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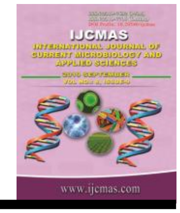

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Availability of Micronutrient Cations in Soils as Influenced by Phosphorus Fertilization- A Review

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A B S T R A C T

Phosphorus and micronutrients (zinc, copper, iron and manganese) are the essential nutrients which are required for normal plant growth. Phosphorus and all micronutrient cations are mutually antagonistic in certain circumstances which can cause yield reductions in many crops due to their deficiencies. Deficiencies typically happen when a nutrient is available in small amounts. In this phenomenon, the nutrient is present in marginal to normal levels but the antagonizing nutrient is available in such a large amount that it induces the deficiency of the other. The effect of phosphorus application on the availability of micronutrients showed that the application of phosphorus decreases the concentrations of Fe, Zn, Cu and Mn in the soils which indicate negative interactions between P and micronutrient cations while the concentration of Mn increases in some cases indicating synergistic as well antagonistic effect of P application on Mn availability in soils to plants.

Introduction

Phosphorus has been considered to be the kingpin in agriculture because it plays a pivotal role in increasing crop production and improving the quality of crops. It is the second major essential element and is required by plants for root development, cell division, flowering seed and fruit formation (Brady, 1984). Phosphorus in soils occurs in the form of primary and secondary orthophosphate. Most possibly all crops take up $H_2PO_4^-$ more readily than HPO_4^{--} and above pH 7.0 the relative concentration of the divalent ion is greater than that of monovalent ion. India is the world’s third largest producer of phosphatic fertilizers and second largest consumer after China (Prasad, 2012). If large amounts of P are supplied in soils, its luxury uptake may disturb the ratios of P to other nutrients including micronutrients (Tagliavini *et al.,* 1991). The present day modern agriculture aims at achieving maximum production per unit area per unit time per unit cost. This has created an imbalance of nutrients in soils and crops not only with respect to macronutrients but also the micronutrients. Rice-wheat is the major cropping system of Punjab and normally phosphorus is applied to wheat. However, in some areas farmers are applying phosphorus to both the crops. But only one- third of applied P is taken up by the current crop that may lead to the buildup of P in plough layer of soils over a period of time. At present only 36% of the area in Punjab is low in P supplying capacity (Sharma *et al.,* 2011). Build up of P in soils can affect pH, CEC and surface charge of soils which in turn may alter the equilibria of micronutrients among their various chemical pools. Not only this, build up of P in soils may lead to various types of nutrient interactions in soils and plants. Nutrient interactions in crop plants are probably one of the most important factors affecting the yields of annual crops. An interaction takes place when the supply of one of the nutrients affects the absorption, distribution or function of the other and it may be negative, positive or neutral (Fageria, 2001). Thus, depending upon the nutrient supply, the interactions between nutrients can either induce deficiencies or toxicities and can modify the growth response. The plants require essential nutrients viz., primary, secondary and micro nutrients. One of the fertilizers that are used a lot in various crop plants is phosphorus, which is applied as phosphorus fertilizers to the soil. The deficiency of micronutrients may emerge when the supply of micronutrients to the soil is less compared to removal through crop harvest which in turn limits crop productivity (Shukla *et al.,* 2009). If large amounts of P are supplied in soils, its luxury uptake may disturb the ratios of P to other nutrients including micronutrients (Tagliavini *et al.,* 1991). Thus, an understanding of the interaction of phosphorus with other nutrients can be of help to maintain a balanced supply of nutrients to get the optimum crop yields.

