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Effect of *Rhizobium* Isolates on Growth of Fenugreek (*Trigonella foenum - graecum* L.)

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A B S T R A C T

The present investigation entitled "to study the effect of *Rhizobium* isolates on germination and growth of Fenugreek (*Trigonella foenum- graecum* L.)" (Variety - Phule Kasturi) at PG farm of Rajarshee Chatrapati Shahu Maharaj College of Agriculture, Kolhapur during *summer* season of the year 2020-21. The randomized block design (RBD) was used for the field experiment. The result of investigation showed that the application of 75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha) + soil + seed both treated with commercial strain (*Rhizobium tropici*) of *Rhizobium*) was found to be more effective and showed vigorous growth and yield characteristics than the treatment of 75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha + soil + seed both treated with efficient strain-B ($RTHH_5$) of *Rhizobium*. These treatments were statistically at par with one another and superior to other treatments. The treatment of 75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha) + soil + seed both treated with commercial strain (*Rhizobium tropici*) of *Rhizobium* showed profuse effect on growth parameters *viz*, maximum plant height (19 cm), primary branches (11), number of roots (13.37), number of leaves (18.67), leaf length (2.05cm) and number of root nodule (19). It also enhanced yield parameters *viz*, maximum yield per plot (5.33 kg), per acre (28.01quintal) and (7.72 tons/ha). It also increased the available N in soil (175.03 kg/ha). Thus, the present investigation confined that an application of *Rhizoium* strains with the seedling dip treatment and soil drenching found to be more effective along with 75 % RDN, and 100% RDPK and saving of 25% dose of nitrogen.

Introduction

Fenugreek (*Trigonella foenum - graecum* L.) is the popular name for *methi* (*Trigonella foenum - graecum* L). It is a member of the *Leguminosae* family. It is grown for leafy vegetables, sauces, and medicinal purposes (seed) as well as fodder in India and other parts of the world. India, Iran, Nepal, Bangladesh, Argentina, Egypt, France, Spain, Turkey, Morocco, China, and Afghanistan are all major fenugreek producers. India is the world's largest producer. It is an essential condiment that ranks third in terms of area and production among all minor spices planted in India. In India, fenugreek

covers 129 and 135 thousand hectares in fiscal years 2019-20 and 2020-21, respectively, with production of 240 and 201 thousand metric tons and productivity of 1860 and 1488 kg/ha (Anonymous, 2020-21). The largest fenugreek-producing states in India include Rajasthan, Gujarat, Uttarakhand, Uttar Pradesh, Madhya Pradesh, Maharashtra, Haryana, and Punjab. Rajasthan is the country's fenugreek bowl, producing over 80 % of the country's fenugreek. In Maharashtra, a yield of 1200 to 1500 kg of seeds and 800 to 100 kg of leaves per hectare is possible. *Rhizobium* belongs to the "Plant growth promoting rhizobacteria (PGPR)" group of bacteria that can affect plant growth and yield through nitrogen fixation, phosphate solubilization, production of IAA, ACC deaminase, chitinase, 1,3 glucanase, and siderophores (Mehta and Patel, 2011).

These bacteria play an important role in the rhizosphere and have been reported to directly and indirectly facilitate plant host proliferation (Chandra *et al.,* 2007). *Rhizobium* inoculation of fenugreek has been shown to boost plant biomass and seed yield in the past (Poi *et al.,* 1991). Kumawat *et al.,* (2017) found that PGPR strains capable of producing IAA, 1,3-glucanase, and ACC deaminase efficiently colonized fenugreek roots, resulting in increased vigor index, nodule number, root and shoot bio mass, and grain yield of 35 percent and 36 percent, respectively, over control in fenugreek. Fenugreek fixes roughly 283 kg nitrogen per hectare per year, according to Saxena and Ahmed (2003).

Materials and Methods

Seed and soil treatment

For the experiment Phule- Kasuri variety seed of fenugreek was used. After seedling dip treatment with efficient isolate A, B and Commercial strains of *Rhizobium*@ 25 ml/L as per experimental treatment except the uninoculated control with spacing of 3m × 3m of plot. After that soil treated with respective two efficient strains and commercial strains as per the treatment details.

