Indian Journal of Agronomy **55** (3): 197—202 (September 2010)

Performance of fenugreek (*Trigonella foenum-graecum*) - pearlmillet (*Pennisetum glaucum*) system as influenced by phosphorus and zinc application to fenugreek

R. SAMMAURIA[1] AND R.S. YADAV

College of Agriculture, Rajasthan Agricultural University, Bikaner, Rajasthan 334 006

Received: May, 2009

ABSTRACT

A field experiment was conducted in split plot design with three replications during winter and rainy seasons of 2003 to 2005 at Bikaner to study the effect of phosphorus (P) levels (0, 8.7, 17.5 and 26.2 kg/ha) and zinc [0, 2.5, 5.0 & 7.5 kg soil application, 0.25%, 0.5% $ZnSO_4$ foliar spray once (45 DAS) twice (45 and 60 DAS)] applied to fenugreek, on the performance of fenugreek (*Trigonella foenum-graecum*) - pearlmillet (*Pennisetum glaucum*) cropping system. Application of 17.5 kg P/ha and 5.0 kg Zn/ha resulted in 24.7 and 14.7% higher seed yield of fenugreek, when compared with control (0.77 and 0.85 tonnes/ha). Residual effects of 26.2 kg P/ha and 7.5 kg Zn/ha applied to fenugreek increased grain yield of pearlmillet by 62 and 22%, respectively. Application of 26.2 kg P/ha and 7.5 kg Zn/ha to fenugreek significantly increased the content and uptake of P and Zn fenugreek and pearl millet. However, increasing levels of either of these two nutrients was found to have depressive effect on content and uptake of other by fenugreek. Combined application of 26.2 kg P/ha + 7.5 kg Zn/ha resulted in the highest yields of both the crops. The net returns and B: C ratios were also highest in 26.2 P and 7.5 kg Zn applied treatments.

Key words: Agronomic characters, Fenugreek, Foliar application, Nutrient uptake, Pearlmillet, Phosphorus, Zinc

After the introduction of *Indira Gandhi Nahar Pariyojana*, the landscape of Indian Thar desert is at active pace of transformation due to assured supply of water. But recently the reduction in water availability has reemphasized the need of its judicious use. Pearlmillet (*Pennisetum glaucum*) is main rainy season crop that is well adapted to harsh agro-climatic conditions of the region. Similarly, fenugreek (*Trigonella foenum-graecum*) is an important *rabi* spice crop of the Rajasthan and its area is increasing in this region due to assured prices. Thus, fenugreek-pearl millet is an upcoming cropping system of this region.

Phosphorus (P) plays vital role in production of fenugreek as its availability not only improves the growth and yield but also enhances the symbiotic N-fixation. Zinc (Zn) content of seeds of fenugreek is the highest among the seed spices, and for sustainable and profitable yields, its external application is essential (Rethinam and Sadanandan, 1994) as the soils of this region are extremely deficient in Zn. Pearlmillet also responds to Zn application to a great extent (Jain, 2004). A greater part of applied P and Zn remain in soil as unutilized residue because only 20% of P and 3-6% of Zn is utilized by the crop to which they are applied (Raju *et al*., 2005; Patel *et al.,* 2003). Therefore, it would be desirable to optimize the nutrient use efficiency and curtail the cost of fertilizers for making the system more remunerative. P application to legumes not only benefits that particular crop and increases its yields but also favourably affect performance of succeeding non-legume crop (Ganeshamurthy *et al*., 2003). Pearl millet due to its finer efficient extracting roots, is capable of giving good production even on residual fertility. Hence, it is of paramount importance to study effect of P and Zn with respect to their direct and residual effect in fenugreek- pearl millet cropping system. In view of this, present investigation was conducted.

