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Efficacy of Indigenous Liquid Compatible Microbial Consortia on French Bean Plant Growth Promoting Traits

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ABSTRACT

An indigenous liquid microbial consortium was developed in order to combat collar rot disease of French bean. Upon *in vitro* study conducted to check out the efficacy of selected best antagonists individually viz., *Pseudomonas fluorescens* (Pf-2 and Pf-12), *Trichoderma asperellum* (T-8 and T-20) and their consortium (*P. fluorescens* Pf-2 + *P. fluorescens* Pf-12 + *T. asperellum* T-8 + *T. asperellum* T-20) on plant growth promoting activities like seed germination, seedling vigour index, shoot length, root length, dry and fresh weight of shoot, dry and fresh weight of root was carried out. Consortium significantly increased vigour index of French bean plants (111.10%), including germination per cent (34.08 %), shoot length (60.64 %) and root length (54.69 %) over control at 10 DAS. *In vivo* experimental results also revealed that consortium significantly increased vigour index (187% at 20 DAS and 183.5% at 60 DAS), germination per cent (42.46% at 10 DAS), shoot length (104.5% at 20 DAS and 110.5% at 60 DAS) and root length (93.1 % at 20 DAS and 92.60 % at 60 DAS) over control. The tested microbial consortium showed outstanding results indicating better plant growth promoting traits.

Keywords Antagonists, Indigenous microbial consortia, Efficacy, Plant growth promoting traits.

INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is one of the most important leguminous vegetable crops. The common bean is recognized as strategic crop, especially in South America, Africa and Asia. In India and most of the tropical Asia, it is a major vegetable crop (Athikho *et al.* 2019). Worldwide production of bean is 28.3 MT (Anon 2019) and China is the largest producer sharing about 76% of world green bean production followed by Indonesia and India. It has possibility to be grown round the year in this region where irrigation facilities are available during dry period. Though French bean crop occupies a very important place among the vegetable crops grown in India, the average yield of this crop on farmers' fields is reasonably poor. Microbial consortia have the potential to

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colonize more effectively in the rhizosphere, express more consistent beneficial traits under various soil conditions and control a wide range of plant pathogens than singly used agents due to their ability to produce various lipopeptide antibiotics (Singh *et al.* 2022). Many of these biological control agents and PGPRs are known to produce amino acids, enzymes, siderophores, phosphate and other growth promoting substances like GA, IAA and cytokinins which help in better growth of crop plants (Raupach and Kloepper 1998). The current trend is to mix BCAs of diverse microbial species having plant growth promoting activities to achieve desired agricultural outcomes. Moreover, application of microbes in a consortium may improve efficacy, consistency and reliability of the microbes under diverse environmental and soil conditions soil Compatible microbes are applied together as a consortium, the crop plants are expected to get a combined benefit of high N and P availabilities for uptake leading to better plant health and yield (Singh *et al.* 2019). With the above aforesaid realities, an attempt was made to study the effect of compatible microbial consortia on French bean plant growth and developmental traits under *in vitro* and *in vivo* condition.

MATERIALS AND METHODS

Preparation of indigenous liquid compatible microbial consortia (CMC)

Liquid suspension of each selected *T. asperellum* isolates (T-8 and T-20) was prepared from 7 days old cultured PDA medium plates. The plates were rinsed with sterile distilled (10 ml) water and the mycelia were carefully scraped off the agar with a bent glass rod. This suspension was filtered through filter paper (Whatman No.1) to separate the spores from the mycelia. The concentration was adjusted to 3.7×10^8 spores/ml (Dubos 1987) with the help of hemocytometer.

In case of bacteria, 250 ml of each selected *P. fluorescens* isolates (Pf-2 and Pf-12) cell suspension was prepared by inoculating the strain into King's B broth followed by shaking for 48 hrs (150 rpm) at room temperature. The bacterial suspension was roughly adjusted optically at 1×10^9 cfu/ml (OD 600=1) (Mulya *et al.* 1996). Liquid consortium was prepared by mixing equal volume (1:1:1:1) of each selected isolate just before use (Srinivasan and Mathivanan 2009).

