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Phosphorus and zinc fertilization in fodder cowpea - A review

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ABSTRACT

Phosphorus is a key nutrient for increasing productivity of legumes. It is required for plant growth and root development. Phosphorus deficiency in soil is widespread and crops grown under deficient situation show significant response to fertilizer phosphorus. At several places normal yield of crops could not be achieved despite judicious use of NPK fertilizers due to deficiency of micronutrients in soil, in general, that of Zn in particular. The knowledge regarding the use of optimum dose of nutrients especially Phosphorus and Zinc is of serious concern. The literature about the performance of fodder cowpea (*Vigna unguiculata*) in relation to phosphorus and zinc nutrition is reviewed in this paper.

Key words: Cowpea fodder, Quality parameters, Phosphorus, Zinc.

Cowpea (*Vigna unguiculata*) is one of the important food legumes and a valuable component of the traditional cropping systems in the semi-arid tropics covering Asia, Africa, Central and South America. (Singh *et al.* 1997). It is an important fodder crop of *kharif* and summer season in India due to its short duration, high yield and quick growth along with high protein content and palatability particularly to small ruminants. Legumes like cowpea by and large are indetminate in growth and thus maintain quality traits over longer periods. (Bimbraw, 2013). Fodder cowpea occupied 0.3 million hectares out of 0.65 million hectare area under pulse and vegetable cowpea types, and the production of cowpea fodder is 5.00 million tones. Cowpea has tap root system with a number of lateral roots occur in upper 40 cm of soil, leaves are trifoliate. Free from any type of toxicity (Bimbraw, 2013). Cowpea is equally important as a nutritious fodder for livestock (Singh and Tarawali, 1997). The nutritive value of cowpea grain, leaves and haulms is very high. The crude protein content ranges from 22 to 30 % in the grain and leaves on a dry weight basis (Nielsen *et al.*, 1997) and from 13 to 17% in the haulms and stems with a high digestibility and low fiber level (Tarawali *et al.*, 1997). Fodder yield and quality of cowpea is limited due to fertility management especially phosphorus and zinc which can play important role in improvement in yield and quality of fodder cowpea.

EFFECT OF PHOSPHORUS

Growth parameters: Although phosphorus is present in much smaller amounts than nitrogen and potassium in plant tissues, phosphorus is the key plant nutrient involved in energy transfer in the plant chemical reactions (Prasad. 2007). Phosphorus is an integral component of several important compounds in plant cells. These compounds include the sugar phosphates involved in respiration, photosynthesis and the phospholipids of plant membranes, 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). Phosphorus has been found to be the life-limiting element in natural ecosystems because it is often bound in highly insoluble compounds and hence it becomes unavailable for plant uptake or utilization (Ozanne 1980). Phosphorus deficiencies lead to a reduction in the rate of leaf expansion and photosynthesis per unit leaf area (Rodriguez *et al.*, 1998). Phosphorus is essential for energy transfer, root development, electron transfer and enhanced maturity. It is an integral part of nucleic acid and essential for cellular respiration and metabolic activity. Next to nitrogen phosphorus is yield limiting nutrient. P deficiencies occur in animals when forages containing 0.10-0.12 % P per fed (Black *et al*. 1949).

Meena and Chand (2014) reported that application of phosphorus up to 20 kg P_2O_5 per ha resulted in increased plant height of fodder cowpea by 12.3%. Further application of phosphorus up to 60 kg P_2O_5 per ha could not enhance the plant height significantly over 20 and 40 kg P_2O_5 per ha. Jat *et al.* (2013) reported that application of 40 kg P_2O_5 per ha in cowpea significantly influenced highest plant height (48.78cm). The stimulating effect of phosphorus on growth of crop might be due to readily availability of applied phosphorus (Singh and Rathore , 2004). Shekara *et al.* (2012) observed that application of 90 kg P_2O_5 per ha recorded significantly higher plant height (48.65cm), in fodder cowpea

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which was at par with 60 kg P_2O_5 per ha (48.65cm). The increased plant height at higher level of was due to increased intermodal length and may be due to cumulative effect of P in the process of cell division and balanced nutrition (Zafar,2003). Magani and Kuchinda (2009) also reported that the effect of Phosphorus level on plant height of cowpea was increasing with increase in P levels from 0 to 75 kg P_2O_5 per ha. Rajasree and Pillai (2001) reported that application of 60 kg P_2O_5 per ha, produced taller plants (86.19 cm) and suggested that increasing levels of of P application increased the LAI and branching in legumes. Phosphorus is known to promote the development of roots thereby favoring the nitrogen fixation in legumes. This increased amount of nitrogen fixed might be utilized by the host plant for its own growth (Rajasree and Pillai, 2001).

