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Effect of Plant Growth Regulators and Biofertilizer on the Yield of Fenugreek (*Trigonella foenum-graecum L.*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation entitled "Effect of plant growth regulators and bio fertilizer on growth and quality of fenugreek (*Trigonella foenum-graecum L.*)" was carried out at the Experimental field, College of Agriculture, RVSKVV, Gwalior during 2020-21 under agro-climatic and soil conditions of Northern Madhya Pradesh. The experiment was laid out in Randomized Block Design (RBD) with three replications. Each replication consists of ten treatments of biofertilizers (viz., Rhizobium, PSB and KSB) and plant growth regulators (viz., GA3 and NAA). All the treatments were randomized separately in each replication. Result showed that the different biofertilizers (i.e. Rhizobium, PSB and KSB) and plant growth regulators (i.e. GA3 and NAA) treatments significantly influenced the yield, yield parameters and economics parameters of fenugreek. Treatment T4 (Rhizobium + NAA)

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gave the maximum yield, yield parameter and economic parameter it was found best treatment combination as compared to all other treatment combinations of biofertilizers and PGRs, while the minimum yield, yield parameters and economics parameters were recorded in treatment T1 (Control).

Keywords: PSB; KSB; NAA; quality; rhizobium.

1. INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) generally known as methi, occupies an important position amongst leafy vegetables and condiment crop largely grown in northern India during Rabi season. Fenugreek is considered to have originated in South-Eastern Europe and West Asia. It is an annual herb belonging to sub family Papilionaceae family Leguminaceae. The genus Trigonella has two species viz., Trigonella foenum-graecum and Trigonellacorniculata. Fenugreek seeds contains alkaloids including trigonelline, saponins, flavonoids, mucilage protein 4.4%, moisture 86%, carbohydrates 6%, mineral matter 1.5%, fiber 1.1%, fat 0.9%, calcium 360.0 mg, sulphur 167.0 mg, sodium 76.1 mg, magnesium 67.0 mg, phosphorous 541 mg, potassium 51 mg, iron 17.2 mg, thiamine 0.05 mg, vitamin „A" 6450 IU and vitamin „C" 54 mg. Fenugreek is grown mainly in China, India, Turkey, Canada, Australia, Northern and Southern Africa, and Southern Europe [1]. In India, during 2020-21 fenugreek was cultivated in 133 thousand hectares land with an annual production of 203 thousand metric tons (NHB, 2020-21). The major fenugreek producing states are Rajasthan, Gujrat, Maharashtra, Madhya Pradesh, Haryana and Uttar Pradesh. Fenugreek is grown round the year for fresh vegetable purposes.

The yield level of fenugreek is very poor in the state of Madhya Pradesh. The reason for low productivity could be due to number of factors which can be related to production. The heavy use of chemical applications leads to adverse environmental, agricultural and healthy consequences.

In India, most of the farmers are small and marginal. Therefore, it is very difficult for them to purchase the chemical fertilizer at the higher cost. Bio- fertilizers are eco-friendly and cheap sources of nutrient, however it has been observed that the crop response to bio-fertilizers is not a spectacular as with chemical. But due to increasing additions of chemical fertilizer, the chemical properties of soil decline the yield after continuous cropping. Therefore, to maintain the soil fertility and to supply plant nutrients in balanced proportion for optimum growth, yield and quality of crop with integrated approach is to be practiced under specific agro-ecological situation through the use of bio- fertilizers of plant nutrients. The use of bio-fertilizers is the eco-friendly alternate sources to meet the nutrients requirement of crops. In recent years, bio-fertilizers have emerged as a promising component of integrated nutrients supply in agriculture. Bio- fertilizers include mainly the nitrogen fixing, phosphate solubilising and plant growth promoting micro-organisms. The bio-fertilizers benefiting the crop production are Azotobactor, Azospirillium, blue green algae, Azolla, PSB, mycorrhizae. However the bio-fertilizers despite of their tremendous potential and benefits are unpredictable & inconsistent in their performance under field condition. Plant growth promoting microorganisms exhibit a gradual increase in demand to the world market. One possible mechanisms for the effectiveness of biofertilizers, such as mobilization of sparingly available plant mineral nutrients nitrogen fixer, phosphorus, potassium and zinc solubilizers, production of growth promoting substances, enhanced and induced resistance 13 to environmental stress factors and direct or indirect suppression of plant pathogens. Eco friendly agricultural system has emerged as an important priority area globally in view of the growing demand for safe and healthy food and long term soil-environmental sustainability and concerns on environmental pollution associated with indiscriminate use of agrochemicals. Microorganisms also play very important role as the component of the biological soil phase and also indicator of soil fertility and soil degradation. Biofertilizers are being essential component of organic farming are the preparations containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilizing or cellulolytic microorganisms used for application to seed and, soil bio-priming or composting areas with the to enhance the effective microorganisms and accelerate those microbial processes which augment enhance the availability of nutrients that can be easily assimilated by plants. Biofertilizers