MATERIALS AND METHODS

The experiment was conducted during the winter and rainy season of 2003-04 and 2004-05 at Agricultural Research Station, Rajasthan Agricultural University, Bikaner. The soil was loamy sand, low in organic carbon (0.14%), available N (104.9 kg/ha), phosphorus (10.9 kg/ha) and

Corresponding author (E mail: rsamrau@yahoo.co.in)

[1]**Present address:** Associate Professor (Agronomy), Dryland Farming Research Station, MPUA&T, Arjia Bhilwara, Rajasthan 311 001

DTPA extractable zinc (0.17 ppm) and high in potassium (206.4 kg k/ha). Treatments comprised of 4 levels of P (0, 8.7, 17.5 and 26.2 kg/ha) and 8 treatments of Zn (0, 2.5, 5.0 and 7.5 kg Zn/ha as soil application, 0.25% $ZnSO_4$ foliar spray at 45 DAS, 0.25 % $ZnSO_4$ foliar spray at 45 and 60 DAS, 0.5% $ZnSO_4$ foliar spray at 45 DAS and 0.5 % $ZnSO_4$ foliar spray at 45 and 60 DAS) in sub-plots. The experiment was laid out in split plot design with three replications. A uniform dose of 30 kg N/ha along with P and soil applied Zn as per treatment were drilled through diammonium phosphate and zinc sulphate (33%), respectively. Formulations for foliar sprays were made by dissolving the weighed amount of $ZnSO_4$ and half amount of slaked lime as neutralizer in water and sprayed as per treatment. Fenugreek 'Rmt1'was sown on 17 and 8 November, 2003 and 2004, respectively in rows 30 cm apart and harvested on 2 and 8 April, 2004 and 2005, respectively. For assessment of residual effect of applied nutrients, pearlmillet 'HHB-67' was raised during rainy season; that was sown on 28 July, 2004 and 5 July, 2005 in rows 30 cm apart and harvested on 11 October and 20 September, respectively. Recommended dose of nitrogen (90 kg/ha) was applied to pearlmillet in two splits, half as basal and remaining as top dress at 30 days after sowing and no other nutrient was applied. For estimation of concentration of nutrient in seed and straw, samples were ground to a fine powder and were analysed by following the standard methods. Economics of treatments were worked out using market price of inputs and minimum support price of outputs.

RESULTS AND DISCUSSION

Yield attributes and productivity of crops

Fenugreek : Application of 26.2 kg P/ha being at par with 17.5 kg P/ha recorded significantly higher number of pods/plant and pod length than 8.7 kg P/ha. However, seeds/pod and test weight increased significantly only up to 8.7 kg P/ha (Table 1). Significant increase in number of pods was also recorded up to 5.0 kg Zn/ha application, however, seeds/pod, pod length and test weight increased only up to 2.5 kg Zn/ha. Among the foliar applications, all treatments remaining at par to each other, enhanced pod/plant significantly.

Significantly higher seed and biological yields of fenugreek were recorded up to application of 17.5 kg P/ha (Table 2). On pooled basis, respective application of 8.7, 17.5 and 26.2 kg P/ha resulted in 19, 26 and 28% higher seed yield when compared with control. Application of different Zn treatments except 0.25% $ZnSO_4$ foliar spray at 45 DAS during 2003-04, significantly improved the yield of fenugreek. However, soil application was found more effective and yields increased up to 5.0 kg Zn/ha. Among the foliar applications, two sprays of 0.5% $ZnSO_4$ was at par with soil application of 2.5 kg Zn/ha. On pooled basis, seed yield of fenugreek increased by 10, 15 and 16% with the soil application of 2.5, 5.0 and 7.5 kg Zn/ha, respectively when compared with control. Application of P improves N-fixation of legumes due to its role in root development and proliferation and supply of required energy for the process (Singh *et al.,* 1999). Increased and continuous availability of N in soil along with applied P resulted in enhanced root, shoot growth and biomass of legumes (Raju *et al.,* 2005). Zinc also has definite metabolic role in different vital processes, as it is the constituent of many enzymes participating in metabolic reactions (Ram *et al.,* 2002a and c).

Pearlmillet : Significant improvement was observed in the yield attributes of pearlmillet due to residual effect of P and Zn. Effective tillers/plant increased due to residual effect of 17.5 kg P/ha , however, ear length and test weight improved significantly only up to 8.7 kg P/ha (Table 1). Among Zn treatments, effective tillers / plant increased up to 5.0 kg Zn/ha, whereas ear length and test weight increased up to 2.5 kg Zn/ha.