In vitro effect of compatible microbial consortia (CMC) on French bean seed

The healthy seed of French bean cv Anupama was selected for experimental purpose. The seeds were obtained from local market. French bean seeds were surface sterilized with 1.0% sodium hypochlorite for 2 min for all treatments, followed by three rinses with sterile distilled water.

Wet seed treatment

The surface sterilized seeds were soaked with liquid formulations of consortia @ 1.0 % or 15 ml formulation of CMC in 1 kg seed (French bean seeds) and shade dried in laminar air flow for 5 hrs (Srinivasan and Mathivanan 2009).

For chemical control treatment

The surface sterilized seeds were treated with Captan 50% WP (seed dressing @ 0.3 % or 3 mg/1 g seed) (Srinivasan and Mathivanan 2009).

For control treatment

The surface sterilized seeds were soaked in sterile distilled water (@1 ml/1 g seed) and shade dried in laminar air flow for 5 hrs (Srinivasan and Mathivanan 2009).

Details of experiment

The experiment was conducted in a Complete Randomized Design (CRD) with seven treatment having four replications. Five seeds per petri plate kept in standard filter paper method (three layered moistened filter papers in petri plates) (ISTA 1993).

In vivo effect of compatible microbial consortia (CMC) on French bean under pot experiment

Pot experiments was conducted to test the efficacy of potential isolates of *Trichoderma* sp. and *Pseudomonas* sp. compatible microbial consortia formulations through seed treatment (ST) and soil drenching in controlling collar rot of French bean.

Details of experiment under pot condition

The experiment was conducted (Sept-Nov) in a Completely Randomized Block Design with seven treatments having four replicates. Based on the previous *in vitro* studies one best compatible microbial consortium (T-8+T-20+ Pf-2+ Pf-12) was selected for further analysis.

The treatment combination was laid out as follows :

1. T_1 : Seed treatment + soil drenching (at the time of sowing +15 DAS +30 DAS)

2. T_2 : Seed treatment + soil drenching (at the time of sowing + 15 DAS)

3. T_3 : Seed treatment + soil drenching (at the time of sowing + 30 DAS)

4. T_4 : Seed treatment + soil drenching (15 DAS + 30 DAS)

5. T_5 : Chemical control

6. T_6 : Positive control (Inoculated)

7. T_7 : Negative control (Un-inoculated)

Soil drenching

For T_1, T_2, T_3 and T_4 (soil drenching @ 1.0% of CMC or 50 ml per pot at 0, 15, 30 DAS) (Wang and Zhuang 2019). For chemical control (three foliar sprays of Captan 50% WP @ 0.2 % or 0.375 g / 50 ml of water per pot at 0, 15, and 30 DAS) and for control (three foliar sprays of sterile distilled water @ 50 ml /pot).

Observations and recording procedures
Per cent germination at 10 DAS

Per cent germination was calculated using the following formula –

$$\text{Per cent germination} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

Seedlings shoot length and root length (cm)

The root length and shoot length of individual seedlings (10 seedlings/replication) were measured. The shoot length was measured from collar region to the tip of the seedling with the help of a scale and the mean shoot length was expressed in cm. The root length measured from collar region to the tip of primary root with the help of a scale and the mean root length was expressed in cm for *in vivo* five plants in each plot were selected randomly for recording the observations and were duly tagged.

Seedling vigour index (SVI)

The vigour index of seedlings was calculated by adopting the method suggested by Abdul Baki and Anderson (1973) and expressed in number by using the below formula.

SVI = Germination (%) × [Mean shoot length (cm) + Mean root length (cm)]

Fresh weight (mg) of seedling shoot and root

The fresh weight (mg) of root and shoot of individual seedlings (10 seedlings /replication) were measured.

Dry weight (mg) of seedling shoot and root

The dry weight of root and shoot of individual seedlings (10 seedlings/replication) were measured after oven drying at 60° C (when constant weight obtained) for 24 hrs. The weight of shoot and root was recorded and mean dry weight of seedlings was calculated and was expressed in mg.