play a very significant role in improving soil fertility by fixing atmospheric nitrogen, both, in association with plant roots and without it, solubilise insoluble soil phosphates minerals and produces plant growth substances in the soil. Biofertilizer contains microorganisms which promote the adequate supply of nutrients to the host plants and ensure their proper development of growth and regulation in their physiology. Effective living microorganisms are used in the preparation of biofertilizers. They are in fact being promoted to harvest the naturally available, biological system of nutrient mobilization.

According to the belief of the ancients, fenugreek stimulates digestive process as well as the metabolism in general. The seeds are used in colic flatulence, dysentery-2-diarrhea, dyspepsia with loss of appetite, chronic cough, dropsy, enlargement of liver and spleen, rickets, gout and diabetes.

2. MATERIALS AND METHODS

2.1 Location and Place of Working

The experiment was conducted at Experimental field, College of Agriculture, Gwalior during Rabi 2020-21 under agro-climatic and soil conditions of Northern Madhya Pradesh.

2.2 Experimental Details

The experiment was laid out in Randomized Block Design (RBD) with three replications. Each replication consists of ten treatments of biofertilizers (viz., Rhizobium, PSB and KSB) and plant growth regulators (viz., GA3 and NAA). All the treatments were randomized separately in each replication. The details of experiment are given below:-

Name of crop : Fenugreek (*Trigonella foenum-graecum* L.) ,Variety : RMT-354 Design : RBD No. of Treatments : 10 Replications : 03 Total no. of treatments : 30 Gross plot size : 2.5 m x 2.5 m Net plot size: 2 m x 2 m Distance between replications : 1.5 m x 1.5 m Distance between rows : 30 cm x 10 cm.

2.3 Detail of Treatments

T1 – Control
T2 – Rhizobium
T3 – Rhizobium + GA3
T4 – Rhizobium + NAA (Naphthalene acetic acid)
T5 – PSB (Phosphate solubilizing bacteria)
T6 – PSB (Phosphate solubilizing bacteria) + GA3 (Gibberellic acid)
T7 – PSB + NAA (Naphthalene acetic acid)
T8 – KSB (Potassium solubilizing bacteria)
T9 – KSB (Potassium solubilizing bacteria) + GA3(Gibberellic acid)
T10 – KSB (Potassium solubilizing bacteria) + NAA (Naphthalene acetic acid)

Note: 1. RDF/basal dose N,P,K (30:25:40 kg/ha) is common for all the treatment 2. Bio-fertilizers dose Rhizobium @ 5 g/kg seed treatment, PSB @ 5g/kg seed treatment and KSB @ 5g/kg seed treatment 3. Plant growth regulators dose GA3 @ 100 ppm and NAA @ 100 ppm.

List 1. Chemical properties of experimental field

S.No.	Soil constituents	Value obtain	Method of determination
1.	Mechanical composition		Bouyoucous Hydrometer method
	Sand (%)	60.68	(Piper, 1950)
	Silt (%)	22.25	
	Clay (%)	17.07	
2.	Soil pH (1:2 soil- water ratio)	7.8	pH meter [2]
3.	Electrical conductivity (ds/m)	0.14	Conductivity meter at 25ºC [2]
4.	Organic carbon (g/kg)	4.83	Walkley and Black method (1934)
5.	Available nitrogen (kg/ha)	218.0	Alkaline potassium permanganate method [3]
6.	Available phosphorus P_2o_5(kg/ha.)	15.12	Olsen's method [4]
7.	Available potassium K_2O (kg/ha)	192.0	Flame photometer [2]

2.4 Statistical Analysis

SPSS-27.0 software was used for statistical analysis. The data obtained were subjected to ANOVA (ANOVA in the RBD design) of Fisher (1958) and Panse and Sukhatme (1978), means of significance separated by a critical difference (CD) of 0.05% (CDP = 0 .05%) level of importance.

