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Development and Standardization of Effervescent Biofertilizer Consortial Tablets for French Bean (*Phaseolus vulgaris* L.)

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Abstract

A new formulation of effervescent tablets containing microbial consortium was prepared for french bean with an objective to improve its survival and effectiveness. Three agriculturally beneficial micro organisms *viz. Rhizobium phaseoli* (dinitrogen fixer), *Pseudomonas fluorescens* (plant growth promoter), and *Bacillus megaterium* (phosphate solubilizer) were used in consortium. Tablets were prepared using wet granulation method with talc or compost as diluents. Enhancement in nitrogen content, phosphorus content and dry weight was observed from triple inoculant consortium followed by dual, single and control. Plant growth in inoculated treatments was robust when supplied with NPK fertilizers, but effect of inoculation was pronounced in plants not receiving chemical fertilizers. However, performance of plants receiving triple inoculants consortium without nutrients (-NPK) was on par with un-inoculated plants with nutrients (+NPK).

Keywords : Biofertilizer, consortium, effectiveness

French Bean (*Phaseolus vulgaris* L.) is one of the most important leguminous crops in the world owing to its nutritional value and rich source of proteins and carbohydrates. It has an added advantage of being a short duration crop there by yielding more profit to the farmers. The demand for the crop has increased significantly, leading to an extensive use of chemical fertilizers without any consideration for soil health and quality, which is a critical factor for realizing sustainable yield (Zahida *et al*., 2016).

Addition of beneficial microorganisms in the form of biofertilizers to soil will help replenish soil health. Biofertilizers are preparations containing beneficial microorganisms which enhance plant growth. They are an integral part of organic farming and their application has shown to enhance soil fertility thereby increasing plant growth and crop yield. Besides accessing nutrients, they also provide growth-promoting factors in plants and control soil borne diseases.

Being a legume, french bean performs best in combination with the bacterium *Rhizobium phaseoli.* Poor crop stands and low yields in dry bean have been reported to be associated with lack of inoculation of seeds prior to planting which also results in little nitrogen contributed to the crop (Atemkeng *et al*., 2011). *Rhizobium* inoculation also serves as a cheaper and usually more effective agronomic practice for ensuring adequate nitrogen nutrition of legumes than the application of nitrogen fertilizer (Wange, 1989).

Biofertilizers manufactured in India presently are carrier based which generally suffer from short shelf life, poor quality, high contamination, low and unpredictable field performances (Vendan and Thangaraju, 2006). Therefore, the commercial use of microbial inoculants requires a good formulation that retains high cell viability and ease in transportation and applicability. Developing efficient formulation and its application is a challenging step in commercialization of microbial inoculants. Several available forms like powder, liquid and granular formulation have immensely contributed to the use of these beneficial microbial inoculants in crop production but effervescent tablets are a noval approach. Effervescent biofertilizer tablets are designed to be dissolved or dispersed in water before administration and helps in easy release of microorganisms into the soil. In this context, effervescent tablet formulations appear to be promising due to their better viability and survivability in adverse soil conditions.

Material and Methods

Preparation of effervescent biofertilizer tablets: Tablets were prepared using different excipients *viz.,* diluents, binders, glidants and disintegrants. Talc and compost were selected as diluents. The tablets were prepared following wet granulation method and a rotary tablet press was used for the purpose of tablet making. These formulations were made in nine treatment combinations- T_1 (Absolute control), T_2 (conventional control) T_3 (*Rhizobium phaseoli*), T_4 (*Pseudomonas fluorescens*), T_5 (*Bacillus megaterium*), T_6 (*Rhizobium phaseoli* + *Pseudomonas fluorescens*), T_7 (*Rhizobium phaseoli* + *Bacillus megaterium*), T_8 (*Pseudomonas fluorescens* + *Bacillus megaterium*) and T_9 (*Rhizobium phaseoli* + *Pseudomonas fluorescens* + *Bacillus megaterium*).

A pot experiment was conducted in green house of University of Agricultural Sciences, GKVK, Bengaluru using nine different treatments to study the performance of the inoculants on the growth of french bean (cv Arka Komal). The experiment comprised nine treatments with two levels of fertilizers (with and without NPK), two levels of effervescent tablets (talc and compost based) and three replications each. Un-inoculated pots were kept as absolute control and pots treated with talc based powder formulation were kept as conventional control.