During 2003-04, significant response was obtained in grain and biological yields due to residual effect of P up to 26.2 kg/ha, however, during 2004 -05, it was seen up to 17.5 kg P/ha only (Table 2). On the pooled basis, residual effects of 8.7, 17.5 and 26.2 kg P/ha resulted in 28, 48 and 62% higher seed yield, respectively over control (1.52 tonnes/ha). Amongst the Zn treatments, residual effect of 7.5 kg Zn/ha resulted in the highest pearlmillet grain and biological yield, however, it was at par with 5.0 kg Zn/ha during 2003-04. No residual effect of Zn foliar sprays was observed on pearlmillet yields. On pooled basis, grain yield of pearlmillet increased by 9, 16 and 22%, when compared with control (1.93 tonnes/ha) with the residual effect of 2.5, 5.0 and 7.5 kg Zn/ha, respectively.

Fenugreek being a legume as preceding crop acted as a catalyst and enhanced the availability of native and applied P from deeper layers whereas pearlmillet extracts its most of P from upper layer with highly extracting fine roots. Further, during rainy season, intermittent wetting and drying and higher temperature conditions increased the solubility and diffusivity of P and Zn (Raju *et al.,* 2005; Adhikari and Rattan, 2002). These results are in consonance with those reported by Jat and Shaktawat (2003). Cereals require higher amount of Zn and its involvement in metabolism of tryptophane and auxin is well documented (Ram *et al.,* 2002b). In present study, early emergence of pearlmillet ears was noticed in Zn treated plots (data not reported) enabling longer grain filling period and thus significant improvement in yield attributes and seed yield.

Table 1. Effect of phosphorus and zinc fertilization of fenugreek on yield attributes and yield of fenugreek, pearl millet (pooled data of 2 years) and cropping system productivity

Treatment	Fenugreek						Pearl millet						
	Pods/ plant	Seeds/ pod	Pod length (cm)	Test weight (g)	Seed yield (t/ha)		Effective tillers/ plant	Ear length (cm)	Test weight (g)	Grain yield (t/ha)		System productivity (t/ha)	
					2003-04	2004-05				2003-04	2004-05	2003-04	2004-05
Phosphorus (kg/ha)													
0	19.2	13.29	9.16	11.38	0.72	0.82	3.33	20.1	6.63	1.50	1.54	3.50	3.37
8.7	22.8	13.70	9.45	11.53	0.78	1.06	3.79	21.2	6.93	1.71	2.18	3.87	4.55
17.5	24.1	14.00	9.80	11.62	0.80	1.12	3.99	21.5	7.06	2.08	2.41	4.32	4.92
26.2	24.4	14.09	9.89	11.74	0.83	1.14	4.13	22.0	7.14	2.40	2.53	4.70	5.07
SEm±	0.2	0.13	0.12	0.07	0.01	0.01	0.07	0.3	0.04	0.04	0.05	0.06	0.06
CD (P=0.05)	0.7	0.39	0.36	0.22	0.04	0.04	0.22	1.0	0.12	0.15	0.18	0.19	0.21
Zinc (kg/ha)													
0	20.8	13.45	9.24	11.30	0.74	0.96	3.47	20.7	6.78	1.83	2.02	3.88	4.16
2.5	23.1	13.99	9.69	11.77	0.79	1.07	4.00	21.8	7.12	1.99	2.22	4.18	4.62
5.0	24.5	14.22	9.89	11.73	0.84	1.11	4.28	22.3	7.19	2.09	2.38	4.44	4.86
7.5	24.7	14.29	9.87	11.73	0.84	1.13	4.47	22.5	7.25	2.15	2.52	4.49	5.04
$ZnSO_4$ (0.25%) spray once	21.8	13.50	9.37	11.38	0.75	1.00	3.50	20.6	6.79	1.83	2.04	3.94	4.27
$ZnSO_4$ (0.25%) spray twice	22.0	13.57	9.49	11.55	0.76	1.00	3.60	20.5	6.80	1.83	2.04	3.96	4.28
$ZnSO_4$ (0.5%) spray once	22.0	13.55	9.46	11.45	0.76	1.00	3.56	20.6	6.79	1.83	2.04	3.94	4.28
$ZnSO_4$ (0.5%) spray twice	22.2	13.60	9.60	11.63	0.77	1.00	3.61	20.7	6.79	1.82	2.04	3.96	4.29
SEm±	0.2	0.14	0.11	0.11	0.01	0.01	0.08	0.3	0.05	0.05	0.05	0.05	0.06
CD (P=0.05)	0.5	0.39	0.30	0.30	0.02	0.03	0.15	0.9	0.13	0.13	0.14	0.14	0.16

