MITIGATING PULSE PRODUCTIVITY CONSTRAINTS THROUGH PHOSPHORUS FERTILIZATION- A REVIEW

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ABSTRACT

Pulses occupy an important position in food and nutritional security in India. Food security has been a major area of concern for agricultural scientists and planners in India since long. India produces over 200 million tonnes of foodgrains every year with an increase of four folds since independence. Increased efforts to produce more food have resulted in tremendous shift in cropping systems towards cereal-cereal based systems. But, still India is far behind in pulses production. In order to harness higher yields, phosphorus nutrition plays an important role besides other crop management factors. Hence, it is imperative to understand the constraints in pulse production to realize higher productivity and maintain soil health. P is important plant nutrient alongwith other major nutrients in pulses. This becomes more important when most of the Indian soils are P deficient and the farmers do not care for P nutrition in pulses resulting in lower pulse production, and making dependent on pulse imports for feeding the huge population causing sizable drain of foreign exchange.

Key words: Nutrition, Phosphorus, Productivity, Pulses.

Agriculture is a critical sector of Indian economy, contributing about 15% of national gross domestic product and more importantly, about half of India’s population is wholly or significantly dependent on agriculture and allied activities for their livelihood (Govt. of India, 2011). But, agriculture in India happens to face several constraints and challenges especially in the areas of food security, natural resource management and application of advanced farm technology to harness crop yield potential, better farm profitability, minimal adverse environmental impact; better soil health and food self-reliance (Choudhary et al., 2012). Food security has been a major area of concern for agricultural scientists and planners in India since long (Govt. of India, 2011). At present, India produces over 200 million tons of foodgrains every year with an increase of four folds since independence (Rehman et al., 2012). But, increased efforts to produce more food have resulted in an increase in tremendous shift in cropping systems towards cereal-cereal based systems. This has marginalized the pulses resulting in quantitative as well as qualitative degradation of productive base, land and farm resources. Stagnant pulse production in India (Fig. 1), compared to population growth rate of 1.44% has further led to steady decline in per capita pulse availability over last two decades (IIPR, 2011). Thus, pulse production in India has fluctuated widely leading to steady decline in the per capita availability over last 20 years (Gregory et al., 2003). However, pulses are still important component of Indian agricultural economy only next to foodgrains and oilseeds in terms of acreage, production and economic value (Choudhary, 2009; Ali et al., 2012).

India is largest producer and consumer of pulses with about 25-28% of global share (IIPR, 2011), and 34% of food use. But, it is paradoxical that India being one of the major pulse growing country at global level, accounted for about 11% share of world pulse imports during 1995-2001 to feed its huge population (Gregory et al., 2003). Thus, there is a challenge for agricultural scientists, extension workers, planners and farming community.
to enhance and sustain pulses productivity and diversify their cropping systems with pulses to meet national pulses requirement. During 2010-11, total area under pulses in India was 26.3 million ha with record production of 18.9 million tons but with low productivity of 719 kg ha\(^{-1}\) (Ali et al., 2012), compared to global pulse productivity of 871 kg ha\(^{-1}\) (IIPR, 2011). Thus, we have to focus on bridging the yield gaps besides area expansion and diversified production systems well equipped with appropriate pulses production technology already generated by research institutions in order to break yield plateau through recent technological advancements (Choudhary et al., 2009).

**Constraints in pulses production:** Pulses are an integral part of average Indian meal and a large proportion of Indian population is vegetarian, and pulses form the main source of protein. The protein content in pulses is about 18–25%, which makes pulses one of the cheapest sources of proteins for human consumption. However, per capita domestic production of pulses has declined from 60 g/day in 1970–71 to 36 g/day in 2007–08. Productivity of pulses in India is very low (719 kg/ha), compared to best-in-class yields of about 1,900 kg/ha in Canada and US. In general, pulses are energy rich crops requiring higher energy to produce unit amount of proteins than production of carbohydrates. It is estimated that one gram of glucose synthesized during photosynthesis produces 0.83 g starch, 0.32 g lipids and 0.40 g proteins. Because of this physiological constraint, pulses productivity is less as compared to cereals production (Choudhary, 2009). Besides this, there are several other constrains in pulses production. Non-availability of good quality HYVs seed of pulses, lack of knowledge about HYVs, poor technical guidance and untimely availability of inputs (agro-chemical, fertilizers etc.) are some of socio-economic and institutional constraints in pulses production in India. In India, pulses are mostly cultivated on marginal soils that too under rainfed situations with minimal external input use. One of major pulse production constraints is sub-optimal nutrient use in India.