Per cent increase of plant growth promotion over control

The per cent increase over control was calculated using the formula :

$$\text{Per cent increase} = \frac{\text{Treatment value} - \text{Control value}}{\text{Control value}}$$

Table 1. *In vitro* effects of CMC on French bean seed germination (%), seedling shoot length, root length and vigour index at 10 DAS. *Values in parentheses are angular transformed values.

Treatments	Seed germination (%) at 10 DAS	Seedling shoot at 10 DAS			Seedling root at 10 DAS			Seedling vigour index at 10 DAS
		Shoot length (cm)	Shoot fresh wt (mg)	Shoot dry wt (mg)	Root length (cm)	Root fresh wt (mg)	Root dry wt (mg)	
T_1 (T-8)	80.25 (63.79)	5.92	991.7	237.0	5.05	173.2	43.00	883.05
T_2 (T-20)	79.75 (63.25)	5.85	990.5	233.5	5.00	173.0	43.00	865.27
T_3 (Pf-2)	81.75 (64.71)	6.07	1003.2	239.2	5.10	177.5	45.50	913.10
T_4 (Pf-12)	81.50 (64.53)	6.02	997.5	237.7	5.02	176.0	44.50	889.95
T_5 (CMC)	89.50 (71.09)	7.02	1228.2	294.0	6.42	223.0	67.50	1201.05
T_6 (Chemical control)	70.25 (56.09)	4.77	679.5	160.7	4.35	105.2	15.25	640.65
T_7 (Control)	66.75 (54.79)	4.37	646.0	151.5	4.15	99.75	14.00	568.65
SEm±	0.15	0.03	1.388	1.29	0.02	0.774	0.18	1.12
CV (%)	1.36	4.53	1.04	4.07	3.38	3.36	3.34	1.16
CD (p= 0.01)	2.14	0.51	19.4	18.10	0.33	10.85	2.61	19.91

The data recorded were subjected to statistical analysis wherever required. The differences exhibited by treatments in various experiments were tested for their significance by employing Completely Randomized Design (CRD) as per the details given by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

In vitro evaluation of plant growth promoting ability of microbial isolates and their CMC

In vitro study conducted to check out the efficacy of selected best antagonists individually viz., Pf-2, Pf-12, T-8 and T-20 and their consortia (Pf-2+Pf-12+T-8+T-20) on seed germination, seedling vigour index, seedlings shoot length, root length, fresh and dry weight of shoot and fresh and dry weight of root was carried out (Srinivasan and Mathivanan 2009).

The result observation on per cent germination of different treatments was recorded on 10 DAS and depicted in Table 1. French bean seed germination per cent was significantly higher in T_5 [CMC (89.50 %)] followed by T_3 [Pf-2] with 81.75 % which is statistically at par with T_4 [Pf-12 (81.50 %)], T_1 [T-8 (80.25 %)] and T_2 [T-20 (79.75 %)]. The lowest seed germination per cent was observed in T_7 [control plate (66.75 %)]. The experimental result revealed that T_5 increased seed germination per cent over control treatment with 34.08%.

The above results are in conformity with the works done by Murthy *et al*. (2013) who reported that *Bacillus* spp. have the rapid multiplication ability in the immediate proximity of germinating seedlings thus increasing the probability of establishment of antagonist in individual roots. Nazir *et al*. (2011) also observes an increased seed germination of tomato and chilli by application of *T. viride* and *T. harzianum.* Further Eutesari *et al.* (2013) also reported that seed germination per cent and seedling growth indices showed improvement when *T. harzianum*, *T. viride, T. viride* and *P. fluorescens* were applied on soybean seedlings.

Root length and shoot length of individual French bean seedlings (60 seedlings/ treatment) were measured. The data on shoot length is depicted in Table 1. Shoot length was longer in all the treated treatments as compared to the control. Among these treatments, significantly longer shoot was recorded in T_5 (7.02

Table 2. *In vitro* effects of CMC on per cent increase of French bean seed germination (%), shoot length, root length, shoot fresh and dry weight, root fresh and dry weight and seedling vigour index at 10 DAS.

