



Behavior of Phosphorus in the Calcareous Soil

Hasan H Mahdi* and Raghad S Mouhamad

Agricultural Research Department, Ministry of Science and Technology, Soil and Water Resources Center, Iraq

*Corresponding author: Dr. Hasan H Mahdi, Ministry of Science and Technology, Agricultural Research Department, Soil and Water Resources Center, Baghdad, Iraq, Tel no: +9647702719152; Email: hasan7628@yahoo.com

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Abstract

Phosphorus (P) is essential for all known forms of life because it is an essential element in many physiological and biochemical processes. The phosphorus component of each cell in all organisms cannot be dispensed and replaced by any other element. Phosphorus found in complex DNA and RNA structures that carry and interpret genetic information and thus control all living processes in plants, animals and humans. It is an essential component of the energy transfer system in all cells. Phosphorus compounds in the soil are two groups: inorganic phosphorus (mineral) compounds, organic phosphorus compounds. Phosphorus fractions in the soil classified as available phosphate ($\text{NaHCO}_3\text{-P}$), aluminum phosphates (Al-P), calcium phosphate (Ca-P) and phosphorus residual (Res-P). Phosphorus fractions in the soil are the sources of phosphorus supply for agricultural crops. Only 10-20% of phosphorus taken with fertilizer by plants when phosphate fertilizers added to the soil, because the majority of phosphorus is quickly fixation or precipitation in non-absorbable forms by the plant. The phosphorus availability of plants depends on soil properties, pH of the soil, soluble iron, aluminum and manganese, calcium minerals, organic matter, activities of microorganisms. The availability of phosphorus varies depending on soil type. The results obtained showed that 69.3 ppm of the extracted phosphorus at equilibrium ($C_e = 0.2$ ppm P) achieves optimum conditions for feeding most field crops. Ultimately, the absorption of phosphorus affects the growth and production of plants.

Keywords: Phosphorus; Phosphorus fractions; Organisms; Phosphate fertilizer

Introduction

Until relatively recently, plant growth and yield productivity limited because deficiency of phosphorus, where small amounts of rocks and soil minerals were released each year due to weathering. As farmers began to use fertilizer in the 19th century, the levels of plant phosphorus available in many soils were very low. This means that little response to other nutrients, especially nitrogen, until phosphate, fertilizer has been used, meaning that phosphorus was a specific nutrient for crop growth. This is showed by the results of the experience

began in 1899 on the soil contains a small percentage of phosphorus in Suffolk, England. Table 1 and Figure 1 shows that when nitrogen applied only, winter wheat, spring barley and Mongolian roots were slightly better than untapped soil. However, giving both nitrogen and phosphorus increases the yield significantly. Table 2 shows how the yield has increased over time and phosphorus has increased in grain and straw. In the 1930s, the average amount of nitrogen and phosphorus applied to arable land in the Netherlands, Belgium, Germany, Denmark, Great Britain and France was 29 kg and 43 kg $\text{P}_2\text{O}_5/\text{ha}^{-1}$ respectively, by 0.67: 1 [1].

Crop and period	Nutrient applied		
	None	Nitrogen	Nitrogen plus Phosphorus
	Yield T/ha		
Winter wheat grain 1900 - 1919	1.56	1.83	2.25
Spring barley grain 1900 - 1919	1.29	1.69	2.10
Man gold roots 1906 - 1919	15.60	17.60	40.40

Table 1: Effect of phosphorus on field yield.

