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Effect of phosphorus and zinc nutrition on growth and yield of fodder cowpea

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ABSTRACT

An experiment consisting of four phosphorus levels (0, 40, 60 and 80 kg/ha P_2O_5) and five zinc levels (0, 10, 20, 30 and 40 kg/ha $ZnSO_4$) was laid out in randomized block design in factorial mode to find out the effect on yield and quality of fodder cowpea [*Vigna Unguiculata* (L.)Walp.]. Growth parameters *viz.* plant height, number of leaves, number of branches, leaf length, leaf width and leaf stem ratio were improved with the application of 60 kg/ha P_2O_5 and 20 kg/ha $ZnSO_4$. Application of 60 kg/ha phosphorus recorded 27.64 t/ha yield, which was 7.50 and 55.6 % higher than 40 kg/ha and no phosphorus application, respectively. Application of zinc in the form of $ZnSO_4$ @ 20 kg/ha increased significantly the green fodder yield (25.89 t/ha). Interaction effect of phosphorus and zinc application was found significant with respect to green fodder, dry matter yield and nutrient uptake. Yield, phosphorus and zinc uptake in cowpea fodder were showing declining trend at combination of application rate more than 60 kg/ha P_2O_5 and 20 kg/ha $ZnSO_4$.

Key words: Cowpea fodder, Fodder yield, Growth, Phosphorus, Zinc.

INTRODUCTION

India sustains about 15% of the world's livestock population and 17% of world human population from 2.3% of world geographical area and 4.2% of world's water resources (Kumar *et al*, 2012). Livestock production is backbone of Indian agriculture contributing 7% to national GDP and source of employment and livelihood for 70% population in rural areas (Kumar *et al*, 2012). India ranks first in terms of milk production (137.7 million tonnes), however, the productivity is quite low mainly because of scarcity of feeds and fodders. Recent reports clearly indicated that India faces a net deficit of green fodder by 61.1%, dry crop residues by 21.9% and for feeds as high as 64% (Kumar *et al.*, 2012). Under such situation, adoption of improved package of practices (Kumar, 2013; 2014a and 2014b) intensive crop rotation, inclusion of short duration crops in existing rotations of grain, fodder and cash crops and better agronomic practices have great significance. Phosphorus is a necessary nutrient for the biosynthesis of chlorophyll. Phosphorus as a constituent of cell nucleus is essential for cell division and development of meristematic tissue. Phosphorus deficiencies lead to a reduction in the rate of leaf expansion and photosynthesis per unit leaf area hence reduction in fodder yield.

Crop yields are often limited by low soil levels of mineral micronutrients such as zinc (Zn). Essentiality of zinc in plants was established as early as 1915 by Maze in maize. Zinc is an essential mineral nutrient and a cofactor of over 300 enzymes and proteins involved in cell division, nucleic acid metabolism and protein synthesis (Marschner 1986). Cakmak (2000) has speculated that zinc deficiency stress may inhibit the activities of a number of antioxidant enzymes, resulting in extensive oxidative damage to membrane lipids, proteins, chlorophyll and nucleic acids. Zinc can affect carbohydrate metabolism at various levels. Further, Zn is required in the biosynthesis of tryptophan, a precursor of the auxin-indole-3-acetic acid (Oosterhuis *et al.*, 1991). Zinc deficiency symptoms include, small leaves, shortened internodes giving the plant a stunted appearance. These all leads to poor fodder qualities. According to ICAR-Indian Institute of Soil Science, Bhopal, in India more than 50% soil samples tested were found deficient in zinc; furthermore in Haryana 60% samples tested were deficient. The deficiency of zinc in soil will lead to poor yield and quality of fodder along with poor zinc uptake. Since, zinc is also a major nutrient in animal nutrition; if we properly apply zinc in soil the deficiency in animal can be rectified.

Availability of zinc in soils and its absorption and translocation in plants is influenced by all other plant nutrients. Zinc in general interacts negatively with phosphorus which depends upon a number of physic-chemical properties of soils. The development of crop production technologies is the master key to unlock the yield potential of crops. Fodder as a group of crop differs from food and commercial crops in several aspects, the principles and practices of their cultivation vary accordingly.