	Per cent increase over control at 10 DAS							
		Seedling shoot				Seedling root		
Treatments	Seed germination (%)	Shoot length	Shoot fresh wt	Shoot dry wt	Root length	Root fresh wt	Root dry wt	Seedling vigour index
T_1 (T-8)	20.22	35.46	53.51	56.43	21.68	73.63	182.0	55.30
T_2 (T-20)	19.46	33.86	53.32	54.12	20.48	73.43	182.0	52.16
T_3 (Pf-2)	22.47	38.90	55.29	57.88	22.89	77.94	225.0	60.58
T_4 (Pf-12)	22.09	37.75	54.41	56.89	20.96	76.44	217.8	56.50
T_5 (CMC)	34.08	60.64	90.12	94.05	54.69	123.6	383.5	111.2
T_6 (Chemical control)	5.24	7.78	5.18	6.07	4.81	5.46	7.894	12.67
T_7 (Control)	-	-	-	-	-	-	-	-

cm) which is followed by T_3 with 6.07 cm which is at par with T_4 (6.02 cm). Minimum shoot length was observed in T_7 (3.02 cm). This experimental result revealed that T_5 increased shoot length (60.64%) over control treatment.

Root length was also longer in all the treatments as compared to the control. Among these treatments, significantly higher root was recorded in T_5 (6.42 cm) than the other treatments tested. This was followed by T_3 (5.10 cm) which was found to be statistically at par with T_1 (5.05 cm). Minimum root length was observed in control (4.35 cm). This experimental result revealed that the T_5 increased root length over control treatment with 54.69%.

The above results are in conformity with findings of Murthy *et al.* (2013) that maximum shoot length (5.76 cm) and root length (8.55 cm) was obtained from seeds treated with *T. harzianum* + *T. asperellum* + *T. viride*. Kabir *et al.* (2013) also reported that PBGR isolate B110 showed the highest shoot and root growth with 26% and 35% increments respectively. Similar findings were also reported by Eutesari *et al.* (2013).

The vigour index of French bean seedlings was calculated by adopting the method suggested by Abdul-Baki and Anderson (1973) and expressed in number. Seedling vigour index was higher in all the treatments as compared to the control (Table 1).

Table 3. Effects of CMC on French bean seed germination (%) at 10 DAS. *Values in parentheses are angular transformed values. Whereas, T_1 : Seed treatment + soil drenching (at the time of sowing +15 DAS +30 DAS); T_2: Seed treatment + soil drenching (at the time of sowing + 15 DAS), T_3 : Seed treatment + soil drenching (at the time of sowing + 30 DAS) ; T_4 : Seed treatment + soil drenching (15 DAS + 30 DAS) ; T_5: Chemical control, T_6: Positive control (Inoculated) ; T_7 : Negative control (Un-inoculated).

Treatments	Seed germination (%) at 10 DAS 2018	2019	Pooled	Per cent increase over positive control
T_1	86.25 (68.43)	84.00 (66.67)	85.12 (67.49)	42.46
T_2	86.25 (68.51)	83.75 (66.50)	85.00 (67.39)	42.26
T_3	85.75 (67.96)	84.00 (66.71)	84.87 (67.18)	42.04
T_4	82.50 (65.29)	79.00 (62.83)	80.75 (64.02)	35.14
T_5	72.50 (58.53)	71.50 (57.78)	72.12 (58.14)	20.70
T_6	61.50 (51.66)	58.00 (49.61)	59.75 (50.63)	-
T_7	72.00 (58.05)	72.00 (58.12)	72.00 (58.06)	20.50
SEm±	0.50	0.77	0.48	
CV (%)	4.49	7.16	4.38	
CD (p=0.05)	5.16	8.01	4.97	

Table 4. *In vivo* effects of CMC on French bean shoot length, fresh and dry weight (g) of shoot at 20 DAS. Whereas, T_1: Seed treatment + soil drenching (at the time of sowing +15 DAS +30 DAS); T_2 : Seed treatment + soil drenching (at the time of sowing + 15 DAS); T_3 : Seed treatment + soil drenching (at the time of sowing + 30 DAS), T_4 : Seed treatment + soil drenching (15 DAS + 30 DAS), T_5 : chemical control, T_6 : Positive control (Inoculated), T_7 : Negative control (Un-inoculated).

