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SEED PELLETIZATION WITH PGPR- A POTENTIAL TOOL FOR IMPROVING THE PRODUCTIVITY OF FENUGREEK

S. SURYAKUMARI, K. GIRIDHAR, K. NIRMAL BABU, A.C. SHIVRAN, V.P. PANDEY, T.P. MALIK, D.G. PATEL and A. RAJANI
All India Co ordinate Research Project on Spices, Horticultural Research Station,
Dr. YSR Horticultural University, Guntur – 522 034

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The present experiment was conducted to study the efficacy of seed pelletized with PGPR on growth and yield of fenugreek at five research centres of All India Coordinated Research Project (AICRP) on Spices research centres across the country in various geographical locations representing South (Guntur-Andhra Pradesh), West (Jagudan-Gujarat and Jobner-Rajasthan) North (Hisar-Haryana) and Central (Kumarganj-Uttar Pradesh) parts of India, treating it as a mega-environment. The experiment was conducted with the same treatments in a randomized block design with three replications from *rabi* 2013 to *rabi* 2015. The geographical location and soil details of the experimental stations are presented Table 1. The soil type in these regions varied from sandy loam to black loam with a soil pH ranging from 7.7 to 8.5. The total rain fall during the rabi season ranged from 20 mm to 200 mm in these regions and the crops were raised under rain fed and irrigated conditions.

Five treatments were evaluated as, T_1 seed pelletized with bio-formulation of FK14 (*Pseudomonas putida*), T_2 with bio-formulation of FL18 (*Microbacterium paraxoydans*), T_3 with bioformulation of FK14 + FL18, T_4 Control (without PGPR) and T_5- Local popular variety. The treatments T_1 to T_4 were evaluated with variety APHU Methi-1 (Lam Methi-2/ LFC-84) cold pelletized with the bioagent at Indian Institute of Spices Research, Calicut and were supplied to all the five test centres in all the three years. The dose of each PGPR formulation was metered at @ 100 g kg^{-1} seed while pelletizing the seed (Nirmal Babu, 2014). The crop was raised following the recommended package of practices at each centre. Data on growth parameters and yield attributes were studied during the crop growth period.

Table 1. Geographical location, soil and agro-climatic details of the test environments

10		Latitude	Longitude	Altitude (above MSL)	Soil		Farming situation	Agro-climatic NARP Zone of India
Location	State				pH	Texture		
Guntur	Andhra Pradesh	16.18° N	80.29° E	032	7.8	Vertisols	Rainfed	AP-1: Krishna Zone
Hisar	Haryana	29.08° N	75.43° E	215	7.7	Sandy loam	Irrigated	HR-2: Western Zone
Jagudan	Gujarat	23.31° N	72.24° E	70	7.9	Sandy loam	Irrigated-dry	GJ-4: North Gujarat Zone
Jobner	Rajasthan	26.58° N	75.23° E	427	8.1	Loamy sand	Irrigated	RJ-5: Semi-arid Eastern Plain Zone
Kumarganj	Uttar Pradesh	25.43° N	88.73° E	28	8.5	Alluvium	Irrigated	UP-7: Eastern Plain Zone

E-mail : surya.surepeddi@gmail.com

The pooled analysis of the three years data from all the evaluating centers of AICRP indicated that the treatments varied significantly for all the yield attributes studied (Table 2). Maximum plant height (74.7 cm), number of branches per plant (5.6), number of pods per plant (37.1), pod length (9.4) and number of seeds per pod (15.5) were recorded in the treatment T3 in which the seed was pelletized with a combination of FK14 and FL18, and the treatment was at par with T1 (the seed pelletized with FK-14) and T2 (the seed pelletized with FL-18). The growth promotion may be due to not only direct effects but also indirect effects of the microbes. The direct effects might have included fixation of atmospheric nitrogen that is transferred to the sink, production of sederophores that chelate iron for availability, solubilisation of minerals such as phosphorus and synthesis of phytoharmones, enhancement of mineral uptake due to increase in specific ion fluxes at the root surface (Shivran *et al*., 2013). The PGPR strains bioformulations might have used one or more or all of these mechanisms in the rhizosphere for increase in yields contributing through increased plant height, number of branches and pods.

Table 2. Growth response of fenugreek to different PGPR bioformulations

Treatments	Plant height (cm)	No. of branches per plant	No. of pods per plant	Pod length (cm)	No. of seeds per pod
T1-FK-14	71.4	5.4	34.7	9.1	14.9
T2-FL-18	74.2	5.3	34.4	9.1	15.1
T3-FK-14 + FL18	74.7	5.6	37.1	9.4	15.5
T4-Control	67.9	5.0	33.5	8.9	14.6
T5-Local check	67.1	4.8	32.5	9.1	14.4
CD at 5 %	4.5	0.3	1.2	0.3	0.6
CV (%)	7.7	14.8	18.6	4.7	12.1

Table 3. Yield response of fenugreek to different PGPR bioformulations

Treatments	Guntur	Hisar	Jagudan	Jobner	Kumargunj	Mean	% increase over control
T1-FK-14	1045	1997	1541	1597	1470	1530	10.0
T2-FL-18	1091	1994	1543	1626	1369	1525	9.50
T3-FK-14 + FL18	1036	2030	1551	1668	1587	1574	13.0
T4-Control	941	1852	1450	1431	1291	1393	-
T5-Local check	781	1973	1370	1373	1301	1360	-
CD at 5 %	91	47.1	NS	77.6	19.0		
CV (%)	15.1	15.6	9.2	10.1	8.8		