Effect of phosphorus fertilization on zinc in soil

Zinc is an important essential element present in plant enzymatic systems. Among the interactions involving macro and micronutrients the interaction between phosphorus and zinc is of greatest potential significance. This interaction is often negative (antagonistic) especially when a soil is deficient in both the nutrients but only one of them is applied through fertilizers. Das *et al.,* (2005) in a greenhouse experiment at the Indian Institute of Horticultural Research (IIHR), Bangalore reported the decrease in the amount of Zn due to combined application of P and Zn might be explained as the antagonistic effect between them. It has been reported that the interaction between Zn and P occurred in soil because added P decreased the available Zn content in plants. The amount of P and Zn in soils showed an increase with their separate applications either as soil or foliar spray while that of the same value significantly decreased both in soils and plants due to their combined applications, suggesting a mutual antagonistic effect between Zn and P affecting each other's availability in soil and content in the stevia plant. Meena *et al.,* (2019) observed that Zinc availability decreases with application of each successive phosphorus level but it was increased with application of zinc. High levels of available phosphorus in soil or high dose of phosphorus application may induce zinc deficiency in the soil characterized by low concentration of available zinc. In an incubation study, Mandal and Haldar, (1980) observed that application of phosphorus @ 5 and 10 mg kg^{-1} soil in lowland rice soils of West Bengal significantly decreased the contents of DTPA-extractable Zn, Cu, Fe and Mn. The rate of decrease gradually reduced with increasing period of incubation from 10 to 70 days. They further observed that the depressive effect of P on extractable Zn was more pronounced on native rather than applied Zn. Manchanda *et al.,* (2012) observed a steep fall in DTPA- Zn when P: Mn ratio in soil was 6.0 and reported that a P: Mn ratio of 3.28 in soil produced 80% of the maximum dry matter yield of shoot of wheat. Furthermore, P-Zn relationship in soils and plants may also be governed by factors like organic matter (Nayak and Gupta, 2000), plant parts (Reddy and Yadav, 1994), plant species and growth stages (Islam *et al.,* 2005). Dwivedi *et al.,* (1975) observed P induced Zn deficiency in corn when P was applied @ 120 mg kg^{-1} soil in a Zn deficient soil (DTPA- Zn 0.2 mg kg^{-1}soil). They further observed that high levels of P rendered the applied n unavailable to plants by immobilizing almost 40% or more of the total Zn absorbed in roots and 20 per cent or more at the nodes of the stem. In a nutrient culture experiment, Soltangheisi *et al.,* (2013) observed that Zn deficiency in sweet corn can enhance P uptake and translocation to such an extent that P may accumulate to toxic levels in its leaves. Mishra and Abidi, (2010) reported that P and Zn application had a synergistic impact on the 1000-seed weight and protein content of the wheat varieties.

Effect of phosphorus fertilization on copper in soil

Awan and Abbasi, (2000) observed that phosphorus application increased P concentration while decreased the copper concentration in the maize plants in sandy loam soil, leading to conclude that an interaction between P and Cu in soil occurs which effect the production of maize fodder significantly. Mandal and Haldar, (1980) reported that the decrease in uptake of Zn, Cu and Fe by rice because of P application was due to decrease in the availability of these nutrients in soils. In a greenhouse study, Haldar and Mandal, (1981) observed that application of phosphorus in alluvial rice soils significantly increased the dry matter yield of root, shoot and grain. But it decreased the concentration of Zn**,** Cu, Fe and Mn in both roots and shoots. This decrease in the concentration of elements in shoots was not due to the dilution effect or to the reduced rate of translocation from roots to tops. They observed that this decrease was more due to the changes in their availability in soil due to P application. Application of 100 kg P ha^{-1} significantly decreased the Cu concentration in maize plants (Awan and Abassi, 2000). Similarly, an antagonistic effect of P on Cu concentration of wheat (Shukla and Singh, 1979; Javadi *et al.,* 1991) has been observed.

