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Efficiency of Endophytic bacterial culture on yield and yield attributes of groundnut

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Abstract— Field experiments were carried out for three consecutive years conducted during 2016, 2018 and 2019 during kharif season at Zonal Agricultural and Horticultural Research Station, Babbur farm, Hiriyur, Karnataka, India to study the alleviation of moisture-deficit stress in groundnut by application of endophytic bacteria under rainfed conditions. The experiment was laid out in randomized block design with three replication and eight treatments. The pooled results of three years revealed that treatment having DGREB-3 culture with intercultural operations significantly recorded higher pod yield (1022 kg ha^{-1}) as compared to control (693 kg ha^{-1}) and it is on par with any DGREB culture (T_2) with two intercultural operations (909 kg ha^{-1}). Any DGREB culture with two intercultural operations significantly recorded highest nodulations at 30 and 60 days (50.2 and 57.8) as compared to control (20.6 and 33.7). In case of higher gross returns (Rs. 46,565), net returns (Rs. 16,997) were recorded with DGREB-3 culture with intercultural operations. Whereas highest B:C (1.66) was recorded with any DGREB culture with two intercultural operations.

Key words: Endophytic bacteria, DGREB culture, Groudnut

Introduction

Now a day's agriculture has been largely achieved through the use of farm equipment, high-yielding crop varieties, intensive tillage, irrigation, fertilizers, pesticides and other manufactured inputs (Foley *et al.*, 2005). However, detrimental effects of the agricultural practices on soil ecology, high irrigation needs as well as effect on human health have been recognized. Therefore new environmentally benign approaches have to be employed to maintain sustainable agricultural production through endophytic bacteria and to overcome threats that lead to loss of crop yield, including plant stresses associated with unfavourable environmental conditions, such as drought, extreme temperatures and soil salinity as well as biotic stress induced by plant pathogens and pests.

The group of endophytes and their existence have been traced in the fossil records suggesting that endophyte-host association may have evolved from the time of emergence of first higher plants on earth (Rodriguez & Redman 1997, Strobel 2003). Endophytic bacteria are a class of endosymbiotic microorganisms that live in internal plant tissues of apparently healthy host plants (Schulz, Boyle, 2006). Unlike phytopathogens, such bacteria do not normally cause any substantial disease symptoms. The endophytes aid nutrient availability and uptake enhance stress tolerance and provide disease resistance (Hamilton *et al*., 2012). Plant growth promoting capability of endophytes could be directly established through production of plant growth hormones, interactions that alter endogenous plant hormone production or activity that increases accessibility of nutrients, such as nitrogen and phosphorus (Glick, 2012). Plant disease resistance promoting properties are associated with the ability of endophytic bacteria to produce a wide range of compounds such as antibiotics or chitinase enzyme, which can inhibit growth of plant pathogens and thus act as biocontrol agents (Brader *et al*., 2014, Wang *et al*., 2014). Endophytes were also shown to stimulate a latent disease defense mechanism, termed as induced systemic resistance (ISR), that confers an enhanced level of protection to a broad spectrum of pathogens (Pieterse *et al*., 2014). In this context, there is a strong case for using endophytic bacterial cultures can provide beneficial effects on groundnut, directly by enhancing crop nutrition or indirectly by reducing damage caused by environmental stress like drought.

Materials and Methods

The proposed field study was conducted at Zonal Agricultural and Horticultural Research Station, Babbur farm, Hiriyur, Karnataka, India during *kharif* seasons of 2016, 2018 and 2019. The experimental site was situated between 13° 57′ 32″ North latitude and 70° 37′ 38″ East longitude at an altitude of 606 metre above mean sea level and comes under agro climatic zone-IV (Central dry zone of Karnataka). The soil of the experimental plot was block in texture and alkaline in reaction. The soil has an organic carbon content of 0.41 per cent and was low in available nitrogen 205 kg/ha, high in phosphorus 23.0 kg/ha and potash 321 kg/ha. The experiment was laid out in randomized block design with three replications. The experiment consisted of eight treatment combinations of seed treatment with different DGREB series cultures. The cultures obtained from National Research Centre for Groundnut (NRCG), Junagadh. Seed treatment with DGREB series culture @ 20g/kg of groundnut was done by sticking solution (jaggary solution @ 125g/liter water) on seeds and it was mixed thoroughly. Seeds were air dried in shade after treatment and then used for sowing. A recommended dose of nitrogen, phosphorus, potash and at 45 days after sowing gypsum was applied. The crops were sown under rainy season but after cessation of monsoon five irrigations each of 50 mm depth were given to groundnut crop at an interval of 15 days. Pest and disease control measures were taken as and when required. The total rainfall received during 2016, 2018 and 2019 was 312.2 mm, 490.4 mm and 788.4 mm, respectively.