Keeping in view aforesaid points a study was planned to evaluate the effects of application of phosphorus and zinc fertilizer on growth and yield of fodder cowpea. An improved understanding of phosphorus and zinc nutrition

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in fodder cowpea would help dairy farmers in better management of their inputs for optimal yield and good quality fodder of cowpea.

MATERIALS AND METHODS

The experiment was conducted at Forage Research and Management Centre, NDRI, Karnal, located at 29º45' N, 76º58' E and at an altitude of 245 m above mean sea level in north-western zone of Haryana. Experiment was laid out in factorial randomized block design consisting of twenty treatment combinations, four phosphorus levels (0, 40, 60 and 80 kg/ha P_2O_5) and five zinc levels (0, 10, 20, 30 and 40 kg/ha $ZnSO_4$) with three replications using cowpea variety C-152 as test crop. Soil of the experimental was low to medium in available nitrogen (191 kg/ha), medium in available phosphorus (18.5 kg/ha), high in available potassium (256 kg/ha) and low in zinc (0.46 ppm). Initial pH of the top 0-15 cm soil ranged between 7.5-7.7 and EC from 0.18-0.26 dS/m. All the recommended agronomical practices were followed during growing period and soil analysis was done (AOAC, 2005). Phosphorus and zinc were applied at sowing time as per treatment in all the plots through SSP (single super phosphate) and $ZnSO_4$ (zinc sulphate 21% zinc), respectively. Nitrogen was also applied at sowing time in the form of urea. Crop was harvested and fodder was taken on at 65 days after sowing (DAS) when 50% flowering was observed in the field. Fresh fodder yield was recorded and samples were collected. Statistical analysis was done using standard procedures of analysis of variance in RBD using IRRISTAT software (IRRI, 1999) and statistical mean differences were found by Fisher's protected least significant difference test at P<0.05 (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height: Plant height is a reliable index of growth of the plant particularly fodder crops, which represents the infrastructure build-up over a period of time. The scrutiny of the data presented in Table-1 indicated that plant height at 30 DAS and at harvesting as influenced by application of both phosphorus and zinc fertilizers. The plant height of the cowpea at 30 DAS increased significantly with application of phosphorus up to 40 kg ha^{-1} over control, while application of 60 kg phosphorus ha^{-1} significantly increased the plant height at harvest, over application of 0 and 40 kg phosphorus ha^{-1}. The increase in plant height due to phosphorus application may be ascribed to its favourable effect on cell division and enlargement, which ultimately reflected in terms of increased plant height. Similar findings were also observed by Meena *et al.* (2014). Application of 20 kg $ZnSO_4$ recorded significant improvement in plant height at both stage of observation.

Leaf length: Leaf length is an important parameter to decide green fodder yield and quality. Data presented in Table 1 showed significant differences in leaf length due to application of phosphoric fertilizer. Application of 60 kg phosphorus per ha increased the leaf length significantly over control and 40 kg/ha. This could be explained on the basis of positive effect of phosphorus at cellular level metabolism and enhanced photosynthetic activity due to more energy availability. Leaf length also increased significantly with the application of $ZnSO_{4.}$ However, differences between various levels of zinc were at par to each other.

Leaf width: Data presented in Table 1 shows that successive increase in rate of P_2O_5 application increased leaf width at both the stages of observation, but, significant improvement was reflected up to 40 kg/ha of $P_2O_{5.}$ The stimulating effect of phosphorus on growth of crop might be due to readily availability of applied phosphorus. Effect of $ZnSO_4$ is also significant at harvest at the application of 10 kg/ha of $ZnSO_4$ which increased the leaf width significantly over control. However, at 40 kg/ha level of $ZnSO_4$ decreased leaf width non- significantly.

TABLE 1: Effect of phosphorus and zinc application on growth parameters.

