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Studies on effect of consortia of beneficial organisms on nutrient dynamics of spinach in pot culture experiment

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Abstract
The research entitled with "Studies on Effect of consortia of beneficial organisms on nutrient dynamics of Spinach in pot culture experiment" was conducted during the year 2017-2018 in two phases. In first phase the consortia was prepared from different nine beneficial bacteria and applied to the spinach. In second phase, pot culture experiment was carried out with six set of treatments replicated trice to study the effect of consortia on beneficial organisms on nutrient dynamics (Available N, P, K, S and DTPA-Fe, Mn, Cu and Zn) of spinach in pot culture experiment. The results revealed that improved Available macronutrients status and plant growth. Amongst the six treatments RDF+ consortia (T_5) showed significantly higher results followed by only consortia (T_3) compared with other treatments and absolute control. Amongst RDF +consortia treatment was highest content of Available macronutrients status.

Keywords: Consortia, RDF, nitrogen, phosphorous, potassium, sulphur and DTPA- Fe, Mn, Cu and Zn

Introduction
The consortia refer to a two or more microbial groups living symbiotically (Hideto Takami, 2019). The rhizosphere inhabits lots of soil microorganisms, such as bacteria and fungi, which compete for water, nutrients and space and sometimes improve their competitiveness by developing an intimate association with plant. The metabolites act as chemical signals for bacteria to move to the root surface, also represent the main nutrient sources available to support growth and persistence in the rhizosphere. Some of the microbes that inhabit this area are bacteria that are able to colonize very efficiently the roots or the rhizosphere soil of crop plants. These bacteria are referred to as plant growth promoting rhizobacteria (PGPR). The most common objective of developing microbial consortium is to capitalise on both the capabilities of individual microbes and their interactions to create useful systems in tune with enhanced productivity and, soil health improvements through efficient metabolic functionality.

Materials and Methods
The research entitled "Studies on Effect of consortia of beneficial organisms on nutrient dynamics of Spinach in pot culture experiment" was conducted during the year 2017-18 in two phase's research project was planned and implemented research work. In the first phase, consortia of nine beneficial bacteria were prepared i.e., *Azotobactor, Azospirillum, Bacillus megaterium (PSB), Baccilus subtilis, Pseudomonas fluroscens, Pseudomonas striata, Rhodococcus ruber, Bacillus licheniformis and Penibacillus thylacticus.* While in second phase these consortia was applied on spinach according to treatments. This bacterial consortium was tested by conducting the pot culture experiment on spinach over a growth stages from first cutting to third cutting. Treatment details T1 (Absolute control), T2 (only RDF), T3 (Only conrtia), T4 (Biofertilizers (*PSB*+ *Azotobactor*), T5 (RDF + consortia) and T6 (RDF+ *PSB* +*Azotobactor*).

Result and Discussion
Effect of application of consortia of beneficial organisms on availability of macro nutrients of spinach grown soil.
Effect on Availability of Nitrogen
Effect of application of consortia of beneficial organisms on available nitrogen content in various treatments from 1st cutting to 3rd cutting stages (Table 1) showed availability of N was

maximum in RDF+ consortia (T_5) application followed by application of only consortia. Maximu N availability was recorded 747.28, 753.89 and 751.67 kg ha^{-1} with T_5 treatment while and 396.91, 302.35 and 304.10 kg ha^{-1} at 1st, 2nd and 3rd cutting respectively. Further it was also observed that as the application of consortia, availability N was maintained in growth media irrespective of cutting stage.

Increase in N availability due to RDF, consortia or *azotobactore* or *PSB* increased biological activity and recommended fertilizer dose which have mobilized the native nutrients and brought in the solution phase. The improvement in N availability due to fertilizer application and increased bacteria population also observed by (Wekha *et al.*, 2016).

Table 1: Effect of application of consortia on Available N (kg ha^{-1}) and Available P_2O_5 (kg ha^{-1}) of spinach grown soil.