3. RESULTS AND DISCUSSION

3.1 Yield Parameters

3.1.1 Number of pods per plant

Result clearly (Table 1) shows that biofertilizers (like- Rhizobium, PSB and KSB) and plant growth regulators (like- GA3 and NAA) were non-significantly influenced on days required for seed germination for fenugreek. The result showed that treatment T4 (Rhizobium + NAA) gave the minimum (4.00) days required for seed germination and it was found 46 significantly superior as compared to all other treatments, while the maximum days required for seed germination (6.67) was recorded in treatment T1 (Control). Similar results for most of the characters were also reported by Bairva et al. [5], Gendy et al. [6], Naimuddin et al. [7], Krishnaveni et al. [8], Godara et al. [9], Pavankumar et al. [10], Sharanya et al. [11], Saxena and Singh [12] and Reddy et al. [13].

3.1.2 Number of seed per pod

The results clearly indicate (Table 1) that the different treatment combination of of biofertilizers and plant growth regulators were significantly influenced the number of seed per pod of fenugreek. The maximum number of seed per pod (16.00) was recorded in treatment T4 (Rhizobium + NAA), it was found significantly superior treatment as compared to other treatments and was at par to treatment T3 (Rhizobium + GA3), T6 (PSB + GA3), T7 (PSB + NAA), T9 (KSB + GA3) and T10 (KSB + NAA). However, the treatment T1 (Control) gave the minimum number of seed per pod (12.00) in fenugreek. These results are supported by the findings of Gendy et al. [6], Pavankumar et al. [10], Raiyani et al. [14], Sharanya et al. [11] and Reddy et al. [13].

3.1.3 Weight of Seed per Pod (g)

The result revealed that the maximum weight of seed per pod (0.170 g) was recorded in treatment T4 (Rhizobium + NAA), it was found significantly superior treatment combination of plant growth regulators and bio fertilizer as compared to other treatments and it was at par to treatment T3 (Rhizobium + GA3), T6 (PSB + GA3), T7 (PSB + NAA), T9 (KSB + GA3) and T10 (KSB + NAA). However, the minimum weight of seed per pod (0.125 g) was observed in treatment T1 (Control). This may be due to increased supply of major plant nutrients and are required in larger quantities for growth and development of plants. The different biofertilizers fixed the nitrogen and available phosphorus to plants this helps to increase in yield. Nitrogen accelerates the development of growth and reproductive phases and protein synthesis, thus promoting number of pod and seed weight per pod this result increase in yield. Findings are in agreement with those of Meena et al. [15], Badar et al. [16], Kumawat et al. [17], Pavankumar et al. [10] and Reddy et al. [13].

Table 1. Effect of plant growth regulators and biofertilizer on number of pods per plant and number of seed per pod of fenugreek

Treatment	Number of pods per plant	Number of seed per pod	Weight of seed per pod (g)
T1 – Control	25.02	12.00	0.125
T2 – Rhizobium	28.02	13.67	0.144
T3 – Rhizobium + GA3	36.89	15.33	0.163
T4 – Rhizobium + NAA	38.07	16.00	0.170
T5 – PSB	27.62	13.00	0.136
T6 – PSB + GA3	34.67	14.33	0.151
T7 – PSB + NAA	37.03	15.67	0.166
T8 – KSB	26.04	12.33	0.129
T9 – KSB + GA3	30.80	14.00	0.148
T10 – KSB + NAA	35.49	14.67	0.155
SEm ±	**0.636**	**0.782**	**0.0082**
CD 5%	**1.890**	**2.323**	**0.0244**

3.1.4 Seed yield per plant (g), Seed yield per plot (g), Seed yield per hectare (q) and Test weight (g)

The data regarding seed yield per plant, seed yield per plot, seed yield per hectare(q) and test weight is presented in Table 2.

The results indicated that the biofertilizers (i.e. Rhizobium, PSB and KSB) and plant growth regulators (i.e. GA3 and NAA) were significantly influenced the different seed yield per plant of fenugreek. Treatment T4 (Rhizobium + NAA) gave the maximum (6.49 g) seed yield per plant and it was found significantly superior as compared to all other treatments. It was at par to treatments T3 (Rhizobium + GA3), T7 (PSB + NAA) and T10 (KSB + NAA), while the minimum seed yield per plant (3.12 g) was recorded in treatment T1 (Control).