Soil processing: Soil sample used for experiment was collected from uncultivated field at GKVK, Bengaluru, which was red sandy loam soil, classified as kandic paleustalfs soils. Five kilograms of soil was filled into 10 kg capacity polythene bags. Homogenization was done by row and column randomization. The soil samples were subjected to three cycles of wetting and drying and its moisture content was raised to field capacity at the end of each cycle. Recommended dose of fertilizers were provided to +NPK pots.

Sowing and maintenance: Seeds were sown in poly bags containing five kilograms soil and effervescent tablets (Talc or compost based) were placed one per poly bag. The poly bags were uniformly watered regularly to maintain moisture at field capacity and other routine care was taken to protect the plants from pests and diseases.

Chlorophyll content: Chlorophyll content was recorded at maximum vegetative growth. Estimation of chlorophyll was done by method suggested by Witham *et al*. (1971). One gram of leaf sample was crushed in pre-chilled 80 per cent acetone and filtered to extract all the chlorophyll present in the leaf. Final volume was made up to 100 ml with 80 per cent acetone as blank and absorbance was recorded at 663 and 645 nm wavelength.

Dry weight of plant: Harvesting was done at 50 per cent flowering. Shoot and root dry weight was recorded after drying the samples at 60 ÚC to a constant weight. Shoots were harvested by separating stem at the collar region from roots. Roots were washed free of soil particles by a slow jet of water.

Nitrogen estimation in plant samples: Concentration of nitrogen in root and shoot was estimated by micro kjeldahl method as outlined by Jackson (1973). Finely ground plant samples (200 mg each) were digested with digestion mixture (100:20:1 of K_2SO_4: $CuSO_4$: Se) and 10 ml of concentrated sulfuric acid at 400°C till solution became clear. The digested samples were then distilled with 40 per cent sodium hydroxide and ammonia evolved was trapped in boric acid (4 per cent w/v) solution with mixed indicator (bromocresol green+ methyl red). After completion of distillation, boric acid solution containing trapped ammonia was titrated against 0.09 N sulfuric acid and volume of acid required to neutralize the alkalinity (ammonia) was recorded. The end point was indicated by change in color of solution from green to pink. Nitrogen content in plant sample was calculated using standard formula.

Phosphorus estimation in plant samples: The procedure outlined by Black (1965) was used to determine the phosphorus concentration in shoots and roots of french bean. Powdered plant samples (0.2 g each) were digested with 10 ml of di-acid mixture (concentrated nitric acid: perchloric acid at the ratio of 9: 4 v/v) on a hot plate. After digestion the volume of the samples were made up to 100 ml with distilled water.

Ten ml of this aliquot was taken in a 50 ml volumetric flask and to this 10 ml of vanadomolybdate reagent (25 g of ammonium molybdate and 1.25 g of ammonium metavanadate in 1000 ml of 2N HNO_3) was added and volume was made to 50 ml. The intensity of yellow colour developed was read at 430 nm using spectrophotometer. The amount of phosphorus present in plant sample was calculated by comparing with a standard graph developed using KH_2PO_4 as phosphorus source.

Statistical analysis: Statistical analysis of the data from green house investigation was done by using factorial complete randomized design (FCRD) and means were separated by Least Significant Difference (LSD) (Little and Hills, 1978).

Results and Discussion

Plants supplied with NPK fertilizers showed robust growth irrespective of the inoculants and the diluents used in the study but effect of inoculation was pronounced in plants not receiving chemical fertilizers. However, performance of plants receiving triple inoculants consortium without nutrients (-NPK) was on par with un-inoculated plants with nutrients (+NPK).

Nitrogen content: The results revealed a significant difference in the nitrogen content of shoots treated with consortial tablets when compared to absolute (1.30%) and conventional control (1.81%). An interaction effect was observed within the plants treated with tablets with two different diluents as well as plants treated with and without fertilizers (Table I). Plants treated with compost based tablets containing triple inoculants recorded maximum nitrogen (3.69%) in shoots showing a significant difference from those treated with talc based tablets containing triple inoculants (3.57%).