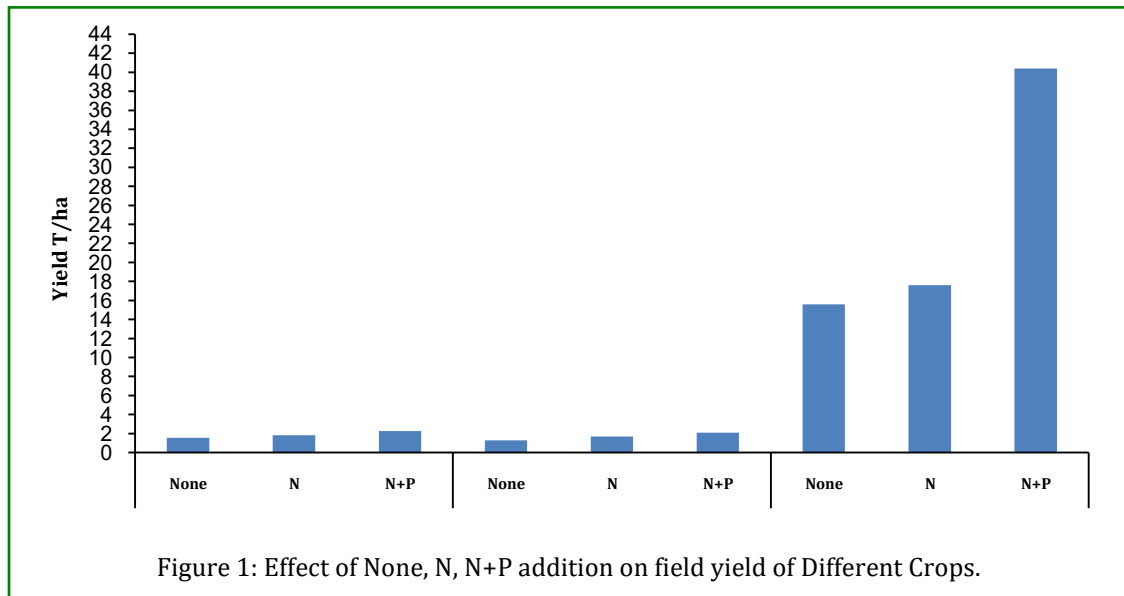


Figure 1: Effect of None, N, N+P addition on field yield of Different Crops.

Period	Yield grain T/ha	Phosphorus in grain plus straw kg P ₂ O ₅ /ha ⁻¹
1852 - 1871	2.70	25
1966 - 1967	3.07	34
1970 - 1975	5.48	50
1991 - 1992	8.69	71

Table 2: Increase in winter wheat yield and phosphorus between (1852-1992).

The adsorption of phosphate ions in some calcareous soils of Ninawa and Kirkuk regions from 0.01 KCl solution containing 1-12 micromoles phosphorus was studied. Different soils were selected in their texture, with a high and varied content of calcium carbonate ranging between 32.4 - 39.8%. The biological experiment was carried out by fertilizing the soil with different levels of phosphate fertilizer by 0, 22, 45, 90 kg P / ha⁻¹ and planted with maize (*Zea mays* L.) in 1 kg pots for five years. Adsorbed phosphorus at equilibrium solution concentration of 0.2 ppm P (Ce = 0.2 ppm P) was determined. It found an inverse association between the amount of phosphorus at equilibrium and the amount of phosphate extracted from soil. The amount of adsorbed phosphorus at Ce = 0.2 ppm P diminished as the rate of applied fertilizers

increase. The results obtained showed that 69.3 ppm of the extracted phosphorus at equilibrium (Ce = 0.2 ppm P) achieves optimum conditions for feeding most field crops [2].

Field experiment carried out in department of Horticulture - Faculty of Agriculture - University of Diyala during the autumn season 2007-2008, the soil was silty clay Loam, the aim of study the effect of seeding date and phosphate fertilizer on growth and yield of (*Trigonella foenum graecum* L.). The experiment included twelve treatments from three dates of cultivation (15/11, 1/12, 15/12) with four levels of phosphate fertilizer (0, 200, 300, 400) kg P₂O₅/ha⁻¹, according of Randomized Complete Block Design (RCBD). The results showed

significant increased in plant height, number of branches per plant, number of pods per plant, The dry and wet weight of root and vegetative branches and dry pods yield / ha where resulted from (400) kg P₂O₅/ha⁻¹. While highest values of pod wet weight, where resulted from (300) kg P₂O₅/ha⁻¹ [3].

Two experiments carried out at AL-Quba district- Mosul city during spring and autumn seasons of 2010 in a sandy loam soil to study the effect of zinc foliar application and phosphorus fertilizer on growth traits, yield components and quality of some sunflower hybrids (*Helianthus annuus* L.). The experiment carried out according to the randomized completely block design, with three levels of zinc (0, 4, 8 mg. L⁻¹) and three levels of phosphorus fertilizer (0, 100 and 200 kg P.ha⁻¹) added as trikalsiyum superphosphate (48% P₂O₅) with three sunflower hybrids (Pheobus, Iraqi flower and Euroflor). The results showed a significant increase in plant height, stem diameter, leaf area, head diameter, number of seeds. Head⁻¹, 1000 seed weight, seed yield, oil percentage, oil yield, protein percentage and protein yield in spring and autumn seasons at level 8 mg. L⁻¹ of foliar zinc application on plant leaves. The addition of phosphorus fertilizer showed significant increase in all parameters in both seasons

except stem diameter in autumn season at level 100 kg.ha⁻¹ [4].