Treatments	Treatment details	Available N (kg ha^{-1})				Available P_2O_5 (kg ha^{-1})			
		Ist cut	IInd cut	IIIrd cut	Mean	Ist cut	IInd cut	IIIrd cut	Mean
T_1	Absolute control	396.91	302.35	304.10	334.45	11.77	11.52	12.35	11.88
T_2	Only RDF	453.61	442.97	439.33	445.30	14.03	14.44	15.96	14.81
T_3	Only consortia	642.27	652.91	638.79	644.65	15.19	15.96	16.83	15.99
T_4	Biofertilizers (*PSB+ Azotobactor*)	593.27	603.31	572.77	589.78	15.88	16.05	17.16	16.36
T_5	RDF + Consortia	747.28	753.89	751.67	750.94	17.72	17.84	18.88	18.14
T_6	RDF+ *PSB +Azotobactor*	612.22	625.56	681.10	639.62	17.04	18.25	19.11	18.13
	S.Em±	28.00	26.00	29.60	27.86	1.6	1.4	1.2	1.4
	C.D. @ 1%	87.00	80.00	90.00	85.66	4.6	4.0	3.8	4.1
	Mean	574.26	563.49	554.62	564.12	15.27	15.67	16.71	15.88

Table 2: Effect of application of consortia on Available Potassium (kg ha^{-1}) and Available Sulphur (mg kg^{-1}) of spinach grown soil.

Treatments	Treatment details	Available K_2O (kg ha^{-1})				Available S (mg kg^{-1})			
		Ist cut	IInd cut	IIIrd cut	Mean	Ist cut	IInd cut	IIIrd cut	Mean
T_1	Absolute control	607.65	603.37	571.71	593.66	18.11	18.68	18.02	18.27
T_2	Only RDF	673.38	690.23	586.82	649.66	19.11	19.48	19.85	19.48
T_3	Only consortia	687.31	745.78	677.55	703.00	20.18	20.53	20.97	20.56
T_4	Biofertilizers (*PSB+ Azotobactor*)	679.70	739.03	562.07	660.26	19.66	19.98	19.02	19.55
T_5	RDF + Consortia	772.57	800.32	704.23	759.04	20.81	20.84	20.38	20.87
T_6	RDF+ *PSB +Azotobactor*	683.99	694.21	658.87	625.69	20.10	20.96	21.37	20.47
	S.Em±	15.72	15.59	22.40	17.90	0.50	0.40	0.30	0.40
	C.D. @ 1%	67.92	67.37	96.79	77.36	1.68	1.29	1.10	1.19
	Mean	684.10	712.15	626.87	674.10	19.66	20.01	19.99	19.88

Effect on Availability of Phosphorous

The effect of application of consortia of beneficial organisms on available P2O5 status is presented in the Table 1. The available P status was ranged between 11.88 to 18.14 kg ha^{-1} among the various treatments. Application of consortia and PSB + Azotobactor with RDF recorded maximum availability of P (18.14 and 18.13 kg ha^{-1}). Further the availability of P enhanced with the growing season of spinach. It was noticed that the P availability increased from 1st cutting to last cutting in all the treatments. The average increase was from 15.27 to 16.71 kg ha^{-1}.

Plant roots and rhizosphere organisms which are found around plant roots excrete phosphatase enzymes capable of hydrolyzing some organic phosphate compounds, releasing inorganic phosphate for by the plants. (Wekha *et al.*, 2016).

Effect on Availability of Potassium

The data on effect of application of consortia of beneficial organisms on available K are presented in Table 33. It showed that average available potassium content irrespective of treatments varied from 593.66 to 703.00 with an average of 674.10 kg ha^{-1}. It was noticed that the P availability increased from 1st cutting to last cutting in all the treatments. The average increase was from 15.27 to 16.71 kg ha^{-1}. Maximum available potassium content was recorded in treatment receiving RDF+ consortia (T_5), and showed significant effect over other treatments. Availability of Potassium was increased from 1st cutting of spinach crop to second cutting in all treatments. The average increase was from 684.10 to 712.15kg ha^{-1} declined at 3rd cutting (626.87 kg ha^{-1}).

Effect on Availability of Sulphur

Table 2 revealed that available sulphur content in soil of spinach was influenced by various treatments. RDF + consortia (T_5) stood first in supplying the available sulphur to spinach followed by only consortia (T_3), RDF+ *PSB+ Azotobactor* (T_6). The cutting wise available sulphur status was not varied.

The results inferred above indicated that the application of consortia with RDF tended to increase availability N, P, K and S. these might be due to release of solid phase nutrients in to solution phase due to microbial activity. They facilitated and increase the mineralization of organic and inorganic sources of nutrients. There was increase in nutrient availability up to second and there after it was decreased. Among the nutrients nitrogen and phosphorous availability was more influenced and found more nutrients for microbial activity. Further there was little variation in Potassium and sulphur might be due to because of its high native content. The results obtained in respect of N, P, K and S can be attributed to.

Table 3: Effect of application of consortia on DTPA-Fe (mg kg^{-1}) and DTPA- Mn (mg kg^{-1}) of spinach grown soil.