The Table 2 clearly shows that the different treatment combination of biofertilizers and plant growth regulators were significantly influenced the seed yield per plot of fenugreek. The maximum seed yield per plot (973.05 g) and seed yield 15.57 quintal per hectare was found in treatment T4 (Rhizobium + NAA), it was found significantly superior treatment as compared to other treatments and was at par to treatment T3 (Rhizobium + GA3), T7 (PSB + NAA) and T10 (KSB + NAA). However, the treatment T1 (Control) gave the minimum seed yield per plot (468.30 g) in fenugreek. Different biofertilizers and PGRs accelerate the development of growth and reproductive phases and protein synthesis, thus promoting pods per plant this result increase in yield. Increase in yield parameters of fenugreek with biofertilizers seems owing to increased supply of plant hormones by the microorganisms or by roots as results of reaction to microbial colonization. The beneficial effect of organic manures like FYM and vermicompost on fenugreek yield might also be due to its continuous contribution in supplying addition plant nutrients and increasing the availability of native soil nutrients. Similar results for most of the characters were also reported by Gendy et al. [6], Naimuddin et al. [7], Meena et al. [15], Krishnaveni et al. [8], Maryhaokip et al. [18], Singh et al. [19], Krishnaveni et al. [8], Godara et al. [20], Godara et al. [9], Pavankumar et al. [10], Raiyani et al. [14], Sharanya et al. [11], Saxena and Singh [12] and Reddy et al. [13].

It was recorded that the different treatment combination of biofertilizers and plant growth regulators were significantly influenced the test weight of fenugreek. The maximum test weight was recorded in treatment T4 (Rhizobium + NAA), it was found significantly superior treatment as compared to other treatments. However, the treatment T1 (Control) gave the minimum test weight in fenugreek. These results are supported by the findings of Naimuddin et al. [7], Meena et al. [15], Shivran et al. (2016), Pavankumar et al. [10] and Sharanya et al. [11].

3.2 Economics of the Treatments

Economics of the treatments is presented in Table 3. The different treatment combination of biofertilizers and plant growth regulators significantly influenced the economical treatment of fenugreek. Treatment T4 (Rhizobium + NAA) significantly superior as compared to all other treatments, it gave the maximum gross returns (108982 Rs./ha), net returns (76882Rs./ha) and B:C ratio (3.4), while the 76 maximum cost of cultivation (32200 Rs/ha) was recorded under treatment T10. However the minimum cost of

Table 2. Effect of plant growth regulators and bio fertilizer on weight of seed per pod, seed yield per plant, seed yield per plot and test weight of fenugreek

Treatment	Seed yield per plant (g)	Seed yield per plot (g)	Seed yield per hectare (q)	Test weight (g)
T1 – Control	3.12	468.30	7.49	10.40
T2 – Rhizobium	4.03	604.80	9.68	10.52
T3 – Rhizobium + GA3	6.01	901.50	14.42	10.60
T4 – Rhizobium + NAA	6.49	973.05	15.57	10.64
T5 – PSB	3.76	564.39	9.03	10.49
T6 – PSB + GA3	5.28	791.49	12.66	10.55
T7 – PSB + NAA	6.16	924.40	14.79	10.62
T8 – KSB	3.35	502.71	8.04	10.44
T9 – KSB + GA3	4.54	681.05	10.90	10.54
T10 – KSB + NAA	5.51	826.75	13.23	10.58
SEm ±	**0.347**	**52.092**	**0.833**	**0.033**
CD 5%	**1.032**	**154.77**	**2.476**	**0.098**

Table 3. Effect of plant growth regulators and bio fertilizer on economics of the treatments of fenugreek

Treatment	Economics of the treatments			
	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	B:C
T1 – Control	30000	52449	22449	1.7
T2 – Rhizobium	30100	67738	37638	2.3
T3 – Rhizobium + GA3	31600	100968	69368	3.2
T4 – Rhizobium + NAA	32100	108982	76882	3.4
T5 – PSB	30150	63211	33061	2.1
T6 – PSB + GA3	31650	88646	56996	2.8
T7 – PSB + NAA	32150	103533	71383	3.2
T8 – KSB	30200	56304	26104	1.9
T9 – KSB + GA3	31700	76278	44578	2.4
T10 – KSB + NAA	32200	92596	60396	2.9

cultivation (30000 Rs./ha), gross returns (52449 Rs./ha), net returns (22449 Rs. /ha) and B:C ratio (1.7) was recorded in treatment T1(Control). Application of different doses of biofertilizers and plant growth regulators improving the growth and yield of fenugreek which ultimately increase the economically yield of fenugreek. Similar results for most of the characters were also reported by Purbey [21], Ashif et al. [22], Mehta et al. [23], Bairva et al. [5], Meena et al. [24] and Godara et al. [20].

4. CONCLUSION

It can be concluded from the result of present investigation that the different biofertilizers (i.e. Rhizobium, PSB and KSB) and plant growth regulators (i.e. GA3 and NAA) treatments significantly influenced the yield parameters, yield and economical parameters of fenugreek. Treatment T4 (Rhizobium + NAA) gave the maximum yield parameter, yield and economical parameter it was found best treatment combination as compared to all other treatment combinations of biofertilizers and PGRs, while the minimum yield parameters, yield and economical parameter were recorded in treatment T1 (Control).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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