Seventy-one surface soil samples (0-20 cm) taken from Atabey Plain -Turkey at different points, to determination the phosphorus availability and change in geochemical fractions. Descriptive physicochemical analyzes and sequential phosphorus fractionation carried out in the soil. These fractions are; sodium bicarbonate [NaHCO₃-P (organic Po, inorganic Pi and Total Pt)], sodium hydroxide [NaOH-P (organic Po, inorganic Pi and Total Pt)], citrate bicarbonate dithionite (CBD-P), hydrochloric acid (Ca-P), and residual (Res-P) phosphorus. Relations of phosphorus fractions with soil properties were discovered by analysis of variance, Pearson correlation analysis and chemo metric analysis. The results of fractions showed (Table 3): Ca-P (% 50.36) > Res-P (% 19.94) > CBD-P (% 12.17) > NaOH-Pt(% 6.94) > NaOH-Pi(% 6.24) > NaHCO₃-Pt (% 1.82) > NaHCO₃-Pi(% 1.57) > NaOH-Po (% 0.71) > NaHCO₃-Po (% 0.25). It was determined that the fractal distribution of these fractions changed according to the land use pattern. The results of this study are thought to provide a useful database to understand the deficiencies / toxicity mechanisms in the Atabey Plain [5].

Fractions	Min	Max	Mean		Std. deflection	Variance	skewness		Kurtosis	
			Statistics	Std. Error			Statistics	Std. Error	Statistics	Std. Error
NaHCO ₃ -Pt	0.73	7.33	1.82	0.14	1.15	1.32	2.53	0.28	8.10	0.56
NaHCO ₃ -Pi	0.35	6.96	1.57	0.13	1.11	1.23	2.48	0.28	8.36	0.56
NaHCO ₃ -Po	0.01	1.16	0.25	0.03	0.25	0.06	1.44	0.28	1.75	0.56
NaOH-Pt	2.53	12.66	6.94	0.27	2.30	5.28	0.67	0.28	0.14	0.56
NaOH-Pi	2.46	11.62	6.24	0.24	2.01	4.03	0.83	0.28	0.63	0.56
NaOH-Po	0.04	3.45	0.71	0.10	0.81	0.66	1.58	0.28	1.99	0.56
CBD-P	4.28	29.37	12.17	0.54	4.59	21.03	1.05	0.28	1.96	0.56
Ca-P	28.8	73.96	50.36	1.18	9.94	98.79	-0.11	0.28	-0.50	0.56
Res-P	5.68	43.35	19.94	0.98	8.25	68.12	0.75	0.28	0.38	0.56

Table 3: Descriptive statistics of the proportional distribution of phosphorus fractions (N: 71).

The Phosphorus in Nature

Phosphorus is not a rare element. It is eleventh in order of abundance in the earth's crust but the concentration in many rocks is very small. However, there are deposits that are sufficiently rich in phosphorus that extraction is commercially viable. Phosphate rock deposits found throughout the world and over 30 countries are currently producing phosphate for use in domestic markets and/or international trade.

The main commercial deposits at present are in the United States, Morocco and West Africa, China, the

Former Soviet Union and South Africa. The three major producing countries, i.e. the USA, China and Morocco currently produce approximately two thirds of the global phosphorus requirement. Morocco, whose reserves amount to an estimated 50% of the world total, also has potential reserves and natural resources that estimated to represent around 60% of total world resources. The only commercial West European deposit is in Finland.

Five countries control 90 percent of the world's known phosphorus supply: Iraq, Algeria, Syria, Russia, Brazil. Iraq is among the top countries for reserves of phosphate rock (Figure 2).



Figure 2: Distribution of global phosphate rock reserves [6].

Table 4 lists the annual production for 2009 and 2010 and an estimate of 2012 production for the major producers and the size of the current phosphate rock reserves. The IFDC estimate of global resources is approximately 290 billion tonnes.

Country	2009 (mt)	2010 (mt)	2012 (mt)	Reserves 2012 (mt)
Algeria	1.8	2.0	1.5	2,200
Australia	2.8	2.8	2.6	490
Brazil	6.4	5.5	6.3	270
Canada	0.7	0.7	0.9	2
China	60.2	65.0	89.0	3,700
Egypt	5.0	5.0	3.0	100
India	-	-	1.3	6
Iraq	-	-	0.2	460
Israel	2.7	3.0	3.0	180
Jordan	5.3	6.0	6.5	1,500
Mexico	-	1.5	1.7	30
Morocco	23.0	26.0	28.0	50,000
Peru	-	0.8	2.6	820
Russia	10.0	10.0	11.3	1,300
Saudi Arabia			1.7	750
Senegal	0.7	0.7	1.0	180
South Africa	2.2	2.3	2.5	1,500
Syria	2.5	2.8	2.5	1,800
Togo	0.9	0.8	0.9	60
Tunisia	7.4	7.6	6.0	100
United States	26.4	26.1	29.2	1,400
Other countries	8.6	6.4	6.0	390
World Total	166.0	176.0	210	67,000

Table 4: World Mine Production and Reserves [7,8].

