PHOSPHORUS MANAGEMENT IN AGRICULTURE: A REVIEW

I. Rashmi*, A.K. Biswas and V.R. Ramkrishana Parama

Indian Institute of Soil Science,  
Birasia Road, Bhopal-462 038, India

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ABSTRACT

Phosphorus is a major limiting nutrient for crop growth. Phosphorus chemistry in soil is complex with its unique property to become less available to crops with slow diffusion and high fixation. It is very well known fact that fate of P depends upon soil type, soil properties, rate of application and other factors. Although from past few decades there is a continuous application of phosphatic fertilizers in order to sustain high productivity alongside other fertilizers which often exceeds crop uptake results in its accumulation in the soil. The accumulated phosphorus thus present in soil is lost if inorganic fertilizers are coupled with huge inputs of organics or animal manure. In many countries phosphorus is considered as non point source of water pollution and agriculture is the major contributor for this source. The phosphorus content causing eutrophication may be alarming from environmental point of view but may be very less from farmer point of view, but continuous loss of P from soil can be critical. Experiments carried out in long term fertilizer experiment in Punjab has already revealed the movement of P through soil profile, which indirectly hints high P build up in Indian soils. The approach using both quantity and intensity parameter like DPS can definitely play an important role in estimating the potential capacity of Indian soils over periodical basis. Soil testing alone cannot give the answers related to the issues of P under sub surface pathways and its accountability of loss. The areas with high soil P status should be identified and appropriate management strategies to be adopted to prevent P loss from soil.

Key words: Degree of phosphorus saturation, Environment, Leaching, Management, Phosphorus loss, Soil P.

The energy currency of the cell referred as “Phosphorus” is a very crucial element for plants, animals and other living beings. Phosphorus is the vital component of cell as DNA and RNA form the genetic code of the living beings. These components build protein structures and other compounds essential for plant growth, vigour, development and yield. Phosphorus is a vital component of ATP, the “energy currency” of the cell. The process of photosynthesis yield ATP which plays an important role in plant germination, growth, maturity etc. Some of the major growth parameters influenced by P are: stimulated root development, increased stalk and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased nitrogen N-fixing capacity of legumes, improvements in crop quality, and increased resistance to plant diseases. Phosphorus deficiency is more difficult to diagnose than a deficiency of nitrogen or potassium. Crops usually display no obvious symptoms of phosphorus deficiency, other than a general stunting of the plant during early growth, and by the time a visual deficiency is recognized it may be too late to correct in annual crops. Some crops, such as maize, tend to show an abnormal discoloration when phosphorus is deficient. The plants are usually dark bluish-green in color with leaves and stem becoming purplish. Most of the crop requirements of P are met by the fertilizers prepared from rock phosphate.

Rock phosphate is the raw material used for manufacturing phosphatic fertiliser on which the food production depend. The world rock phosphate reserves are predicted to be exhausted within 50-100 years (Smil, 2000, Gunther 2005). With

*Corresponding author’s e-mail: rashmi_csa@gmail.co.in  
1Soil Science and Agril. Chemistry, UAS, Bangalore-560 001, India
increasing population pressure global food production will need to increase by 70% by 2050 (Fraiture, 2007). This situation will result in import of more phosphorus fertilisers for sustaining food security in future. Like oil and other non-renewable resources, good quality rock phosphate reserves utilization will reach a maximum peak, thereafter the production will drop year upon year, seeing a widening gap between demand and supply. If measures for efficient utilization of these resources either socially or economically are not made to the way, agricultural yield will be severely affected in the future (Cordell et al., 2009). As compared to the developed countries where phosphorus demand has already reached its stabilized levels, in developing economies the annual increase of 3-4% in global demand of phosphorus is predicted (Maene, 2007, FAO, 2007). The global food crisis during 2007-2008 due to phosphate rock and fertilizer demand exceeding supply and prices increased by 700% (Minemakers Limited, 2008) indicating the worse situation for the developing countries in terms of human nutrition. So the need of the hour is to focus on the phosphorus management strategies for Indian soils.