Result and discussion

Growth and yield attributes

The growth and yield attributes of crops differed significantly during first (2016), second (2018) and third (2019) year of experiments and the pattern of response to endophytic bacterial cultures application was similar in all the three years. Therefore, only pooled data of the three years are used to highlight the results and discussed in this chapter (Table 1, 2 & 3).

There is no statistically difference between the plant populations among the treatments. The highest number of branches per plant (3.9), nodule count at 30 and 60 days after sowing (50.2 and 57.8, respectively) were recorded by any DGREB culture with two intercultural operations (T_2). Whereas, significantly higher number of pods per plant (29.7) and 100 kernel weight (40.7 g) were recorded in treatment receiving DGREB-3 culture with intercultural operations (T_3). They may confer benefits to their host plants *via* multiple mechanisms including biological nitrogen fixation (Doty, *et al.,* 2016) enhancing the bioavailability of phosphorous (P), iron (Fe) and other mineral nutrients (Bulgarelli, *et al.,* 2013), production of phytohormones including indole acetic acid (IAA), abscisic acid (ABA), gibberellic acid (GA), brassinosteroids (BR), jasmonates (JA) and salicylic acid (SA) (Fahad, *et al*., 2015), generation of antioxidants for increased plant productivity and tolerance to biotic or abiotic stresses.

Pod yield and Economics

The pooled analysis of the data indicated that, DGREB-3 culture with intercultural operations (T_6) recorded significantly higher pod yield, kernel yield and haulm yield (1022, 619.3 and 1369 kg/ha, respectively) (Table 4 and Fig.1). However, higher gross returns (Rs. 46,565), net returns (Rs. 16,997) was recorded with DGREB-3 with intercultural operations (T_6) and B:C ratio (1.66) was recorded with any DGREB culture with two intercultural operations (T_2) (Table 5 and Fig.1).

Pod Yield: In 2016, Pod yield differed significantly due to different DGRB cultures. The treatment DGREB-3 culture with intercultural operations (T_6) recorded significantly higher pod yield (929 kg/ha) and it was on par with (T_2) any DGREB culture (848 kg/ha), (T_8) DGREB-5 with inter cultivation (802 kg/ha), (T_7) DGREB-4 with inter cultivation (795 kg/ha) and (T_4) DGREB-1 with inter cultivation (770 kg/ha) as compared to other treatments and control. However, in 2018 only DGREB-3 culture with intercultural operations (T_6) recorded significantly higher pod yield (909 kg/ha) compared to other treatments. Whereas, 2019 DGREB-3 culture with intercultural operations (T_6) recorded significantly higher pod yield (1230 kg/ha) over other treatment except (T_2) any DGREB culture (909 kg/ha).

Kernel Yield: Highest kernel yield noticed in 2016 was DGREB-3 culture with intercultural operations (T_6) recorded significantly higher pod yield (619 kg/ha) and it was on par with (T_2) any DGREB culture (552 kg/ha), (T_8) DGREB-5 with inter cultivation (546 kg/ha), (T_7) DGREB-4 with inter cultivation (532 kg/ha), (T_5) DGREB-2 with inter cultivation (524 kg/ha) and (T_4) DGREB-2 with inter cultivation (508 kg/ha) as compared to other treatments and control. In 2018, DGREB-3 culture with intercultural operations (T_6) recorded significantly higher pod yield (606 kg/ha) and it was on par with (T_2) any DGREB culture (539 kg/ha), (T_8) DGREB-5 with inter cultivation (533 kg/ha) compared to other treatments. However, in 2019 only DGREB-3 culture with intercultural operations (T_6) recorded significantly higher pod yield (632.9 kg/ha) compared to other treatments.