The case of the Iraq reserves may be taken as an example, where “USGS restated from zero to 5800 Mt PR overnight in 2012, and “downgraded again by 93 % to a mere 430 Mt PR ...” Iraq data in the USGS MCS are factually based on

PR-Ore data. The uptake and correction of the Iraq data was neither a clandestine directive nor did 5370 Mt PR-Ore disappear. As has been well reported [6], the exploration of the 22 Iraq occurrences including seven deposits and a resource estimate of 9.5 Gt PR-Ore has been underway since 1965 by the Iraq Geological Survey and its predecessor organization. Exploration and drilling began in 1963. For all deposits, “pilot scale beneficiation” was done “using simple beneficiation techniques” to check whether PR-M could be produced with the available technology [9]. The story of the USGS data is that the exploration in Iraq obviously reached a certain level of maturity in 2011. Unfortunately, for historical reasons the classification system labeling the Iraq reserves was the Russian system [6]. So, The US Geological Survey estimates world phosphate rock reserves and resources at more than 300 billion metric tons. The phosphate rock resources of Iraq are estimated at 9.5 billion metric tons. Iraq’s phosphate resources are about 3.1% of currently estimated world phosphate rock resources and reserves. Since many of the Iraqi phosphate deposits have not been fully delineated the current resource estimates represent a minimum.

Phosphorus and Soil

It is helpful to know something of the relationship between plant nutrition, soil texture, root growth, and the availability of nutrients in the soil in order to understand how it might be possible to increase the efficient use of phosphorus in agriculture. The nitrogen, phosphorus, potassium, carbon, Sulphur, hydrogen and many others is the important elements for Plant nutrition. Plant roots take up all nutrients from the aqueous solution in the soil apart from carbon, hydrogen and oxygen, which are acquired from carbon dioxide in the air via the leaves and the water in the soil. Soils are identified as heavy (clayey), loamy and light (sandy). This relates to the proportion of the mineral particles of clay, silt, fine sand and sand, which are partly responsible for the overall texture of

each soil. In addition, there is soil organic matter, which mostly consists of organic material broken down by earthworms and the population of microscopic microbes, which inhabit the soil. Roots grow along the passage ways in the soil, but the root tip of cereal plants, for example, can only enter pores larger than about $50\mu\text{m}$ (0.05 mm) in diameter. Thus, roots do not grow in compacted soil and so cannot take up the nutrients it contains. Well-structured soils have interconnecting pores of many different sizes containing both air and soil solution. Since plant roots cannot enter the smaller pores, the nutrients have to move towards the root. As the root takes up nutrients from the soil solution, the concentration decreases and, to redress the balance, nutrients move in the soil solution towards the root by a process known as diffusion (Figure 3).

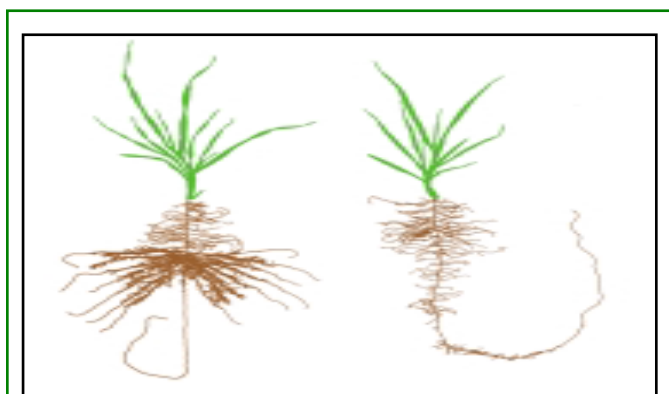


Figure 3: Plant roots proliferate in zones of the soil that enriched with phosphorus (left) compared to soil without phosphorus enrichment (right) [10].

The chemistry of phosphorus in the soil is complex because the phosphorus is associated with many different compounds to which it is bound with a range of bonding energies or strengths. When phosphates fertilizers are added to soil, only the plant root takes up a fraction of the phosphorus immediately (Figure 4). The remainder becomes adsorbed (attached to the surface) to soil particles. Where the attachment is weak, the phosphorus can transfer back into the soil solution. After the initial adsorption, further reactions lead to absorption (assimilation), which means that the bond is stronger and the phosphorus becomes less readily available. The speed of these reactions and therefore the speed at which a deficiency in phosphorus becomes apparent depend very much on the type and size of the mineral particles, the presence of other elements such as aluminum, iron and calcium, soil acidity and organic matter. Organic phosphorus in soil can be associated with soil organic matter (humus) or recently added organic debris coming from plants or animals. These organic molecules cannot

use directly by plants. They have to break down by soil microbes to release inorganic phosphate ions that can take up by plant roots or enter into the same reactions as other fertilizer phosphate ions [1].

