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Somdutt
Research Scholar, Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

LN Dashora
Professor, Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

SL Mundra
Professor, Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

J Choudhary
Professor, Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Piyush Choudhary
Research Scholar, Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Correspondence
Somdutt
Research Scholar, Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Effect of inorganic and organic sources of fertilization on productivity of fenugreek (*Trigonella foenum-graecum* L.) under agro-climatic conditions of Southern Rajasthan

Somdutt, LN Dashora, SL Mundra, J Choudhary and Piyush Choudhary

Abstract
A field experiment was laid out to study the effects of inorganic and organic sources of fertilization on growth, yield attributing characters and yield of fenugreek during *rabi*, 2017-18 at Instructional Farm of Agronomy, Rajasthan College of Agriculture, Udaipur (Raj.). The results revealed the superiority of 100% RDF brought significant improvements in various growth parameters *viz.*, plant height, number of branches plant^{-1}, dry matter accumulation, CGR and RGR of fenugreek at successive growth stages of crop as well as at harvest. Number and weight of nodules plant^{-1} were statistically higher under 75% RDF. These enhancements manifested in improvement in yield attributing characters *viz*. number of pods plant^{-1}, pod length, seeds pod^{-1}, seed weight plant^{-1} and test weight, consequently increased seed (2218.7 kg ha^{-1}) and haulm yield (8932.5 kg ha^{-1}). The application of FYM 5 t ha^{-1} + *Rhizobium* + PSB significantly improved plant height (92.2 and 94.0 cm) and dry matter accumulation (14.27 and 25.16 g plant^{-1}) at 90 DAS and at harvest, respectively. Significant improvement in number of nodules (11.9 and 30.2) and nodule weight plant^{-1} (33.2 and 50.5 mg) was recorded under vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB at 45 and 60 DAS, respectively. Yield attributes *viz.*, number of pods plant^{-1} (26.8) and pod length (10.7 cm) was significantly higher under FYM 5 t ha^{-1} + *Rhizobium* + PSB. Seed weight plant^{-1} (13.0 g) and seed yield (2141.9 kg ha^{-1}) significantly increased with application of vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB. Significant improvement was recorded in number and weight of nodules plant^{-1} with combined application of 75% RDF + vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB at 45 and 60 DAS. Treatment combination 100% RDF + vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB recorded significantly higher grain yield (2540.7 kg ha^{-1}), which was at par with 100% RDF + FYM 5 t ha^{-1} + *Rhizobium* + PSB (2285 kg ha^{-1}). Among different treatment combinations the highest net return (₹ 70,781.15 ha^{-1}) was recorded under 100% RDF + vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB and highest BC ratio (1.96) was recorded under *Rhizobium* + PSB.

Keywords: Inorganic, organic sources of fertilization, fenugreek, growth, yield, Rajasthan

1. Introduction
The fenugreek (*Trigonella foenum-graecum* L.), is an annual herb and belongs to leguminous family. It is a seed spices crop which is multi used, every part of crop consumed in one or other form. It has important position amongst leafy vegetables, condiment, seed spices and medicine. Its grains are used to form a concentrate feed for animals, besides this, it has immense medicinal utility. It is a source for preparing raw materials of pharmaceutical industry, like in steroidal hormones (Helambe and Dande, 2012) [3]. The seeds are bitter in taste due to the presence of alkaloid "*Trigonelline*". Fenugreek seeds have high nutritive value containing protein (9.5%), fat (10%), crude fibre (18.5%), carbohydrates (42.3%) and many other nutrients and vitamins. It also contains a good percentage of gums (23.06%), mucilage (28%), trigonelline (0.13-0.35%) and saponins (1.7%), having calorific value 370 calories 100 g^{-1} seed. Its fresh tender leaves and pods are rich in iron, calcium, ascorbic acid and protein, are eaten as fried vegetables (Das, 2007) [1].

India ranks first in fenugreek production in the world and produced 248 thousand tonnes of fenugreek seed from an area of 2.3 lakh hectares with the productivity of 1089 kg ha^{-1}. In India the major fenugreek producing states are Rajasthan, Gujarat, Madhya Pradesh, Haryana, Uttar Pradesh and Maharashtra. Rajasthan accounts for over 77 per cent of India's output (Spice Board of India, Cochin, Ministry of Commerce & Industry, Government of India, 2016).

Nitrogen plays significant role in plants proper growth, development and reproduction. Nitrogen is an integral constitute of chlorophyll, amino acids, nucleic acid and ATP. Now, it is well documented that nitrogen is one of the most abundant elements on earth. Phosphorus is second most major nutrient after nitrogen which is essential for root initiation and their

development. Besides, recommended dose of fertilizers, use of low-cost nutritional inputs is an hourly requirement. The foremost organic manures like farmyard manure (FYM), vermicompost and biofertilizers that can largely supplement or replace fertilizers. Application of organic manures not only improves the soil organic carbon for sustaining the soil physical health but also increases plant nutrients. Biofertilizers enhances soil fertility, crop productivity and production in agriculture as they are eco-friendly.

