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Studies on Bioresource based Seed Production Modules in Fenugreek (*Trigonella foenum graecum* L.)

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ABSTRACT

Background: Fenugreek (*Trigonella foenum-graecum* L.) family: fabaceae, locally known as '*Methi*' is a self pollinated leguminous spice crop. The plant originated in India and Northern Africa. In India, it is commonly consumed a condiment and used medicinally as a lactation stimulant. There are numerous other folkloric uses of fenugreek, for example, in the treatment of indigestion and baldness. The crop has immense medicinal value and is a good source of vitamins, protein and essential oils. The leaves are used as a vegetable and the seeds as spice for adding medicinal value and flavor to the human food and also forage for cattle.

Methods: The present investigation was conducted during 2017-18 and 2018-2019 under laboratory and field conditions in the Department of Seed Science and Technology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). In both the years, ten bioresources based seed production modules were tested under field conditions. The field experiment comparised of 10 bioresource based seed production modules with one untreated control was laid out in Randomized Complete Block Design (RCBD) with three replications.

Result: It can be concluded from the present investigation that bioresource based seed production Module-5 consist of seed treatment with *Rhizobium* strain-B2@ 100 ml/kg seeds, soil application of *Trichoderma viride* mixed with FYM @ 2 L/20 kg and arbuscular mycorrhizal (AM) fungi @ 2 kg of soil inoculum/m^2 and foliar application of water extracts of garlic (*Allium sativum*) and drake (*Melia azedarach*) @ 5% is an effective treatment module which improved plant growth, pod yield, seed yield and reduced the incidence of downy mildew as compared to untreated control.

Key words: Fenugreek, Grain attributes, Organic farming, *Rhizobium*, *Trichoderma viride*, Vegetative growth, Yield attributes.

INTRODUCTION

Fenugreek (*Trigonella foenum graecum* L.) family: fabaceae, locally known as '*Methi*' is a self pollinated leguminous spice crop. The plant originated in India and Northern Africa. In India, it is mostly use as a condiment and as medicinally for lactation stimulant. There are many other folkloric uses of fenugreek, for example, in the treatment of indigestion and baldness (Upaganlawar *et al*. 2013). The crop has immense medicinal value and is a good source of vitamins, protein and essential oils. The leaves are used as a vegetable and the seeds as spice for adding flavor as well as medicinal value to the human food and also forage for cattle. Current trends in agriculture, worldwide, are centered on reducing the use of chemical pesticides and fertilizers and instead utilizing locally available bioresource, manures, bio-fertilizers and bio-pesticides for crop production. Bio-resources based organic farming systems are, therefore, encouraged and developed for cultivation of various crops. Application of right and appropriate nutritional bioresource like rhizobia, plant growth promoting rhizobacteria (PGPRs), arbuscular mycorrhizal (AM) fungi through manures and biofertilizers and management of diseases and pests by microbial biological control agents and plant product based biopesticides improve the quality of produce with higher yield without any residual toxicity of pesticides. A judicious use of organic manures, biofertilizers and biopesticide may be effective not only in sustaining crop productivity through improvement in soil health, but also in supplementing chemical fertilizers of the crops (Jaipaul *et al*., 2011).

Under present scenario of organic agriculture production system, there is an urgent need to reduce the usage of chemicals fertilizers and search other organic alternatives for production of crops especially horticultural crops like spices as these crops are mostly consumed as raw. Keeping in view the importance of fenugreek crop the present investigation was conducted to use locally available bioresource *viz.,* Rhizobia, PGPRs, biocontrol agents, plant products (garlic, drake extracts *etc*.) as seed treatment, soil application and foliar sprays to develop a bio-resources based module for production of fenugreek seed crop.

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MATERIALS AND METHODS

The present investigation on use of bioresource based seed production modules in Fenugreek (*Trigonella foenum graecum* L. was conducted at Research Farm and Laboratory of Department of Seed Science and Technology, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the *Rabi* season of 2017-18 and 2018-19. The experimental farm is located at altitude of 1183 m above mean sea level with latitude of 30.51°N and longitude of 77.09°E in the mid hill zone of Himachal Pradesh. The soil of a research farm was normal to medium having pH of 6.5-6.9. The field experiment comparised of 10 bioresource based seed production modules with one untreated control was laid out in Randomized Complete Block Design (RCBD) with three replications. The seeds of fenugreek cultivar IC-74 (after treatment) were sown in the field as per the modules in a plot having size 0.9 m × 0.9 m accommodating 36 plants per plot at the spacing of 30 × 7.5 cm. Irrigation and intercultural operations performed as per existing recommendations for the crop. Sowing of seed was done in last week of October and harvesting was done in the first fortnight of May during both years.