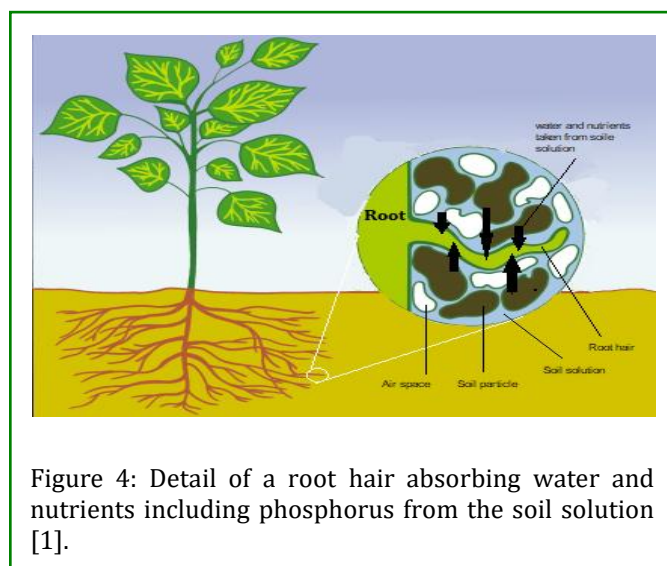


Figure 4: Detail of a root hair absorbing water and nutrients including phosphorus from the soil solution [1].

Phosphorus Chemistry in Soils

Phosphorus in soils; organic phosphorus and inorganic phosphorus. The phosphorus collected under these two groups plays an important role in meeting the phosphorus requirements of the compounds.

Inorganic phosphorus in soils:

a. Calcium containing.

Calcium-containing inorganic phosphorus compounds: fluorapatite [$3\text{Ca}_3(\text{PO}_4)_2\text{CaF}_2$], carbonateapatite [$3\text{Ca}_3(\text{PO}_4)_2\text{CaCO}_3$], hydroxyapatite [$3\text{Ca}_3(\text{PO}_4)_2\text{Ca}(\text{OH})_2$], oxybutatite [$3\text{Ca}_3(\text{PO}_4)_2\text{CaO}$], tricalcium phosphate [$\text{Ca}_3(\text{PO}_4)_2$], dicalcium phosphate [$\text{Ca}_2(\text{HPO}_4)_2$] and monocalcium phosphate [$\text{Ca}(\text{H}_2\text{PO}_4)_2$]. The solubility of the compounds increases as the fluorapatite passes towards monocalcium phosphate. Fluorapatite is usually the origin of phosphorus in soils. Hydroxyapatite is also commonly found in soils. Carbonateapatite is considered found in soils and especially in calcareous soils. The most important compounds in the direction of plant feeding are di and mono-calcium phosphate compounds. Evidence of the presence of tricalcium phosphate [$\text{Ca}_3(\text{PO}_4)_2$] in soils is not satisfactory. Mainly soluble inorganic phosphorus forms; the primary orthophosphate (H_2PO_4^-) and the secondary orthophosphate (HPO_4^{2-}) ions.

b. Iron, aluminum.

Inorganic phosphorus compounds containing iron and aluminum: phosphate ions easily form compounds with iron and aluminum. The properties of the resulting

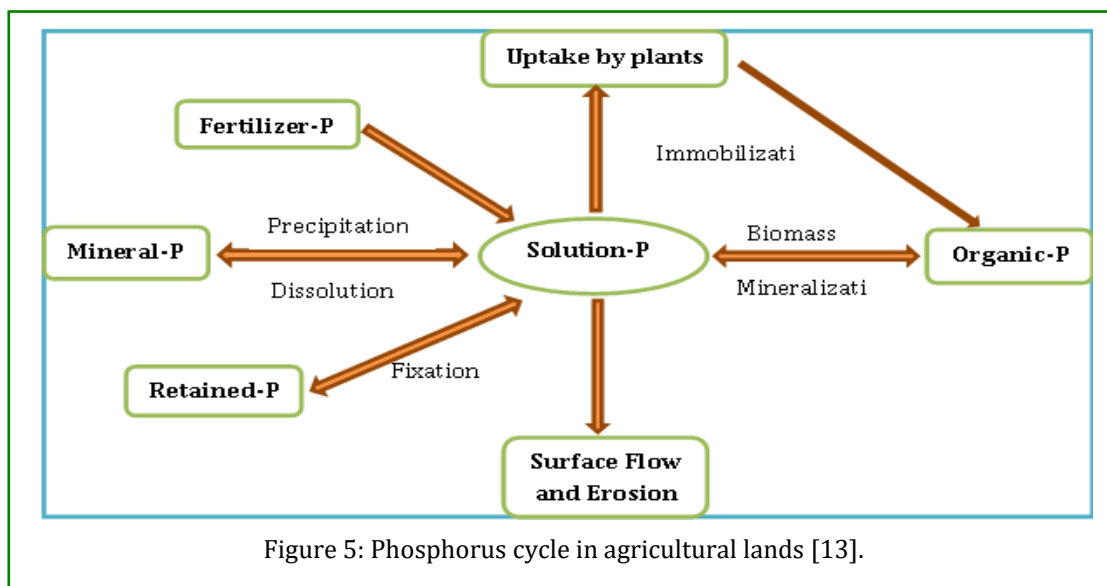
compounds vary depending on the degree of crystallization, the age and the proportion of metal hydroxide and phosphate ions. In the well-drained soils, the most common crystal compounds of iron and aluminum phosphates are the variskite-barranite-strengite group. The formula of variskite ($\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$), the strengite formula ($\text{FePO}_4 \cdot 2\text{H}_2\text{O}$) and the barranite are the mixture of the two above compounds, regardless of the ratio [11].