2. Materials and Methods

The experiment was carried out during *Rabi*, 2017-18 at Instructional Farm of Agronomy, Rajasthan College of Agriculture, Udaipur (Rajasthan). Experimental site's soil texture was clay- loam, slightly alkaline in reaction, low in available nitrogen and medium in available phosphorus. The experiment was laid out in factorial randomized block design with three replications. The experiment comprising three levels of inorganic sources (50% RDF, 75% RDF and 100% RDF) and five levels of organic sources (FYM 10 t ha^{-1}, Vermicompost 5 t ha^{-1}, *Rhizobium* + Phosphate solubilising bacteria (PSB), Vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB and FYM 5 t ha^{-1} + *Rhizobium* + PSB) of nutrients. The variety Pratap Raj Methi-45 (PRM-45) was used and maintained 30 cm row to row and 10 cm plant to plant spacing, using seed rate of 25 kg ha^{-1}. Before sowing seed were treated with biofertilizers *viz. Rhizobium meliloti* and PSB as per treatment recommendations. Full dose of nitrogen and phosphorus was applied as a basal. Five plants were selected randomly from each plot to record observations on growth and yield attributing characters.

3. Results and Discussion

3.1 Growth characters

A perusal of data (Table 1) indicates that the application of 100% RDF (40 kg N + 40 kg P) significantly improved plant height at 30, 60, 90 DAS and at harvest over 75 and 50% RDF. Phenological parameters *viz.* days to 50 per cent flowering and days to maturity were not significantly altered by inorganic sources of nutrients. Increasing levels of inorganic sources from 50% RDF to 100% RDF significantly strengthen number of branches $plant^{-1}$, dry matter accumulation at subsequent stages and at harvest. Greater RGR at 30-60 and 60-90 DAS, CGR at 60-90 DAS, number of nodules and nodules weight $plant^{-1}$ at 45 and 60 DAS obtained under application of 100% RDF as compared to 75 and 50% RDF. This could be due to early and abundant nitrogen availability resulting in a better nutritional environment in the root zone for growth and development of plant. The results of significant improvement in overall growth of fenugreek crop under the influence of 100% RDF (40 kg N + 40 kg P) are in close conformity with findings of Mehta *et al*. (2012) [5].

Data (Table 1) shows that significant increment in plant height (92.2 cm and 94.0 cm) at 90 DAS and at harvest was recorded with the application of FYM 5 t ha^{-1} + *Rhizobium* + PSB. Similarly, the maximum dry matter accumulation by $plant^{-1}$ at 90 DAS (14.27 g) and at harvest (25.16 g) was also observed under the application of FYM 5 t ha^{-1} + *Rhizobium* + PSB. Application of vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB significantly increased number of nodules $plant^{-1}$ at 45 (11.9) and 60 DAS (30.2). Similarly, significant increment in weight of nodules $plant^{-1}$ at 45 (33.2 mg) and 60 DAS (50.5 mg) were also recorded with the application of Vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB. Application of vermicompost promotes the lush growth of plants which may be due to the presence of plant growth promoters like auxins and cytokinin in vermicompost, which are responsible for cell division and cell elongation. The results of present investigation indicated higher growth characters under influence of organic sources of fertilization are in close conformity with findings of Vedpathak and Chavan (2016) [7].

3.2 Yield attributes and yield

The results (Table 2) revealed that the Application of 100% RDF significantly enhanced yield attributing aspects consequently grain, haulm and biological yields. This fertility level produced seed yield of 2218.7 kg ha^{-1} which was significantly higher over 75% and 50% RDF. Use of 100% RDF recorded 222.6 and 595.1, 1839.4 and 3075.7 and 2061.8 and 3670.7 kg higher seed, haulm and biological yield, respectively over 75% and 50% RDF. Higher yield emerges due to cumulative effect of overall increase in plant growth of fenugreek crop as obvious from significant increase in plant height, dry matter accumulation, number of branches, CGR and RGR with the application of inorganic sources particularly by 100% RDF. The results are in close conformity with findings of Godara *et al.* (2017) [2].

Application of FYM 5 t ha^{-1} + *Rhizobium* + PSB significantly increased number of pods $plant^{-1}$ (26.8) and pod length (10.7 cm). Whereas, the maximum seed weight $plant^{-1}$ was recorded with the application of Vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB. Statistically higher seed (2141.9 kg ha^{-1}) and biological yield (9852.3 kg ha^{-1}) was recorded with the application of Vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB. This may be due to *Rhizobium* and PSB, which have enhanced the availability of N and P in soil as major plant nutrients as well as inoculation of both N_2 fixer and PSB benefit plants than any group of organisms alone and may have additional benefits. These results are in close conformity with findings of Mehta *et al.* (2012) [5] and Godara *et al.* (2017) [2].

