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Review

Role of Phosphorous in Wheat production: A review

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Wheat (*Triticum aestivum* L.) is the main staple food of Pakistan and occupies a central position. Soil nutrient status is important for maintaining high quality and sustainable crop production. High yielding wheat varieties demand sufficient nutrient supply to produce maximum grain yield. There are many factors which are responsible for low yield of wheat but poor crop nutrition and use of local varieties with low yield potential are the most important form which the phosphorus is the most important one because Phosphorus (P) is one of the most widely occurring nutrients for development and growth of wheat. The present review describes the role of phosphorus fertilizer and improved varieties in good and quality wheat production.

Keywords: Wheat; Phosphorus; Pakistan; Crop production

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the main staple food of Pakistan (Anjum et al., 2020) and occupies a central position in the agricultural policies and grown over 200 million hectares in the range of environment throughout the world with an annual production more than 650 million metric tons by 2025 (Yadav et al., 2010). Despite remarkable growth in food production, the risks were exposed by food crisis in the recent years. Therefore, wheat production must continue to increase by 2 percent annually particularly in developing world including South-East Asia to meet future demands imposed by population and prosperity growth Reynolds et al. (2006). Commercially cultivated wheat is basically of two types i.e. durum wheat (*Triticum turgidum* L.) and bread wheat (*Triticum aestivum* L.) that differ in their genetic complexity, adaptation as well as use. A wide range of products are now made and consumed worldwide from both types of wheat. Wheat is used mainly for human consumption and supports nearly 35 percent of the world population. It is nutritious, easy to store, transport and can be processed into various types of food. The demand for wheat is expected to grow faster than any other major agricultural crop. Soil nutrient status is important for maintaining high quality and sustainable crop production.

It is very important to maintain soil nutrient at sufficient level. Application of fertilizers is optional but their costs are too high for farmer. High use of these fertilizers is not profitable Shaheen et al. (2004). Almost all the soils have poor fertility status due to lack of organic matter. Our soils are phosphorus deficit (Khan et al., 2020; Ali et al., 2020) It is estimated that 80-90% of the soil falls in the range between low to medium in phosphorus and nitrogen concentration and high in calcareousness Zia (1990). Soils developed under harsh climate are poor in organic matter and nutrient like nitrogen, phosphorus and sulfur. High yielding wheat varieties demand sufficient nutrient supply to produce maximum grain yield Ali and Yasin (1991). Response of varieties varies to nutrient with respect to their makeup in term of their genes and physiological life process, Chandra et al. (1992). Phosphorus use efficiency is only 11-21% (Zia, 1990), which otherwise could be utilized efficiently through proper management practices. Plant species and varieties also play an important role in obtaining nitrogen and phosphorus from soil for their production. The

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characteristics of wheat that show efficiently N and P are taken up by the plant. Crop production can be enhanced by the use of strains which is efficient in taking P from the soil Monasterio et al. (2002). It is recommended to use optimum dose phosphatic fertilizers with high yield and nutrient responsive plant genotypes, Andrews et al. (2004). There are many factors which are responsible for low yield of wheat but poor crop nutrition and use of local varieties with low yield potential are the most important Hussain et al. (2002). Crop production can be enhanced by use of species which are efficient in utilizing P Alam et al. (2003). It is important to cultivate wheat under optimum levels of phosphorus to obtain maximum yield. The present review describes the role of phosphorus fertilizer and improved varieties in good and quality wheat production.

Role of Phosphorus in Crop Production

More than 30 million metric tons of phosphorous are being used in phosphate fertilizers per year worldwide, from which 99% is obtained from rock phosphate (IFA, 2005). The utilization of phosphorus fertilizers has enhanced the crop production many times probably by making narrow ratio of N: P. It has been investigated by several researchers that phosphorus is vital for starch and fat metabolism and cellular respiration (Rehman et al., 2006). Mosali et al. (2006) reported that P is being required as an important part of compounds carrying energy (ATP and ADP) in approximately all biochemical process and pathways. P is a vital element which also needed for the production of energy from photosynthesis and transportation of carbohydrates (Raghonthama, 1999). Phosphorus helps in improving growth of roots and to sustain high water potential to leaves. This improvement in root growth helps in more water and nutrient uptake and also improves the efficiency of nitrate reductase. Phosphorus improves the root growth and maintains high leaf water potential. Phosphorus also maintains the cell turgidity by maintaining the high leaf water potential which in turn increases the stomata conductance and photosynthetic rate (Waraich et al., 2011).