Haulm Yield: In 2019 highest haulm yield was recorded in (T_6) DGREB-3 culture with intercultural operations (1276 kg/ha) and it was on par with (T_2) any DGREB culture (1257 kg/ha) and (T_8) DGREB-5 with inter cultivation (1079 kg/ha) as compared to other treatments and control. Whereas in 2018, DGREB-3 culture with intercultural operations (T_6) recorded significantly higher pod yield (1249 kg/ha) and it was on par with (T_2) any DGREB culture (1230 kg/ha) compared to other treatments. However, in 2019 DGREB-3 culture with intercultural operations (T_6) recorded significantly higher pod yield (1581 kg/ha) over other treatment except (T_2) any DGREB culture (1532 kg/ha). This is due to endophytic bacteria can help their host plants in getting increased amounts of limiting plant nutrients, which include nitrogen, iron and phosphorus (Glick, 2012). The endophytic bacteria produce an enzyme called 1-aminocyclopropane-1-carboxylate (ACC) deaminase that can hydrolyse ACC, which is a precursor of plant hormone ethylene. ACC degrading bacteria can bind to plant roots and cleave the exuded ACC into α-ketobutyrate and ammonia, and use it as a nitrogen source (Sun *et al.,* 2009). Thus, hydrolysis of ACC can alleviate plant stress, thereby improving plant growth under stress conditions.

Conclusion

Endophytic bacteria are the plant beneficial bacteria that thrive inside plants and can improve plant growth under normal and challenging conditions. They can benefit host plants directly by improving plant nutrient uptake and by modulating growth and stress related phytohormones. Indirectly, endophytic bacteria can improve plant health by targeting pests and pathogens with antibiotics, hydrolytic enzymes, nutrient limitation and by priming plant defences in sustainable agriculture system.

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Table 1: Initial and final plant populations, Number of branches in groundnut by application of endophytic bacteria under rainfed conditions during *kharif* 2016, 2018 and 2019 at Zonal Agricultural and Horticultural Research stations, Hiriyur, UAHS, Shivamogga

Sl. No.	Treatments	Initial Plant population				Final Plant Papulation				No. of Branches/Plant			
		2016	2018	2019	Mean	2016	2018	2019	Mean	2016	2018	2019	Mean
T_1	Control (i/c-2)	180	193	426	266	101	98	272	157	3.0	2.7	2.7	2.8
T_2	Any DGREB (i/c-2)	167	182	374	241	109	94	291	165	4.0	3.7	3.9	3.9
T_3	Un-inoculated Control (with Suggested inter cultivation)	170	173	372	238	94	88	287	156	3.0	2.9	2.9	2.9
T_4	DGREB-1 (with Suggested intercultivation)	158	168	394	240	91	85	296	157	3.0	2.9	2.9	3.0
T_5	DGREB-2 (with Suggested inter cultivation)	184	201	325	237	99	101	283	161	4.0	3.7	3.8	3.8
T_6	DGREB-3 (with Suggested inter cultivation))	191	206	370	255	109	106	262	159	4.0	3.4	3.5	3.7
T_7	DGREB-4 (with Suggested inter cultivation))	180	188	369	246	104	96	269	156	4.0	3.4	3.6	3.7
T_8	DGREB-5 (with Suggested inter cultivation)	194	215	361	257	106	112	266	161	4.0	3.7	3.8	3.8
S.Em ±		15.92	12.43	15.73	12.09	5.62	8.32	10.52	6.57	0.26	0.47	0.06	0.05
CD (P=0.05)		NS	NS	NS	NS	NS	NS	NS	NS	0.75	1.42	0.19	0.17

Table 2: Days to 50 % flowering, Number of Podsand Kernel weight as influenced by application of endophytic bacteria to Groundnut under rainfed conditions during *kharif* 2016, 2018 and 2019 at Zonal Agricultural and Horticultural Research stations, Hiriyur, UAHS, Shivamogga

Sl. No.	Treatments	Days to 50 % flowering				No.of Pods/Plant				100 Kernel Wt.(g)			
		2016	2018	2019	Mean	2016	2018	2019	Mean	2016	2018	2019	Mean
T_1	Control (j/c-2)	35	32.3	32.4	33.2	25	23.5	24.9	24.5	38	35.3	35.9	36.4
T_2	Any DGREB (j/c-2)	36	34.3	34.2	34.8	29	27.9	28.2	28.4	40	38.7	39.2	39.3
T_3	Un-inoculated Control (with Suggested inter cultivation)	38	35.3	35.8	36.4	23	21.6	22.9	22.5	37	35.5	36.3	36.3
T_4	DGREB-1 (with Suggested intercultivation)	38	35.3	35.1	36.1	26	25	26.5	25.8	39	37.7	39.3	38.7
T_5	DGREB-2 (with Suggested inter cultivation)	38	34.3	34.4	35.6	26	24.5	25.0	25.2	38	37.2	38.7	38.0
T_6	DGREB-3 (with Suggested inter cultivation))	37	34.3	34.5	35.3	30	28.9	30.1	29.7	41	39.9	41.3	40.7
T_7	DGREB-4 (with Suggested inter cultivation))	36	32.3	32.5	33.6	25	23.5	24.3	24.3	39	37.2	37.9	38.0
T_8	DGREB-5 (with Suggested inter cultivation)	36	32.3	32.2	33.5	27	26	27.0	26.7	40	38.7	38.4	39.0
S.Em ±		0.69	1.00	1.29	0.24	2.66	0.50	0.52	0.16	1.17	1.00	0.56	0.30
CD (P=0.05)		2.02	3.10	3.94	0.73	7.83	1.40	1.60	0.49	3.45	2.90	1.70	0.93