Treatments	Shoot length (cm) at 20 DAS			Fresh weight (g) of shoot 20 DAS			Dry weight (g) of shoot at 20 DAS		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1	15.95	15.80	15.85	8.97	9.47	9.22	0.51	0.54	0.53
T_2	15.80	15.72	15.75	8.73	9.42	9.07	0.50	0.54	0.52
T_3	15.50	15.47	15.47	8.72	9.48	9.09	0.51	0.54	0.52
T_4	14.52	14.40	14.45	8.15	8.90	8.39	0.48	0.50	0.49
T_5	9.87	9.75	9.80	6.27	6.39	6.33	0.37	0.37	0.37
T_6	8.00	7.60	7.77	4.78	4.98	4.88	0.23	0.28	0.26
T_7	9.95	9.82	9.87	6.29	6.40	6.35	0.37	0.37	0.37
SEm±	0.07	0.08	0.08	0.03	0.10	0.04	0.01	0.00	0.01
CV (%)	4.13	4.93	4.40	3.28	9.34	4.11	9.4	4.40	5.61
CD (p=0.05)	0.77	0.91	0.84	0.35	1.08	0.46	0.01	0.02	0.03

Among these, significantly higher seedling vigour index was recorded in T_5 (1201.05) followed by T_3 (913.10). Minimum seedling vigour index was observed in control (568.65). This experimental result revealed that the T_5 increased vigour index over control treatment with 111.2%.

The above findings are in harmony with the observation of Sudharani *et al*. (2014) who reported that combination of *Azotobacter chroococcum* + *B. megaterium* + *P fluorescens* + *B. subtilis* + *T. harzianum* showed enhanced vigour of cabbage seedlings. Bhakthavatchalu *et al.* (2013) also recorded higher seed germination (92.0%) with an overall better seed vigour index when cowpea seeds were treated with *P. aeruginosa* FP6.

The fresh weight of shoot and root of individual French bean seedlings (60 seedlings/ treatment) were measured. Fresh weight of seedling shoot was higher in all the treatments as compared to the control. Among these treatments, significantly higher fresh weight of shoot was recorded in T_5 (1228.2 mg) than the other treatments. This was followed by T_3 (1003.2 mg) which is statistically at par with T_4 (997.5 mg), T_1 (991.7 mg) and T_2 with 990.5 mg. Minimum fresh weight of shoot was observed in T_7-control (646.0 mg). This experimental result also revealed that the T_5 increased fresh weight of shoot (90.12%) over control treatment (Table 2).

Root fresh weight was also higher in all the treated treatments as compared to the control. Among these treatments, significantly higher fresh weight of root was recorded in T_5 (223.0 mg) than the other treatments which was followed by T_3 (177.5 mg) statistically at par with T_4 (176.0 mg), T_1 (173.2 mg) and T_2 (173.0 mg). Minimum root fresh weight was observed in control (0.10 mg). This experimental result revealed that the T_5 increase root fresh weight over control treatment with 123.6%.

The findings of the present work are in agreement with the work done by Murthy *et al. (*2013) who reported that application of consortia of *Trichoderma* spp. significantly increased the fresh weight of shoot at 10 DAS. Maximum fresh weight of shoot was obtained from seed treated with *T. harzianum* + *T. asperellum* + *T. viride* (1.25 mg) followed by *T. harzianum* + *T. asperellum* (1.26 mg) as compared to control (0.75 mg).