**Plant nutrition in pulses:** Pulses in India are generally cultivated on marginal and sub-marginal lands, which are characterized by poor soil fertility and moisture stress, and consequently their yield potentials have not been realized. Further, more than 90% area under pulses is rainfed. Therefore, there is a great scope of increasing the production in rainfed as well as irrigated areas through nutrient management. Out of 16 essential elements, pulses specially need adequate amount of P, Ca, Mg, S and Mo (Thiyagarajan et al., 2003). Calcium and magnesium are required to stimulate growth and to increase size of nodules, pod formation and grain setting. Sulphur is required for nodulation and protein synthesis. Mo for nitrogen fixation and assimilation and boron for reproduction, are required. Phosphorus is required for proper root growth and growth of rhizobia. For producing one ton of biomass, pulse crops in general remove about 30-50 kg N, 2-7 kg P\(_2\)O\(_5\), 12-30 kg K\(_2\)O, 3-10 kg Ca, 1.5 kg Mg, 1-3 kg S, 200-500 g Mn, 5g B, 1g Cu and 0.5 g Mo from soil (Ahlawat and Ali, 1993). Among all, phosphorus nutrition is of utmost importance in pulses. It is observed that most of Indian soils are deficient in available P status (Fig. 2), especially acid
Role of phosphorus in pulse production: Balanced nutrition in pulses along with better crop management practices results in harnessing of higher crop yields in pulses. In pulses, phosphorus (P) nutrition is very important besides other nutrients. Since, pulses harbour the atmospheric nitrogen (N) fixers; P also helps in nodule formation and N fixing efficiency of Rhizobium strains. It is reported that response of pulses to insoluble P like rock phosphate is very higher due to inherent capacity of pulses. Though, their response to P can also be increased by use of efficient and appropriate Rhizobium strains suitable to different pulses as well as P solubilizers (Bacillus polymixa, Aspergillus awamorri, Pseudomonas striata etc.). Vesicular arbuscular mycorrhiza (VAM) also helps in solubilization of P (Suri and Choudhary, 2012). Various functions of phosphorus in pulses and other crops are enlisted below:

1. Phosphorus (P) is used in plants as constituent of nucleic acids, phospholipids, co-enzymes NAD and NADP. Found in cell membranes and cell walls. Phosphorus is, therefore, important in cell division and development of new tissue.
2. P is constituent of ATP which is an energy transfer compound in various biochemical reactions. Thus, phosphorus is associated with complex energy transformations in the plants.
3. Found in meristematic region of actively growing plants where it is involved in synthesis of nucleoproteins.
4. P helps in photosynthesis, respiration and N metabolism, carbohydrate metabolism, fatty acid metabolism, as a constituent of co-enzymes NAD and NADP in oxidation and reduction reactions.
5. P also enhances nodule formation and N fixing efficiency of Rhizobium strains. Thus, production of pulses is increased by P application.
6. P is involved in nitrogen metabolism and thus, it helps in protein synthesis and ultimately productivity of legumes.
7. P helps in growth of roots. This function is important in root nodulation in legumes and nutrient and water transport mechanism in plants in general.

Deficiency symptoms of phosphorus: Plants deficient in phosphorus are stunted in growth and often have an abnormal dark-green color due to sugar accumulation and causing anthocyanin pigments to develop, producing a reddish-purple color (Fig. 3). However, reddish-purple color always does not indicate P deficiency but may be a normal plant characteristic. Reddish-purple color may be induced by other factors also.

Phosphorus management and balanced nutrition in pulses: Like other crops, pulses also need balanced plant nutrition including phosphorus. Fertilizer management in major soils in major pulse crops is mentioned in Table 1. It is revealed from Table 1 that P is major nutrient in pulses over N & K. Being legumes, pulses are able to fix atmospheric nitrogen.

Legume nitrogen fixation starts with formation of a nodule (Fig. 4). A common soil

![Healthy vs Phosphate-deficient plant](image)

**Table 1: Fertilizer management in legumes in India.**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Fertilizer management</th>
</tr>
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<tbody>
<tr>
<td>Blackgram (Vigna mungo)</td>
<td>NPK @ 20:60:40 kg/ha</td>
</tr>
<tr>
<td>Kidneybean (Phaseolus vulgaris)</td>
<td>NPK @ 20:60:40 kg/ha</td>
</tr>
<tr>
<td>Pigeonpea (Cajanus cajan)</td>
<td>NPK @ 30:80:60 kg/ha</td>
</tr>
<tr>
<td>Cowpea (Vigna sinensis)</td>
<td>NPK @ 20:60:40 kg/ha</td>
</tr>
<tr>
<td>Chickpea (Cicer arietinum)</td>
<td>NPK @ 20:60:40 kg/ha</td>
</tr>
<tr>
<td>Lentil (Lens culinaris)</td>
<td>NPK @ 20:60:20-30 kg/ha</td>
</tr>
<tr>
<td>Mungbean (Phaseolus radiatus)</td>
<td>NPK @ 20:50:40 kg/ha</td>
</tr>
<tr>
<td>Clusterbean (Cyamopsis tetragonoloba)</td>
<td>NPK @ 20:60:20 kg/ha</td>
</tr>
<tr>
<td>Horsegram/Kulthi (Macrotyloma uniflorum)</td>
<td>NPK @ 15:45:0 kg/ha</td>
</tr>
<tr>
<td>Soybean (Glycine max)</td>
<td>NPK @ 20:60:40 kg/ha NPK @ 20:30:30 kg/ha</td>
</tr>
</tbody>
</table>

(Source: Choudhary, 2009; Sepat et al., 2013)
bacterium, Rhizobium, invades the root and forms root nodules. Biological nitrogen fixation is the process that changes inert N\(_2\) to biologically useful NH\(_3\). Thus, pulses require less fertilizer N though their P requirement is high. It is inevitable to add the fertilizer P in pulses through phosphatic fertilizers. A breakthrough is essential in this matter to promote P fertilizer use in legumes by the farmers. It is observed that farmers use sub-optimal doses of P fertilizers in pulses. In order to meet P requirement of various pulses, farmers can add P to their fields through any of the following P containing fertilizers keeping in view the P requirement of legume crops (Table 2).