Organic phosphorus in the soils owes its origin mainly to plant and partly to the animal tissues. Most naturally, occurring organic forms of phosphorus are esters of ortho-phosphoric acid and numerous mono and diesters have been characterized. These organic phosphorus esters have been identified in five classes of compounds:

- i. Inositol phosphates,
- ii. Phospholipids,
- iii. Nucleic acid,

- iv. Nucleotides and
- v. Sugar phosphates

The first three are dominant groups. The organic fraction found in humus and organic materials that may or may not be associated with humus. Much of the remainder of phosphorus groups in soils believed to originate from microorganisms, especially from bacterial cells, which are known to contain a number of stable esters. Not all of the phosphorus groups in soils may be intimately associated with the humus fraction of the organic matter [12]. In the framework of the dynamic equilibrium in the soil, the concentration or changeable amounts of any element in the soil solution are the result of the complex reactions shown in Figure 5. However, these factors may vary considerably depending on the intensity factor, the concentration of the ion in the soil solution, the relative effect of the environmental conditions and the properties of the element [13].



Inorganic Phosphorus Fractions in Soils

Different sequential fractionation procedures have been developed that extract different forms of phosphorus in the soil.

Chang & Jackson [14] using different extractants subdivided the inorganic phosphate into number fractions. Water soluble, Al, Fe, Ca, occluded Fe and occluded Al. Syres et al. [15] concluded that apatite and lattice fixation are primary sources of non-extractable Phosphorus, where P associated with hydrated sesquioxides is its secondary source. Kuo [16] using different extractants sub-divided the inorganic phosphate into number fractions. Soluble and loosely bound P, Al- Phosphate, Fe-

Phosphate, Reductant-soluble P and Ca-Phosphate. Concentrations of five inorganic phosphorus fractions, which include of soluble / loosely bound-P, aluminum (Al-P), iron (Fe-P), calcium (Ca-P), and occluded-P, were obtained by following a sequential chemical fractionation procedure. Soluble or loosely bound-P, Al -P, and Fe-P were the main sources contributing to plant-available P, whereas Fe-P and Al-P were the two most important sources for contribution to plant-available P [17]. Phosphorus bound to aluminum (Al-P), iron (Fe-P) and calcium (Ca-P) constitutes the major active forms of inorganic phosphorus. Relatively less active are the occluded and reductant-soluble forms of phosphorus.

Chemical fractionations of soil in organic phosphorus provides a method for determine the prevailing individual forms of inorganic phosphorus in soils, most commonly soluble phosphorus Al-P, Fe-P, occluded-P and Ca-P. Fractionation of inorganic phosphorus is determine to characterize the effects of soil types and phosphorus sources on the fate and potential availability and mobility of phosphorus in soils. Inorganic phosphorous fractionation has been widely used to interpret native inorganic phosphorus status and the applied phosphorus to soils [14].

Phosphorus Fixation in Soils

Phosphorus reacts with the contact surfaces of the soil particles in the soil in a short time to become less soluble and less useful compounds. Phosphate ions are also combined with elements such as Ca, Mg, Al and Fe in the environment to form a precipitate. It is defined as "phosphorus fixation".

The main phosphorus fixation types are:

- Precipitate formation into active cations such as Fe, Al, and Mn.
- Adsorption reactions with Fe, Al and Mn hydroxides.
- Adsorption of phosphorus by aluminum-silicate clays.
- Lime - alkaline soils phosphorus fixation.
- Biological and organic phosphorus fixation.