Plants inoculated with dual inoculants showed significantly higher nitrogen content, with tablets containing *Rhizobium phaseoli* and *Bacillus megaterium* recording higher nitrogen content with and without NPK (3.07% and 2.85%, respectively) irrespective of the diluent when compared to single inoculants (Table II). All treatments showed significant differences in nitrogen content when treated with and without NPK except control. The same pattern of result was observed in root nitrogen content and total nitrogen content with maximum nitrogen recorded in compost based tablets containing triple inoculants (1.41 %) followed by talc based tablets (Fig. 1). Enhancement in the plants ability to take up nitrogen might be due to the effective colonization of *Rhizobium phaseoli* and the synergistic effect of *Bacillus megaterium* and *Pseudomonas fluorescens* might be the reason for an increased uptake (Tilak *et al*., 2006).

Highest root phosphorus was observed in compost based triple inoculants (0.193 %) followed by composed based tablets containing dual inoculants, *R. phaseoli* and *B. megaterium* when compared to conventional (0.133 %) and absolute control (0.199%) (Table III).Treatments containing *Bacillus megaterium* recorded higher root phosphorus content when compared to all other treatments. This may be due to its phosphorus solubilization and plant growth promotion by producing growth hormones which helps the plant in nutrient uptake and building up its biomass as discussed by Kang *et al*. (2009). All treatments treated with NPK yielded significantly higher phosphorus content when compared to those without NPK (Fig. 2).

Phosphorus content: Highest phosphorus content was recorded in shoots of plants treated with triple inoculant formulation and NPK (0.78%) followed by dual inoculation with *R. phaseoli* and *B. megaterium* and NPK (0.63%) irrespective of the diluent used (Table IV). The least nitrogen in shoots were observed in absolute control (0.24%) followed by conventional control (0.34%). A two way interaction effect was observed between treatments, diluents and fertilizers which denote that different diluents and application of NPK affects the inoculants thereby resulting in significant difference between the treatments.

Chlorophyll content: Chlorophyll content was recorded highest in plants treated with compost based tablets containing triple inoculants (4.39 mg/g of leaf) followed by compost based tablets containing dual inoculants, *R. phaseoli* and *B. megaterium* (4.20 mg / g of leaf) when compared to conventional (3.76 mg / g of leaf) and absolute control (3.40 mg / g of leaf)

TABLE I

Effect of effervescent tablets on shoot nitrogen content in french bean

Treatments	Root nitrogen (per cent)								
	Talc		Compost		Main effect of T	-NPK		+NPK	
	-NPK	+NPK	-NPK	+NPK		Talc	Compost	Talc	Compost
Absolute control	1.28 (1.30)^{Lh}	1.32	1.29 (1.30)^{Li}	1.34	1.30	1.28 (1.27)^{Qi}	1.29	1.32 (1.33)^{Qg}	1.34
Conventional control	1.69 (1.78)^{Kg}	1.86	1.76 (1.84)^{Kh}	1.91	1.81	1.69 (1.73)^{Oh}	1.76	1.86 (1.89)^{Pf}	1.91
Rhizobium phaseoli	2.59 (2.61)^{le}	2.63	2.66 (2.78)^{je}	2.86	2.65	2.59 (2.64)^{Me}	2.66	2.63 (2.74)Nd	2.86
Pseudomonas fluroescens	2.26 (2.28)^{Hf}	2.31	2.21 (2.29)^{Hg}	2.37	2.28	2.26 (2.23)^{Kg}	2.21	2.31 (2.34)^{Le}	2.37
Bacillus megaterium	2.53 (2.56)^{Fe}	2.75	2.55 (2.66)^{Gf}	2.81	2.61	2.53 (2.47)^{lf}	2.55	2.75 (2.75)^{jd}	2.81
R. Phaseoli + P. fluorescens	2.90 (2.97)^{Ec}	3.04	2.95 (3.00)^{Ec}	3.11	2.98	2.90 (2.85)^{Gc}	2.95	3.04 (3.07)^{Hc}	3.11
R. phaseoli + P. megaterium	3.05 (3.06)^{Cb}	3.15	3.07 (3.13)^{Db}	3.20	3.10	3.05 (3.06)^{Eb}	3.05	3.15 (3.14)^{Fb}	3.20
B. megaterium+B. fluorescens	2.75 (2.89)^{Bd}	3.03	2.76 (2.88)^{Bd}	3.00	2.88	2.75 (2.76)^{Cd}	2.76	3.03 (3.01)^{Dc}	3.00
R. phaseoli+P. fluorescens+ B. megaterium	3.30 (3.47)^{Aa}	3.64	3.40 (3.57)^{Ba}	3.75	3.52	3.30 (3.35)^{Aa}	3.40	3.64 (3.69)^{Ba}	3.75
	Main effect of NPK					Pooled effect of NPK			
	2.47a	2.62b	2.50a	2.70b		2.49		2.66	
CV					2.26				
		F calc.		S.Em±		LSD at 5%			
D		28.50 *		0.008		0.022			
N		242.65 *		0.008		0.002			
T		1655.37 *		0.017		0.047			
DxN		5.37 *		0.011		0.032			
DxT		3.06 *		0.024		0.067			
TxN		8.80 *		0.024		0.067			
DxTxN		0.94	0.033		-				