The dry weight of root and shoot of individual seedlings (60 seedlings /treatment) were measured after oven drying at 60°C for 24 hrs and expressed in mg. Dry weight of seedling shoot was also higher in all the treated treatments as compared to the control. Among these treatments, significantly higher dry weight of shoot was recorded in T_5 (294.0 mg) than the other treatments. Next followed by T_3 (239.2 mg) which is statistically at par with T_4 (237.7 mg). Minimum shoot dry weight was observed in control (151.5 mg). This experimental result revealed that the T_5 increased shoot dry weight (94.05 %) over

Table 5. *In vivo* effects of CMC on French bean root length, fresh and dry weight (g) of root at 20 DAS. Whereas, T_1: Seed treatment + soil drenching (at the time of sowing +15 DAS +30 DAS), T_2 : Seed treatment + soil drenching (at the time of sowing + 15 DAS), T_3 : Seed treatment + soil drenching (at the time of sowing + 30 DAS); T_4 : Seed treatment + soil drenching (15 DAS + 30 DAS), T_5: Chemical control, T_6: Positive control (Inoculated), T_7 : Negative control (Un-inoculated).

Treatments	Root length (cm) at 20 DAS			Fresh root weight at 20 DAS			Dry root weight at 20 DAS		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T_1	9.17	9.12	9.15	0.55	0.58	0.56	0.10	0.11	0.11
T_2	9.15	9.15	9.15	0.54	0.58	0.56	0.10	0.11	0.11
T_3	9.15	9.02	9.08	0.54	0.58	0.56	0.09	0.10	0.10
T_4	8.37	8.05	8.21	0.51	0.56	0.54	0.09	0.10	0.09
T_5	5.75	5.77	5.76	0.38	0.37	0.37	0.07	0.07	0.07
T_6	4.80	4.72	4.76	0.31	0.30	0.31	0.06	0.05	0.05
T_7	5.77	5.80	5.78	0.38	0.38	0.38	0.07	0.06	0.07
SEm±	0.05	0.06	0.06	0.01	0.01	0.00	0.17	0.24	0.39
CV (%)	5.14	6.56	6.33	3.94	3.60	2.72	4.82	6.51	3.98
CD (p=0.05)	0.56	0.71	0.68	0.02	0.03	0.01	0.01	0.01	0.01

control treatment.

Root dry weight was also higher in all the treated treatments as compared to the control. Among these treatments, significantly higher dry weight of root was recorded in seed treated with T_5 (67.50 mg) than the other treatment tested which was followed by T_3 (45.50 mg), T_4 (44.50 mg), T_1 (43.00 mg), T_2 (43.00 mg) which were found to be statistically at par with each other. Minimum root dry weight was observed in control (14.00 mg). This experimental result also revealed that the T_5 increased root dry weight (383.5 %) over control treatment.

The above findings confirm the work of Eutesari *et al.* (2013) who reported that seedling growth indices namely root length, seedling length and dry weight of root showed improvement when *T. harzianum*, *T. viride*, *T. atroviride* and *P. fluorescens* were applied on soybean seedlings. The findings of present work are in harmony with the findings of earlier workers. Kumar *et al.* (2010), Sudharani *et al.* (2014), Verma and Shahi (2017) and Singh *et al.* (2019).

In vivo evaluation of compatible microbial consortia (CMC) and its potential plant growth promotion of French bean under pot conditions

The present study was conducted to test the efficacy of selected best consortium through seed treatment and soil drenching in checking plant growth promoting traits and controlling collar rot of French bean under pot conditions during 2018 and 2019. In this study, the application of microbial consortium (Pf-2+Pf-12+T-8 +T-20) at regular interval (0, 15 and 30 DAS) had effectively increased on seed germination, seedling vigour index, seedlings shoot length, root length, fresh and dry weight of shoot and fresh and dry weight of root.

Per cent germination at 10 DAS

Pooled data of the seed germination per cent was significantly higher in all CMC treated treatments. Highest per cent germination was found in treatment T_1 (85.12 %), T_2 (85.00 %), T_3 (84.87%) and T_4 (80.75 %) which were statistically at par with each other (Table 3). The lowest seed germination per cent was observed in T_6 [positive control (59.75 %)] treatment. This experimental result also revealed that the per cent increase of seed germination over control was maximum on T_1 with 42.46%.

The improvement in French bean seed germination might be due to food reserve mobilization by bio-agents. The results of the present findings confirm the work of Maiyappan *et al*. (2010) who reported the efficacy of microbial consortium of four rhizobacteria against *S. rolfsii*, *F. oxysporum* and *R. solani* recorded with high per cent seed germination of green gram under pot condition.

