Chapter 6

PHOSPHORUS (P)

6.1. GENERAL FEATURES

Phosphorus is one of the most important macronutrients required for normal growth and development of crop plants. Its atomic weight is 31, and has an isotope ^{32}P. It does not occur as abundantly as other nutrients do. The concentration of P in surface soil varies from 0.02 to 0.1%. The quantity of P in the soil does not reflect the availability to the plants. Phosphorus is absorbed by the plant largely as orthophosphate ions ($H_2PO_4^-$ and HPO_4^{2-}), present in the soil solution largely depends upon soil pH and quantity present in the soil. The ion $H_2PO_4^-$ is absorbed faster than HPO_4^{2-}, and the main site of P absorption is root tip and elongation zones of roots. The greater accumulation of P is performed through root tip area. Plants may also absorb organic P as nucleic acid and phytin in special cases. Phosphorus moves from soil to root surface through diffusion and mass flow, and the earlier is greater than the later.

6.2. ORGANIC P

It represents about 50% of the total P and varies with soil depth. The organic P is mineralized and converted to available form through the activity of enzyme phosphase. This enzyme present in the microorganisms which helps in the mineralization process. Many of the organic P has been characterized as inositol phosphates (10-50%), phospholipids (1-5%) and nucleic acid (0.2-2.5%). Generally, P mineralization and immobilization take place simultaneously as follows:

Uptake of P by the Plants

It is mainly taken up by the plant as $H_2PO_4^-$ and HPO_4^{2-} forms which are present in the soil solution.

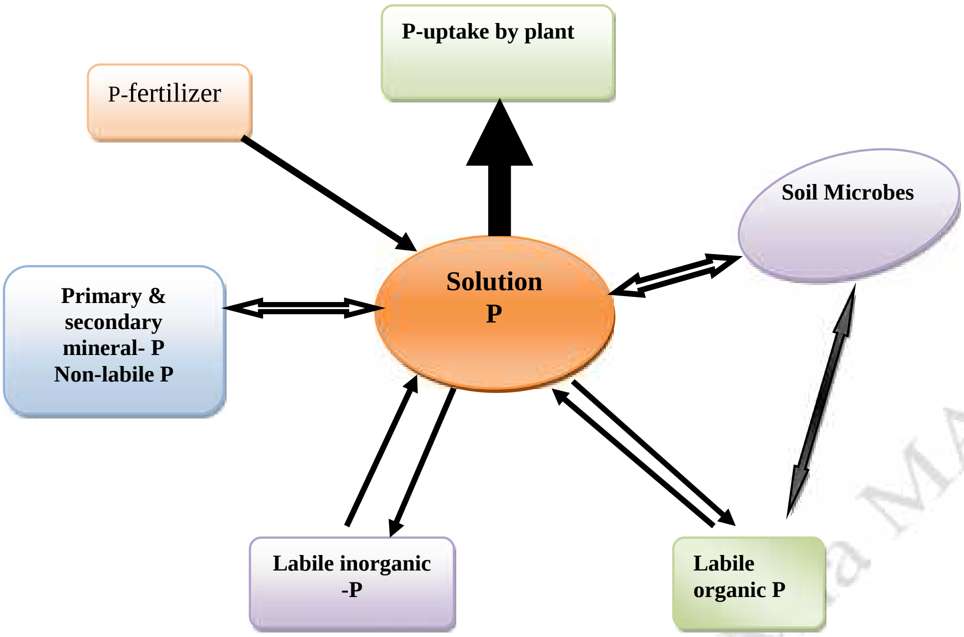


Figure 6.1. Simplified schematic representation of P cycle in soil.

Table 6.1. Phosphorus containing fertilizers with their chemical formulae and approximate P concentration

Name of fertilizer	Chemical formula	Concentration (appox. % P)
Rock phosphate	$[Ca_3(PO4)_2]_3$. $CaFx.(CaCO_3)x.(Ca(OH)_2)_2$	6.16-28.6
Single super phosphate (SSP)	$Ca(H_2PO_4)_2$	7-9.5
Triple super phosphate (TSP)/ CSP	$Ca(H_2PO_4)_2$	19-23.5
Diammonium phosphate (DAP)	$(NH_4)_2HPO_4$	20-23
Monopotassium phosphate	KH_2PO_4	22.44
Dipotassium phosphate	K_2HPO_4	18
Bone meal		9

Conversion Factor of P

% P= $P_2O_5 \times 0.44$
% P_2O_5=P×2.27

6.3. Assimilation of Phosphorus

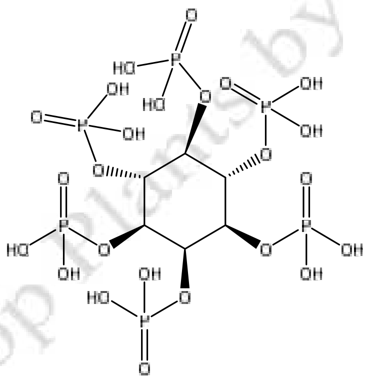
The main step of assimilation of P in the cell is the formation of ATP (adenosine triphosphate). The overall reaction of the process is the addition of inorganic phosphate with ADP (adenosine diphosphate) to form a phosphate ester bond.

