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Response of Best Management Practices on Growth, Productivity and Profitability in Fenugreek (*Trigonella foenum-graecum* L.) under Transitional Plain of Luni Basin of Rajasthan

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ABSTRACT

The field experiments were conducted during *rabi* (November–March, 2018–19 and 2019–2020) with *Trigonella foenum-graecum* L. sown at Agricultural Research Sub-station Sumerpur, Pali, Agriculture University, Jodhpur, Rajasthan, India to investigate the impact of treatments on growth, productivity and economics of *Trigonella foenum-graecum* L. There were ten treatments namely control (T_1), 50% RDF (T_2), 75% RDF (T_3), 100% RDF (T_4), 50% RDF+Vermicompost at 2 t ha^{-1} (T_5), 75% RDF+Vermicompost at 2 t ha^{-1} (T_6), 50% RDF+Vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1} (T_7), 75% RDF+Vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1} (T_8), 50 % RDF+Vermicompost at 2t ha^{-1}+Seed treatment with Rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1} (T_9) and 75 % RDF+Vermicompost at 2 t ha^{-1}+Seed treatment with Rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1} (T_{10}) replicated three times and arranged in a randomized block design (RBD). The treatment consisting combination of 75% RDF+VC at 2 t ha^{-1}+ bioinoculants significantly improved the status of organic carbon, available N and P of soil after harvest of the crop. Among the integrated treatments, application of 75% RDF+VC at 2 t ha^{-1}+bioinoculants recorded maximum productivity (1.65 t ha^{-1}). The treatment T_4 (100% RDF) provided highest B:C ratio (2.88) followed by treatment T_{10} (2.60) and T_8 (2.58) which were at par with the 100% RDF. Overall, the study concluded that 75% RDF along with 2 t ha^{-1} vermicompost and bioinoculants optimized fenugreek yield, improved soil fertility and increased profitability.