Pearl millet equivalent grain yield of system (PMEGY)

The PMEGY increased significantly up to application of 26.2 kg P/ha in 2003-04 and up to 17.5 kg P/ha in 2004-05 (Table 2). This implies that recurrent application of phosphorus leads to its accumulation in soil and its further external application reduces. During 2004-05, the yield levels were higher, yet the significant response was obtained up to 17.5 kg P / ha, validating the fact that greater proportion of applied P remains in soil that can be utilized by the succeeding crops. Further, results strengthen the suggestion that P needs to be applied on system basis for better utilization and profitability.

Significant PMEGY response was obtained up to application of 5.0 kg Zn/ha in 2003-04 however, during 2004-05 the PMEGY increased up to 7.5 kg Zn/ha. Zn requirement of both the crops and Zn-fixation potential of the soil of experimental site is very high. Under such conditions, higher amount of Zn is needed and such application can be cost effective only when it is applied on system basis. The hypothesis of greater fixation potential of soil is further verified by the fact that the highest dose was promising during second year where in accumulated amount of Zn would be even greater.

Interaction effect

Fenugreek recorded significant improvement in seed yield up to application of 17.5 kg P/ha and 5.0 kg Zn/ha (Table 3). Significantly higher seed yield was obtained with the combined application of 26.2 kg P + 7.5 kg Zn/ha when compared with other combinations. The combination of sub-optimum level of Zn with higher levels of P resulted in antagonistic effect. Increased availability of P probably caused the reduction in solubility, uptake and translocation of Zn leading to significant reduction in seed yield.

The highest pearlmillet grain yield was also recorded with the combined application of 26.2 kg P + 7.5 kg Zn/ha that was significantly better than any other combination however, it was at par with the combination of 26.2 kg P + 5.0 kg Zn/ha. The combinations comprised of higher levels of these nutrients were in synergy in improving the yield, however, combination of sub-optimum level of one or another gave antagonistic effects.

Nutrient content and uptake

Direct effect : P content (seed and straw) increased with application of P and the highest contents and uptake were recorded with 26.2 kg P/ha (Table 4). However, increasing levels of P had depressive effect on Zn concentration. Zinc uptake by seed increased only up to 8.7 kg P/ha but straw uptake decreased with the application of 26.2 kg P/ha. Elevated level of P in soil due to its external application might have enabled corresponding increase in the content in plant system. Increase in dry matter production and / or coupled with improvements in contents facilitated significantly greater uptake of P. Decrease in Zn content might be due to the reduced translocation of Zn in plant body under environment of increased concentration of P (Sharma and Bapat, 2000). However, increasing dry matter resulted in the highest total Zn uptake with 8.7 kg P/ha.

Zinc content in seed and straw increased up to 7.5 kg Zn/ha, however, foliar applications remained statistically at par to each other, but improved Zn contents over con-

Table 2. Interaction effect of P and Zn application on seed / grain yield of fenugreek – pearlmillet cropping system (t/ha) (pooled data of 2 years)