Table 6.2. Recommended dose of P-fertilizer for different crops

Name of Crops	Soil Analyses Interpretation *(Soil fertility level)*	Dose (kg ha^{-1})
Rice	Optimum	0-8
	Medium	9-16
	Low	17-24

	Very low	25-32
Wheat	Optimum	0-10
	Medium	11-20
	Low	21-30
	Very low	31-40
Maize	Optimum	0-25
	Medium	26-50
	Low	51-75
	Very low	76-100
Jute	Optimum	0-4
	Medium	5-8
	Low	9-12
	Very low	13-16
Cotton	Optimum	0-17
	Medium	14-34
	Low	35-51
	Very low	52-68

Source: Fertilizer Recommendation Guide (2012).



Phytic acid

Phytic Acid

i. Phosphate in the soil solution is readily taken up by plant roots and incorporate into a variety of organic compounds including sugar phosphates, phospholipids and nucleotides
ii. P is found about 0.2 to 0.8% of the total dry matter.
iii. P remains in oxidized form in the cell i.e. no reduction is required like N and S assimilation.
iv. It remains as esterified through a hydroxyl group to a carbon chain C-O-P simple phosphate ester (sugar phosphate) or remain as energy phosphate bond P-P (e.g. ATP)
v. Phosphate along with protein/fat is incorporated into biological membrane as phospholipid and phosphoprotein.

Phytic acid or phytate is the principal storage form of phosphorus. It is a saturated cyclic acid found in many plant tissues especially in bran and seeds. Phytic acid has a strong affinity in binding different minerals namely Ca, Zn, Fe etc.

6.4. Physiological and Biochemical Functions of Phosphorus

Phosphorus has profound functions on growth and development of crop plants. The main functions have been summarized here under different sub-headings:

6.4.1. Energy Transfer

The most important function of P is the transfer or storage of energy as adenosine triphosphate (ATP), adenosine di-phosphate (ADP), adenosine monophosphate (AMP), guanosine triphosphate (GTP), uridine triphosphate (UTP), cytidine triphosphate (CTP) etc. When the terminal phosphate molecules split off from ATP or ADP a large amount of energy (12000 cal mol^{-1}) is liberated. Energy obtained through photosynthesis and metabolism of carbohydrate and lipid is stored in phosphate compounds for further utilization by the plant. ATP is the storehouse of energy of all kind of biological reactions. The ATP is the energy rich phosphate bond which is required for the synthesis of starch. Similarly other phosphate bond compounds like ADP, AMP, GTP, UTP are required for the synthesis of simple sugar viz. sucrose and cellulose.

6.4.2. Structural Components of Several Compounds

Phosphorus acts as a structural element of DNA, RNA, coenzyme, phosphoprotein, phopspholipid, glycolipid etc. Amine choline is often the dominant partner forming phosphotidal choline (lechithin).

6.4.3. Participation of P in Oxidation-reduction Reaction

Phosphorus plays an important role in the oxidation reduction reaction such as NAD and NADP are in oxidation reduction reaction in which hydrogen transfer take place.

6.4.4. Regulatory Role of Organic Phosphate

i. Inorganic P controls some regulatory role of some key enzymes.
ii. It can stimulate the phosphofructokinase enzyme which enhances the ripening of some fruits like tomato.
iii. Large quantities of P are found in seed and fruit; hence it is regarded as essential for seed formation, and is also associated with the maturity of crop.
iv. Phosphorus is required for better root growth, and increased root growth in different crop plants have been found by the application of P-fertilizer.
v. Crop quality has been found to be improved by the balanced application of P-fertilizer. Similarly resistance to diseases has also been found by the balanced application of P.

6.5. Phosphorus Deficiencies in Crop Plants

6.5.1. Deficiency of P resulted in the lowering of cell and leaf size but unaffecting the chlorophyll content. However, the photosynthetic activity of chlorophyll is reduced due to deficiency of P.

6.5.2. Generally P deficiency occurs in crop plants where soils are acidic, leached and calcareous. Cold weather can cause a temporary deficiency.

6.5.3. All plants may be affected due to deficiency of P, although this is an uncommon disorder. The ventral site of tomato leaves and the stem may turn into purple color due to P-deficiency..

6.5.4. Generally, the plants become dark green or purple color due to anthocyanin pigmentation under P deficiency condition.

Figure 6.2. Purple colored leaf in maize (*Zea mays* L.) due to deficiency of phosphorus.

6.5.5. Plant growth may be stunted due to P deficiency, and sometimes the deficiency symptoms are confusing with the symptoms of nitrogen deficiency. Symptoms include poor growth, and leaves may turn blue/green but not yellow—oldest leaves may be affected first. Fruits may become small in size and acidic in taste.

6.5.6. The P-deficiency in tomato may result in necrosis of thin walled central pith cells of stem and thereby may produce large intercellular space (Lyon and Garcia, 1944).

6.5.7. Phosphorus deficiency delays the flower initiation and decreases the number of flower in crop plants (Bould and Parfitt, 1973; Rossiter, 1978).

6.5.8. The common susceptible plants are carrots, lettuce, spinach, apples, gooseberries etc.

6.5.9. Phosphorus deficiency increases the secretion of phytase from roots of various plant species which may provide an efficient mechanism for certain plants to utilize inositol hexaphosphate in soil (Bilyeu et al., 2008; Li et al., 1997).

6.5.10. Deficiency of P decreases the synthesis of DNA and RNA which cause restriction of nuclear division or might cause defects in parts of chromosome or gene suppression.

6.6. REFERENCES

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