KEYWORDS: Fenugreek, growth, productivity and profitability, soil health

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1. INTRODUCTION

India is the leading seed spice producing and exporting country in the world where, it is grown in the states of Rajasthan, Gujarat, Tamil Nadu, Uttar Pradesh, Himachal Pradesh, Madhya Pradesh and Andhra Pradesh. Fenugreek (*Trigonella foenum-graecum* L.) is an annual diploid species with chromosome number 2n=16. It is popularly known as "Methi", belongs to the family "Fabaceae". In Rajasthan, fenugreek is commercially cultivated as spice in most of the district like Nagaur, Chittorgarh, Bundi, Churu, Jhalawar, Jhunjhunu, Jodhpur, Sikar, Jaipur etc. Fenugreek is extensively used as fresh leaves (green leafy vegetable), chopped leaves (flavouring agent), seeds (spice, condiment or medicines), extracts and powders (medicines). Rajasthan represents major share of India's production, accounting for over 80% of the nation's total fenugreek production. However, farmers are not able to achieve its potential yield due to various factors. Besides aberrant weather conditions, the soils of Rajasthan are poor in nitrogen (N), phosphorus (P), and zinc (Zn) (Ram et al., 2021). Fenugreek contains different types of minerals and vitamins such as potassium (603 mg (100 g^{-1}), magnesium (42 mg (100 g^{-1}), calcium (75 mg (100 g^{-1}), zinc (2.4 mg (100 g^{-1}), manganese (0.9 mg (100 g^{-1}), copper (0.9 mg (100 g^{-1}), iron (25.8 mg (100 g^{-1}), vitamin C (220 mg (100 g^{-1}) and β carotene (19 mg (100 g^{-1}) (Wani and Kumar, 2018; Al-Jasass and Al-Jasser, 2012). The productivity of the crop is low due to many limiting factors such as lack of proper management of fertilizers and nutrients. Fertilizer application plays an important role in augmentation of crop production. However, indiscriminate and exclusive use of inorganic fertilizers may lead to deteriorate environment, like water pollution, soil degradation and greenhouse gas emissions (Tilman et al., 2002; Khan et al., 2008; Wen et al., 2017; Chen et al., 2018). Fertilizer is one of the important inputs in crop production. Application of required quantities of chemical fertilizers is expensive as the cost of chemical fertilizers is ever increasing. Organic manures like vermicompost, FYM and composts etc., are a potential source of macro and micronutrients and it improves soil structure by providing binding effect to soil aggregates, increases water holding capacity, improves buffering capacity of soils, soil productivity and enzymatic activity of soils. It is well known fact that organic manures (FYM, Biocompost or Vermicompost) accelerate the process of decomposition as well as ready energy source for microbial proliferation, add plant nutrients, increases water retention capacity, microbial population, humic substances of the soil (Parewa et al., 2014, Soobhany et al., 2017, Nurhidayati et al., 2018, Parewa et al., 2019). Biofertilizers also play an important role in the increasing availability of mineral nutrients. They increase the biological fixation of atmospheric nitrogen and also enhance phosphorus availability to the crop by solubilizing fixed phosphorus of soil. Therefore, introduction of efficient strain of Rhizobium, *Azosprillium* and PSB in the soil may be helpful in more nitrogen, phosphorus fixation and consequently boosting up productivity of crop and soil fertility. Conjunctive use of inorganic and organic sources of nutrients not only supplies nearly all nutrients throughout the growing period of crop but also sustain soil health (Sharma et al., 2014; Parewa et al., 2021; Parewa et al., 2022). A judicious combination of chemical fertilizers, organic manures and biofertilizer should be formulated for crops and cropping system within the ecological, social and economic possibilities. Considering the above facts and views the main objective of the experimental trial was to find out the best management practices for growth, productivity, profitability, and sustainable soil health management in fenugreek under the agro-climatic conditions of the Transitional Plain of Luni Basin in Rajasthan.

2. MATERIALS AND METHODS

The research was carried out during *Rabi* season (November–March) of 2018–19 and 2019–20 at Agricultural Research Sub Station, Sumerpur (25.09° N and 73.05° E and 272 m above the mean sea level) in the Pali District, Rajasthan, India. Soil samples were collected randomly from 0–15 cm depth on the site using soil auger, mixed thoroughly, bulked, air dried and sieved to pass through a 2 mm sieve for chemical analysis. All physico-chemical properties of the experimental field's soil were determined by the standard methods. The soil of experimental field was sandy loam in texture having low soil organic carbon (0.36%), low available N (200 kg ha^{-1}), low available phosphorus (19.40 kg ha^{-1}), medium available potassium (260.0 kg ha^{-1}), bulk density (1.30 Mg M^{-3}), particle density (2.62 Mg M^{-3}) with slightly alkaline in nature pH 8.2 (1:2.5 soil: water ratio). The crop was sown using variety (RMt- 305) in the month of November, 2018 and 2019 at recommended spacing. There were ten treatments namely control (T_1), 50% RDF (T_2), 75% RDF (T_3), 100% RDF (T_4), 50% RDF+Vermicompost at 2 t ha^{-1} (T_5), 75% RDF+Vermicompost at 2 t ha^{-1} (T_6), 50% RDF+Vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1} (T_7), 75% RDF+Vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1} (T_8), 50% RDF+Vermicompost at 2 t ha^{-1}+Seed treatment with Rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1} (T_9) and 75% RDF+Vermicompost at 2t ha^{-1}+Seed treatment with Rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1} (T_{10}) replicated three times and arranged in a randomized block design (RBD). Fertilizer and fenugreek (RMt- 305) seeds were obtained from the Agricultural Research Sub Station, Sumerpur. Vermicompost was prepared at farm for experimental purpose. Rhizobium and PSB were collected from the department of Soil Science and Agricultural Chemistry, Rajasthan College of Udaipur, MPUAT, Udaipur (Rajasthan). The different inorganic and organic nutrient sources alone and in combinations were applied uniformly as per the treatment and incorporated into the soil at the time of sowing. The irrigation and all other operations were performed as per recommendation for the crop. The data on various growth, yield attributes and yield were recorded in different treatments and analysis of initial and post harvest soil samples were done by adoption of standard procedure. Experimental data recorded in various observations were statistically analyzed in accordance with the 'Analysis of Variance' technique as described by (Fisher, 1950). The critical difference (CD) for the treatment comparisons were worked out where ever the variance ratio (F test) was found significant at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1. Growth attributes