Treatment	Phosphorus level (kg/ha)							
	Fenugreek				Pearlmillet			
	0	8.7	17.5	26.2	0	8.7	17.5	26.2
Zn level (kg/ha)	0.704	0.884	0.896	0.902	1.264	1.834	2.163	2.429
0	0.784	0.972	0.984	0.978	1.717	2.042	2.250	2.405
2.5	0.841	0.956	1.035	1.072	1.876	2.116	2.414	2.534
5.0	0.837	0.940	1.033	1.117	2.129	2.103	2.497	2.617
7.5	0.735	0.894	0.930	0.939	1.283	1.859	2.171	2.439
$ZnSO_4$ (0.25%) spray once	0.744	0.899	0.938	0.948	1.287	1.874	2.176	2.413
$ZnSO_4$ (0.25%) spray twice	0.740	0.895	0.934	0.944	1.309	1.861	2.160	2.414
$ZnSO_4$ (0.5%) spray once	0.746	0.900	0.946	0.952	1.299	1.846	2.128	2.440
$ZnSO_4$ (0.5%) spray twice	0.746	0.900	0.946	0.952	1.299	1.846	2.128	2.440
P x Zn (Zn at same level of P)								
SEm ±		0.013				0.010		
CD (P=0.05)		0.271				0.036		
P × Zn (P at same/different levels of Zn)								
SEm ±		0.003				0.031		
CD (P=0.05)		0.010				0.090		

Table 3. Effect of phosphorus and zinc application on nutrient concentration and uptake by fenugreek and pearlmillet (pooled data of 2 years)

Treatment	Phosphorus content (%)				Zinc content (mg / kg)				P uptake (kg/ha)		Zn uptake (g/ha)	
	Seed	Straw	Grain	Stover	Seed	Straw	Grain	Stover				
Phosphorus (kg/ha)												
0	0.484	0.104	0.334	0.127	26.03	15.67	32.96	20.01	5.34	45.39	10.3	136.0
8.7	0.509	0.110	0.386	0.147	24.83	13.94	32.26	19.54	6.75	49.28	14.8	161.7
17.5	0.544	0.119	0.399	0.153	23.63	12.99	31.70	19.22	7.58	48.92	17.6	183.2
26.2	0.563	0.122	0.408	0.156	22.48	12.24	31.13	18.89	7.93	47.25	19.5	191.9
SEm±	0.003	0.001	0.004	0.001	0.19	0.13	0.41	0.20	0.06	0.51	0.3	3.3
CD (P = 0.05)	0.008	0.002	0.011	0.004	0.58	0.40	1.27	0.62	0.18	1.57	0.8	10.1
Zinc (kg / ha)												
0	0.530	0.115	0.392	0.149	17.21	10.36	27.24	16.53	6.53	32.29	15.3	135.0
2.5	0.529	0.115	0.380	0.145	25.59	14.33	34.34	20.82	7.13	50.54	15.7	182.1
5.0	0.518	0.112	0.378	0.144	35.70	19.21	40.74	24.71	7.31	72.82	16.4	227.6
7.5	0.505	0.110	0.366	0.139	42.41	20.91	44.77	27.12	7.17	82.26	16.4	257.1
$ZnSO_4$ (0.25%) spray once	0.531	0.115	0.385	0.147	18.01	10.93	27.13	16.46	6.75	35.05	15.1	135.3
$ZnSO_4$ (0.25%) spray twice	0.531	0.115	0.386	0.148	18.26	11.31	27.17	16.49	6.79	36.22	15.2	135.7
$ZnSO_4$ (0.5%) spray once	0.530	0.116	0.383	0.147	18.19	11.06	27.25	16.51	6.77	35.51	15.0	135.8
$ZnSO_4$ (0.5%) spray twice	0.529	0.114	0.385	0.147	18.56	11.56	27.45	16.66	6.78	36.98	15.1	137.1
SEm±	0.004	0.001	0.004	0.001	0.22	0.13	0.41	0.20	0.07	0.51	0.3	3.4
CD (P=0.05)	0.011	0.002	0.011	0.004	0.60	0.37	1.16	0.56	0.20	1.43	0.7	9.5

Table 4. Economics, and biological yield of fenugreek-pearlmillet system (mean data) as influenced by P and Zn fertilization

