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Study of Yield, Nutrient Content and Uptake of Fenugreek as Influenced by Phosphorous and Zinc Fertilization

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ABSTRACT: Phosphorus (P) and zinc (Zn) are essential nutrients for plant growth, and due to high intensive agricultural production, their deficiency in soils and the antagonistic interaction between P and Zn are important concerns world-wide. Thus, the present experiment was laid out at research farm of Rajasthan Agriculture Research Institute, Durgapura, in split plot design during rainy seasons of 2015-16 and 2016-17 which was replicated three times to study the growth, productivity and economics of fenugreek - pearl millet cropping system. There were four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5/ha /ha) and six treatments of zinc and zinc solubilizer [0, 2.5 and 5.0 kg Zn/ha, zinc solubilizer (*Bacillus endophyticus*), 2.5 kg Zn/ha + zinc solubilizer & 5 kg Zn/ha + zinc solubilizer) tested on fenugreek crop. The results were found as the highest total nitrogen and potassium contents and uptake by fenugreek were recorded with 40 kg P_2O_5/ha while, phosphorus content was up to 60 kg P_2O_5/ha and zinc content was decreasing trend. Similarly all contents and uptake and yield were recorded with5 kg Zn/ha + zinc solubilizer.

Keywords: fenugreek, Nutrient content and uptake, phosphorus, yield, zinc and zinc solubilizer.

INTRODUCTION

Spices comprise fragrant products of plant origin used for imparting flavor and taste to food and beverages. Rajasthan is the major producer of fenugreek, which annually produces 1.6 lakh tonnes from an area of 1.2 lakh ha having average productivity of 1218 kg/ha (GOR, 2016-17). The seeds of fenugreek contain "Diosgenin steroid which is used for the production of steroidal drugs and hormones such as testosterone, glucocorticoids and progesterone (Kakani and Anwer, 2012).) Phosphorous deficiency is a major constraint to crop production as 80 % Indian soils are low to medium in phosphorus availability due to very low P-use efficiency (15–20%) thus enrichment with P fertilization to soil is potential alternative to achieve optimum plant growth and higher productivity (Paramesh *et al.,* 2020). Phosphorus increasing water and nutrient uptake by plants by enhancing root development and early tillering capacity (Jinger *et al.*, 2018). Zinc fertilization enhances zinc utilization and regulates plant growth by increasing physiological activity in plant and fenugreek seeds contain the highest amount of zinc among seed spices (Kumar *et al.,* 2014). In India, after nitrogen and phosphorus, zinc is the third most important essential plant nutrient (Singh *et al.,* 2015) as Zn use efficiency is seldom exceeds 2%. Due to intensive cultivation and use of high yielding varieties the repeated applications over the years lead to their build up in the soil which, affecting production potential of soil by affecting soils and plant interactions (Paramesh *et al.,* 2020). The microbial activities in plant rhizosphere are potential tool that fulfill zinc requirement of plant by solubilising the complex zinc in soil through the production of phytohormones, antibiotics, siderophores, vitamins, antifungal substances, and hydrogen cyanide (Goteti *et al*., 2013). Hence, it is plausible that exploitation of native zinc mineralizing and solubilizing bacteria may aid in overcoming zinc deficiency and increase availability of zinc to crops. To test this hypothesis, this experiment was performed to study the effect of P and Zn fertilization on nutrient content, uptake and yield of fenugreek and to evaluate their interaction effect on plant growth.

MATERIALS AND METHODS

During winter seasons of the years 2015-16 and 2016-2017 an experiment was conducted at research farm of

Rajasthan Agricultural Research Institute-Durgapura (SKNAU, Jobner). The physicochemical properties of the field at 0-30 cm soil depth such as the soil was loamy sand texture, in which available nitrogen and phosphorous content of soil was low, medium in potassium status and low in zinc content (139.2, 26.6, 182 kg/ha and 0.37 ppm) during 2015-16. The respective properties, during 2016-17 were as (134.2, 24.5, 180 kg/ha and 0.35 ppm). During respective years the pH of the soil was 8.3 and 8.1 and organic carbon content was 0.17 and 0.14 per cent. The experiment was replicated with three times under split plot design and there were four phosphorous levels (0, 20, 40 and 60 kg P_2O_5/ha) tested as main plot treatments and six zinc treatments (0, 2.5, 5.0 kg Zn/ha, zinc solubilizer (*Bacillus endophyticus*), 2.5 kg Zn/ha + zinc solubilizer and 5 kg Zn/ha + zinc solubilizer). The all plots were fertilized with a uniform dose of 20 kg N/ha along with phosphorous and zinc as per treatment were drilled through DAP and zinc sulphate (21%). The compensatory dose of sulphur was applied through elemental sulphur to compensate the sulphur obtained from different levels of zinc.