Note : Means with same superscript are statistically on par at P d" 0.05 by DMRT.
D-Diluent , N- Nutrient, T- Treatment with different inoculants

TABLE I1

Effect of effervescent tablets on root nitrogen content in french bean

Treatments	Root nitrogen (per cent)				
	Talc		Compost		Main effect of T
	-NPK	+NPK	-NPK	+NPK	
Absolute control	0.56	0.68	0.61	0.66	0.63 g
Conventional control	0.73	0.82	0.78	0.83	0.79 f
Rhizobium phaseoli	1.44	1.50	1.45	1.52	1.47 a
Pseudomonas fluorescens	0.82	0.95	0.88	0.95	0.90 e
Bacillus megaterium	0.96	1.06	0.95	1.10	1.02 d
R. phaseoli + *P. fluorescens*	1.13	1.16	1.19	1.24	1.18 c
R. phaseoli + *B. megaterium*	1.35	1.06	1.35	1.38	1.37 b
B. megaterium + *P. fluorescens*	0.95	1.06	0.97	1.06	1.01 d
R. phaseoli + *P. fluorescens* + *B. megaterium*	1.30	1.40	1.31	1.41	1.35 b
	Mean values				
Talc	1.07 a		-NPK		1.04 a
Compost	1.09 b		+NPK		1.12 b
CV			4.33		
	F calc.		S.Em±		LSD at 5 %
D	5.27 *		0.060		0.018
N	72.74 *		0.060		0.018
T	442.21 *		0.014		0.038
DxN	0.16		0.009		-
DxT	0.72		0.019		-
NxT	1.39		0.019		-
DxNxT	0.50		0.027		-

Note : Means with same superscript are statistically on par at P d" 0.05 by DMRT.
D-Diluent , N- Nutrient, T- Treatment with different inoculants

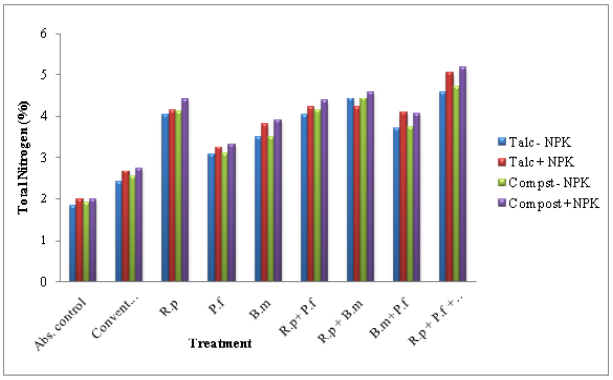

Fig. 1: Total nitrogen (per cent) as influenced by inoculation of effervescent biofertilizer tablets in french bean (*Phaseolus vulgaris* L.)

Note: R.p: *Rhizobium phaseoli,* P.f*: Pseudomonas fluorescens,* B.m*: Bacillus megaterium*

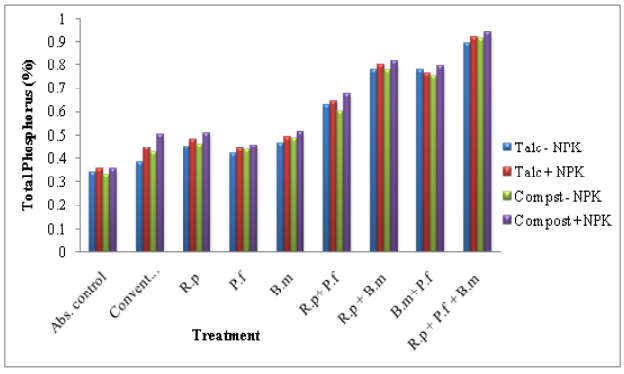

Fig. 2: Total phosphorus (per cent) as influenced by inoculation of effervescent biofertilizer tablets in french bean (*Phaseolus vulgaris* L.)