Treatments	Treatment details	DTPA-Fe(mg kg^{-1})				DTPA- Mn (mg kg^{-1})			
		Ist cut	IInd cut	IIIrd cut	Mean	Ist cut	IInd cut	IIIrd cut	Mean
T_1	Absolute control	1.86	1.94	2.05	1.95	20.18	20.89	18.12	19.73
T_2	Only RDF	2.58	2.84	3.06	2.82	22.21	26.44	18.98	22.54
T_3	Only consortia	3.37	3.87	4.67	3.97	25.21	25.96	21.26	24.14
T_4	Biofertilizers (*PSB+ Azotobactor*)	2.82	3.07	3.46	3.11	19.22	20.98	17.66	19.28
T_5	RDF + Consortia	3.95	4.62	5.06	4.54	28.17	32.76	26.72	29.21
T_6	RDF+ *PSB +Azotobactor*	2.82	3.15	3.94	3.30	22.93	24.98	16.44	21.45
	S.Em±	0.04	0.06	0.031	0.04	0.04	0.03	0.02	0.03
	C.D. @ 1%	0.18	0.27	0.44	0.29	0.12	0.13	0.11	0.12
	Mean	2.50	3.312	1.447	2.41	22.98	25.33	19.86	22.72

Table 4: Effect of application of consortia on DTPA-Cu (mg kg^{-1}) and DTPA- Zn (mg kg^{-1}) of spinach grown soil.

Treatments	Treatment details	DTPA-Cu (mg kg^{-1})				DTPA- Zn (mg kg^{-1})			
		Ist cut	IInd cut	IIIrd cut	Mean	Ist cut	IInd cut	IIIrd cut	Mean
T_1	Absolute control	1.90	1.97	2.12	1.99	0.36	0.42	0.46	0.41
T_2	Only RDF	2.46	2.68	3.03	2.72	0.53	0.58	0.63	0.58
T_3	Only consortia	5.61	5.46	4.67	5.24	0.84	1.22	1.13	1.06
T_4	Biofertilizers (*PSB+ Azotobactor*)	3.98	4.13	3.77	3.96	0.67	0.64	0.58	0.63
T_5	RDF + Consortia	4.57	5.78	4.90	5.08	0.96	1.34	1.25	1.18
T_6	RDF+ *PSB +Azotobactor*	4.20	5.19	4.5	4.63	0.73	0.88	0.75	0.78
	S.Em±	0.13	0.11	0.04	0.09	0.00	0.00	0.00	0.00
	C.D. @ 1%	0.58	0.34	0.21	0.37	0.02	0.02	0.02	0.02
	Mean	3.78	4.20	3.83	3.93	0.68	0.85	0.71	0.74

Effect of application of consortia of beneficial organisms on micronutrients of spinach at various cuttings.

Effect on DTPA-Fe and DTPA-Mn content

The data on effect of consortia of beneficial organisms on available content of Fe and Mn at different harvesting stages are presented in Table 20. At treatment RDF + Consortia (T_5) shows highly significant over all other treatments that same trend was followed by Mn. The Fe content was observed 3.95, 4.62 and 5.06 mg kg^{-1}at 1st, 2nd and 3rd cutting respectively. And Mn content 28.17, 29.61and 26.76 at 1st, 2nd and 3rd cutting respectively in treatment T5. Absolute control showed minimum Fe and Mn content. The application of consortia of beneficial organisms on spinach at various stages showed significant effect on Fe and Mn compared with other treatments.

Effect on DTPA-Cu and DTPA-Zn content

The effect of application of consortia of beneficial organisms prepared from different nine bacteria of URS with recommended dose of N, P and K to well grown spinach pot culture showed significant improvement in DTPA extractable Cu and Zn status. The content of Cu and Zn in RDF + consortia (T_5) treatment was recorded at 1st cutting i.e., 4.57, 2nd cutting i.e., 5.78 and 3rd cutting 4.90 mg kg^{-1} and Zn 0.96, 1.34 and 1.45 mg kg^{-1} at 1st ,2nd, and 3rd cutting respectively. From the result RDF + consortia (T_5) showed significantly higher content of Cu and Zn over the other treatments.

Conclusion

1. Treatment with RDF + Consortia (T_5) showed significant effect on available N, P, K and S.
2. In case of micronutrients i.e., DTPA-Fe, Mn, Zn and Cu content showed significant available after the application of consortia of beneficial organisms on spinach crop.

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