The data of growth attributes have been presented in tabular form for the convenient of presentations. Pooled data of plant height at harvest of the crop revealed that among all the treatments, 75% RDF+Vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1} (T_8) was found significantly superior (Table 1). At the time of harvest of fenugreek, maximum plant height was recorded under treatment (T_{10}) 75% RDF+vermicompost at 2 t ha^{-1}+Seed treatment with Rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1} (27.92 cm) which was at par with treatment (T_8) 75% RDF+vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1} (27.32 cm) and significantly superior over control and 50% RDF. The higher plant height might be attributed due to rapid mineralization. The combined application of inorganic and organic source of nutrients along with soil application of biofertilizer ensured regular availability of nutrient throughout crop growing season. Moreover, organics and biofertilizers, have solubilizing effect on native soil nutrients due to the action of organic acids produced during decomposition and resulted in higher growth attributes. The beneficial effect of integrated organic and inorganic sources of nutrients on growth parameters was also reported by Kumar et al., 2024 and Biswasi et al., 2020. Kumar et al. (2024) reveled significantly higher growth parameters in cauliflower such as plant height, number of leaves, length of leaves, width of leaves, plant spread under the treatment of 75% nitrogen through RDF+25% nitrogen through FYM+Azotobacter at 5 kg ha^{-1} as compared to control and 100% N through RDF (120:80:40 kg ha^{-1}). Similarly, Biswasi et al. (2020; 2025) recorded significantly superior growth parameters such as plant height, leaf area index and dry matter accumulation of maize crop with application of 75% recommended dose of nitrogen (RDN) and 25% RDN supplied through fertilizer and vermicompost, respectively as compared to 100% recommended dose of fertilizer.

Table 1: Effect of different nutrient sources on growth and yield attributes, yield of fenugreek and economics (Pooled)

Treatment	Plant height (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	Test weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	B:C Ratio
T_1	21.30	22.03	11.77	11.53	1.13	2.30	3.43	2.44
T_2	24.13	25.57	13.60	11.82	1.30	2.54	3.83	2.54
T_3	25.98	26.49	13.70	11.93	1.33	2.58	3.91	2.55
T_4	27.17	29.08	15.10	12.85	1.54	2.78	4.32	2.88
T_5	26.97	26.91	14.73	12.80	1.42	2.65	4.06	2.23
T_6	27.45	27.98	15.10	12.98	1.49	2.87	4.36	2.34
T_7	27.15	28.87	14.90	12.93	1.47	2.82	4.29	2.29
T_8	27.32	30.12	15.50	13.10	1.65	2.93	4.58	2.58
T_9	27.30	29.28	15.63	12.95	1.49	2.85	4.35	2.38
T_{10}	27.92	30.10	15.67	13.13	1.64	2.92	4.55	2.60
SEm±	1.26	1.15	0.47	0.40	0.05	0.09	0.14	0.13
CD (p=0.05)	3.62	3.29	1.35	1.14	0.15	0.26	0.40	0.37