Note: R.p: *Rhizobium phaseoli,* P.f*: Pseudomonas fluorescens,* B.m*: Bacillus megaterium*

TABLE I1I

Effect of effervescent tablets on root phosphorus content in french bean

Treatments	Root nitrogen (per cent)				
	Talc		Compost		Main effect of T
	- NPK	+ NPK	- NPK	+ NPK	
Absolute control	0.113	0.118	0.111	0.119	0.116 f
Conventional control	0.132	0.128	0.127	0.133	0.130 e
Rhizobium phaseoli	0.139	0.141	0.140	0.141	0.140 cd
Pseudomonas fluorescens	0.130	0.132	0.136	0.138	0.134 de
Bacillus megaterium	0.149	0.151	0.150	0.152	0.150 c
R. phaseoli + *P. fluorescens*	0.157	0.152	0.150	0.155	0.153 c
R. phaseoli + *B. megaterium*	0.160	0.172	0.171	0.176	0.169 b
B. megaterium + *P. fluorescens*	0.158	0.143	0.141	0.145	0.146 c
R. phaseoli + *P. fluorescens* + *B. megaterium*	0.162	0.188	0.183	0.193	0.181 a
CV			6.45		
	F calc.		S.Em±		LSD at 5 %
D	0.81		0.001		0.004
N	3.59		0.001		0.004
T	53.01 *		0.003		0.008
DxN	0.51		0.002		0.005
DxT	1.25		0.004		0.011
TxN	1.46		0.004		0.011
DxTxN	0.87		0.005		0.011

Note : Means with same superscript are statistically on par at P d" 0.05 by DMRT.
D-Diluent, N- Nutrient, T- Treatment with different inoculants

(Table V) (Fig. 3). A two way interaction effect was observed between diluents, nutrient and inoculants which depicts that the diluents used and fertilizers (+/-) have a prominent effect on the inoculants and their interaction with the plants. Higher chlorophyll content in triple inoculants may be due to the synergistic effects of *Pseudomonas fluorescens* and *B. megaterium* on *R. phaseoli* which resulted in higher uptake of nitrogen (Samavat *et al*., 2012).

Total dry weight of plants: Highest shoot dry weight, irrespective of the nutrient level, was observed in plants receiving triple inoculation (16.48 g) followed by plants treated with dual inoculants, *Rhizobium phaseoli* and *Bacillus megaterium* (16.31 g) when compared to conventional (13.93 g) and absolute control (11.24 g) (Table VI). All treatments receiving NPK yielded significantly higher shoot dry weight when compared to those without NPK (Fig. 4). The same pattern of result was recorded in root dry weight of plants receiving triple inoculation recording highest root dry weight (1.52 g) followed by plants treated with dual inoculants, *Rhizobium phaseoli* and *Bacillus megaterium* (1.32 g) when compared to conventional (0.90 g) and absolute control (0.61 g) (Table VII).

There was no significant difference in the root dry weight of plants with and without NPK. This might be because of more number of nodules on the roots of –NPK plants when compared to +NPK plants. Various