Observations to be recorded

Plant height (in cm)

Number of primary branches

Number of leaf

Number of root number

Leaf length (in cm)

Number of root nodule

Yield per plot/per acre/ per hectare

Results and Discussion

Effect of *Rhizobium* isolates and commercial strain on growth of Fenugreek.

Plant height

All over average results showed that maximum height (14.12cm) was observed in treatment T_7 (75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha + soil + seed both treated with commercial strain (*Rhizobium tropici*) of *Rhizobium*) followed by T4 (75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha + soil + seed both treated with efficient strain- B ($RTHH_5$) *Rhizobium*) and T_1(75 % RDN and 100 % RDPK (30:20:20 NPK/kg ha + soil + seed both treat with efficient strain - A ($RTHH_1$) of *Rhizobium*) which recorded values (12.11cm and 10.85cm), respectively. These three treatments were statistically on par with one another. The least height of (7.89cm) was recorded by the treatment T_{10} (100 % of RDPK with seed + soil without treatment).

Primary branches

All over average results showed that the maximum number of primary branches (8.22) was observed in treatment T_7 (75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha + soil + seed both treated with commercial strain (*Rhizobium tropici*) of

Rhizobium) followed by T_4 (75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha + soil + seed both treated with efficient strain of - B ($RTHH_5$) *Rhizobium*) and T1 (75 % RDN and 100 % RDPK (30:20:20 NPK/kg ha + soil + seed both treat with efficient strain - A ($RTHH_1$) of *Rhizobium*) which recorded values (7.47 and 6.38) of primary branches These three treatments were statistically on par with one another. The least primary branches of (4.34) were recorded by the treatment T_{10} (100 % of RDPK with seed + soil without treatment).

Number of root

All over average results showed that maximum number of roots of per plant of fenugreek (9.29) was observed in treatment T_7 (75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha) + soil + seed both treat with commercial strain (*Rhizobium tropici*) of *Rhizobium*) followed by T_4 (75 % RDN and 100 % of RDPK (30:20:20 NPK kg /ha + soil + seed both treat with efficient strain of - B ($RTHH_5$) *Rhizobium*)and T_1 (75 % RDN and 100 % RDPK (30:20:20 NPK/kg ha + soil + seed both treat with efficient strain - A ($RTHH_1$) of *Rhizobium*) which recorded values (8.03 and 6.90) respectively.

These three treatments were statistically at par with one another. The least number of roots of (4.44) was recorded by the treatment T_{10} (100 % of RDPK with seed + soil without treatment).

Number of leaves

All over average results showed that maximum number of leaf per plant (12.01) was observed in treatment T_7 (75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha) + soil + seed both treat with commercial strain (*Rhizobium tropici*) of *Rhizobium*) followed by T_4 (75 % RDN and 100 % of RDPK (30:20:20 NPK kg /ha + soil + seed both treat with efficient strain of - B(RTHH5) of *Rhizobium)* and T1 (75 % RDN and 100 % RDPK (30:20:20 NPK/kg ha + soil + seed both treat with efficient strain – A($RTHH_1$) of *Rhizobium*) which recorded values (10.69 and 9.57), respectively. These three treatments were statistically at par with one another. The least number of leaves (7.23) was recorded by the treatment T_{10} (100 % of RDPK with seed + soil without treatment).

Leaf length of per fenugreek plant

All over average results showed that maximum leaf length of per plant (1.63cm) was observed in treatment T7 (75% RDN and 100 % RDPK (30:20:20 NPK kg/ha) + soil + seed both treat with commercial strain (*Rhizobium tropici*) of *Rhizobium*) followed by T4 (75 % RDN and 100% of RDPK (30:20:20 NPK kg /ha + soil + seed both treat with efficient strain of - B (RTHH5) of *Rhizobium*)and T_1 (75 % RDN and 100% RDPK (30:20:20 NPK/kg ha + soil + seed both treat with efficient strain - A (RTHH1) of *Rhizobium*) which recorded values (1.56cm and1.35cm), respectively. These three treatments were statistically at par with one another. The least length of leaf (1.17cm) was recorded by the treatment T10 (100 % of RDPK with seed + soil without treatment.