Studies carried out at IARI New Delhi with balanced P fertilization in pigeonpea-wheat system shows that available soil P improved with the increase in applied P both in pigeonpea and wheat. Both pigeonpea and wheat receiving 17.2 kg P/ha with phosphate solubilizing bacteria improved the bacterial count in soil rhizosphere over lower levels at harvest of these crops (Ahlawat and Singh, 2006). Both the crops, i.e. pigeonpea and wheat showed favourable response to P. Only a small fraction (15-20%) of applied P is usually utilized by the first crop and the left over is utilized by subsequent crops. It is for this reason that the total productivity of the cropping system was enhanced through direct response of P in pigeonpea and wheat, and residual response of P in wheat.

**Biofertilizers for P management in pulses:**

**Phosphate Solubilizing microorganisms (PSM):**

Phosphorus (P) is one of the major essential macronutrients for plants and is applied to soil in the form of phosphate fertilizers. However, a large portion of soluble inorganic phosphate which is applied to the soil as chemical fertilizer is immobilized rapidly and becomes unavailable to plants. PSM are a group of beneficial bacteria and fungi capable of hydrolyzing organic and inorganic phosphorus from insoluble compounds. Thus, P-solubilization ability of the microorganisms is considered to be one of the most important traits associated with plant phosphate nutrition. When PSM like Bacillus polymixa, Aspergillus awamori, Pseudomonas striata etc. are used with rock phosphate, they can save about 50% of P requirement of phosphatic fertilizer. Application of biofertilizer either through seed inoculation or soil application along with phosphorus fertilizer proved to improve productivity, enhanced P use efficiency, apparent P recovery and soil health (Ahlawat and Singh, 2007) in fieldpea (Singh et al. 2012), lentil (Singh et al. 2008; Singh et al. 2011), greengarm (Singh et al. 2009) and pigeonpea (Singh and Ahlawat, 2006).

**B. Vesicular arbuscular mycorrhiza (VAM):**

Vesicular arbuscular mycorrhiza is mostly recommended for upland and transplanted crops. It mainly improves uptake of available phosphorus by VAM inoculated plants. There is also an enhanced absorption of water and other nutrients such as N and K and certain micronutrients (Zn, Cu) (Choudhary, 2011). These effects are mainly attributed to the reason that VAM hyphal network in soil matrix increases mobilization and absorption

<table>
<thead>
<tr>
<th>Chemical fertilizers</th>
<th>Nutrient content (%)</th>
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<tbody>
<tr>
<td>Ammonium Phosphate Sulphate (APS)</td>
<td>N 16-20 P(_2)O(_5) 20 K(_2)O -</td>
</tr>
<tr>
<td>Single Super phosphate (SSP)</td>
<td>- 16 - -</td>
</tr>
<tr>
<td>Double Super Phosphate (DSP)</td>
<td>- 32 - -</td>
</tr>
<tr>
<td>Triple Super phosphate (TSP)</td>
<td>- 46-48 - -</td>
</tr>
<tr>
<td>Di Ammonium Phosphate (DAP)</td>
<td>18 46 - -</td>
</tr>
<tr>
<td>Rock Phosphate</td>
<td>- 3-8 (Available) -</td>
</tr>
<tr>
<td>Mono Ammonium Phosphate (MAP)</td>
<td>11 48 - -</td>
</tr>
</tbody>
</table>
of plant nutrients from rhizosphere and outside the rhizosphere in the soil system, allowing an increase in the uptake of macro (especially P) and micronutrients by the crops (Suri et al., 2011).

Mycorrhizal fungi derive an enormous survival advantage from teaming up with plants. Instead of having to compete with all the other soil heterotrophs for decaying, organic matter, the mycorrhizal fungi obtain sugars directly from the plant's root cells. This represents an energy cost to the plant, which may lose as much as 5-30% of its total photosynthates production to its mycorrhizal fungi symbionts (Singh et al. 2010).

**CONCLUSION**

Of the major nutrients (N,P,K), P is most important nutrient for pulses. Balanced fertilization with NPK along with biofertilizers has been proved beneficial in pulses both under rainfed and irrigated conditions. Hence, P needs to be taken care of while balanced fertilization in pulses. Farmers and extension functionaries must recognize that it is highly needed to include P nutrition in their nutrient management practices in balanced manner in present day intensive farming to harvest higher pulse yields of superior quality earning maximum sustainable profitability.

**REFERENCES**