Treatment	Plant height (cm)		Leaf length (cm)		Leaf width (cm)		No. of branches		No. of leaves		Leaf stem ratio
	30 DAS	harvest	30 DAS	harvest	30 DAS	harvest	30 DAS	harvest	30 DAS	harvest	harvest
Phosphorus (kg/ha)											
0	41.6	104.1	8.9	9.7	6.7	8.3	10.1	31.0	37.2	89.2	0.41
40	46.8	150.8	10.1	11.4	7.3	9.0	11.3	35.1	42.9	94.7	0.47
60	48.9	162.6	10.7	12.1	7.7	9.3	12.0	36.9	45.1	97.7	0.49
80	51.1	165.7	11.2	12.3	8.1	9.5	12.7	38.3	46.9	99.5	0.51
SEm ±	1.17	2.58	0.25	0.26	0.27	0.21	0.33	0.59	0.86	1.40	0.009
CD (P=0.05)	2.38	5.23	0.51	0.54	0.55	0.44	0.68	1.19	1.75	2.79	0.02
$ZnSO_4$ (kg/ha)											
0	42.4	125.6	9.6	10.5	6.8	8.4	10.5	31.9	38.5	90.8	0.43
10	45.8	144.3	10.1	11.1	7.3	8.9	11.1	34.5	41.8	94.1	0.46
20	48.7	152.2	10.5	11.6	7.8	9.3	11.9	36.3	44.4	96.5	0.48
30	49.3	153.8	10.6	11.8	7.8	9.3	12.1	37.0	45.2	97.5	0.49
40	49.3	153.1	10.5	11.8	7.6	9.2	12.0	37.0	45.2	97.3	0.49
SEm ±	1.31	2.88	0.28	0.30	0.30	0.24	0.37	0.66	0.96	1.56	0.009
CD (P=0.05)	2.67	5.84	0.57	0.61	0.61	0.49	0.76	1.33	1.96	3.12	0.02

Number of branches: It is explicit from the data given in Table 1 that application of 80 kg P_2O_5/ha significantly increased the number of branches at 30 DAS and at harvest over control, 40 and 60 kg P_2O_5/ ha. At 30 DAS and at harvesting stage $ZnSO_4$ application up to 20 kg per ha, significantly improved the number of branches per plant over 0 and 10 kg $ZnSO_4$/ha. Hamsa *et al.* (2012) also observed that application of 18 kg/ha zinc caused significantly maximum number of branches (12.33) over the control in cowpea. This might be due to the auxin metabolism and increased photosynthetic rate by zinc nutrition.

Number of leaves: Number of leaves per plant is an important index of plant growth and development which determines the capacity of plant to trap solar energy for photosynthesis. At 30 DAS, number of leaves significantly improve with the application of P_2O_5 up to 80 kg/ha. However at harvesting P_2O_5 affect the number of leaves significantly only up to 60 kg/ha.

At 30 DAS, $ZnSO_4$ increased the number of leaves significantly up to 20 kg/ha over control and 10 kg $ZnSO_4$/ ha. But at harvesting number of leaves increased significantly only up to the application of 10 kg $ZnSO_4$/ha over control.

Leaf stem ratio: Leaf stem ratio is an important factor which is helpful to determine the palatability of any fodder. Fodder with high leaf: stem ratio is generally preferred by the animals due to more palatability and digestibility. Increasing the level of P_2O_5 from 0 to 80 kg/ha, significantly increase the Leaf stem ratio of cowpea over 0, 40 and 60 kg P_2O_5/ha. Application of $ZnSO_4$ up to 20 kg/ha significantly increased the Leaf: stem ratio of cowpea over 0 and 10 kg $ZnSO_4$per ha (Table 1). Kumar *et al.* (2014) also observed that the application of 10 kg zinc/ha registered significantly higher values of growth parameters. The profound increase in these growth parameters was probably due to the involvement of zinc in auxin metabolism, which led to higher hormonal activity and growth performance.