Treatments combinations and observations

Nine indigenous isolates of bioagents including three plant growth promoting rhizobacteria (PGPR-1, PGPR-2 and PGPR-3), three rhizobial biofertilizers (*Rhizobium* strain-B1, *Rhizobium* strain-B2 and *Rhizobium* strain-P1) and three biocontrol agents (*Trichoderma harzianum, T. viride* and *T. virens*) were screened for their efficacy as seed treatment under laboratory conditions following standard methods of seed quality and health testing as prescribed by International Seed Testing Association (ISTA). On the basis of these tests, PGPR-1, *Rhizobium* strain-B2 and *T. viride* were selected from their respective categories for further studies. These bioagents were used to work out the bioresource based seed production modules and their evaluation under field and storage conditions. Ten bioresource based seed production modules were used *viz*., Module-1 [PGPR(ST) + AMF and *Trichoderma* (SA) + Garlic and Drake (FA)], Module-2 [PGPR (ST) + AMF and *Trichoderma*(SA) + Garlic (FA)], Module-3 [PGPR (ST) + AMF and *Trichoderma* (SA) + Garlic (FA)], Module-4 [PGPR (ST) + *Trichoderma* (SA) + Garlic (FA)], Module-5 [*Rhizobium* (ST) + AMF and *Trichoderma* (SA) + Garlic and Drake (FA)], Module-6 [*Rhizobium* (ST) +AMF and *Trichoderma*(SA) +Garlic(FA)], Module-7 [*Rhizobium* (ST) + *Trichoderma* (SA) + Garlic and Drake (FA)], Module-8 [*Rhizobium* (ST) + *Trichoderma* (SA) + Garlic (FA)], Module-9 [*Trichoderma* (ST) + *Trichoderma* (SA) + Garlic and Drake (FA)], Module-10 [Bijamrita (ST) + Jeevamrita (SA) + Agniastra (FA)] and Untreated control (T_{11}). Observations on various growth and yield parameters such as days to germination, field emergence, days to 50 per cent flowering, number of branches per plant, average number of leaves per plant, plant height at 60, 90 and harvest days, number of pods per plant, number of seeds per plant, seed yield per plant, seed yield per ha, 1000 seed weight and B:C ratio as well as incidence of downy mildew disease were recorded as per the standard methods prescribed by ISTA and pooled for mean analysis.

Statistical analysis

The data during the investigation were subjected to statistical analysis by adopting appropriate method of analysis of variance as described by Panse and Sukhatme (2000). Before going for statistical analysis, all the observations in respect of field emergence (%) and incidence of diseases (%) were transformed into square root transformation values. The data recorded were analyzed using MS-Excel and OPSTAT as per the design of experiment. Whereas the variance ratios (F-value) were found significant at 5 per cent level of probality, the critical difference (CD) values were computed for making comparison among treatment means.

RESULTS AND DISCUSSION

Emergence and growth parameters

Findings of the present study (Table 1) reveals that seed germination and plant height of fenugreek crop was not influenced significantly with the application different bioresource based seed production modules, though the height of the plants increased from germination to harvest irrespective of the treatments applied. Bioresource based Module-5 [*Rhizobium* (ST) + AMF and *Trichoderma* (SA) + Garlic and Drake (FA)] exhibited earliest days to germination (11.50), field emergence (92.47%) and days to 50 per cent flowering (87.67%) as compared to untreated control. Data of this study further showed that the number of branches per plant (11.90) and average number of leaves per plant (147.51) of fenugreek were significantly affected with the application of different bioresource based seed production modules. The plant height at 60, 90 days and at harvesting was significantly higher (20.08 cm, 38.97 cm and 48.60 cm, respectively) as compared to the rest of the modules. Earlier workers (Lal *et al*., 2017; Karel *et al*., 2016 and Deswal *et al*., 2017) have also observed similar results after using organic modules for production of fenugreek. They were of the opinion that organic modules including *Rhizobium* seed treatment and soil application of AM fungi and *Trichoderma* enhanced the seed germination attributes because of the positive response of *Rhizobium*, AM fungi, *Trichoderma* in solubilizing and sequestration of many plants nutrients and their supply to the developing seedlings. The inoculation of bio-fertilizer like *Rhizobium* increases the number of such microorganisms in the soil rhizosphere and consequently improves the extent of microbiologically fixed nitrogen for plant growth (Saxena and Singh, 2019). The inoculation of AM fungi in soil also helped in enhancing the plant growth thereby resulting into early flowering (Sharma *et al*., 2005). The effect of seed inoculation with *Rhizobium* increased number of branches and showed a significant and positive result in improving nitrogen nutrient contents of plant (Malav *et al*., 2018). Similar results were observed by Badar *et al*. (2016) upon *Rhizobium* inoculation in increasing the number of leaves in fenugreek plants. The ability of *Trichoderma*

spp. to produce phytohormones is also one of the factors in the increasing plant height (Chowdappa *et al*., 2013).