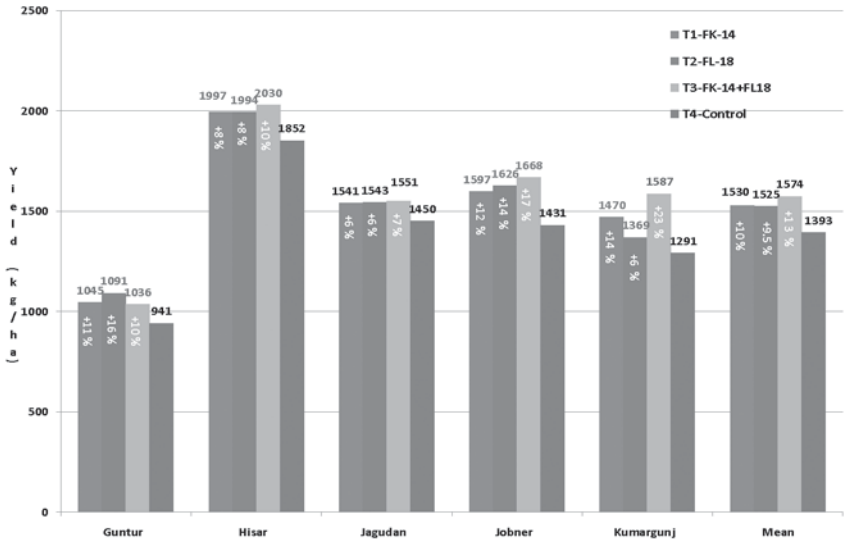

Fig. 1. Yield response of fenugreek to PGPR formulations

The yield of fenugreek varies from place to place based on the geographical location. Fenugreek yield varied from about 250 kg ha^{-1} at Guntur, Andhra Pradesh under rainfed condition to about 1600 kg ha^{-1} in Hisar, Haryana under irrigated conditions. Irrespective of the yield potential of the soils and environmental influence in these locations, treatment with PGPR has recorded significantly higher yields (Table 3, Fig. 1). The pooled data of the study on PGPR bioformulations in the five centres of AICRP on Spices recorded highest seed yields when the seed was pelletized with PGPR bio formulation combination of FK 14 and FL18 (1574 kg ha^{-1}). The treatment recorded 13.0 % increase in yield over control. The yields in the treatments seed pelletized with FK14, FL18 or combination of FK14 + FL18 were at par with each other at Guntur, Kumarganj, Hisar and Jobner.

Table 4. Economics of bioformulations use in fenugreek (BCR)

Treatments	Guntur	Hisar	Jagudan	Jobner	Kumargunj	Mean BCR
T1-FK-14	1.83	2.66	2.26	1.96	1.96	2.13
T2-FL-18	1.91	2.66	2.27	2.00	1.83	2.13
T3-FK-14 + FL18	1.82	2.71	2.28	2.04	2.12	2.19
T4-Control	1.76	2.47	2.16	1.78	1.72	1.98
T5-Local check	1.46	2.63	2.04	1.71	1.73	1.91
CD at 5 %	91	47.1	NS	77.6	19	
CV (%)	15.1	15.6	9.2	10.1	8.8	

The economics of the experiment revealed that all the treatments pelletized with bio formulations FK14, FL18 or a combination of both, recorded higher benefit to cost ratio over the untreated controls at all the test centres, indicating that the PGPR fortification on seeds was much economical and beneficial over untreated seed. The treatment with bioformulations combination of FK-14 and FL-18 resulted in highest benefit- cost ratio across locations (2.19).

The rhizosphere and endophytic microbial flora play an important role in crop productivity and growth promoting abilities of rhizobacteria are well documented. Besides growth promotion the plants are also protected against pathogen by induction of induced systemic resistance (Harman *et al*., 2004). In technology assessment and refinement trials conducted in farmers' fields, the PGPR strains even without pelletisation improved the yield of fenugreek from 10% to 35%.The enhanced growth and increase in yield was so apparent that farmers were willing to adopt the technology in all the locations.The germination percentage was also higher and the farmers need to invest less on seeds. The plants from treated seed grew vigorously from the beginning resulting in increased number of branches and the difference was perceptible from the beginning. As the growth of the crop was vigorous, weed growth is also suppressed thereby saving money on herbicides. The increased yield brings higher returns and profitability to farmers. In the farmers' demonstrations, they also claimed fewer incidences of pests and diseases.

The seed pelletisation of fenugreek with rhizobacterial bioformulation FK 14 or FL 18 or a combination of FK14 and FL18 resulted in higher growth and yield of the crop as against the untreated controls, hence, can be recommended for all the fenugreek growing areas of the country. In varying agro-climatic zones of the country, seed pelletisation of fenugreek with rhizobacterial bioformulation combination of FK14 and FL18 can be recommended for higher yields with maximum benefit from the costs invested. Further, the present investigation concluded the advantage of bioformulation pelletisation in fenugreek, irrespective of test environment on mega-environment scale.

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