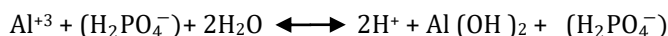
The fixation reactions of phosphorus in the soil and the resulting insoluble compounds show significant changes depending on factors such as soil pH, humidity, temperature, amount and type of soil, soil organic matter, amount and activity of lime, presence of oxide minerals and variety [11,13].

Phosphorus Reactions in Soil

Acid soils

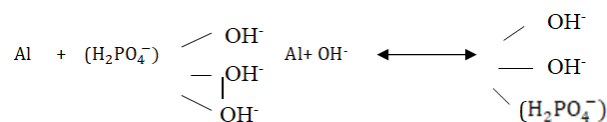
In the acid-reactive soils, the primary orthophosphate form of phosphorus (H_2PO_4^-) and the secondary orthophosphate (HPO_4^{2-}) form in calcareous alkaline soils. Therefore, plants use more than one of the phosphorus form according to their location. In acid soils, the conversion of Fe, Al and Mn elements into unfavorable forms assumed to occur in the form of the following chemical equivalents:

- Phosphorus formed by precipitation with cations such as Fe, Al and Mn in the soil.



This reaction mostly directed to the right in acid-reactive soils when Fe and Al amounts are greater than H_2PO_4^- .

- Fixation of phosphate ions with aqueous oxides of Fe, Al and Mn in colloidal structure.



Fe, Al and Mn have a higher amount of aqueous oxides in the soil with this equation is more suitable for the P fixation.

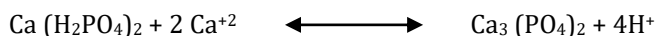
- Fixation of phosphorus with the help of Al and similar ions in the structure of silicate clays.

In this case, H_2PO_4^- ions fixed by replacing them with hydroxyl ions attached to Al atoms.

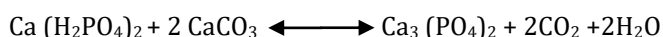
Alkaline Soils

The phosphorus fixed in soils with high pH is mostly dicalcium phosphate (CaHPO_4) and tricalcium phosphate $\text{Ca}_3(\text{PO}_4)_2$. In these, the solubility of tricalcium phosphate is very limited. It is fixed in three forms at alkaline soils.

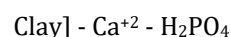
a. It considered that the phosphorus fixation in calcareous alkaline soil with $\text{pH} > 7.5$ is similar to the following chemical equation.



- The phosphorus precipitation on the surface of CaCO_3 fixed by reacting with Ca as in the chemical equation.



- In calcareous alkaline soils, phosphorus fixation is also high. Clays saturated with Ca^{2+} , which is a bivalent cation, fix more phosphorus than a valence ion saturated clay.



In this way, the fixation due to clay surfaces in the soil around $\text{pH} = 7$ [18,19].

Phosphorus Deficiency in Soils

Plant species and genotypes grown in soils with phosphorus deficiency generally have a fringe root system extending to the side and deep in the soil. The root systems of such plants consist of large amounts of thin roots and dense root hairs, allowing them to be in close proximity with the soil particles. Phosphorus, iron, and

other nutrients mobilized because of root secretions and close proximity to soil particles, making them useful in plants in the rhizosphere [20].

Phosphorus Fertilizers in Soils

Phosphorus rocks are the source of phosphorus in the world. Phosphorous fertilizers derived from phosphorous rocks, phosphorus-containing iron shoots, bones and some different substances. In phosphorus fertilizers, phosphorus usually found in phosphate form. Some of the phosphorous fertilizers are water-soluble and some are insoluble. The effective rate of phosphorus in the fertilizer usually expressed in terms of useful phosphorus pentoxide (P_2O_5). In the soil with little permeability, the phosphate cannot penetrate deep into the soil. However, there is a loss of phosphate in soils with high permeability

such as sand, perlite and pumice. On the other hand, as the phosphorus immobilized in the soil, giving fertilizer near to the plant root region increases the efficiency of fertilization. Phosphorous fertilizers usually applied to tape. However, phosphorus fertilizer with pH of 5.5 - 6.5 and containing phosphorus up to high levels can be applied to the soil surface (Figure 6).

Phosphoric fertilizers are:

- Phosphoric acid,
- Normal superphosphate,
- Triple superphosphate,
- Monoammonium phosphate,
- Diammonium phosphate and
- other compound fertilizers containing phosphorus [20,13].

