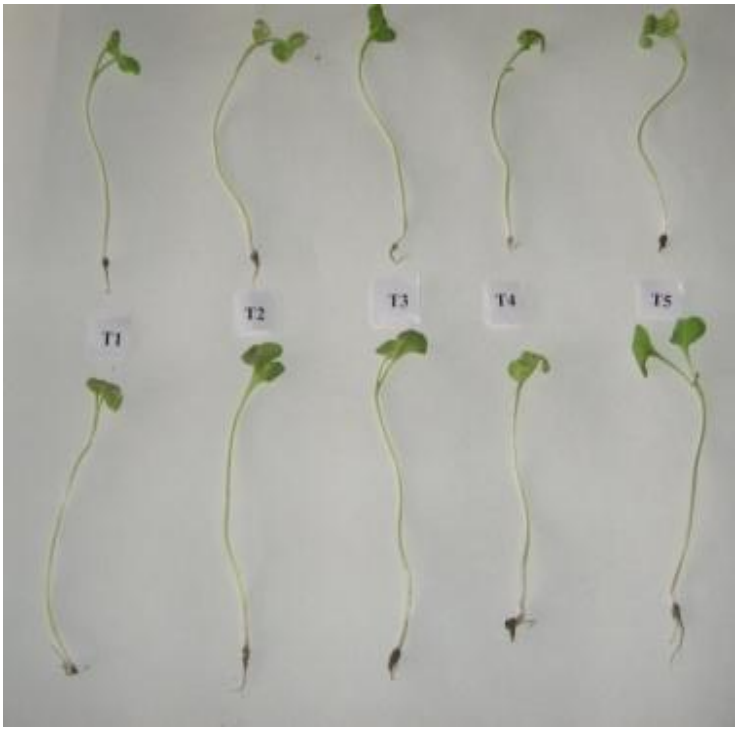

Fig.1 Effect of microbial consortia on seedling health

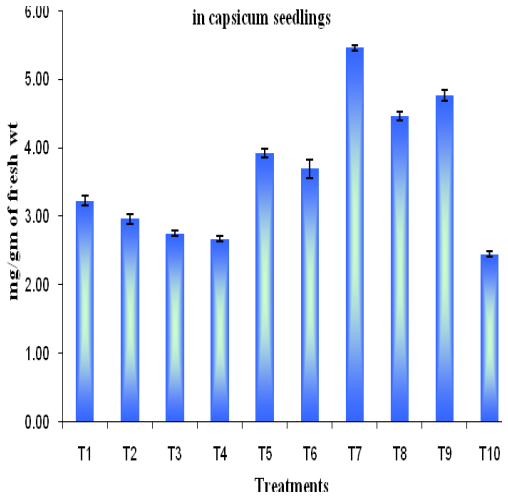

Fig.2 Effect of microbial consortia on protein concentration

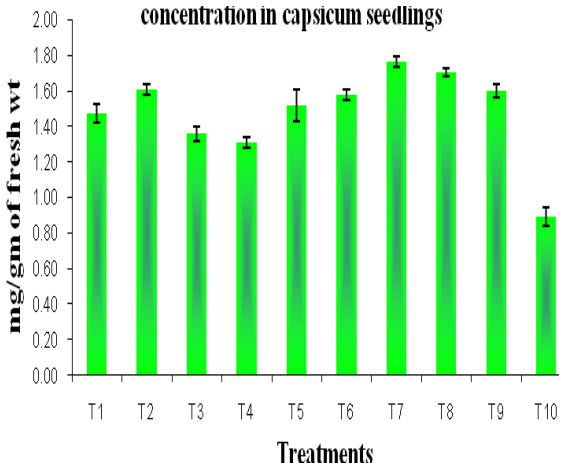

Fig.3 Effect of microbial consortia on Phenol concentration

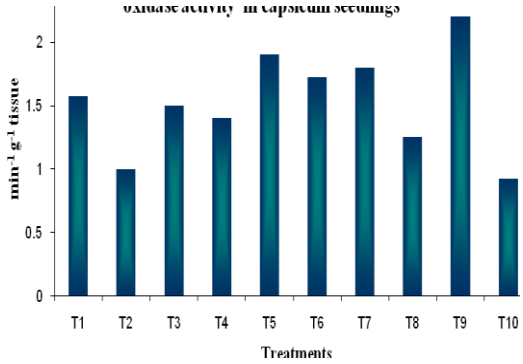

Fig.4 Effect of microbial consortia on Polyphenol oxidase activity

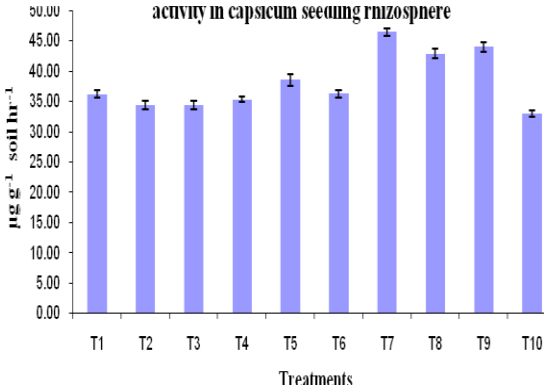

Fig.5 Effect of microbial consortia on Soil microbial activity in seedling rhizosphere

Fig.6 Preparation of microbial consortium enriched nursery mix and filling up of pro-trays for planting

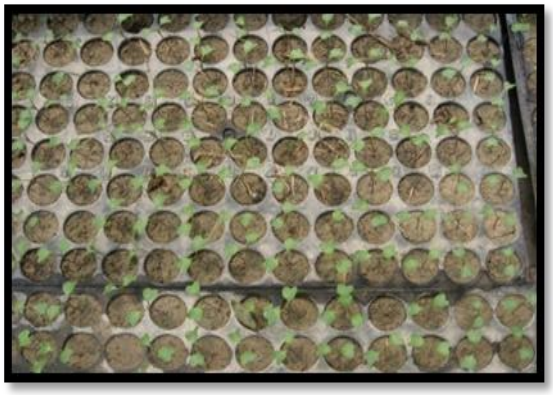

Fig.7 Containerized (Pro-tray) seedling production of Capsicum

In this entire experiment, strategy was taken to grow the crops in organic manner using PGPM consortia. For various physical and biochemical attributes, UBT-18+UBPS-

9+UBAZ-1 consortia was found very much effective. Like it increased vigor index, root length, dry and fresh root weight, Protien content, Phenol, Polyphenol oxidase and dehydrogenase activity. It also increase plant resistance through Salicylic Acid signalling and increase plant defence enzyme like PAL, PPO, Peroxidase etc.

This microbial consortia also can increase the nutrient uptake by changing the plant root architecture. Containerized pro-tray seedling production system was helpful to avoid the root injury, transplanting shock. Application of microbial consortia through soil and seed bio priming was most effective to increase the root colonization over pathogenic microbes.

Vermicompost was found most effective among all other compost, @Vermicompost : Soil 2:3 dose but vermicompost is costlier than FYM so using of FYM instead of Vermicompost is more cost effective. Integration of entire system can reduce the pre and post emergence damping off, bacterial wilt disease incidence.

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