Appropriate nutrition is the elementary requirement of every living entity. The crucial elements for plants to fulfill the lifecycle are now 17 (Waraich et al., 2011). Amongst the main nutrient P is a vital nutrient which in being needed by the crop plants. It involves in the catalysis of several basic reactions of plant. Phosphorus plays an important role in capturing solar energy and converting it into beneficial plant material and is required for developing and producing a standard plant (Ryan, 1997). Phosphorus also plays an important role in production of important nutrient elements like ATP, DNA, RNA and other cell parts of plants. It is essential and vital in almost all stages of plant life comprising photosynthesis, flowering stage, reproduction, production of seed, maturity and development of root. Substantial loss in yield was caused by its shortage (Haven et al., 1999). The use of phosphorus fertilizers may also help to lower the several impacts of drought under rain fed conditions (Khan et al., 2010). The application of macronutrients shows increase in water use efficiency. Some macronutrients like P plays an important role in improving water use efficiency of crops (Waraich et al., 2008). PPI (1999) described that balanced form of P application increased water use efficiency and support crop to get optimum performance under control moisture conditions. The application of P fertilizers may enhance plant growth significantly in drought conditions (Garg et al., 2004). Improvement in stomata conductance is resulted due to optimistic effects of P on plant growth (Bruck et al., 2000). Improved cell membrane stability was also reported due to positive effects of P in plants (Sawwan et al. 2000). P fertilizers made rise in percent yield of wheat Rehman et al., (1992). Alam et al. (2003) described that P applications significantly increased the number of tillers per plant, plant height and straw and grain yield of wheat and also uptake of P in the grain.

Scientific application of fertilizers can enhance farmer yield and quality (Jiagu et al., 2004). Phosphorus is compulsory for formation of protoplasm, increasing yield and capacity and is considered as a crucial element for growth and yield of plant. It is fundamental part of nucleic acid and is necessary for cellular respiration and metabolic activity. Sensible use of P will help in increasing per unit yield. Rock phosphate is the organic source of P fertilizer. All commercial fertilizers of P like MAP, DAP, TSP and SSP are made by treating rock phosphate with strong sulphuric acid to raise water solubility and plant accessibility. Phosphorus has a key role for continuity and existence of the plants. Phosphorus is somewhat less mobile and least available nutrient in the soil. There is very little movement of P from its site of application. Plants absorbs it in the form of soluble orthophosphate ion but its solubility is restricted by the presence of calcium in alkaline and neutral soil, while in acidic soils due to presence of aluminum and iron due to which phosphorus is fixed and become unavailable to plants.

Effect of Phosphorus on Wheat Germination and Growth

Germination assures good crop stand that ultimately accounts for better grain yield of wheat. The maximum yield can be expected when germination of seed is uniform and optimum. Raza (2002) reported that germination of wheat was not affected by the application of phosphorus. According to Hyder (2002) increasing P from 0 to 100 kg per hectare phosphorous caused a non-significant increase in germination of wheat seeds. Phosphorus may cause salt injury during emergence of wheat seed and thus may be applied safely at the sowing time (Shahid, 2004). Hussain et al. (2004a) performed a field experiment to study the effect of P on germination of wheat and reported that phosphorus had no significant effect on germination of wheat seed. Hussain et al. (2004b) reported that germination of wheat seed is not significantly affected by the application of different levels of phosphorus. It might be attributed to the fact that germination is mainly controlled by the reserved food material in the seed. Khan (2003) reported that the number of tillers per plant in wheat is an important parameter and is mostly controlled genetically. Pareek (2004) concluded that the number of tillers per unit area significantly increased with an increase in phosphorus application. They observed that deficiency of phosphorus restricts tiller development. Sanjeeve et al. (1999) observed that by increasing application of phosphorus the number of productive tillers are increased significantly. Valerio et al. (2009) reported that tillers emergence, development and survival are extremely important in wheat because tillers are the main quantative component in grain yield and significantly influenced by phosphorous application. Taakahashi and Anwar (2007) reported that P application significantly influenced tillers development and increase in P level increased the number of fertile tillers. Phosphorus fertilization has great influence on wheat yield by increasing the number of tillers per plant and its deficiency has been reported as one of the main resource for reduction in number of tillers per plant (Prystupa et al., 2003). Valle (2010) reported that phosphorus availability seems to have the main influence on wheat ability to differentiate and expand leaves and phosphorus has great influence on tillers development. Boot stage is also very critical regarding water and nutrition point of view and any type of stress at this stage may cause considerable reduction in yield. Lodging caused a considerable reduction in yield and the cause of lodging is excessive use of N while phosphorus reduced the excessive effect of nitrogen. Plant height is a function of crop nutrition, ecological conditions and the genetic makeup. Balanced combination of NPK significantly increased plant height (Hussain et al., 2004a). Bashir et al. (2015) reported that maximum height (101.56 cm) of wheat was attained at 125 kg P_2O_5 ha^{-1} and lowest height (92.99 cm) was noted in the plot where no phosphorus was applied. Maximum number of wheat productive tillers were recorded at 90 kg P ha^{-1} and minimum number of productive tillers were recorded when no P was applied (Ali et al., 2020).