Green fodder yield: Green fodder yield is one of the most important factors to determine the efficacy of any agronomic management practices. Increasing the level of P_2O_5 from 0 to 60 kg/ha, significantly increased the green fodder yield of cowpea over 0 and 40 kg P_2O_5/ha. Maximum green fodder yield (Table 2) was observed with application of 80 kg P_2O_5/ ha (281.7 q/ha), which is statistically at par to 60 kg/ha (276.4 q/ha) application of P_2O_5, and the minimum yield was obtained in control (177.6 q/ha). This might be due to the fact that phosphorus is the key plant nutrient involved in energy transfer in the plant chemical reactions (Prasad. 2007). Phosphorus is also an integral component of several important compounds in plant cells *viz.* the nucleotides used in plant energy metabolism and in molecules of DNA and RNA (Taiz and Zeiger. 1991). Phosphorus is a necessary nutrient for the biosynthesis of chlorophyll, where phosphorus as pyridoxal phosphate must be present for the biosynthesis of chlorophyll (Ambrose and Easty, 1977). Phosphorus as a constituent of cell nucleus is essential for cell division and development of meristematic tissue (Russell, 1973). In the present study due to the aforesaid reasons various growth parameters showed improvement, which was statistically superior over no phosphorus application. Green fodder yield mainly depends on these growth parameters, like plant height, leaf width and length, number of leaves and branches, the individual improvement in these parameters had cumulative effect on total green fodder yield of cowpea. Bhilare *et al.* (2002) also observed that growing of cowpea variety UPC-951 with application of 60 kg P_2O_5/ha showed higher green forage. Jamadagni *et al.* (2002) revealed that fodder yield of cowpea increased with increase in phosphorus levels linearly. Sheoran *et al.* (1994) reported that application of 60 kg P_2O_5/ha, improved forage yield and quality of cowpea. Application of $ZnSO_4$ up to 20 kg/ha significantly increased the green fodder yield of cowpea over 0 and 10 kg $ZnSO_4$/ha. Further increase in dose of $ZnSO_4$ had not caused significant improvement in green fodder yield. The increase in green fodder yield can be explained on the basis of several earlier findings and facts. Zinc a cofactor of over 300 enzymes and proteins involved in cell division, nucleic acid metabolism and protein synthesis (Marschner 1986). Zinc can affect carbohydrate metabolism at various levels. Improved yield due to zinc application was also observed by Pandya *et al.* (2007) in cowpea, Sutaria *et al.* (2013) and Bhoya *et al.* (2013) in sorghum and Mohan and Singh (2014) in teosinte.

TABLE 2: Effect of phosphorus and zinc application on green fodder yield (q/ha)

Treatments	Green fodder yield (q/ha)	Dry matter yield (q/ha)
Phosphorus (kg/ha)		
0	177.6	35.5
40	257.0	51.5
60	276.4	55.4
80	281.7	56.5
SEm ±	4.41	0.95
CD (P=0.05)	8.92	1.93
$ZnSO_4$ (kg/ha)		
0	213.5	42.7
10	245.5	48.9
20	258.9	51.9
30	262.1	52.7
40	260.9	52.3
SEm ±	4.93	1.06
CD (P=0.05)	9.97	2.16

A critical examination of data presented in Table 3 revealed that interaction of phosphorus and zinc application on green fodder and dry matter yield was found significant at 5 % level of significance. At lower level of zinc response of applied phosphorus was found significant up to 60 kg/ha P_2O_5, while at higher zinc levels i.e. more than 20 kg/ha

TABLE 3: Interaction effect of phosphorus and zinc application on yield (q/ha).

Green fodder yield(q/ha)				
Treatment	**Phosphorus (kg/ha)**			
$ZnSO_4$ (kg/ha)	0	40	60	80
0	120.0	218.2	249.0	266.7
10	165.0	248.2	278.0	291.0
20	190.0	268.5	285.0	292.0
30	200.0	275.5	288.3	284.7
40	213.0	274.5	281.9	274.3
SEm ±	PxZn=9.85	CD (P=0.05)	PxZn=19.95	
		Dry matter yield		
0	24.1	43.4	49.7	53.8
10	32.9	49.0	55.8	58.0
20	37.8	53.7	57.3	58.8
30	40.0	55.5	57.9	57.3
40	42.6	55.7	56.4	54.4
SEm ±	PxZn=2.13	CD (P=0.05)	PxZn= 4.33	