Yield attributes

The data presented in Table 2 showed that the number of pods per plant and number of seeds per plant, seed yield per plant and seed yield per ha were influenced significantly by the application of various bioresource based seed production modules as compared to untreated control. The highest number of pods per plant (75.73), number of seeds per plant (16.73), seed yield per plant (12.86 g), seed yield per ha (12.69 q) and 1000 seed weight (12.64 g) were recorded in the plots grown under the Module -5 [*Rhizobium* (ST) + AMF and *Trichoderma* (SA) + Garlic and Drake (FA)] as compared to other modules tested. The Module-5 provided higher emergence and plant growth in field as compared to the rest of the modules. More number of leaves per plant and number of branches per plant resulted by the seed and soil treatments with bio-agents, as discussed earlier, increased the photosynthetic area and favoured physiological activities in plants which resulted in the production of more number of pods per plant as well as number of seeds per pod. Present findings corroborated the earlier research reports of Samawat and Borah (2001), Chandrakar *et al*. (2001), Negi *et al*. (2004) and Saxena and Singh (2019) who advocated that the *Rhizobium* and other bio-agents improved the availability of nutrients and balanced supply of N throughout the life cycle of the crop thereby reduced leaf senescence and increased availability of assimilate demanded by developing seed and thus resulted in a significant improvement in seed yield attributes incase of fenugreek (Raiyani *et al*., 2018, Choudhary *et al*. 2011 and Purbey and Sen, 2007). In addition, the application of organic manures with *Trichoderma viride* also had a significant effect on the plant growth and yield parameter (Mulani *et al*., 2008). Application of AM fungi to the soil has been shown to improve the soil structure and their capability to increase the plant growth and yield through efficient

Table 1: Effect of bioresource based seed production modules on emergence and growth parameters in Fenugreek.

Module	Field emergence (%)	Days to germination	Days to 50% flowering	Plant height (cm) after days			No branches per plant	No of leaves per plant
				60	90	At harvest		
Module-1	90.29 (9.50)	13.83 (27.67)	90.83	18.82	37.15	47.10	18.82	37.15
Module-2	87.58 (9.36)	15.00 (30.00)	93.33	18.10	35.72	46.47	18.10	35.72
Module-3	84.66 (9.20)	16.50 (33.00)	94.83	17.67	34.30	45.00	17.67	34.30
Module-4	85.96 (9.27)	15.50 (31.00)	94.33	17.92	35.47	45.77	17.92	35.47
Module-5	92.47 (9.62)	11.50 (23.00)	87.67	20.08	38.97	48.60	20.08	38.97
Module-6	83.52 (9.14)	17.00 (34.00)	96.17	17.53	33.95	44.53	17.53	33.95
Module-7	89.55 (9.46)	14.50 (29.00)	91.67	18.25	36.62	46.67	18.25	36.62
Module-8	80.40 (8.97)	18.00 (36.00)	97.00	17.33	33.40	43.83	17.33	33.40
Module-9	90.94 (9.54)	13.17 (26.33)	90.00	18.95	37.67	47.52	18.95	37.67
Module-10	91.48 (9.56)	12.50 (25.00)	88.67	19.70	38.10	48.05	19.70	38.10
Control	78.80 (8.88)	19.17 (38.33)	98.33	16.80	31.93	42.18	16.80	31.93
Mean	86.88 (9.32)	15.15 (30.30)	92.98	18.29	35.75	45.97	18.29	35.75
$CD_{(0.05)}$	2.19	0.98	1.68	0.42	1.38	1.59	0.42	1.38

*Pooled data of the same experiments conducted during 2018 and 2019.

Table 2: Effect of bioresource based seed production modules on yield attributes* in Fenugreek.