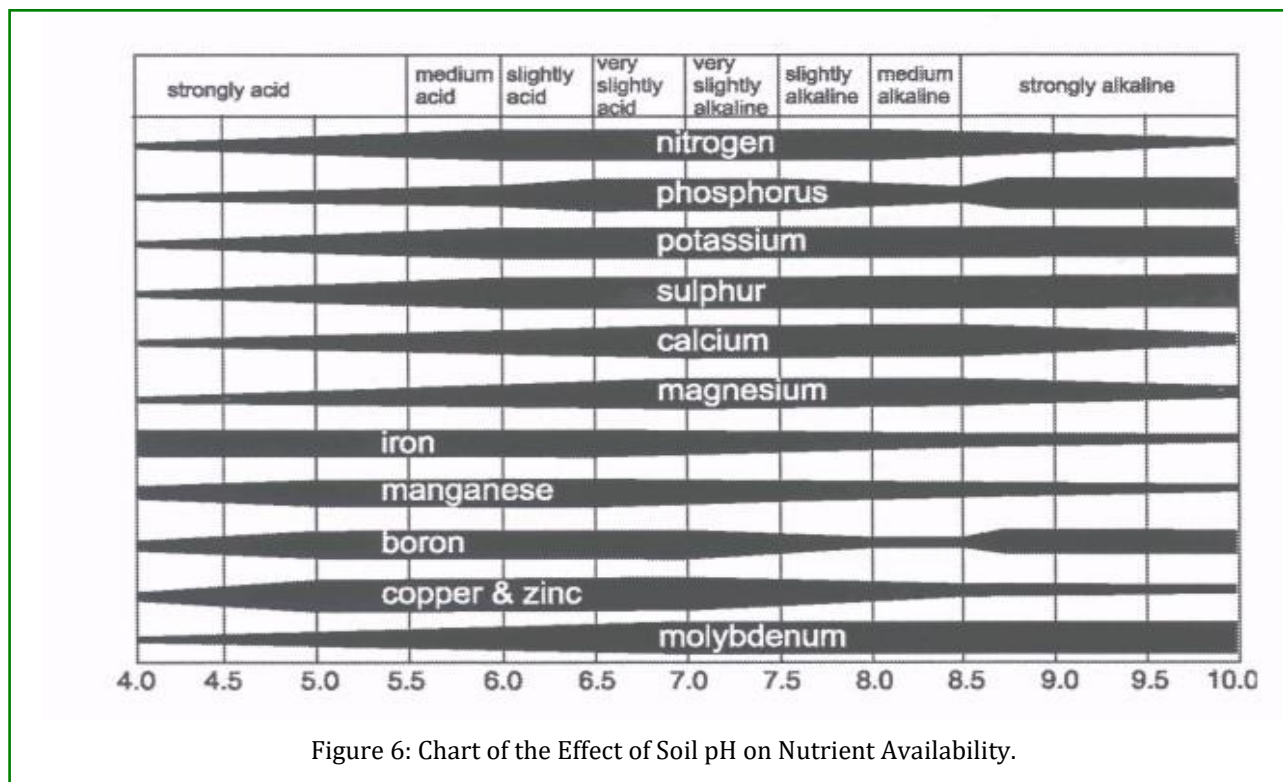


Figure 6: Chart of the Effect of Soil pH on Nutrient Availability.

Conclusion

Potassium plays significant roles in enhancing crop quality. High levels of available P improve the physical quality in plants and crops since it actively take part in enzyme activation, photosynthesis, starch synthesis, protein synthesis. The effects of P deficiency can cause reduced yield potential and quality of grain and fruits. Under normal conditions, the uptake of P by plant may affect because it depends upon the availability in soil.

Since most of P is bounded with minerals and is not available to plants. Therefore, the application of P in form of fertilizer suggested that again depends upon soil properties because soil properties significantly affect the availability of P to plant and crops. Also, 30% of the global soils are calcareous having free calcium carbonate. These soils will fizz when exposed to an acid solution based on the acid liberation of carbonate as carbon dioxide. In calcareous soils the excess alkaline reaction insolubilizes Phosphorus as insoluble calcium phosphate which is not

available to plants. Phosphorus is most needed for early root development so the application of phosphate needs to be concentrated as starter fertilizer near the developing root systems. To create the needed acidity under the calcareous soil condition the use of sulfur with the phosphate source and the ability to add organic amendment and phosphorus solubilizing bacteria would allow a complete package for addressing the calcareous constraint. Under calcareous soil conditions besides the immobilizing of phosphorus micronutrients such as Zn, Fe, Mn, and Cu are often constrained. The use of seed treatment be employed to provide the critical micronutrients for crop production with very little material needed reducing any potential negative impacts. Since the semi arid and arid condition of most calcareous soils are low in organic matter the use of organic amendment helps address a wide array of soil issues under these conditions. Under the dry conditions the organic material is also important for addressing water dynamics and salinity issues.

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