Number of root nodules per fenugreek plant

All over average results showed that maximum number of nodules per plant (14.17) was observed in treatment T_7 (75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha) + soil + seed both treat with commercial strain (*Rhizobum tropici*) of *Rhizobium*) followed by T_4 (75 % RDN and 100 % of RDPK (30:20:20 NPK kg /ha + soil + seed with efficient strain of - B ($RTHH_5$) *Rhizobium)*and T_1 (75 % RDN and100 % RDPK (30:20:20 NPK/kg ha + soil + seed both treat with efficient strain - A ($RTHH_1$) of *Rhizobium*) which recorded values (12.50 and 10.88), respectively. These three treatments were statistically at par with one another. The least number of nodules (7.92) was recorded by the treatment T_{10} (100 % of RDPK with seed + soil without treatment.

Table.1 Treatment details

T_1	**75 % of RDN and 100 % of RDPK (30:20:20 NPK kg/ha) + soil+ seed both treat with efficient strain - A of *Rhizobium*.**
T_2	75 % of RDN and 100 % RDPK (30:20:20 NPK kg/ha) + soil without treatment+ seed treat with efficient strain - A of *Rhizobium.*
T_3	75 % of RDN and 100 % of RDPK (30:20:20: NPK kg/ha) + soil treat with efficient strain - A of *Rhizobium* + Seed without treatment.
T_4	75 % of RDN and 100 % of RDPK (30:20:20 NPK kg/ha) + soil + seed both treat with efficient strain - B of *Rhizobium.*
T_5	75 % of RDN and 100 % of RDPK (30:20:20 NPK kg /ha) + Soil without treat + Seed treat with efficient strain - B of *Rhizobium.*
T_6	75 % of RDN and 100 % of RDPK (30:20:20 NPK kg /ha) + Soil treat with efficient strain - B of *Rhizobium* + Seed without treatment.
T_7	75 % of RDN and 100 % of RDPK (30:20:20 NPK kg/ha) +Soil + Seed both treat with commercial strain of *Rhizobium.*
T_8	75 % of RDN 100 % of RDPK (30:20:20 NPK kg/ha) Soil without treatment + Seed treat with commercial strain of *Rhizobium.*
T_9	75 % of RDN and 100 % of RDPK (30:20:20 NPK kg/ha) + Soil treat with commercial strain of *Rhizobium* + Seed without treatment.
T_{10}	75 % of RDN and 100 % of RDPK (30:20:20 NPK kg/ha) + Soil + Seed both without treatment.
T_{11}	100 % RDF (40:20:20 NPK kg/ha) + Soil + Seed both without treatment.

Table.2

Treatments	Plant height (cm)			
	At 15 DAS	**At 30 DAS**	**At 45 DAS**	**Mean**
T_1	7.00	10.22	15.33*	10.85
T2	6.00	9.00	14.00	9.67
T_3	5.50	10.00	13.33	9.61
T_4	8.33**	11.33**	16.67**	12.11**
T_5	5.00	9.67	12.67	9.11
T_6	5.67	9.33	14.33	9.78
T_7	9.67**	12.70**	19.00**	14.12**
T_8	6.00	9.00	12.33	9.11
T_9	5.67	8.26	13.67	9.20
T_{10}	4.00	7.67	12.00	7.89
T_{11}	6.67	9.67	15.00	10.44
S.E.m.±	**0.87**	**0.80**	**1.33**	**1.00**
C.D at 5%	**2.51**	**2.30**	**3.82**	**2.87**

*****Data are mean of three replications; **Treatments are on a at par

Table.3

Treatments	Number of roots per plant			
	At 15 DAS	At 30 DAS	At 45 DAS	Mean
T_1	3.13	7.00	10.55	6.90
T_2	2.90	6.00	9.33	6.08
T_3	3.10	6.50	10.33	6.64
T4	4.00**	8.43**	11.67**	8.03**
T_5	1.85	5.13	10.00	5.66
T_6	2.47	5.67	9.53	5.89
T_7	4.50**	10.00**	13.37**	9.29**
T_8	2.67	6.00	9.27	5.98
T_9	2.43	5.67	8.00	5.37
T_{10}	1.82	4.17	7.33	4.44
T_{11}	3.03	6.87	10.13	6.68
SEm±	0.47	0.99	0.93	0.79
CD at 5%	1.35	2.86	2.67	2.29