$ZnSO_4$ it was found to increase significantly only up to 40 kg/ha P_2O_5. Further, it was interesting to note that at higher levels of both phosphorus and zinc the green fodder yield was reduced. Possible reasons for phosphorus and zinc interaction is the dilution effect, which is more widely termed p-induced Zn deficiency (Olsen, 1972) include; High level of soil available p or high p application rate may decrease Zn availability; slow rate of translocation of zinc from roots to shoot; accumulation of zinc in roots; increased growth due to P application causing a dilution effect and low concentration of zinc in shoot tissues and metabolic disorder at cellular level due to P and zinc imbalance. From the data it can be concluded that combination of 60 kg P_2O_5 and 20 kg $ZnSO_4$ gave significant maximum yield of cowpea fodder. Singh *et al.* (2014) also stated that application of 40 kg/ha P_2O_5 and 30 kg $ZnSO_4$/ha is recommended for achieving the maximum yield advantages in a geranium-garlic intercropping system. Mousavi. (2011) stated that zinc absorption capacity is reduced by high phosphorus utilization and zinc in plant and soil has an antagonism state with phosphorus (negative interaction), which could be reason for lower yield at combination of higher doses of zinc and phosphorus.

Dry matter yield: Application of phosphorus and zinc sulphate significantly increased the dry matter yield of cowpea. Data presented in Table 2 indicate that dry matter yield was significantly increased with application of 60 kg P_2O_5/ha over 0 and 40 kg P_2O_5/ha. Increase in levels of $ZnSO_4$, increased the dry matter yield significantly up to 20 kg/ha. The trend in dry matter yield was similar to green fodder yield, as DM content was not influenced by any treatment.

Nitrogen uptake: Nitrogen uptake increased significantly with increasing levels of phosphorus and highest nitrogen uptake is observed with application of 60 kg P_2O_5/ha (Table 4). The increase in uptake with higher application of phosphorus resulted from enhance dry matter yield and nitrogen content. Application of 10 kg of $ZnSO_4$ significantly increased the nitrogen uptake over control. The increase in nitrogen uptake with 10 kg $ZnSO_4$ application may be due to increase in dry matter yield.

Phosphorus uptake: Phosphorus uptake increased significantly with increasing levels of phosphorus and highest phosphorus uptake is observed with application of 60 kg P_2O_5/ha i.e. 21.76 kg/ha and lowest in control i.e. 11.06 kg/ha (Table 4). The increase in phosphorus uptake with higher application of phosphorus resulted from enhance supply of phosphorus to the plant during early growth stage at which it was utilized in larger quantities. Similar finding were reported by Deo and Khandelwal (2009) for mustard. Application of 10 kg of $ZnSO_4$ significantly increased the phosphorus uptake over control. The increase in phosphorus uptake with 10 kg $ZnSO_4$

TABLE 4: Effect of phosphorus and zinc application on nutrient uptake.

Treatments	Nitrogen (kg/ ha)	Phosphorus (kg / ha)	Zinc (gm / ha)
Phosphorus (kg/ha)			
0	87.67	11.01	160.18
40	143.08	18.18	249.16
60	160.21	20.56	259.37
80	162.73	21.76	252.07
SEm ±	4.72	0.64	9.00
CD (P=0.05)	9.56	1.29	18.22
$ZnSO_4$ (kg/ha)			
0	108.41	16.09	176.26
10	133.82	18.58	218.30
20	147.89	19.01	245.96
30	151.78	18.48	254.13
40	150.22	17.22	256.32
SEm ±	5.28	0.71	10.06
CD (P=0.05)	10.68	1.44	20.37

TABLE 5: Interaction effect of phosphorus and zinc application on nutrient uptake.

Phosphorus uptake(kg/ha)				
Treatments	Phosphorus (kg/ha)			
$ZnSO_4$ (kg/ha)	0	40	60	80
0	7.36	15.43	19.24	22.33
10	10.32	17.82	22.05	24.15
20	11.84	19.50	21.53	23.17
30	12.52	19.66	20.87	20.87
40	13.02	18.49	19.08	18.30
Mean	7.36	15.43	19.24	22.33
SEm ±	PxZn=1.42	CD (P=0.05)	PxZn= 2.88	
Zinc(gm/ha)				
0	87.27	180.01	209.02	228.76
10	135.07	220.58	257.72	259.85
20	170.46	266.30	273.97	273.10
30	191.73	286.24	280.53	258.02
40	216.35	292.68	275.61	240.64
Mean	160.18	249.16	259.37	252.07
SEm ±	PxZn=20.12	CD (P=0.05)	PxZn= 40.75	

application may be due to increase in dry matter yield. Interaction effect was recorded significant influence on phosphorus uptake. The phosphorus uptake by cowpea plants decreased at higher levels of applied zinc.