T_1: Control; T_2: 50% RDF; T_3: 75% RDF; T_4: 100% RDF; T5: 50% RDF+vermicompost at 2 t ha^{-1}; T_6: 75% RDF+vermicompost at 2 t ha^{-1}, T_7: 50% RDF+Vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1}; T_8: 75% RDF+vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1}; T_9: 50% RDF+vermicompost at 2 t ha^{-1}+seed treatment with rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1} and T_{10}: 75% RDF+vermicompost at 2 t ha^{-1}+Seed treatment with rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1}; *: RDF: 20 kg ha^{-1} nitrogen and 40 kg ha^{-1} phosphorus

3.2. *Yield attributes*

The yield attributes of fenugreek were strongly influenced due to chemical fertilizer alone and combined use of inorganic, organic sources along with biofertilizers and indicated significant difference with respect to number of pods plant^{-1}, number of seeds pod^{-1} and test weight recorded significantly higher values over control during experimentation (Table 1). The pooled data of number of pods plant^{-1} recorded highest by the application of 75% RDF+vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1}, which was at par with treatment T_{10} and found superior over treatment T_1, T_2, T_3 and T_5. The highest pooled number of seeds pod^{-1} (15.67) and test weight (13.13 g) were recorded by application of 75% RDF+vermicompost at 2 t ha^{-1}+seed treatment with Rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1}. The prevalence of organic and inorganic source of nutrient combinations could be ascribed to increase in amount of yield parameters. Supply of nutrient through organic and inorganic sources promotes flowering and fruiting and its subsequent partitioning in the sink. The results corroborated with those of Tank et al., (2022) and Kumar et al. (2024). Tank et al., (2022) reported that treatment consisting 50% RDF along with *Rhizobium* at 1.5 kg ha^{-1} gave maximum number of pods, number of seeds, pod length of fenugreek as compared to control and 100% RDF (40:20:20 NPK kg ha^{-1}).

3.3. *Effect on yields*

The yields were significantly improved by application of inorganic fertilizer alone or in combination with vermicompost and biofertilizer over the control (Table 1). The highest pooled seed (1.65 t ha^{-1}), stover (2.93 t ha^{-1}) and biological yield (4.58 t ha^{-1}) were obtained with conjunctive use of 75% RDF+vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1} which was at par with 75% RDF+vermicompost at 2t ha^{-1}+Seed treatment with Rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1}. The positive response to combined application of inorganic fertilizers, vermicompost and biofertilizer might be attributed to the better nutrient availability and its favourable effect on soil physical and chemical properties resulting in increased yield attributes and finally higher yield (Parewa et al., 2022; Kumar et al., 2024a). The results on yield thus confirmed the trend observed earlier worker in the yield attributing characters and upheld the need of supplementing the RDF through inorganic with organic. The results further emphasized the utter need for organic manuring along with chemical fertilizers. The higher yield might be due to fact that integration of chemical fertilizer, organic nutrient sources and biofertilizer enhanced direct nutrients availability to the plant and improved soil fertility (Parewa et al., 2022).

3.4. *Effect on soil properties*

The mean data of the two year 2018–19 and 2019–20 revealed that bulk density (BD) of soil influence significantly (Table 2). The maximum bulk density (1.30 Mg M^{-3}) was obtained under treatment T_1 (control) and lowest under T_5 to T_{10} (1.27 Mg M^{-3}). The treatment T_5 to T_{10} remained at par with each other and significantly higher over other treatments. Bulk density value was decreased from 1.30 to 1.27 Mg M^{-3} under treatment of combination of fertilizer,

Table 2: Effect of different nutrient sources on selected soil properties of experimental filed after harvesting of fenugreek crop (Mean of two years)