Shoot length and root length (cm) at 20 DAS

The shoot and root length of individual French bean

Table 6. *In vivo* effects of CMC on per cent increase of shoot and root length, fresh and dry weight of shoot and root of French bean plant at 20 DAS over positive control. Whereas, T_1: Seed treatment + soil drenching (at the time of sowing +15 DAS +30 DAS), T_2: Seed treatment + soil drenching (at the time of sowing + 15 DAS), T_3: Seed treatment + soil drenching (at the time of sowing + 30 DAS), T_4: Seed treatment + soil drenching (15 DAS + 30 DAS), T_5 : Chemical control, T_6: Positive control (Inoculated), T_7: Negative control (Un-inoculated).

	Per cent increase over positive control					
	Shoot			Root		
Treat-ments	Length	fresh weight	Dry weight	Length	fresh weight	Dry weight
T_1	104.5	88.93	103.85	93.1	81.08	120.00
T_2	103.2	85.86	100.00	92.6	81.01	120.00
T_3	99.6	86.27	100.00	89.8	80.02	100.00
T_4	86.4	71.92	88.46	69.8	74.67	80.00
T_5	26.4	29.91	42.30	21.1	19.23	40.00
T_6	00.00	00.00	00.00	00.00	00.00	00.00
T_7	27.3	29.71	42.30	21.4	22.23	40.00

(20 plants/treatment) were measured at 20 DAS. Data on shoot length are depicted in Tables 4–5. Shoot length was longer in all the treated treatments as compared to control. At 20 DAS pooled data revealed that there was not much significant difference recorded among the CMC treated treatments i.e., T_1, T_2, T_3 and T_4 (15.85 cm, 15.75 cm, 15.47 cm and 14.45 cm) which were statistically at par with each other. Minimum shoot length was observed in T_6 control at 20 DAS (7.77 cm). This experimental result revealed that the T_1 increased shoot length with 104.5% at 20 DAS over control treatment depicted in Table 6.

Similarly, root length of individual French bean (20 plants/ treatment) was measured at 20 DAS. At 20 DAS, pooled data of the results revealed that T_1, T_2 and T_3 did not differ significantly with 9.17 cm, 9.15 cm and 9.02 cm respectively. Minimum root length was observed in control (4.75 cm at 20). This experimental result revealed that the T_1 increase root length with 93.1 % at 20 DAS over positive control treatment depicted in Table 6.

The increase in plant shoot and root length may be due to increase in the levels of growth hormones viz., IAA, gibberellic acid and defence enzymes viz., peroxidase, polyphenol oxidase and superoxide dismutase as reported by Biam and Majumdar (2019). Indole 3 acetic acid (IAA) is one of the most physiologically active auxins which is a common product of L-tryptophane metabolism produced by several microorganism PGPR. Microorganisms isolated from rhizosphere region of various crop have an ability to produce IAA as secondary metabolites due to rich supply of substrates. IAA helps in production of longer roots with increased number of root hairs and root laterals which are involved in nutrient uptake (Lynch 1985).

The results of the present findings are in agreement with the findings of earlier worker Kumar *et al*. (2010) who reported that combined application of *T. harzianum* and *P. fluorescens* resulted in significant growth of seedling (18.38 cm at 30 DAS) in sweet pepper. Similarly Khan *et al.* (2018) also tested three compatible microbial bio-agents, viz. *T. viride*, *B. thuringiensis* and *P. fluorescens* for plant growth parameters in lettuce plant. They further added that there was significant increased in root and shoot in treatments where bio-formulations *of T. viride* + *B. thuringiensis* + *P. fluorescens* were applied as combination of root treatment (2.0 %) and foliar treatment (1.0 %). The highest shoot length (34.00 cm) and root length (27.75 cm) was recorded when lettuce plants was treated with application of consortia of *T. viride* + *B. thuringiensis* + *P. fluorescens*.