TABLE IV

Effect of effervescent tablets on shoot phosphorus content in french bean

Treatments	Shoot phosphorus (per cent)								
	Talc		Compost		Main effect of T	- NPK		+ NPK	
	- NPK	+ NPK	- NPK	+ NPK		Talc	Compost	Talc	Compost
Absolute control	0.23 (0.23)^{Lf}	0.24	0.22 (0.23)^{Lf}	0.24	0.23	0.23 (0.23)^{Lf}	0.22	0.24 (0.24)^{Lf}	0.24
Conventional control	0.25 (0.29)^{Je}	0.32	0.30 (0.33)^{Ke}	0.37	0.31	0.25 (0.33)^{Kd}	0.30	0.32 (0.34)^{Kd}	0.37
Rhzobium phaseoli	0.31 (0.33)^{Hd}	0.34	0.32 (0.35)^{Id}	0.37	0.34	0.31 (0.32)^{Kd}	0.32	0.34 (0.35)^{Kd}	0.37
Pseudomonas fluorescens	0.29 (0.30)^{Ge}	0.31	0.30 (0.31)^{Gf}	0.32	0.30	0.29 (0.29)^{Ie}	0.30	0.31 (0.31)^{Je}	0.32
Bacillus magaterium	0.32 (0.33)^{Ed}	0.34	0.34 (0.35)^{Fd}	0.36	0 34	0.32 (0.33)^{Gd}	0.34	0.34 (0.35)^{Hd}	0.36
R. phaseoli + *P. fluroescens*	0.47 (0.48)^{Dc}	0.49	0.45 (0.48)^{Dc}	0.52	0.48	0.47 (0.46)^{Ec}	0.45	0.49 (0.50)^{Fc}	0.52
R. phaseoli + *B. megaterium*	0.62 (0.62)^{Cb}	0.63	0.61 (0.62)^{Cb}	0.64	0.62	0.62 (0.61)^{Cb}	0.61	0.63 (0.63)^{Dh}	0.64
B. megaterium + *P. fluorescens*	0.62 (0.62)^{Cb}	0.62	0.61 (0.63)^{Cb}	0.65	0.62	0.62 (0.61)^{Cb}	0.61	0.62 (0.63)^{Db}	0.65
R. *phaseoli* + *p. fluorescens* *B. megaterium*	0.73 (0.73)^{Aa}	0.73	0.78 (0.7)^{Bb}	0.79	0.76	0.73 (0.73)^{Aa}	0.73	0.73 (0.78)^{Ba}	0.75
	Main effect of NPK					Pooled effect of NPK			
	0.430^{a}	0.45^{b}	0.434^{a}	0.476^{b}		2.49		2.66	
CV					3.43				
		F calc.		S.Em±		LSD at 5%			
D		18.60 *		0.003		0.006			
N		122.37 *		0.003		0.006			
T		1703.81 *		0.006		0.013			
DxN		8.61 *		0.005		0.008			
DxT		2.69 *		0.009		0.018			
TxN		4.73 *		0.009		0.018			
DxTxN		0.65		0.001		-			

Note : Means with same superscript are statistically on par at P d" 0.05 by DMRT. D-Diluent, N- Nutrient, T- Treatment with different inoculant

TABLE V

Effect of effervescent tablets on total chlorophyll content in french bean

Treatments	Total chlorophyll (mg / g of leaf)								
	Talc		Compost		Main effect of T	-NPK		+NPK	
	-NPK	+NPK	-NPK	+NPK		Talc	Compost	Talc	Compost
Absolute control	3.10 (3.23)^{Hd}	3.36	3.13 (3.28)^{Hf}	343	3.25	3.10 (3.11)^{Jf}	3.13	3.36 (3.40)^{Ke}	3.43
Conventional control	3.60 (3.66)^{Gc}	3.73	3.60 (3.70)^{Ge}	3.80	3.68	3.60 (3.60)^{He}	3.60	3.73 (3.76)^{Id}	3.80
Rhizobium phaseoli	4.10 (4.11)^{Fb}	4.13	4.03 (4.08)	4.13	4.10	4.10 (4.06)^{Gb}	4.03	4.13 (4.13)^{Ec}	4.13
Pseudomonas fluorescens	3.96 (4.03)^{Fd}	4.10	3.80 (3.91)^{Fd}	4.00	9.97	3.96 (3.90)^{Fd}	3.80	4.10 (4.05)^{Ec}	4.0
Bacillus magaterium	4.03 (4.08)^{Cb}	4.13	3.93 (3.98)^{Ec}	4.03	4.03	4.03 (3.98)^{Fc}	3.90	4.13 (4.08)^{Ec}	4.03
R. phaseoli + P. fluroescens	4.13 (4.15)^{Cb}	4.16	4.00 (4.08)^{Db}	4.16	4.11	4.13 (4.06)^{Cb}	4.00	4.16 (4.16)^{Ebc}	4.16
R. phaseoli + B. megaterium	4.1 (4.15)^{Cb}	4.2	4.03 (4.11)^{Cb}	4.20	4.13	4.1 (4.06)^{Cb}	4.03	4.2 (4.20)^{Db}	4.20
B. megaterium + P. fluorescens	4.1 (4.05)^{Cb}	4.0	4.00 (4.10)^{Cb}	4.20	4.07	4.1 (4.05)^{Cb}	4.00	4.0 (4.10)^{Cb}	4.20
R. phaseoli + P. fluorescens B. megaterium	4.36 (4.38)^{Aa}	4.4	4.2 (4.29)^{Ba}	4.38	4.33	4.36 (4.28)^{Aa}	4.2	4.4 (4.39)^{Ba}	4.38
	Main effect of NPK					Pooled effect of NPK			
	2.47^{a}	2.62^{b}	2.50^{a}	2.70^{b}		2.49		2.66	
CV					1.91				
		F calc.		S.Em±		LSD at 5%			
D		5.58 *		0.010		0.029			
N		78.22 *		0.010		0.029			
T		210.72 *		0.031		0.062			
DxN		10.43 *		0.021		0.041			
DxT		2.23 *		0.044		0.087			
TxN		2.48 *		0.044		0.087			
DxTxN		1.08		0.043		-			