Meena and Chand (2014) reported that the number of branches per plant in fodder cowpea increased with each successive level of phosphorus up to 60 kg P_2O_5 per ha. Jat *et al.* (2013) found that application of 40 kg P_2O_5 per ha significantly increased branches per plant (5.06), over control and 20 kg per ha. The stimulating effect of phosphorus on growth of crop might be due to readily availability of applied phosphorus. Shekara *et al.* (2012) observed that the application of 90 kg P_2O_5 per ha recorded significantly higher number of branches per plant (5.53) in forage cowpea which was at par with 60 kg P_2O_5 per ha (5.22). Magani and Kochinda (2009) reported that significant increase in the number of branches in cowpea due to phosphorus application. Mathew and Manorama Thampatti (2007) reported that the numbers of branches per plant were significantly influenced by the application of phosphogypsum. Rajasree and Pillai (2001) also reported that enhancing the Phosphorus level from 0 to 30 or 60 kg P_2O_5 per ha, increased the number of branches per plant, in C-152 variety of forage cowpea.

Meena and Chand (2014) reported that the number of leaves per plant was increased significantly in forage cowpea with the application of phosphorus up to 40 kg/ha. Rajasree and Pillai (2001) reported that, there was an increase in number of leaves per plant with each level of increase in phosphorus level in C-152 variety of cowpea. P application increases the root proliferation and also favors' the extensive exploitation of treated soil areas for nutrients and moisture, which eventually reflects in better vegetative growth. Shekara *et al.* (2012) observed that the application of 90 kg P_2O_5 per ha recorded significantly higher leaf stem ratio (0.46) in fodder cowpea which was at par with 60 kg P_2O_5 per ha (0.44).

Yield: Green fodder yield of cowpea has been increased with the increase in level of phosphorus. Dixit *et al.* (2014) showed that application of 60 kg P_2O_5 per ha gave significantly higher green fodder yield (42.9 t per ha) of sorghum + cowpea than without phosphorus. Similarly, Bhavya *et al.* (2014) reported that the application of 25 kg N and 50 kg P_2O_5 per ha, significantly higher green fodder yield (5.35 t per ha) over 15 kg N and 30 kg P_2O_5 per ha. Shekara *et al.* (2012) observed that the application of 90 kg P_2O_5 per ha recorded significantly higher green fodder yield (242.8q/ha). Likewise, Kumar *et al.* (2012) reported that with increase in P_2O_5 level from 0 to 60 kg per ha along with 40 kg S resulted in maximum green fodder yield of cowpea as compared to other treatment combination. Saidou *et al.* (2012) also observed that the phosphorus application significantly increased the fodder yield and shoot- root ratio of cowpea in sahel and sudan savanna of west africa. Bhilare and Patil (2002) observed that growing of cowpea variety UPC-951 with application of 60 kg P_2O_5 per ha showed better proposition for achieving higher green forage and dry matter yield. 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 per ha, improved forage yield and quality of cowpea.

Dixit *et al.* (2014) showed that application of 60 kg P_2O_5 per ha gave significantly higher dry matter per cent (25.5%) and dry fodder yield (11 t per ha) of sorghum + cowpea system. Jat *et al.* (2013) reported that application of 40 kg of phosphorus per ha significantly increase dry matter accumulation due to the stimulating effect of phosphorus on growth of crop might be due to readily availability of applied phosphorus to soil increase the concentration of $H_2PO^-_4$ and HPO^{--}_4 ions in the rhizosphere and thereby enhancing phosphorus availability to crops. Shekara *et al.* (2012) observed that the application of 90 kg P_2O_5 per ha recorded significantly higher dry matter yield (39.01q per ha) of fodder cowpea. Kumar *et al.* (2012) reported that with increase in P_2O_5 level from 0 to 60 kg per ha resulted in maximum dry matter yield of cowpea. Singh *et al.* (2011) also stated that pod per plant, stover yield and grain yield of cowpea significantly increase with the application of 60 kg per ha over 0, 20 and 40 kg per ha. This could be due to phosphorus increased the intensity of nodulation and thus nitrogen fixation. Magani and Kochinda (2009) reported that dry matter yield per plant in cowpea increased significantly with levels of P fertilizer (0, 37.5, and 75 kg per ha) due to an increase in the uptake of available nutrients as well as better cell division and development of meristematic tissues (Nataraja *et al.* 2005).