Effect of phosphorus fertilization on manganese in soil

A synergistic (Kuo and Mikkelsen, 1981) as well antagonistic (Soni *et al.,* 2000) effect of P fertilization on Mn availability in soils to plants has been reported. Singh *et al.,* (2005) observed that availability of Mn in a near neutral non-calcareous soil was increased when the build up of available P in soil exceeded 60 mg P kg^{-1} soil. Chatterjee *et al.,* (1983) reported a significant decrease in DTPA extractable Mn with P application @ 100 mg P kg^{-1} in an acidic soil (pH 6.5) incubated for 30 days. However, in an alkaline soil (pH = 7.6), Mamo and Parson, (1987) reported a significant increase in DTPA extractable Mn with P application @ 400 mg P kg^{-1} soil incubated for 28 days. Misra and Mishra, (1968) reported that P application to alkali soils decreased the retention of Mn by soil colloids and increased the availability of Mn. However, in near neutral soil (pH = 7.3) having 11.5 ppm DTPA-Mn, the availability of Mn in soil was not influenced by P application even up to 120 kg P_2O_5 ha^{-1} (Rao *et al.,* 1984). Singh *et al.,* (2005) observed a significant increase in dry matter yield of root and shoot of wheat with graded levels of applied P in a Typic Haplustept but P and Mn concentration in both root and shoot were inversely related with each other. Soni *et al.*, (2000) reported that when P and Mn was applied @ 0 to 60 mg P kg^{-1} soil and 0 to 50 mg Mn kg^{-1} soil respectively in a reclaimed sodic soil (pH = 8.7) then increasing levels of P decreased the concentration of Mn in wheat at each level of applied Mn. Recovery of added Mn was lower at higher levels of P application. However, Karelia, (1990) and Patel, (1992) observed that application of P significantly increased the content and uptake of Mn by wheat crop.

Effect of phosphorus fertilization on iron in soil

An antagonistic effect of P on Fe concentration in moong bean has been observed (Yadav *et al.*, 2002). Dhaliwal and Mandal, (2019) reported that the mean available Fe in soil at harvest extracted by DTPA decreased significantly by 3.2%, 4.5%, and 6.9%, respectively, over control with application of 100, 200 and 400 mg P kg−1 soil. So DTPA-Fe was significantly negatively correlated with Olsen P (r = −0.833**). The decrease in availability of Fe with P fertilization may be due to the formation of Fe–phosphates in soil (Olsen, 1972). Intensive cultivation of high-yielding cultivars with heavy applications of nitrogen (N), phosphorus (P), and potassium (K) fertilizers leads to the occurrence of Fe and Mn deficiencies (Cakmak, 2002). Khan and Zande, (1976) and Badhe and Mundwaik, (1982) reported a significant decrease in Fe content of wheat plant with increasing dose of P fertilizer. Karelia, (1990) found that application of P at its highest levels (P 180) significantly decreased the Fe content in grain and straw of wheat crop, whereas Fe uptake by grain and straw as well as its total uptake were significantly higher at P 120 level. Patel, (1992) observed that Fe content in grain was found to increase up to 60 kg P_2O_5 ha^{-1} of P application level but further addition of P (90 kg P_2O_5 ha^{-1}) showed negative effect on Fe content.

Adriano *et al.*, (1971) reported that in corn seedlings with high P levels, shoot growth was increased only by high Zn. The most marked interaction at high P levels was between Fe and Zn which mutually antagonized translocation more than absorption. Dev *et al.*, (1983) reported that application of 7.5 mg P kg^{-1} soil P enhanced the Mn concentration of chickpea while its concentration decreased when P was applied @ 15 and 30 mg kg^{-1} soil. In a field experiment Zhang *et al.*, (2012) observed that application of phosphorus up to 400 kg P ha^{-1} did not influence the DTPA-extractable zinc, copper, iron and manganese in a alkaline calcareous loam soil under the wheat crop. However, they observed a significant reduction in the concentration of zinc in wheat grain by 17 to 56 per cent by P application. But the accumulation of shoot iron, copper and manganese was increased with applied P. Li *et al.*, (2007) also did not observed any significant effect of P application on DTPA extractable micronutrient cations in soil under long term inorganic and organic fertilizer application. Goel and Duhan, (2014) observed a significant decrease in DTPA extractable Zn, Cu, Fe and Mn with application of varying levels of P (0-37.5 kg P ha^{-1}) to a Typic Torripsamment of Hisar. In an alkaline calcareous soil of Pakistan, Ali *et al.*, (2014) observed a decrease in the availability of Zn and Cu but an increase in the availability of Fe and Mn with that application of P (0-150 kg P ha^{-1}).

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