Table 3: Effect of Endophytic bacteria on Nodulations number, Nodule weight and Shelling Percentage of groundnut under rainfed conditions during *kharif* 2016, 2018 and 2019 at Zonal Agricultural and Horticultural Research stations, Hiriyur, UAHS, Shivamogga

Sl. No.	Treatments	Nodule Count (30 days)				Nodule Count (60 days)				Shelling (%)				Nodule Wt. (g)	
		2016	2018	2019	Mean	2016	2018	2019	Mean	2016	2018	2019	Mean	Fresh wt. (g) 2019	Dry wt. (g) 2019
T_1	Control (j/c-2)	21	18.6	22.07	20.6	34	32.3	34.67	33.7	65	62.2	62.6	63.3	0.27	0.05
T_2	Any DGREB (j/c-2)	50	47	53.73	50.2	58	56.4	59.10	57.8	65	63.2	64.0	64.1	0.38	0.09
T_3	Un-inoculated Control (with Suggested inter cultivation)	27	25.5	28.17	26.9	38	34.8	36.53	36.4	66	64.2	64.4	64.9	0.30	0.07
T_4	DGREB-1 (with Suggested intercultivation)	43	40.2	43.37	42.2	54	52.2	56.73	54.3	66	64.2	64.4	64.9	0.25	0.03
T_5	DGREB-2 (with Suggested inter cultivation)	35	33.3	36.50	34.9	44	41.2	44.50	43.2	69	66.6	66.4	67.3	0.38	0.09
T_6	DGREB-3 (with Suggested inter cultivation))	38	36.8	37.40	37.4	52	51	54.53	52.5	66	63.7	63.8	64.5	0.43	0.16
T_7	DGREB-4 (with Suggested inter cultivation))	44	42.1	43.77	43.3	54	52.4	54.87	53.8	66	64.2	64.6	64.9	0.31	0.08
T_8	DGREB-5 (with Suggested inter cultivation)	41	39.2	40.73	40.3	53	51.9	53.13	52.7	68	65.9	65.8	66.6	0.39	0.09
S.Em ±		2.13	2.10	1.46	0.56	2.26	1.90	1.14	0.43	2.32	1.30	0.38	0.17	0.05	0.02
CD (P=0.05)		6.28	6.10	4.44	1.71	6.66	5.70	3.48	1.33	6.83	3.80	1.17	0.53	0.16	0.07

Table 4: Effect of endophytic bacteria on Pod yield, Kernel yield and Haulm yield of groundnut under rainfed conditions during *kharif* 2016, 2018 and 2019 at Zonal Agricultural and Horticultural Research stations, Hiriyur, UAHS, Shivamogga

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Sl. No.	Treatments	Pod yield(Kg/ha)				Kernel Yield (Kg/ha)				Haulm Yield (Kg/ha)			
		2016	2018	2019	Mean	2016	2018	2019	Mean	2016	2018	2019	Mean
T_1	Control (i/c-2)	645	629	804	693	421	407	419.0	415.7	879	860	1014	918
T_2	Any DGREB (i/c-2)	848	829	1065	909	552	539	542.5	544.5	1257	1230	1532	1340
T_3	Un-inoculated Control (with Suggested inter cultivation)	680	664	861	735	453	439	426.4	439.5	708	691	1034	811
T_4	DGREB-1 (with Suggested intercultivation)	770	752	918	813	508	494	504.8	502.3	859	840	1054	918
T_5	DGREB-2 (with Suggested inter cultivation)	764	745	906	805	524	512	525.9	520.6	892	869	1072	944
T_6	DGREB-3 (with Suggested inter cultivation))	929	909	1230	1022	619	606	632.9	619.3	1276	1249	1581	1369
T_7	DGREB-4 (with Suggested inter cultivation))	795	774	930	833	532	519	535.1	528.7	1055	1032	1235	1107
T_8	DGREB-5 (with Suggested inter cultivation)	802	784	978	854	546	533	541.6	540.2	1079	1056	1260	1132
S.Em ±		55.35	2.50	58.27	17.91	38.91	28.00	3.50	3.83	73.61	23.00	31.57	23.36
CD (P=0.05)		162.78	7.40	176.70	54.35	114.44	83.00	10.62	11.62	216.48	68.00	95.78	70.87