Quality parameters: Application of 60 kg P_2O_5 per ha in sorghum + cowpea – chickpea cropping system, produced 1669 kg per ha protein yield (Dixit *et al.*, 2014).Similarly, Kumar et al. (2012) reported that application of 60 kg P_2O_5 per ha increase crude protein content significantly in cowpea. Shekara *et al.* (2012) observed that the application of 90 kg P_2O_5 per ha recorded significantly higher crude protein yield (5.88 q per ha), which was at par with 60 kg P_2O_5 per ha

(5.66 q per ha) but superior over 30 kg P_2O_5 per ha, in cowpea. This result may be attributed to the fact that Phosphorous fertilization often increases nodulation and hence increase nitrogen or CP content in legumes. Magani and Kochinda (2009) reported that crude protein content of cowpea seed increased significantly (P d" 0.01) with increased rate of P (0, 37.5, and 75 kg per ha). Kumar *et al.* (2012) reported that ether extract and ash content were increased with each increment of P_2O_5 levels, in forage cowpea.

Increased root length and root dry weight with the addition of phosphorus can improve nutrient uptake from the soil and lesser loss of macro and micronutrients from the soil-plant systems (Fageria *et al.*, 2014). Jha *et al.* (2014) observed that the application of 80 kg P_2O_5 per ha recorded significantly higher crude fiber yield (6.1 q per ha). Kumar *et al.* (2012) reported that crude fiber and NFE content were decreased with each increment of P_2O_5 levels, in forage cowpea.

Economics: Dixit *et al.* (2014) stated that the phosphorus application at 60 kg P_2O_5 per ha produced maximum net return of Rs. 35011 per ha in fodder cowpea. Due to higher system productivity and higher economic return with higher level of nutrient application resulted in increased benefit cost ratio with the application of 60 kg P_2O_5 per ha (0.84) in fodder – food cropping system.

Jat *et al.* (2013) reported that the higher net return of Rs. 8895 and benefit cost ratio of 1.96 were recorded under 40 kg P_2O_5 per ha, in cowpea. Jha *et al.* (2014) observed that the application of 80 kg P_2O_5 per ha recorded significantly highest Green Forage Yield (244.8q/ha), dry matter yield (45.6q/ha), net monetary returns (18132 Rs/ha) and B:C ratio (2.61). Shekara *et al.* (2010) reported that application of 80 kg P_2O_5 per ha recorded significantly higher green fodder (572.2 q per ha) and net monetary returns (Rs. 27115/ha).

EFFECT OF ZINC

Crop yields are often limited by low soil levels of mineral micronutrients such as zinc (Zn). 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 deficiency symptoms include, i.e. small leaves, shortened internodes giving the plant a stunted appearance means poor fodder qualities. 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 physico-chemical properties of soils.

Growth parameters: Application of 10 kg zinc per ha registered significantly higher values of plant height, the profound increase in growth parameters was probably due to the involvement of zinc in auxin metabolism, which led to higher hormonal activity and growth performance at critical crop growth stages (Kumar and Bohra, 2014). Hamsa and Puttaiah (2012) observed that the application of 18 kg per ha zinc caused significantly higher number of leaves per plant (27), in cowpea.

Yield: Pandya and Bhatt (2007) was observed that application of sulphur and zinc with recommended dose of NPK fertilizers increased the green fodder yield of cowpea over control. Kumar and Bohra (2014) reported that application of 10 kg zinc per ha registered significantly higher values of dry matter content, leaf area index (LAI), chlorophyll content (SPAD value), stem girth, and CGR over control, but it remained statistically at par with 5 kg Zn per ha. Bhoya *et al.* (2013) reported that the application of zinc @ 4 kg zinc per ha was found significantly superior and produced highest dry matter yield (120 q per ha) than application of 2 kg zinc per ha. Weldua *et al.* (2012) observed that zinc fertilization significantly increased yield and yield components and above ground biomass at maturity stage of faba bean plant. Chavan *et al.* (2012) stated that application of 40 kg per ha zinc, gave significantly higher grain (1553kg per ha) and stover yield (2010 kg per ha) in cowpea. Anitha *et al.* (2005) revealed that foliar application of micronutrients like iron and zinc has significant Influence on the yield of cowpea.