Module	No of pods per plant	No of seeds per plant	Seed yield per plant (gm)	Seed yield per ha (q)	1000 seed weight (gm)
Module-1	71.62	15.63	10.90	11.02	11.92
Module-2	69.62	14.80	9.67	9.29	11.29
Module-3	67.75	13.93	8.79	8.52	10.70
Module-4	68.37	14.33	9.09	8.82	11.15
Module-5	75.73	16.73	12.86	12.69	12.64
Module-6	65.33	13.62	8.05	7.58	10.32
Module-7	70.73	15.12	10.47	10.36	11.67
Module-8	62.78	12.98	7.75	7.11	10.08
Module-9	72.92	16.05	11.22	11.97	12.21
Module-10	74.57	16.23	12.09	11.99	12.48
Control	59.29	12.52	7.13	6.13	9.55
Mean	68.97	14.72	9.82	9.59	11.27
$CD_{(0.05)}$	0.84	0.48	0.79	0.86	0.65

*Pooled data of the same experiments conducted during 2018 and 2019.

Table 3: Economics of bioresource based seed production modules used for Fenugreek seed production.

Module	*Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C ratio
Module-1	1,10,200	75,319.06	34,880.94	1.46
Module-2	92,900.00	74,119.06	18,780.94	1.25
Module-3	85,200.00	75,149.06	10,050.94	1.13
Module-4	88,200.00	73,949.06	14,250.94	1.19
Module-5	1,26,900.00	75,194.06	51,705.94	1.69
Module-6	75,800.00	73,994.06	1,805.94	1.02
Module-7	1,03,600.00	75,024.06	28,575.94	1.38
Module-8	71,100.00	73,824.06	2,724.06	0.96
Module-9	1,19,700.00	74,199.06	45,500.94	1.61
Module-10	11,99,00.00	74,034.06	45,865.94	1.62

*The gross returns were worked out on the basis of sale price of fenugreek at Rs. 100/-kg fixed by the University.

*Pooled data of the same experiments conducted during 2018 and 2019.

Table 4: Effect of bioresource based seed production modules on incidence of disease in Fenugreek.

Module	Incidence of downy mildew*
Module-1	9.26 (3.04)
Module-2	6.02 (2.45)
Module-3	7.87 (2.81)
Module-4	6.94 (2.64)
Module-5	1.39 (1.18)
Module-6	3.24 (1.80)
Module-7	5.09 (2.26)
Module-8	4.17 (2.04)
Module-9	10.19 (3.19)
Module-10	2.31 (1.52)
Module-11	12.50 (3.54)
Mean	6.27 (2.50)
$CD_{(0.05)}$	0.20

*Pooled data of experiments conducted in two years 2018 and 2019.

**Figs in parentheses are square root transformed values.

nutrient uptake is well documented (Smith and Read, 1997). The increase in yield can also be attributed to the application of *Trichoderma* spp. along with FYM which helped in increasing the population of other beneficial microorganisms in the soil and by protecting the crop from the menace of disease causing microorganisms (Sharma *et al*., 2012).

Economics

The data presented in Table 3 revealed that the B:C ratio was influenced with the application of various bioresource based seed production modules. The highest B:C ratio (1.69) with net return of 51,705.94 were recorded in the crop grown under the Module -5 [*Rhizobium* (ST) + AMF and *Trichoderma* (SA) + Garlic and Drake (FA)] as compared to other modules. These findings are more or less related to that observed by Lal *et al*. (2017), Lal *et al*. (2012), Mishra *et al*. (2010) and Jaipaul *et al*. (2011) who have also observed higher net return in organic modules as compared to other modules in crops like fenugreek, coriander and pea.

Disease incidence

The study further revealed that the lowest incidence of downy mildew (1.39%) was observed in plots receiving Module-5 [*Rhizobium* (ST) + AMF and *Trichoderma* (SA) + Garlic and Drake (FA)] followed by followed by 2.31 per cent in Module-10, 3.24 per cent in Module-9 and 4.17 per cent in Module-1 (Table 4). Shekhawat *et al*. (2016) have reported that *Trichoderma* sp. used as soil application suppressed the downy mildew disease in fenugreek. The foliar application of *Melia* which contain *Azadirachtin*, a limuloid-compound also controlled many pytophagous pests by their pesticidal property. *Azadirachtin* has best effects, including IRG, feeding deterrence and reproduction inhibition (Ali *et al*., 2017). In addition to improvement in N nutrition, *Rhizobium* has also observed to impart resistance against many plant diseases (Al-Ani *et al*., 2012).

CONCLUSION

It is evident from results of this study that the application of bioresource based Module-5 comprising of seed treatment with *Rhizobium* strain-B2 @ 100 ml/kg seeds, soil application of *Trichoderma viride* mixed with FYM @ 2 L/20 kg and AM fungi @ 2 kg of soil/ m^2 and foliar application of extracts of garlic and drake @ 5 % improved yield attributing character, seed yield, net return and reduced incidence of downy mildew disease in fenugreek.

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Conflict of interest

All authors declare that they have no conflicts of interest.

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