Zinc uptake: Zinc uptake increased significantly with increasing levels of $ZnSO_4$ application. Significantly highest zinc uptake was found with 20 kg $ZnSO_4$/ha (245.96 gm/ha) and lowest in control (176.26gm/ha). The increase in zinc uptake at 20 kg $ZnSO_4$/ha over control and 10 kg $ZnSO_4$/ha is 39.54% and 12.67% respectively (Table 4). An increasing trend of zinc uptake was observed with phosphorus application and maximum zinc uptake was found with 60 kg phosphorus per ha (259.37 gm/ha) and lowest in control (160.18 gm/ha). The increase in zinc uptake with phosphorus application is due to increase in green fodder and dry matter yield. The uptake of zinc is increased up to 60 kg phosphorus/ha and then decreased with 80 kg phosphorus/ha. This is may be due to the phosphorus was found to inhibit the translocation of zinc from root to the above ground portion of the plant thus adversely affect the zinc concentration in plant.

Interaction effect was recorded significant influence on zinc uptake. The uptake of Zn increased with the application of Zn and decreased with the application of P (Table 5).

Soil nutrient status: Nitrogen status of the soil was improved from the initial status (191 kg/ha) because of leguminous crop (Table 6). With the increased in level of phosphorus there was significant reduction in soil nitrogen status up to 60 kg/ha. Similarly nitrogen status at harvest was decreased with zinc levels also. This may be due to more dry matter yield under phosphorus and zinc treatments. Phosphorus status at harvest was improved with the levels of phosphorus application and maximum status was observed with 80 kg P_2O_5 /ha. With the increase in dose of $ZnSO_4$ the phosphorus status had lowered. Application of phosphorus slightly enhanced the zinc status in soil due to decrease in uptake of zinc by crop where phosphorus was applied. The improvement in soil zinc status was observed significantly with the successive in zinc levels from 0 to 40 kg/ha $ZnSO_4$.

TABLE 6: Effect of phosphorus and zinc application on nutrient content in soil at harvest.

Treatments	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Zinc (ppm)
Phosphorus (kg/ha)			
0	236.84	10.31	0.61
40	214.41	17.68	0.62
60	200.52	24.00	0.62
80	196.86	31.09	0.62
SEm ±	5.27	0.68	0.007
CD (P=0.05)	10.67	1.40	0.015
$ZnSO_4$ (kg/ha)			
0	229.05	22.95	0.43
10	220.85	20.56	0.57
20	207.97	20.15	0.64
30	201.57	20.01	0.72
40	201.33	20.17	0.73
SEm ±	5.89	0.77	0.008
CD (P=0.05)	11.93	1.56	0.02

CONCLUSIONS

From results of experiment, it may be concluded that application of 60 kg/ha P_2O_5 and 20 kg/ha $ZnSO_4$ will better both in terms of production and quality of fodder cowpea. Higher doses of phosphorus and zinc interacted negatively; therefore, use of balanced dose is necessary for better quality and productivity.

REFERENCES

Ambrose, E.J. and Easty D.M. (1977) *Cell Biology.* The English Language Book Society and Longman, London.

AOAC. (2005). *Official Methods of Analysis*. 18th rev. edn. Association of Official Analytical Chemists, Arlington, Virginia, USA.

Bhilare, R.L. and Patil, V.S. (2002). Response of forage cowpea varieties to phosphorus application. *Forage Research* **28:** 179-180.

Bhoya, M., Chaudhary, P.P., Raval, C.H. and Bhatt, P.K. (2013). Effect of nitrogen and zinc on growth and yield of fodder sorghum (*Sorghum bicolor* (L.) *moench*) varieties. *Journal of Progressive Agriculture* **4(1).**

Cakmak, I. (2000). Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. *New Phytol* **146:** 185-205.