Quality parameters: The increase in protein content due to zinc addition might be attributed to its involvement in nitrogen metabolism of plants. Chavan *et al.* (2012) stated that application of 40 kg per ha zinc gave maximum protein content in cowpea grains over 0 and 20 kg zinc. Zinc treated crops were more vigorous than others and had better growth because zinc play key role in stabilizing RNA and DNA structure, and involves in biosynthesis of growth promoting hormones such as IAA and gibberellins (Mousavi, 2011). Kumar *et al.* (2002) reported that application of zinc at 9.0 kg per ha resulted in increased nodulation, uptake of nutrients, protein content and protein yield over control in C-152 variety of fodder cowpea. Safak *et al.* (2009) stated that zinc is an activator of many enzymes involved in photosynthesis, cell elongation and cell division. Thus yield, crude protein and zinc concentration significantly affected by zinc fertilization. Yilmaz *et al.* (1997) reported that in plants without added zinc, concentrations of zinc were about 10 mg-kg^{-1} both in shoots and grain and increased to 18 mg-kg^{-1} dry weight (DW) by soil application of zinc.

EFFECT OF PHOSPHORUS AND ZINC INTERACTION

Application of phosphorus increase grain yield of cowpea, P level in soil and leaves, but decreased foliar concentration of Zn, such negative interaction is due to reduction in zinc translocation through the endodermis and epidermis of roots that causes a reduction in its absorption by plant (Benvindo *et al.,* 2014). 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), therefore zinc utilization is essential to obtain high yield and quality in crops. This negative interaction or antagonistic effect of phosphorus and zinc might be due to one or more reasons, 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 and metabolic disorder at cellular level due to p and zinc imbalance (Olsen, 1972). Akhtar *et al.* (2010) reported that an increase in P supply caused a signiûcant reduction in speciûc Zn uptake and tissue Zn concentration of Brassica. The reduction in tissue Zn concentration cannot be ascribed entirely to a dilution effect. It is suggested that high PUE may depress plant Zn uptake and therefore cause a reduction in Zn concentration of Brassica grown in low-Zn soils. Oseni. (2009) reported that cowpea yield was decreased with increasing zinc application. Zinc – phosphorus interaction showed that cowpea yields were slightly lower when phosphorus applied in combination with zinc than without zinc. The observed effects could be attributed to the fact that phosphorus application reduces the zinc requirements for optimum plant growth. Islam *et al.* (2005) Observed that the interactive effects of phosphorus and zinc in most of the sampling stages of rice and mungbean showed increase in P concentrations when the doses of zinc were increased in combination with the doses of P. Singh *et al*. (1988) observed that application of zinc (0, 5 or 10 mg zinc per kg soil) without phosphorus application had no effect on dry matter yields of bean plants. However, zinc application in combination with phosphorus application resulted in significant dry matter yield responses. The zinc concentration in bean plant tops was significantly reduced due to phosphorus application. application of phosphorus induced zinc deficiency. Translocation of zinc from roots to tops appeared to be restricted at 80 and 160 mg applied phosphorus kg^{-1} soil treatments, as evidenced by the reduction of zinc uptake in non- zinc treatments. Thus, plant dilution effects and reduced translocation of zinc from roots to tops were the two mechanisms responsible for the observed phosphorus induced zinc deficiency.

REFERENCES

Akhtar, M.S., Yoko Oki and Tadashi Adachi. (2010). Growth behavior, nitrogen-form effects on phosphorus acquisition, and phosphorus–zinc interactions in *Brassica* cultivars under phosphorus-stress environment. *Communications in Soil Science and Plant Analysis* **41 :** 2022–2045.

Ambrose, E.J. and Easty D.M. (1997) *Cell Biology.* The English Language Book Society and Longman, London.

Anitha, S., Srinivasan, E. and Purushothaman, S.M. (2005). Response of cowpea to foliar nutrition of zinc and iron in the oxisols of kerala. *Legume Research* **28 :** 294-296.

Benvindo, R.N., Prado, R.D., Nobrega, J.C.A. and Flores, R.A. 2014. Phosphorus fertilization on the nutrition and yield of cowpea grown in an arenosols. *American-Eurasian Journal of agriculture and Environmental Science* **14:** 434-439.