Note : Means with same superscript are statistically on par at P d" 0.05 by DMRT. D-Diluent, N- Nutrient, T- Treatment with different inoculants

TABLE V1

Effect of effervescent tablets on shoot dry weight in french bean

Treatments	Shoot dry weight (g)				Main effect of T
	-NPK		+NPK		
	Talc	Compost	Talc	Compost	
Absolute control	10.80	11.13 (10.96)^{Gd}	11.53	11.50 (11.51)^{He}	11.24
Conventional control	14.06	13.56 (13.81)^{Fc}	14.03	14.06 (14.05)^{Fcd}	13.93
Rhizobium phaseoli	14.03	13.96 (14.00)^{Fc}	14.26	14.73 (14.50)^{Gc}	14.25
Pseudomonas fluorescens	13.86	13.36 (13.61)^{Fc}	13.76	13.53 (13.65)^{Fd}	13.63
Bacillus magaterium	14.63	14.53 (14.58)^{Cb}	15.28	15.06 (15.17)^{Eb}	14.87
R. phaseoli + *P. fluroescens*	14.90	15.20 (15.05)^{Cb}	16.60	16.26 (16.43)^{Da}	15.74
R. phaseoli + *B. megaterium*	15.56	16.30 (15.93)^{Aa}	16.78	16.60 (16.69)^{Ba}	16.31
B. megaterium + *P. fluorescens*	15.26	16.26 (15.76)^{Aa}	16.50	16.43 (16.46)^{Ba}	16.11
R. phaseoli + *P. fluorescens* + *B. megaterium*	15.93	16.23 (16.08)^{Aa}	16.83	16.93 (16.88)^{Ba}	16.48
Pooled effect	14.70		14.76		
Cv			2.85		

	F calc.	S.Em±	LSD at 5%
D	0.511 *	0.057	-
N	58.40 *	0.057	0.161
T	194.38 *	0.121	0.341
DxN	1.82 *	0.081	-
DxT	1.23 *	0.171	-
TxN	2.46 *	0.171	0.482
DxTxN	1.48	0.241	-

Note : Means with same superscript are statistically on par at P d" 0.05 by DMRT.
D-Diluent, N- Nutrient, T- Treatment with different inoculants.

TABLE VII

Effect of effervescent tablets formulations on root dry weight in french bean

Treatments	Shoot dry weight (g)				
	-NPK		+NPK		Main effect of T
	Talc	Compost	Talc	Compost	
Absolute control	0.51 (0.51)^{Ie}	0.51	0.69 (0.72)^{Je}	0.75	0.61
Conventional control	0.84 (0.83)^{Gd}	0.83	0.92 (0.96)^{Hd}	1.01	0.90
Rhizobium phaseoli	1.31 (1.30)^{Fc}	1.30	1.33 (1.33)^{Fb}	134	1.32
Pseudomonas fluorescens	1.13 (1.13)^{Dc}	1.13	1.20 (1.20)^{Ec}	1.20	1.16
Bacillus magaterium	1.18 (1.17)^{Dc}	1.16	1.18 (1.18)^{Dc}	1.19	1.18
R. phaseoli + *P. fluroescens*	1.21 (1.21)^{Dc}	1.20	1.22 (1.22)^{Dc}	1.23	1.21
R. phaseoli + *B. megaterium*	1.31 (1.30)^{Bb}	1.30	1.35 (1.34)^{Cb}	1.33	1.32
B. megaterium + *P. fluorescens*	1.20 (1.19)^{Bb}	1.18	1.20 (1.20)^{Bc}	1.19	1.19
R. phaseoli + *P. fluorescens* *B. megaterium*	1.50 (1.50)^{Aa}	1.51	1.51 (1.53)$_{Aa}$	1.55	1.52
Pooled effect	1.15		1.16		
Cv			3.17		