Treatment	Cost of cultivation (Rs / ha)*		Net Returns (Rs / ha)			B: C ratio	Biological yield (t/ha)			
			Fenugreek	Pearl millet	System		Fenugreek		Pearlmillet	
	Fenugreek	System					2003-04	2004-05	2003-04	2004-05
Phosphorus (kg / ha)										
0	6,496	12,044	8,617	13,668	22,285	1.85	2.20	2.48	5.36	5.85
8.7	6,832	12,381	11,372	18,738	30,110	2.43	2.38	3.22	5.90	8.00
17.5	7,169	12,717	11,992	22,336	34,328	2.70	2.45	3.42	7.17	8.80
26.2	7,506	13,054	11,973	24,491	36,464	2.79	2.49	3.44	8.05	9.01
SEm±							0.04	0.03	0.16	0.20
CD (P=0.05)							0.15	0.10	0.55	0.60
Zinc (kg / ha)										
0	6,496	12,044	10,329	18,556	28,886	2.40	2.27	2.91	6.39	7.55
2.5	7,063	12,611	11,453	20,326	31,779	2.52	2.40	3.27	6.74	8.00
5.0	7,498	13,046	11,940	21,771	33,711	2.58	2.56	3.36	7.01	8.46
7.5	7,933	13,481	11,708	22,812	34,520	2.56	2.50	3.41	7.10	8.84
$ZnSO_4$ (0.25%) spray once	6,714	12,262	10,682	18,728	29,410	2.40	2.31	3.04	6.42	7.60
$ZnSO_4$ (0.25%) spray twice	6,932	12,480	10,619	18,785	29,404	2.36	2.34	3.05	6.46	7.62
$ZnSO_4$ (0.5%) spray once	6,800	12,348	10,666	18,760	29,426	2.38	2.32	3.04	6.44	7.62
$ZnSO_4$ (0.5%) spray twice	7,104	12,653	10,511	18,728	29,239	2.31	2.34	3.05	6.42	7.64
SEm±							0.03	0.04	0.17	0.19
CD (P=0.05)							0.09	0.11	0.48	0.53

PMEGY, Pearlmillet equivalent grain yield of system; (mean data); *Cost of cultivation of pearlmillet: Rs 5,548

trol. Antagonistic effect of Zn application was noticed on P content in seed and straw and significant decrease was noticed with application of 5.0 kg Zn/ha. Nourishment with Zn up to 7.5 kg/ha also increased zinc uptake in all three categories.

Soil application of Zn in extremely deficient soil increased its availability, thus improvement in Zn contents of fenugreek could be assigned to increased absorption of it in view of greater availability in the rhizosphere and greater translocation due to increased metabolic activity of plant as a result of Zn fertilization (Dubey *et al.,* 2001). Increased contents of Zn concomitant with increased dry matter production resulted in its higher uptake. On the contrary, antagonistic effect of Zn application on P content could be ascribed to impeded translocation of P due to increased Zn availability, which interfered the absorption and/or translocation of phosphorus absorbed by the roots (Jain, 2004; Ram *et al.,* 2002c). However, increase in uptake of P might be result of increase in seed and straw yields that was compensated to some extent the decrease in contents. The poor response of foliar applications of Zn on nutrient uptake was due to sub-optimum amounts of Zn application through foliar route and those too were made available once or twice and for limited period during the crop growth. Besides, there was poor absorption of the nutrient due to low canopy area of the crop at its foliar sprays as fenugreek is a slow growing crop during its early growth phase, which had poor canopy to intercept the foliar spray efficiently particularly at 45 DAS. Low uptake of nutrient by fenugreek due to foliar application of Zn when compared with its soil application has also been reported by Meena (2003).

Residual effect : The highest contents of P in pearlmillet grain and stover and uptake were recorded with the residual effect of 26.2 kg P/ha that was significantly better than 8.7 kg P/ha (Table 5). Residual effects of 26.2 and 17.5 kg P/ha resulted in significant decrease in Zn content of grain and stover. However, significantly higher Zn uptake by pearlmillet grain and stover was recorded up to 26.2 and 17.5 kg P/ha, respectively. Significantly higher P uptake by succeeding pearlmillet could be attributed to increased P contents and increased grain and stover production with the increasing levels of P. Significant increase in P content and uptake of pearlmillet seed and stover in fenugreek - pearlmillet sequence has also been reported by Jat and Shaktawat (2003). Increasing quantum of yields of grain and stover due to the residual P increased the uptake of Zn irrespective of their contents.