Effect of Phosphorus on Wheat Yield and Yield Components

After heading, the pollination occurs that determine the number of grains per spike. The grain development progresses through eight stages viz. water ripe, milk ripe, soft dough, medium dough, hard dough, mealy ripe, kernel hard and dead ripe. Among all grain development stages, the milk ripe is the most important one and any stress especially nutrient deficiency affect the yield by influencing grain size (Khan 2003). Spike length plays a key role in determining the productivity of wheat. More the spike length more will be spikelet's and number of grains per spike and ultimately higher will be the yield. Application of phosphorus significantly increased the spike length (Hussain et al., 2004a). In the previous research Khan (2003) has shown that irrigation or nutrition stress especially phosphorus stress at this stage may have serious effect on crop yield because of less grain number per spike or shrunken grains. Number of grains per spike is greatly influenced by crop nutrition and ecological conditions (Jawar et al., 2004). Number of spikelets per spike, rate of spikelet initiation and length responded positively to applied phosphorus (Ahmad and Rashid, 2003). Number of fertile spikelets per spike was significantly increased by increasing phosphorus from 60 to 90 kg ha^{-1} (Hussain et al., 2008). Monasterio et al. (2002) also reported that higher dose of phosphorus increased the number of spikelets per spike. Abbas et al. (2000) studied the effect of phosphorus on three wheat cultivars and concluded that spike length, spike numbers and numbers of spikelets per spike were significantly increased by each increment in phosphorus application. The 1000-grain weight makes major contribution to grain yield of wheat and is greatly influenced by ecological conditions and nutrition supply. 1000-grain weight was increased with increase in phosphorus levels (Kinaci, 2000). Memon and Puno (2005) reported that there was a linear increase in 1000-grain weight with increasing levels of super phosphate and urea but upto certain limit. Hussain et al. (2008) evaluated the wheat response with different phosphorus application in soil having property of calcareous silty loam. They observed that grain yield was increased when wheat was fertilized with phosphorus at the rate from 60 to 120 kg P per hectare and maximum grain yield was achieved at 120 kg P per hectare. They reported that number of grains per spike, 1000-grain weight and number of tillers per plant were significantly affected by P applications. Phosphorus applied at 120 kg per hectare enhanced all these parameters and produced high yield per hectare. Ali et al. (2020) reported that 90 kg P ha^{-1} produced maximum biological yield (6554 kg ha^{-1}) and grain yield (3955 kg ha^{-1}) of wheat.

Effect of Phosphorus on Wheat Quality

Hussain et al. (2002) reported that application of P significantly affected the protein contents of wheat. Zhu et al. (2012) conducted a field experiment on growth and yield of weak-gluten wheat. They applied 5 different levels of phosphorus (0, 72, 108, 144 and 180 kg/ha) to wheat. They observed that phosphorus at the rate of 108 kg/ha produced maximum grain yield but the protein contents in grain was lower than 11.5%, threshold for the protein content to evaluate weak-gluten wheat suitable for production of cake and biscuits. Kai et al. (2012) studied the effect of phosphorus applications on protein contents and phosphorus use efficiency (PUE) in spring weak-gluten wheat grown under field conditions. Results showed that with increase in phosphorous fertilizers grain yield and phosphorus agricultural efficiency (AEP) increased in quadratic equation, but partial factor productivity of phosphorus (PEPP) decreased in a logarithmic equation. Ali et al. (2020) reported that 90 kg P ha^{-1} gave maximum fat (2.55%) and crude protein contents (12.22%) of wheat. Adnan (2016) observed maximum P concentration (2631.5mg Kg^{-1}) at 135 kg P_2O_5 ha^{-1} while lowest concentration of P (2099.2mg Kg^{-1}) was observed at 45 kg P_2O_5 ha^{-1}.