Treatments	pH	Bulk density (Mg M^{-3})	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1	8.20	1.30	0.36	191.00	16.03	257.90
T_2	8.19	1.29	0.37	207.33	18.10	258.13
T_3	8.18	1.29	0.38	211.00	19.00	258.47
T_4	8.17	1.28	0.39	216.00	19.97	258.87
T_5	8.18	1.27	0.39	216.67	18.53	262.07
T_6	8.17	1.27	0.40	218.67	19.90	262.07
T_7	8.17	1.27	0.39	219.67	18.77	262.13
T_8	8.17	1.27	0.42	220.33	20.07	262.53
T_9	8.18	1.27	0.39	218.00	18.63	262.13
T_{10}	8.17	1.27	0.42	220.33	20.03	262.97
SEm±	0.006	0.006	0.010	3.074	0.233	1.659
CD (p=0.05)	NS	0.02	0.03	9.13	0.69	NS
Initial value	8.2	1.30	0.36	200.00	19.40	260.00

vermicompost and bioinoculants treatments. Similarly, organic carbon (0.42%), available nitrogen (220.33 kg ha^{-1}) and phosphorus (20.07 kg ha^{-1}) were recorded highest in treatment T_8 followed by T_{10} which were significantly higher over control. The increment was due to slow release of nutrients through manures and enriching the available pool of nutrients. Integrated application of diverse source of nutrients not only increased the nutrient uptake but also improved soil fertility and helped to get desired production with sustainable soil health (Parewa et al., 2014; Parewa et al., 2022). Similar findings were also found by Kumar et al., (2024a) noticed significant improvement in soil properties like organic carbon and available N, P and K with the treatment 75% NPK+FYM at 2.5 t ha^{-1}+vermicompost at 1.5 t ha^{-1} and Mohammed and Alkobaisy (2024) reported that half of recommended dose of mineral fertilizer with vermicompost at 8 Mg h^{-1} and biofertilization recorded the significantly higher and maximum values of total nitrogen, available phosphors and available potassium.

3.5. *Effect on economics*

Integrated application of fertilizer, organic manure and biofertilizer had significant influence on the economics of the fenugreek crop. Combined application of 75% RDF+vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1} fetched maximum gross return (₹ 92480), net return (₹ 66730), which was at par with T_8 (75% RDF+Vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1} +PSB at 2.5 kg ha^{-1}) and T_{10} (75% RDF+vermicompost at 2 t ha^{-1}+seed treatment with Rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1}) (Table 1). The highest benefit cost (B:C) ratio (2.88) was recorded with the application of 100% RDF (T_4) which remain at par with T_{10} (75% RDF+vermicompost at 2 t ha^{-1}+seed treatment with Rhizobium at 600 g ha^{-1}+PSB 600 g ha^{-1}) and T_8 (75% RDF+vermicompost at 2 t ha^{-1} +Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1}) and superior over rest of the treatments. This might be due to the fact that inorganic sources enhance nutrient availability resulting in vigorous plant growth and dry matter production which in turn resulted in better flowering and pod formation thereby giving higher yield attributes and yield and economics over control. These results were very close to the findings of Parewa et al. (2022) that stated 75% RDF+FYM at 10 tha^{-1} and PGPR+VAM gave significant higher net return and B:C ratio in comparison to 100% RDF in wheat and similarly, Tank et al. (2022) also found highest B:C ratio (3.44:1) under treatment 50% RDF and *Rhizobium* at 1.5 kg ha^{-1} as compared to control and 100% RDF.

4. CONCLUSION

The maximum pooled seed, stover and biological yield (1.65, 2.93 and 4.58 t ha^{-1}) were recorded with 75% RDF+Vermicompost at 2 t ha^{-1}+Rhizobium at 2.5 kg ha^{-1}+PSB at 2.5 kg ha^{-1} (T_8) followed by 75 % RDF+Vermicompost at 2 t ha^{-1}+Seed treatment with Rhizobium at 600 g ha^{-1}+PSB at 600 g ha^{-1} (T_{10}) treatments. 100% RDF gave a higher B:C ratio, T_8 and T_{10} proved more beneficial for soil health and sustainable production. Therefore, integrating 75% RDF with vermicompost and biofertilizers (either soil-applied or seed-treated) was recommended for sustainable yield improvement.

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