The plant samples were analysed for estimation of N with methods of Snell and Snell, (1949), P and K with Jackson, (1973) and Zn contents through the method (Lindsay and Norvell, 1978). The total uptake of nitrogen, phosphorous, potassium and zinc by the crop at harvest of each treatment was computed by multiplying seed and straw yields with their respective contents and adding the same as per formula given below.

$$\text{Nutrient uptake (for NPK) (kg/ha)} = \frac{\text{Nutrient content in seed (\%)} \times \text{Seed yield (kg/ha)} + \text{Nutrient content in straw (\%)} \times \text{Straw yield (kg/ha)}}{100}$$

$$\text{Nutrient uptake (for Zn) (g/ha)} = \frac{\text{Nutrient content in seed (ppm)} \times \text{Seed yield (kg/ha)} + \text{Nutrient content in straw (ppm)} \times \text{Straw yield (kg/ha)}}{1000}$$

RESULT AND DISCUSSION

A. Total nutrient content

The significant increase in total nitrogen and potassium contents of fenugreek was recorded when crop was fertilized up to 40 kg P_2O_5/ha and beyond that the increase was non-significant, during both the years. However, this significant increase in phosphorous content was up to with application of 60 kg P_2O_5/ha, during both the years. Data presented in Table 1, reveal that application of different levels of phosphorous significantly decreased the total zinc content of fenugreek. The highest decrease in zinc content of seed and straw was recorded with the application of 60 kg P_2O_5/ha and it was significantly effective in reducing zinc content, over all preceding levels, during both the years. This might be due to more absorption and translocation of nutrients from source to sink led to improve the contents of nutrients in to plant parts (Jinger *et al.,* 2020). On the contrary, zinc content of seed and straw decreased significantly with every increase in applied phosphorous due to higher concentration of phosphorous in soil form insoluble zinc phosphate which reduces uptake of zinc by seed and straw, eventually reduces the zinc content in seed and straw which suggest the mutual antagonistic effect of excessive P on Zn-absorption and further translocation from roots to other parts of the plants (Paramesh *et al.,* 2020).

Table 1: Effect of phosphorous and zinc fertilization on total nutrient contents of fenugreek during both the years.

Treatments	Nitrogen content (%)		Phosphorous content (%)		Potassium content (%)		Zinc content (ppm)	
	2016	2017	2016	2017	2016	2017	2016	2017
Phosphorus (P_2O_5 kg ha^{-1})								
0.0	3.504	3.538	0.483	0.491	2.406	2.372	30.87	32.19
20	3.686	3.733	0.512	0.525	2.517	2.533	28.66	29.36
40	3.798	3.852	0.536	0.548	2.617	2.606	26.33	26.99
60	3.860	3.917	0.553	0.563	2.653	2.637	24.84	25.27
SEm±	0.027	0.025	0.0034	0.0033	0.017	0.020	0.220	0.258
CD (P=0.05)	0.094	0.087	0.012	0.011	0.060	0.069	0.76	0.89
Zinc(kg ha^{-1})								
0.0	3.484	3.565	0.548	0.565	2.407	2.402	23.00	23.72
2.5	3.666	3.726	0.532	0.543	2.520	2.512	26.10	27.08
5.0	3.787	3.818	0.509	0.516	2.602	2.590	30.02	30.09
Zinc solubilizer	3.626	3.687	0.530	0.546	2.485	2.481	24.91	25.72
2.5 + zinc solubilizer	3.822	3.860	0.508	0.517	2.608	2.602	30.02	31.01
5.0 + zinc solubilizer	3.888	3.905	0.498	0.503	2.666	2.635	32.00	33.09
SEm±	0.034	0.035	0.0052	0.0054	0.016	0.017	0.32	0.32
CD (P=0.05)	0.098	0.099	0.015	0.015	0.047	0.050	0.90	0.92

The fertilization to the crop with zinc resulted in increased total nitrogen and potassium contents of fenugreek and the highest increase was obtained with the application of 5 kg Zn/ha + zinc solubilizer which was at par with 2.5 kg Zn/ha + zinc solubilizer except in increasing potassium content. However, improvement in total phosphorous content was in deceasing with increasing level of zinc fertilization, might be due to dilution effect. Further, effects of all the zinc treatments were significantly superior over control, during both the years. The treatment effect of 2.5 kg Zn/ha was non-significantly differed with zinc solubilizer in improving total nitrogen content during both the years. However, every treatment of zinc significantly enhanced the total zinc content over control and the highest zinc content was recorded with application of 5.0 kg Zn/ha + zinc solublizer which was significantly better over rest of the treatments followed by 2.5 kg Zn/ha + zinc solubilizer and 5.0 kg Zn/ha. Since the zinc enhanced biological nitrogen fixation (BNF) increased the availability of nitrogen in the rhizosphere and increased the nitrogen concentration of the fenugreek crop. The increase in total nitrogen, potassium and zinc uptake may be due to synergistic interaction between nitrogen and zinc and due to the positive relationship between potassium and zinc.