Deo, C. and Khandelwal, R.B. (2009). Effect of zinc and phosphorus on yield, nutrient uptake and oil content of mustard grown on the gypsum-treated sodic soil. *Journal of Indian Society of Soil Science* **57 :** 66-70.

Hamsa, A. and Puttaiah, E.T. (2012). Residual effect of zinc and boron on growth and yield of french bean (*Phaseolus vulgaris* L.)-rice (*Oryza sativa* L.) cropping system. *International Journal of Environmental Sciences* **3 :** 167-171.

IRRI. (1999). IRRISTAT for windows version 4.0. Biometric Unit, IRRI, Los Banos, Philippines.

Jamadagni, B.M., Shetye, V.N. and Ingale, B.V. (2002). Response of forage yield of cowpea to different levels of phosphorus. *Forage Research* **28:** 23-25.

Kumar, R. (2014 a). Assessment of technology gap and productivity gain through Crop technology demonstration in chickpea. *Indian Journal of Agric. Res*., **48:** 162-164.

Kumar, R. (2014 b). Crop technology demonstration: an effective communication approach for dissemination of wheat production technology. *Agril. Sci. Digest* **34:**131-134.

Kumar, R. (2013). Evaluation of crop technology demonstration of mustard crop in transitional plain of inland drainage zone of Rajasthan. *Int. J. Agri. Stat.Sci.* **9:** 657-660.

Kumar, S., Agarwal, R.K., Dixit, A.K., Rai, A.K. and Rai S.K. (2012). Forage Crops and Their management. IGFRI, Jhansi (UP) India. pp60.

Marschner, H. (1986). *Functions of mineral nutrients: macronutrients*. In: Haynes RJ, editor. Mineral Nutrition of Higher Plants. Academic Press, Orlando, FL. 195–267.

Meena, L.R. and Chand, R. (2014). Response of fodder cowpea to varying levels of nitrogen and phosphorus under rainfed condition of Rajasthan. *The Indian Journal of Small Ruminants* **20:** 121-123.

Mohan, S. and Singh, M. (2014). Effect of nitrogen, phosphorus and zinc on growth, yield and economics of teosinte (*Zea mexicana*) fodder. *Indian Journal of Agronomy* **59:** 471- 473.

Mousavi, S.R. (2011). Zinc in crop production and interaction with phosphorus. *Australian Journal of Basic and Applied Sciencs* **5:** 1503-1509.

Olsen, S.R. (1972). *Micronutrients interactions.* (In) Micronutrients In Agriculture

Oosterhuis, D. Hake, K., Burmester, C. (1996). Foliar feeding cotton. *Cotton Physiology Today. National Cotton Council of America*, **2 :** 1–7.

Pandya, C.B. and Bhatt, V.R. (2007). Effect of different nutrient levels on yield and nutrient content of fodder cowpea. *Legume Research* **30 :** 218 – 220.

Prasad, R. (2007). *Crop nutrition – Principle and Practices.* 1st edition : 1-272. New Vishal Publications, New Delhi-India.

Russell, E.W. (1973). *Soil Condition and Plant Growth.* The English Language Book Society and Longman, London.

Sheoran, R.S., Ram, S., Joshi, U.N. and Singh, J.V. (1994). Response of forage cowpea varieties to varying levels of phosphorus under irrigated conditions. *Forage reseaech* **20:** 185-189.

Singh, S., Muni Ram and Yadav, N. (2014). Effect of phosphorus and zinc application on the growth and yield of Geranium (*Pelargonium graveolens*) intercropped with garlic (*Allium sativum*). *Indian Journal of Agricultural Research* **48:** 1 – 8.

Sutaria, G.S., Ramdevputra, M.V., Ansodaria, V.V., Akbari, K.N. (2013). effects of potassium and zinc nutrition on yield and quality of forage sorghum. *Indian Journal of Agricultural Research* **47:** 540-544.

Taiz, L. and Zeiger, E. (1991). *Plant Physiology: Mineral Nutrition*. The Benjamin/Cummings Publishing Company, Inc. Redwood City, CA.