	F calc.	S.Em±	LSD at 5%
D	1.10 *	0.005	-
N	72.43 *	0.005	0.014
T	603.46 *	0.011	0.030
DxN	2.95 *	0.007	-
DxT	0.828 *	0.015	-
TxN	10.21 *	0.015	0.482
DxTxN	0.582	0.02	-

Note : Means with same superscript are statistically on par at P d" 0.05 by DMRT.
D-Diluent, N- Nutrient, T- Treatment with different inoculants.

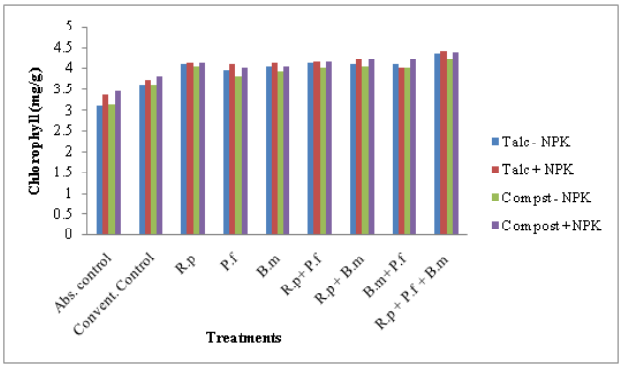

Fig. 3: Chlorophyll content (mg/g of plant) as influenced by inoculation of effervescent biofertilizer tablets in french bean (*Phaseolus vulgaris* L.)

Note: R.p: *Rhizobium phaseoli,* P.f*: Pseudomonas fluorescens,* B.m*: Bacillus megaterium*

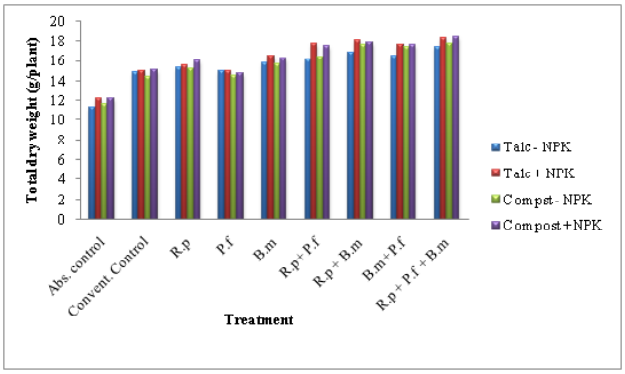

Fig. 4: Total dry weight (g) as influenced by inoculation of effervescent biofertilizer tablets in french bean (*Phaseolus vulgaris* L.)

Note: R.p: *Rhizobium phaseoli,* P.f*: Pseudomonas fluorescens,* B.m*: Bacillus megaterium*

direct and indirect mechanisms of the inoculants such as atmospheric nitrogen fixation, insoluble phosphate solubilization and production of growth hormones might have contributed to the high plant dry matter content in plants treated with consortia (Dutta *et al.*, 2014).

The study revealed that all plants treated with effervescent biofertilizer consortial tablets showed a pronounced and significantly higher nutrient uptake, chlorophyll content and total dry matter when compared to absolute control. The effervescence from the tablet might have positively affected the early and quick release of microorganisms into the rhizosphere thereby resulting in effective colonization by the inoculants.

Plants treated with compost based tablets recorded maximum nutrient uptake and dry matter content when compared to those treated with talc which suggests that the diluent used has an influence on the microbial population in the tablet. The granular nature of compost might have helped in easy compression of the formulation into a tablet by applying less force, thereby increasing the viability of inoculants in it and performed better when compared to talc based tablets.

The results also revealed a significantly higher plant dry matter and nutrient content in plants treated with tablets when compared to conventional control (talc based powder formulation) which assures a high microbial load in the tablet when compared to the powder formulation and their effective release into the rhizosphere. Tablet formulation not only gives stability in their performance but also reduce contaminants to a permissible level due to its low water content. These findings have opened up a new and better option of formulation that can even be applied to soils under stress.

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