*Data are mean of three replications; **Treatments are on a at par

Table.4

Treatments	Number of branches per plant			
	At 15 DAS	At 30 DAS	At 45 DAS	Mean
T_1	3.17	6.87	9.10	6.38
T_2	2.77	6.00	8.00	5.59
T_3	2.97	5.50	8.93	5.80
T_4	4.07**	8.33**	10.00**	7.47**
T_5	2.17	5.00	8.67	5.28
T_6	2.80	5.67	9.00	5.82
T_7	4.33**	9.33**	11.00**	8.22**
T_8	3.00	6.00	8.60	5.87
T_9	2.77	5.67	9.00	5.81
T_{10}	2.02	4.00	7.00	4.34
T_{11}	3.07	6.67	9.00	6.25
SE m±	0.38	0.84	0.63	0.61
C.D at 5%	1.09	1.19	1.83	1.37

*Data are mean of three replications; **Treatments are on a at par

Table.5

Treatments	Leaf number per plant			
	At 15 DAS	At 30 DAS	At 45 DAS	Mean
T_1	3.17	10.55	15.00*	9.57
T_2	2.77	9.33	13.67	8.59
T_3	2.97	10.20	13.00	8.72
T_4	4.07**	11.67**	16.33**	10.69**
T_5	2.17	10.33	12.33	8.28
T_6	2.80	9.67	14.00	8.82
T_7	4.33**	13.03**	18.67**	12.01**
T_8	3.00	9.33	12.00	8.11
T_9	2.77	8.59	13.33	8.23
T_{10}	2.02	8.00	11.67	7.23
T_{11}	3.07	10.00	14.67	9.25
S.E.m±	**0.11**	**0.78**	**1.33**	**0.74**
C.D at 5%	**0.33**	**2.25**	**3.82**	**2.13**

*****Data are mean of three replications; **Treatments are on a at par

Table.6

Treatments	Leaves Length (cm)			
	At 15 DAS	At 30 DAS	At 45 DAS	Mean
T_1	0.81	1.50	1.73	1.35
T_2	0.63	1.40	1.75	1.26
T_3	0.77	1.41	1.74	1.31
T_4	1.07**	1.59**	2.01**	1.56**
T_5	0.77	1.46	1.77	1.33
T_6	0.80	1.41	1.75	1.32
T_7	1.13**	1.71**	2.05**	1.63**
T_8	0.73	1.49	1.94	1.30
T_9	0.80	1.42	1.75	1.32
T_{10}	0.57	1.38	1.56	1.17
T_{11}	0.78	1.43	1.77	1.33
S.E.m±	**0.10**	**0.06**	**0.09**	**0.08**
C.D at 5%	**0.29**	**0.18**	**0.25**	**0.24**

*Data are mean of three replications; **Treatments are on a at par

Table.7

Treatments	Number of roots nodule per plant			
	At 15 DAS	At 30 DAS	At 45 DAS	Mean
T_1	0.00	6.67	15.10	10.88
T_2	0.00	5.33	13.17	9.25
T_3	0.00	6.00	14.00	10.00
T_4	0.00	8.33**	16.67**	12.50**
T_5	0.00	4.93	13.00	8.97
T_6	0.00	5.67	14.33	10.00
T_7	0.00	9.33**	19.00**	14.17**
T_8	0.00	6.00	12.33	9.17
T_9	0.00	5.87	13.00	9.43
T_{10}	0.00	4.00	11.83	7.92
T_{11}	0.00	6.63	14.33	10.48
S.Em±	-	**0.86**	**1.32**	**1.09**
C.D at 5%	-	**2.48**	**3.81**	**3.14**