Zinc contents in grain and stover of pearlmillet also increased with the residual effect of soil applied Zn up to 7.5 kg/ha (Table 4). However, P content in pearlmillet grain and stover decreased significantly with the application of 7.5 kg Zn/ha. Uptake of P and Zn increased up to 5.0 and 7.5 kg Zn/ha. Residual effect of Zn foliar sprays was not significant in improving uptake of nutrients. Increase in grain and stover yield due to residual Zn facilitated greater uptake of nutrients, irrespective of their content.

Economics

Application of 26.2 kg P / ha and 7.5 kg Zn/ha gave the highest net monetary returns and benefit: cost ratios of the system.

Consequently application of 26.2 kg phosphorus and 7.5 kg zinc to fenugreek is recommended for increasing the fenugreek–pearlmillet system productivity and fetching high returns.

REFERENCES

Adhikari, T. and Rattan, R.K. 2002. Thermodynamics of zinc adsorption in soils. *Journal of Indian Society of Soil Science* **50**(1): 43–46.

Dubey, B.K., Sharma, C.P. and Chatterjee, C. 2001. Response of pigeon pea to applied zinc in stifluvent soils of Western Uttar Pradesh. *Journal of Indian Society of Soil Science* **49**(3): 471–475.

Ganeshamurthy, A.N., Srinivasarao, Ch., Singh, K.K. and Ali, M. 2003. Management of phosphorus for higher pulse productivity in different agro-climatic regions in India. *Fertilizer News* **48**(5): 23–24, 27–34 and 37–41.

Jain, N.K. 2004. Studies on P and zinc fertilization in wheat (*Triticum aestivum*) and their residual effect on pearlmillet (*Pennisetum glaucum*). Ph.D. (Agronomy) Thesis, Rajasthan Agricultural University, Bikaner, India.

Jat, B.L. and Shaktawat, M.S. 2003. Effect of residual phosphorus, sulphur and biofertilizers on productivity, economic returns and nutrient content of pearlmillet (*Pennisetum glaucum*) in fenugreek [*Trigonella foenum-graecum* (L.)] - pearlmillet cropping sequence. *Indian Journal of Agricultural Sciences* **73**(3): 134–137.

Meena, D.R. 2003. Effect of zinc fertilization on growth, yield and quality of fenugreek (*Trigonella foenum-graecum*). M.Sc. (Agriculture) Thesis, Rajasthan Agricultural University, Bikaner, India.

Patel, K.P., Singh, M.V. and Patel, K.C. 2003. Crop response to secondary and micro-nutrients in alluvial and calcareous soils. *Fertilizer News* **48**(4): 21–32 and 35–37.

Raju, R.A., Subba Rao, A. and Rupa, T.R. 2005. Strategies for integrated phosphorus management for sustainable crop production. *Indian Journal of Fertilizer* **1**: 25–28 & 31–36.

Ram, V., Mishra, S.K. and Upadhyay, R.M. 2002a. Influence of sulphur, zinc and biofertilizer on biological nitrogen fixation and microbial population in mungbean. *Indian Journal of Pulses Research* **15**(1): 66–69.

Ram, V., Mishra, S.K. and Upadhyay, R.M. 2002b. Influence of sulphur, zinc and biofertilizer on quality characteristics in mungbean. *Indian Journal of Pulses Research* **15**(2): 139–141.

Ram, V., Mishra, S.K. and Upadhyay, R.M. 2002c. Effect of sulphur, zinc and biofertilizer on yield and nutrients uptake in mungbean. *Indian Journal of Pulses Research* **15**(2): 169–171.

Rethinam, P. and Sadanandan, A.K. 1994. Nutrition and management of seed spices. *Advances in Horticulture* **9**: 499–513.

Sharma, B.L. and Bapat, P.N. 2000. Levels of micro-nutrient cations in various plant parts of wheat as influenced by zinc and phosphorus application. *Journal of Indian Society of Soil Science* **48**(1): 130–134.

Singh, A.K., Ram, H. and Maurya, B.R. 1999. Effect of nitrogen and phosphorus on microbial population, growth and nodulation of green gram. *Journal of Indian Society of Soil Science* **47**(1): 159–161.