B. Total nutrient uptake

During 2016-17 increasing level of phosphorus significantly enhanced the total nitrogen phosphorus, potassium, zinc uptakes by crop as compared to the control and the highest values of uptake were recorded with of 60kg P_2O_5 ha^{-1} that was significantly better than the preceding levels. However, during 2015-16, uptake of all these nutrients significantly increased only up to 40 kg P_2O_5 ha^{-1}, beyond that it was at par with 60 kg P_2O_5 ha^{-1}. Thus, enrichment with phosphorus application increased root growth and its functional activity also increased microbial activity in plant root nodules, resulting in higher translocation of nutrients from plant rhizosphare to aerial parts. Since uptake of nutrients is primarily a function of dry matter production and nutrient contents, increased dry matter production implies improvement in nutrient contents. The results corroborate with Fageria *et al*. (2016).

The highest uptake values of all these nutrients were recorded with 5kg Zn ha^{-1} + zinc solubilizer, followed by 2.5kg Zn ha^{-1} + zinc solubilizer, 5 kg Zn ha^{-1} and 2.5kg Zn ha^{-1} during 2015-16. Application of every treatment of zinc resulted significant variations to each other in increasing total nitrogen and potassium uptake; however, during 2016-17, only effect of 5 kg Zn ha^{-1} was statistically at par with that of 2.5kg Zn ha^{-1} + zinc solubilizer. During both the years, total uptake of phosphorus increased significantly with 5kg Zn ha^{-1} over zinc solubilizer but it was found at par with that of 2.5kg Zn ha^{-1} + zinc solubilizer and 5kg Zn ha^{-1} + zinc solubilizer. Effect of 5kg Zn ha^{-1} and 2.5kg Zn ha^{-1} were almost same. Every treatment had significant variations to each other in total uptake of zinc. During both the years, effect of 5kg Zn ha^{-1} statistically was at par with 2.5kg Zn ha^{-1} + zinc solubilizer (Table 2). Biological nitrogen fixation increased by zinc, thus the availability of nitrogen in the rhizosphere is increased and that in turn improved its uptake. Singh *et al.*, (2015) observed that, Zn increased the cation exchange capacity of roots which might have helped in increased absorption of zinc from the soil and consequently increased zinc uptake in fenugreek. The synergistic relationship between nitrogen and zinc and also the positive interaction of potassium and zinc resulted in enhanced total nitrogen, potassium and zinc uptake. The present findings support the results of Morshedi and Farahbakhsh (2010).

Table 2: Effect of phosphorous and zinc fertilization on total nutrient uptake by fenugreek during both the years.

Treatments	Nitrogen uptake (kg/ha)		Phosphorous uptake (P_2O_5 kg/ha)		Potassium uptake (K_2O kg/ha)		Zinc uptake (g/ha)	
	2016	2017	2016	2017	2016	2017	2016	2017
Phosphorus (P_2O_5 kg ha^{-1})								
0.0	35.82	43.65	12.98	13.72	42.94	44.66	41.35	45.36
20	41.83	54.60	16.08	17.64	52.33	57.88	43.96	48.68
40	46.80	62.90	18.88	20.59	60.98	65.73	45.15	49.56
60	49.44	66.48	20.23	22.03	64.32	68.58	44.37	48.66
SEm±	0.91	0.66	0.41	0.12	1.43	0.72	1.05	0.53
CD (P=0.05)	3.14	2.30	1.42	0.42	4.93	2.51	NS	1.85
Zinc(kg ha^{-1})								
0.0	36.56	46.55	16.00	17.24	45.84	47.80	31.67	33.83
2.5	41.26	54.41	17.06	18.48	52.92	57.33	39.70	43.74
5.0	45.16	60.34	17.22	18.72	58.08	63.81	48.43	53.25
Zinc solubilizer	39.56	51.83	16.24	17.85	50.01	52.74	36.33	39.47
2.5 + zinc solubilizer	47.72	62.64	17.80	19.27	60.41	64.82	50.48	55.90
5.0 + zinc solubilizer	50.59	65.68	17.94	19.40	63.61	68.78	55.63	62.21
SEm±	0.52	0.89	0.28	0.30	0.81	0.85	0.67	0.79
CD (P=0.05)	1.50	2.54	0.80	0.86	2.32	2.43	1.91	2.27