Genotypic Response to Phosphorus in Wheat

Different cultivars of the same crop respond differently to applied phosphorus. The reason is that the variation in their root system and the ability to absorb nutrients from the soil. The cultivars with thick and longer roots are more efficient to absorb nutrients from the soil. Five wheat varieties were tested at different phosphorus levels and results showed that germination was not effected by phosphorus. Both phosphorus and varieties affected significantly the number of fertile tillers m^{-2} and spike length. The interaction among phosphorus and varieties showed that plant height, number of grains $spike^{-1}$, 1000-grain weight, straw yield, grain yield, biological yield and harvest index was affected significantly. Phosphorus contents in grain and straw varied considerably depending on the species, genotypes and mineral nutrition (Jelie et al., 1999). In an experiment Moudrv and Devoracek (1999) evaluated the mineral uptake efficiency of 10 wheat varieties and concluded that in low input system spelt wheat had better mineral uptake than common wheat and recorded significant differences in phosphorus contents of different varieties. Alam and Shah (2002) evaluated the performance of 5 wheat varieties at different levels of phosphorus and concluded that Punjab-96 produced the maximum yield against the lowest for Pasban-90 while Punjab-90 was superior to Inqalab-91 in utilizing the absorbed phosphorous for grain production. Plant phosphorus efficiencies (uptake, utilization and agronomic) were found to differ significantly between cultivar in an experiment conducted by Zhu *et al.* (2001). The result of this study indicated that there is wide variation in tolerance to phosphorous deficiency among wheat cultivars that can be exploited in breeding new wheat cultivars for high phosphorous deficiency tolerance. Phosphorus applied at 120 kg/ha enhance yield and all yield components (Hussain *et al.,* 2008). Alam *et al.* (2003) determined the effect of phosphorus on the wheat. Three genotypes of wheat viz. Punjab-96, Inqalab-91 and Pasban-90 were studied. After harvesting the crop, they concluded that there was significant difference in wheat in term of phosphorus uptake, grain and straw yield and 1000-grain weight. They concluded that application of phosphatic fertilizers along with selection of suitable variety can improve phosphorus fertilizer efficiency and enhanced the yield. Wen-Shou (2004) performed a field experiment to investigate yield and phosphorous use efficiency of 100 cultivars of spring wheat under different levels of phosphorous. The phosphorous contents of grain, stem and leaves, phosphorous accumulation in grain and above ground parts, phosphorous use efficiency and yield increment significantly varied at 1% level among the cultivars at the same phosphorous rate. Under low levels of phosphorous, the grain yield ranged from 0.367 to 0.716 kg m^{-2} (0.55 kg m^{-2} on average). The level of P utilization efficiency for grain production ranged from 160.1 to 448.3 g g^{-1} (223.1 g g^{-1} on average). Eight cultivars characterized by high yield and phosphorous use efficiency were selected. Under high levels of phosphorous, the grain yield ranged from 0.438 to 0.761 kg m^{-2} (0.643 kg m^{-2} on average). The level of phosphorous use efficiency for grain production varied from 150.9 to 350.9 g g^{-1} (229.8 g g^{-1} on average). Korkmaz et al. (2010) conducted an experiment to determine behavior of wheat genotypes to different phosphorus levels in typical environmental conditions of Turkey. They utilized 5 wheat varieties (Genc-99, Balatilla, Adana-99, Golia and Panda) and 5 phosphorus levels (0, 9, 17, 35 and 70 kg/ha) were applied. They observed that increase in phosphorus level enhanced the leaf (0.18-0.44%) and grain P (0.08-0.18%) concentration of the varieties. They found grain value ranged from 1.4-4.85 t/ha and optimum yield were achieved with 35 kg P/ha application rate in both years. They found that respective yield differed among different varieties, particularly Balatilla and Adnana-99 were significant different from other genotypes and performed very well. Yasin et al. (2008) performed an experiment to assess the response of wheat genotypes to poor and sufficient levels of phosphorus in solution culture. Considerable differences in growth parameters such as total plant dry matter (TDM) and some phosphorus related parameters were understandable at deficient and sufficient phosphorous levels. TDM ranged from 0.89 to 1.51 1.56 to 2.5 g per plant at deficient and adequate phosphorous levels respectively. They found that genotype-91773 produced nearly doubled shoot dry matter of Pasban at inadequate phosphorus level while genotype-90640 produced the highest root dry matter at sufficient phosphorus level. Only 3 genotypes 89626, 90627 and 91773 showed a phosphorus stress factor.

CONCLUSION

It is concluded from the above review that high yielding wheat varieties demand sufficient nutrient supply to produce maximum grain yield. So, it is important to cultivate wheat under optimum levels of phosphorus to obtain maximum yield and quality.

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