Bhavya, M.R., Palled, Y.B., Pushpalatha Ullasa, M.Y. and Nagaraj, R. 2014. Influence of seed rate and fertilizer levels on dry matter distribution and dry matter yield of fodder cowpea (cv. Swad). *Trend in Biosciences* **7 :** 1516-1521.

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).

Bimbraw, A.S. (2013). *Production, utilization and conservation of forage crops in India.* 1st edition. Jaya Publishing House, Delhi.

Black, W.H., Tash, L.H., Jones, J.M. and Kleberg, J.R. (1949). Comparison of methods of supplying phosphorus to range cattle. *USDA Technical Bulletin No.* 980.

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

Chavan, A.S., Khafi, M.R., Raj, A.D. and Parmar, R.M. (2012). Effect of potassium and zinc on yield, protein content and uptake of micronutrients on cowpea (*Vigna unguiculata (L.)walp*). *Agricultural Science Digest* **32 :** 175-177.

Dixit, A.K., Kumar, S., Rai, A.K., and Palsaniya, D.R. (2014). Productivity and profitability of fodder sorghum + cowpea – chickpea cropping system as influenced by organic manure, phosphorus and sulphur application in central India. *Range Management & Agroforestry* **35 :** 66-72.

Fageria, N.K., Moreira, A., Moraes L.A.C. and Moraes, M.F. (2014). Root growth, nutrient uptake, and nutrient-use efficiency by roots of tropical legume cover crops as influenced by phosphorus fertilization. *Communications in Soil Science and Plant Analysis* **45 :** 555–569.

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.

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.

Jat, S.R., Patel, B.J., Shivran, A.C., Kuri, B.R. and Jat, G. (2013). Effect of P and S levels on growth and yield of cowpea under rainfed conditions. *Annals of Plant and Soil Research* **15 :** 114-117.

Jha, A.K., Shrivastava, A. and Raghuvanshi, N.S. (2014). Effect of different phosphorus levels on growth, fodder yield and economics of various cowpea genotypes under Kymore plateau and Satpura hills zone of Madhya Pradesh. *International Journal of Agricultural Sciences* **10 :** 409-411.

Kumar, A., Yadav, P.K., Yadav, R.K., Singh, R. and Yadav, H.K. (2012). Growth biomass production and quality characters of cowpea as influenced by Phosphorus and sulphur fertilization on loamy sands of semi-arid sub tropics. *Asian Journal of Soil Science* **7 :** 80-83.

Kumar, P., Nagaraju, C. and Yogananda P. (2002). Studies on sources of phosphorus and zinc levels on cowpea in relation to nodulation, quality and nutrient uptake. *Crop Research* **24 :** 299-302.

Kumar, R. and Bohra, J.S. (2014). Effect of NPKS and Zn application on growth, yield, economics and quality of baby corn. *Archives of Agronomy and Soil Science* **60 :**1193-1206.

Magani, I.E. and Kuchinda, C. (2009). Effect of phosphorus fertilizer on growth, yield and crude protein content of cowpea (V*igna unguiculata* [L.] Walp) in Nigeria. *Journal of Applied Biosciences* **23 :** 1387 – 1393.

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

Mathew, J. and Manorama Thampatti, K.C. (2007). Response of cowpea (*Vigna unguiculata*) to phosphogypsum application. *Legume Research* **30 :** 271 – 274.

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.

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

Nataraja, T.H., Halepyati, A.S., Desai, B.K. and Pujari, B.T. (2005). Interactive effect of phosphorus, zinc, and iron on the productivity and nutrient uptake by wheat (Triticum durum Desf.). *Karnataka Journal of Agriculture Science* **18 :** 907-910.

Nielsen, S.S., Ohler, T.A. and Mitchell, C.A., (1997). Cowpea leaves for human consumption: production, utilization and nutrient composition. In: Singh, B.B., Moham Raj, D.R., Dashiell, K.E., Jackai, L.E.N. (Eds.), Advances in Cowpea Research. Co-publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Science (JIRCAS), IITA, Ibadan, Nigeria, pp. 326–332.

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

Oseni, T.O. (2009). Growth and Zinc uptake of sorghum and cowpea in response to phosphorus and zinc Fertilization. *World Journal of Agricultural Sciences* **5 :** 670-674.