Effect of CMC on fresh and dry weight (g) of shoot at 20 DAS

The fresh and dry weight of shoot of individual French bean (20 plants/ treatment) was measured at 20 DAS. The pooled data on fresh shoot weight is depicted in Table 4. Fresh shoot weight was higher in all the CMC treated treatments as compared to positive control. At 20 DAS pooled data of fresh shoot weight revealed that CMC treated treatments i.e., T_1, T_2 and T_3 with 9.22 g, 9.07 g and 9.09 g respectively did not show significant difference among them. Minimum fresh shoot weight was observed in T_6 [positive control (4.88 g)].

Perusal of the pooled data revealed that dry shoot weight was higher in all the CMC treated treatments as compared to positive control depicted in Table 6. At 20 DAS, CMC treated treatments viz., T_1, T_2, T_3

and T_4 (0.53 g, 0.52 g) found highest dry weight of shoot which are statistically at par with each other. Minimum dry shoot weight was observed in positive control (0.26 g). Increase in dry shoot weight over positive control was observed highest in all CMC treated treatments over positive control.

The increase in mean plant fresh and dry weight upon microbial consortia treated treatments may be due to higher metabolic activity that leads to the better mobilization efficiency of reserved food by bio-agents that might contribute for the better growth of plants. Works akin to the present findings were also reported by Sandheep *et al.* (2013). They reported that combined inoculation of *T. harzianum* and *P. fluorescens* on vanilla plants registered the maximum length of vine (82.88 cm), highest number of leaves (26.67/ plant), recorded the highest fresh weight of shoots (61.54 g plant^{-1}), fresh weight of roots (4.46 g plant^{-1}) and dry weight of shoot (4.56 g plant^{-1}) where as the highest dry weight of roots (2.08 g plant^{-1}) were achieved with treatments of *P. fluorescens*. Lamsal *et al.* (2013) also reported that, *in vivo* assay of all the bacterial isolates were found to be capable of enhancing different growth parameters (shoot/root length, fresh biomass and dry matter) in comparison with non-inoculated control plants.

Effect of CMC on fresh and dry weight (g) of root at 20 DAS

Data on fresh and dry root weight are presented in Table 5. At 20 DAS, pooled data of fresh root weight was found to be highest in T_1, T_2, T_3 and T_4 with 0.56 g and 0.54 g respectively which is statistically at par with each other. Minimum fresh root weight was observed in T_6 [positive control (0.31 g)].

Perusal of the data revealed that at 20 DAS, dry root weight was higher in all the CMC treated treatments depicted in Table 6. T_1, T_2 and T_3 with 0.11 g; 0.10 and 0.09 g respectively which were statistically at par with each other. Minimum dry root weight was observed in T_6 control with 0.02 g.

The investigation of present works are in conformity with the findings of earlier worker like Khan *et al.* (2018) who reported there was significant increase in shoot dry weight and root dry weight of lettuce plants in treatments with bio-formulations of *T. viride* + *B. thuringiensis* + *P. fluorescens* as combination of root treatment (2.0 %) and foliar treatment (1.0%). The highest shoot dry weight (16.41 g) and root dry weight (5.62 g) was recorded when lettuce plants treated with application of consortia of *T. viride* + *B. thuringiensis* + *P. fluorescens*. Similarly, Eutesari *et al.* (2013), Kabir *et al.*(2013), Lamsal *et al.* (2013), Sandheep *et al.* (2013) and Sharma *et al.* (2015) reported that the application of BCAs increased fresh and dry weight of plant over control.

In these present studies, an attempt was made to study the effect of compatible microbial consortia on French bean plant growth and developmental traits in which effective results were obtained with microbial consortia treated treatments under *in vivo* conditions. The improvement in French bean seed germination might be due to food reserve mobilization. Also the increase in mean plant fresh and dry weight upon microbial consortia treated treatments may be due to higher metabolic activity that leads to the better mobilization efficiency of reserved food that might contribute for the better growth of plants which might helps in increased seed germination, shoot length and root length and hence increase in the mean plant fresh and dry weight. Moreover, the increase in plant vigour index upon microbial consortia treated treatments may be due to increased seed germination percentage, shoot length, root length and dry weight of French bean plants.

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