C. Biological yield

A perusal of data presented in Fig. 1 showed that biological yield differed on account of varied phosphorous levels. Significant increase in biological yield was recorded up to application of 40 kg P_2O_5/ha that was higher over control and 20 kg P_2O_5/ha but was statistically at par with 60 kg P_2O_5/ha, during both the years. Application of 40 kg P_2O_5/ha, improved the biological yield by 29 and 33 per cent higher over control during respective years. Moreover, Phosphorus fertilization enhanced nutrients availability to the crop which led to greater synthesis and utilization of assimilates into the pods also phosphorus is a key component of ATP which involved in energy transformation in plant and also in seed formation ultimately improved the performance of various yield attributes and finally yield. The results corroborate with Paramesh *et al*. (2020); Jinger *et al.* (2021).

Further examination of data indicates that significant enhancements in biological yield were recorded with the zinc treatments. Treatment effect of 5.0 kg Zn/ha + zinc solublizer produced the highest biological yield, during both the years that was significantly superior over rest of the treatments, during 2016-17. During 2015-16, every treatment was found significantly varying to each other except 2.5 kg Zn/ha + zinc solublizer which was statistically at par with 5 kg Zn/ha + zinc solublizer. However, during 2016-17, response of 5 kg Zn/ha was also significantly better over control, zinc solublizer alone and 2.5 kg Zn/ha, but remained statistically at par with 2.5 kg Zn/ha + zinc solublizer. The increase in biological yield in terms of per cent, over control, was obtained 25 and 31 per cent, with application of 5.0 kg Zn/ha + zinc solublizer, respectively, during 2015-16 and 2016-17. Carbohydrate metabolism is positively influenced by zinc nutrition by improving photosynthesis, formation and transport of sucrose, and starch biosynthesis. It is well known fact that application of zinc in soil complexed as insoluble form and make unavailable to plants so application of zinc solubilizer is alternative to build the zinc pools in soil and improve concentration of zinc in plant.

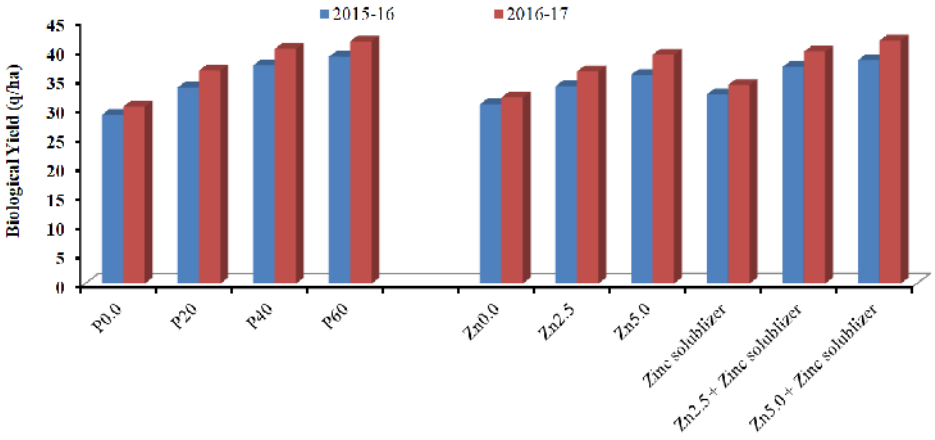

Fig. 1. Biological yield of fenugreek crop obtained with phosphorous and zinc fertilization.

CONCLUSION

On the basis of this study it is concluded that the highest nutrient content and uptake of fenugreek crop was observed under 60 kg P_2O_5/ha and 5 kg Zn/ha + zinc solublizer, while decreasing trend was recorded with phosphorous and zinc contents with increasing level of these nutrients. P and Zn fertilization could be a sustainable approach for obtaining better crop yield particularly under arid regions of Western India. Further, their interaction effect and different kinds of Zn solubilizer could be evaluated with diverse cropping system and moisture regime under different land use.

FUTURE SCOPE

P and Zn fertilization could be a sustainable approach for obtaining better crop yield particularly under arid regions of Western India. Further, their interaction effect and different kinds of Zn solubilizer could be evaluated with diverse cropping system and moisture regime under different land use.

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Conflict of Interest. None.

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