Table 5: Economics by application of endophytic bacteria for alleviation of moisture- deficit stress in groundnut under rainfed conditions during *kharif* 2016, 2018 and 2019 at Zonal Agricultural and Horticultural Research stations, Hiriyur, UAHS, Shivamogga

Sl. No.	Treatments	Gross returns (Rs./ha)				Net returns (Rs./ha)				B: C ratio			
		2016	2018	2019	Mean	2016	2018	2019	Mean	2016	2018	2019	Mean
T_1	Control (i/c-2)	34553	27999	29727	30760	9553	9937	11665	10385	1.38	1.55	1.65	1.53
T_2	Any DGREB (i/c-2)	45234	36895	44203	42111	19734	12091	17399	16408	1.77	1.49	1.71	1.66
T_3	Un-inoculated Control (with Suggested inter cultivation)	35386	29526	32731	32548	86	698	3903	1562	1.00	1.02	1.14	1.05
T_4	DGREB-1 (with Suggested intercultivation)	40645	33473	36938	37019	4845	5440	8905	6397	1.14	1.19	1.32	1.22
T_5	DGREB-2 (with Suggested inter cultivation)	40172	33144	36524	36613	4372	4970	8350	5897	1.12	1.18	1.30	1.20
T_6	DGREB-3 (with Suggested inter cultivation))	49236	40451	50009	46565	13436	13998	23556	16997	1.38	1.53	1.89	1.60
T_7	DGREB-4 (with Suggested inter cultivation))	42202	34452	38705	38453	6402	6985	11238	8208	1.18	1.25	1.41	1.28
T_8	DGREB-5 (with Suggested inter cultivation)	42325	34888	39318	38844	6525	7115	11545	8395	1.18	1.26	1.42	1.28
S.Em. ±			Data not subjected to ANOVA										

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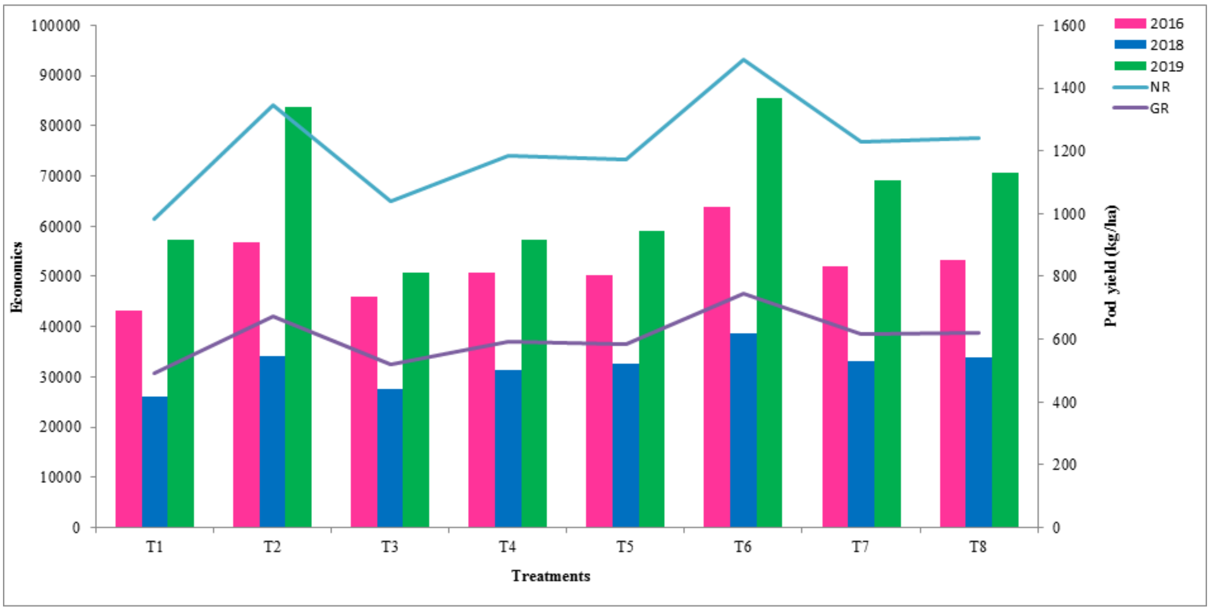

Fig. 1: Effect of endophytic bacterial cultures on pod yield and economics of groundnut under rainfed condition