3.3 Economics

Data presented in Table 2 clearly indicates that the maximum net return (` 55,804 $ha^{-1}$) was recorded under 100% RDF, whereas minimum (` 34,553 ha^{-1}) was recorded under 50% RDF. Further data shows that maximum net return (` 58,771 $ha^{-1}$) was recorded under *Rhizobium* + PSB. Among different treatment combinations the highest net return (` 70,781.15 ha^{-1}) was recorded under 100% RDF + vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB, which statistically superior over all rest of treatment combinations. The highest B-C ratio (1.29) was recorded with application of 75% RDF, which was higher over 100% RDF (1.23) and 50% RDF (0.98). Among organic sources of nutrients highest B-C ratio (1.96) was recorded under *Rhizobium* + PSB, which was higher over all other treatments. These results are in closely in line with the findings of Godara *et al.* (2017) [2] and Malav *et al.* (2018) [4].

Table 1: Effect of inorganic and organic sources of fertilization on growth characteristics of fenugreek

Treatments	Plant height (cm)		Number of branches plant^{-1}		Dry matter accumulation (g plant^{-1})		Number of nodules (plant^{-1})		Nodules weight (mg plant^{-1})	
	90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest	45 DAS	60 DAS	45 DAS	60 DAS
Inorganic sources										
50% RDF	76.7	81.0	5.27	5.33	11.10	18.32	7.2	22.1	16.6	36.8
75% RDF	84.9	86.9	5.61	5.81	12.93	22.23	8.2	29.4	22.7	47.4
100% RDF	96.4	99.1	6.31	6.41	15.73	28.01	7.5	26.7	16.8	43.5
SEm ±	1.78	1.86	0.11	0.11	0.32	0.49	0.2	0.7	0.4	1.0
CD (P=0.05)	5.16	5.39	0.32	0.33	0.93	1.43	0.6	2.0	1.1	3.0
Organic sources										
FYM 10 t ha^{-1}	79.8	83.6	5.53	5.63	12.51	20.67	6.6	23.1	18.0	39.1
Vermicompost 5 t ha^{-1}	83.6	87.1	5.62	5.73	12.66	21.31	6.3	23.4	13.9	34.7
Rhizobium + PSB	85.1	88.1	5.68	5.78	13.04	22.19	6.6	26.7	15.0	42.1
Vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB	89.3	92.4	5.80	5.93	13.80	24.93	11.9	30.2	33.2	50.5
FYM 5 t ha^{-1} + *Rhizobium* + PSB	92.2	94.0	6.02	6.17	14.27	25.16	6.8	26.8	13.4	46.5
SEm ±	2.30	2.40	0.14	0.15	0.41	0.64	0.3	0.9	0.5	1.3
CD (P=0.05)	6.66	6.96	NS	NS	1.20	1.84	0.8	2.5	1.5	3.9

Table 2: Effect of inorganic and organic sources of fertilization on yield attributes yield and economics of fenugreek

Treatments	Yield attributes						Yield (kg ha^{-1})		Economics	
	Number of pods plant^{-1}	Pod length (cm)	Seeds pod^{-1}	Seed weight (g plant^{-1})	Test weight (g)	Seed	Haulm	Biological	Net return (₹ ha^{-1})	B-C ratio
Inorganic sources										
50% RDF	19.9	9.4	15.7	10.6	11.0	1623.6	5856.8	7480.4	34553.1	0.98
75% RDF	24.4	10.2	16.8	12.3	11.4	1996.1	7093.1	9089.3	49378.7	1.29
100% RDF	30.9	11.3	17.9	14.2	12.0	2218.7	8932.5	11151.1	55804.3	1.23
SEm ±	0.5	0.2	0.3	0.2	0.2	40.5	281.0	271.7	1417.7	0.04
CD (P=0.05)	1.6	0.5	0.7	0.7	0.6	117.4	814.1	787.1	4107.0	0.11
Organic sources										
FYM 10 t ha^{-1}	22.9	9.8	16.4	11.7	11.2	1783.9	6471.2	8255.1	31991.3	0.63
Vermicompost 5 t ha^{-1}	24.2	10.0	16.7	12.0	11.3	1837.3	7174.0	9011.3	30970.3	0.56
Rhizobium + PSB	24.9	10.3	16.8	12.3	11.4	1902.2	7384.0	9286.2	58771.4	1.96
Vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB	26.6	10.6	17.0	13.0	11.8	2141.9	7710.4	9852.3	55639.0	1.30
FYM 5 t ha^{-1} + *Rhizobium* + PSB	26.8	10.7	17.1	12.9	11.7	2065.3	7731.1	9796.4	55521.6	1.39
SEm ±	0.7	0.2	0.3	0.3	0.3	52.3	362.8	350.8	1830.3	0.05
CD (P=0.05)	2.0	0.7	NS	0.9	NS	151.6	NS	1016.1	5302.1	0.14

4. Conclusion

On the basis of results emanated from the present investigation conducted during *Rabi* 2017-18, it is concluded that under prevailing agro-climatic conditions, fenugreek crop fertilized with 75% RDF (30 kg N + 30 kg P ha^{-1}) and vermicompost 2.5 t ha^{-1} + *Rhizobium* + PSB proved most efficient in enhancing yield of fenugreek. In view of the above, it is to opine that under the prevailing agro-climatic conditions of southern Rajasthan to realize reasonably higher seed yield of fenugreek with better medicinal values and to minimize dependency on chemical fertilizers the crop should be fertilized with a combination of inorganic fertilizers, organic manures with inoculation of bio-fertilizers.

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