*Data are mean of three replications; **Treatments are on a at par

Table.8

Treatments	Fenugreek yield		
	Per plot (kg)	Per acre (Quintal)	Per hectare (Tones)
T_1	4.67	26.24	6.38
T_2	3.79	25.17	5.59
T_3	3.83	24.33	6.00
T_4	5.33**	28.01*	7.01
T_5	4.00	24.73	5.28
T_6	3.33	23.54	5.82
T_7	6.33**	30.00**	7.72
T_8	3.72	25.07	5.87
T_9	3.83	23.62	5.81
T_{10}	2.33	22.67	4.34
T_{11}	4.17	26.11	6.25
SEm±	**0.62**	**1.25**	**0.39**
C.D at 5%	**1.79**	**3.60**	**1.12**

*Data are mean of three replications;
** Treatment on apar

These findings support Karmany *et al.,* (2000) hypothesis that the variation in fenugreek crop performance across treatments could be attributable to changes in the amount of nodules developed on plant roots and their biological nitrogen fixing. Inoculation of fenugreek seed with *Rhizobium* considerably increased nodulation and fresh weight of nodules above un-inoculated control, as reported by Poi *et al.,* (1991) and Karmany *et al.,* (2000).

Yield of fenugreek per plot

45 day after the harvesting all over average results showed in table 4.16 and fig 13 the maximum yield

of per plot (6.33kg) per plot and (30qt) per acre and finally (7.72 tones/ha) per hectare was observed in treatment T_7 (75 % RDN and 100 % RDPK (30:20:20 NPK kg/ha) + soil + seed both treat with commercial strain (*Rhizobium tropici*) of *Rhizobium*) followed by T_4 (75 % RDN and 100 % of RDPK (30:20:20 NPK kg /ha + soil + seed both treat with efficient strain of- B ($RTHH_5$) *Rhizobium)* and T1 (75 % RDN and 100 % RDPK (30:20:20 NPK/kg ha + soil + seed both treat with efficient strain - A ($RTHH_1$) of *Rhizobium*) which recorded value of per plot (5.33 kg) per plot and (28.01qt) per acre, (7.01 tones) per hectare and per plot (4.67 kg) per plot and (26.24 qt) per acre and finally (6.38 tones/ha), respectively. These three treatments were statistically at par with each another. The least yield of per plot (2.33 kg) per plot and (22.67qt) per acre and finally (4.34 tones/ha) per hectare was recorded by the treatment T_{10} (100 % of RDPK with seed + soil without treatment.

The results were similar to those reported by Adak and Sachan (2013) who found that the treatment involving NPK + *Sino Rhizobium* + *Bacillus* + FYM @ 5.0 t ha^{-1} produced the highest total biological yield (70.71q ha^1), total N (224.45 kg ha^1), P (11.78 kg ha^1), and K (161.39 kg ha^1) uptake, and Singh and Patel (2016) found that the fenugreek crop isolated six *Rhizobium melitoli* strain. The seed yields obtained with FRS-7 over two years were 10.14 and 19.96 q ha^{-1} respectively, which were 36.8 % and 45.9 % higher than the control. Raiyarani *et al.,* (2018) reported that the higher value growth parameters have seed yield (1712 kg/ha) and straw yield (2814 kg/ha) were recorded under the treatment FYM 4 tone + *Rhizobium* (seed inoculation)+ *PSB*+ *KSB* soil application; being on par with treatment (20:40:00 kg N-P_2O_5 K_2O/ha) treatment (FYM 4 tone + *Rhizobium* (seed inoculation.

Present investigation concluded that application of *Rhizobium* strain as seed treatment and soil drenching found to be more effective along with 75 % N, and 100 % P and K. Application of commercial strain (*Rhizobium tropici*) of *Rhizobium* as seed + soil treatment along with 75 % N and 100 % dose of P and K gives well plant establishment, profuse leaf growth and higher yield. The treatment of efficient Strain - B ($RTHH_5$) as seed + soil along with 75 % N and 100 % dose of P and K also showed the significant effect on growth of fenugreek. Thus, Strain - B ($RTHH_5$) of *Rhizobuim* on par to the effects of commercial strain (*Rhizobium tropici*) of *Rhizobium*. It can be applied to field with 75 % N and 100 % dose of P and K for getting vigorous growth and higher yield.

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