Ozanne P.G. (1980). Phosphate nutrition of plants-a general treatise. In: FE Khasawneh, EC Sample, EJ Kamprath, editors. The Role of Phosphorus in Agriculture. Madison, Wisconsin: *American Society of Agronomy* : 559-89.

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.

Rajasree, G. and Pillai, G.R. (2001). Performance of fodder legumes under lime and phosphorus nutrition in summer rice fallows. *Journal of tropical agriculture* **39 :** 67-70.

Rodriguez, D., Zubillaga, M.M. and Ploschuck, E. (1998). Leaf area expansion and assimilate prediction in sunflower growing under low phosphorus conditions. *Plant Soil* **202 :** 133-47.

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

Safak, C., Hikmet, S., Bulent, B., Oseyin, A. and Bither, C. (2009). Effect of zinc on yield and some related trades of Alfa-alfa. *Journal of Turkish Agriculture* **14 :** 136-143.

Saidoul, A.K., Singh, B.B., Abaidoo, R.C., Iwuafor, E.N.O. and Sanginga, N. (2012). Response of cowpea lines to low Phosphorus tolerance and response to external application of phosphorus. *African Journal of Microbiology Research* **6 :** 5479-5485.

Shekara, B.G., Sowmyalatha, B.S. and Bharatkumar, C. (2012). Effect of phosphorus levels on forage yield of forage cowpea. *Journal of Horticulture Letters* **2:** 12-13.

Shekara, B.G., Lohithaswa, H., Govindappa, C.M. and Pavan, R. (2010). Response of fodder cowpea genotypes to varied levels of phosphorus. *Forage Research* **36:** 91-93.

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, A., Baoule, A.L., Ahmed, H.G., Dikko A.U., Aliyu, U., Sokoto, M.B., Alhassan, J., Musa, M. and Haliru, B. (2011). Influence of phosphorus on the performance of cowpea (*Vigna unguiculata* (L) Walp.) varieties in the Sudan savanna of Nigeria. *Agricultural Sciences* **2 :** 313-317.

Singh, B.B., Cambliss, O.I. and Sharma, B. (1997). *Recent advances in cowpea breeding*. In: Singh, B.B., Mohan Raj, D.R., Dashiel, K., Jakai, L.E.N. (Eds.) advances in cowpea research. Co-publication of IITA and ZIRCSA, IITA, Ibadan, Nigeria : 32-49.

Singh, B.B., Tarawali, S.A., (1997). *Cowpea and its improvement: key to sustainable mixed crop/livestock farming systems in West Africa*. In: Renard, C. (Ed.), Crop Residues in Sustainable Mixed Crop/Livestock Farming Systems. CAB International in Association with ICRISAT and ILRI, Wallingford, UK : 79–100.

Singh, J.P., R.E. Karamanos and J.W.B. Stewart, (1988). The mechanism of phosphorus-induced zinc deficiency in bean (*Phaseolus vulgaris* L.). *Canada Journal Soil Science* **68 :** 345-358.

Singh, S. and Rathore, P.S. (2004). Response of cowpea [*Vigna unguiculata* (L.) Walp] to phosphorus and thiourea. *Haryana.Journal of Agronomy* **20 :** 102-103.

Tarawali, S.A., Singh, B.B., Peters M. and Blade, S.F., (1997). *Cowpea haulms as fodder*. In: Singh B.B., Mohan Raj, D.R., Dashiell, K., Jackai, L.E.N. (Eds.), Advances in Cowpea Research. Co-publication of International Institute of Tropical Agricultural Sciences and the JIRCAS, IITA, Ibadan, Nigeria : 313–325.

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

Weldua, Y., Haileb, M. and Habtegebrielb, K. (2012). Effect of zinc and phosphorus fertilizers application on yield and yield components of faba bean (V*icia faba* L.*)* grown in calcaric cambisol of semi-arid northern Ethiopia. *Journal of Soil Science and Environmental Management* **3:** 320-326.

Yilmaz, A., Ekiz, H., Torun, B., Gultekin, I., Karanlik, S., Bagci, S.A. and Cakmak, I. (1997). Effect of different zinc application methods on grain yield and zinc concentration in wheat cultivars grown on zinc-deficient calcareous soils. *Journal of plant nutrition* **20 :** 461-471.

Zafar, M., Maqsood, M., Ramzan, M., Amzan, A. and Zahid, A. (2003). Growth and yield of lentil as affected by phosphorus. *Journal of Agriculture Biology* : 1560- 8530.