Soil P Chemistry: Indian soils usually contain 44 to 3580 mg kg\(^{-1}\) of total P (Suresh kumar 1999) and traces to 2160 mg kg\(^{-1}\) of organic P. Among the different organic forms, Inositol P (60%) followed by phospholipids (7%) and nucleic acids (3%). In general, inorganic P (Pi) is the predominant form of soil P, constituting 20 to 80% of the total P in the surface layer (Tomar 2003). Very little P is present in soil solution, its concentration being less than 0.1 ppm P. At present 5% of the Indian soils have adequate available P, 49.3% are under low category, 48.8% under medium and 1.9% under high category (Pattnayak et al., 2009). Among the different inorganic forms of P, Al-P and Fe-P constitute 25% (generally 8-10%) of total P, while Ca-P constitutes 40-50% or even more of total P in many neutral, alkaline and calcareous soils. Soil pH controls phosphorus availability in the soil and thus considered as a critical factor in phosphate sorption. Inorganic P is chemically occluded by hydrous oxides of Al, Fe, Mn at a pH < 5 while at pH of 6-7 P is considered available to plants also is in sorbed phase by hydrous oxide of Al, Fe, Mn etc., while at a higher pH > 7.5 P is again sorbed by silicate and calcium minerals. Soil pH interacts with phosphorus in two ways one can be with an increase in soil pH net negative charge of soils increases and decreases ionic activities of Al\(^{3+}\), Fe\(^{3+}\) in acid soils and Ca\(^{2+}\) in neutral soils, thereby reducing the adsorption and precipitation reactions, respectively and other can be P ionic species affects pH involving H\(_2\)PO\(_4^-\), HPO\(_4^{2-}\), PO\(_4^{3-}\) and the latter two ions may be preferentially adsorbed (Haynes 1983). Thus the dynamics of P in soil is a complex cycle. The major drawback in taking P by crops from soils is due to its fixation with soil components and least with other factors. Most commonly used indices like soil P test, sorption isotherm, equilibrium P potential, isotopically exchangeable studies etc have been used to understand the chemistry of P in soils. Phosphate sorption is a complex reaction between the components of soil and P source and involves both adsorption and precipitation reactions, the former appears to dominate over a short period at low concentration in soil solution (Rajan and Watkinson, 1976; Mehadi and Taylor, 1988) and precipitation at higher concentration for longer period (Lin et al., 1983). In many acid soils, the content and reactivity of oxides, hydroxides and oxyhydroxides of Fe and Al are the components that predominantly influence phosphate sorption because these oxides are proved to be the most effective P sorbents (Singh and Gilkes 1991, Milap Chand et al., 1995, Tek Chand and Tomar 1993).

The P sorption is an important phenomenon by which the nutrient gets fixed in soil resulting seldom movement. The phosphorus sorption capacity can be very well defined by the quantity and intensity factors. The relation of quantity and intensity of P can explain the ease by which the soil allows the P to desorb or sorb phosphorus. The phosphorus sorption capacity is explained by Langmuir, Freundlich, Tempkin sorption isotherms which describe quantity / capacity relation of phosphorus over different P concentrations. The different factors related to the P sorption capacity assess the effect of P accumulation and movement of phosphorus in the soil.

The long term fertilizer experiment (LTFE) is an approach to understand the dynamics of P in subtropics. More recently phosphorus accumulation, leaching and residual effects on crop yields from long
term field experiment in subtropics had been illustrated by Aulakh et al., (2007). Field study on groundnut-based cropping system established in 1975 on semi irrigated sandy loam soils of PAU, Ludhiana. In this study effect of 25 years of annual application of P fertilizer, increased Olsen P status in the plough layer (0-15cm) and found only 4-9% accumulated in surface soil layer. After 29 years, 45-256 kg of residual P fertilizer had accumulated as Olsen P/ha in the uppermost 150cm with 43-58% below 60cm depth indicating enormous movement of applied P to deep layers in coarse textured soils with low retention capacity for nutrients. Thus the movement of P is now becoming an important concern in India, although research has yet to be done to identify the factors affecting it and the consequences thereafter. Heckrath et al (1995) measured the P content in the drainage water collected from > 150 year old long term Broadbalk Continuous wheat experiment at Rothamsted (Johnston, 1969). The tile drains were set at 65cm below soil surface and Olsen P estimated ranged between 7 to 110mg kg\(^{-1}\) soil. They found high total P and molybdate reactive P concentrations (upto ~ 3mg total P L\(^{-1}\)) in drainage water from the soils having Olsen P above 57 mg kg\(^{-1}\). There was a little Olsen P concentration below this Olsen P concentration (<57 mg kg\(^{-1}\)) which they termed as “change point”, the point above which there was a drastic increase in Olsen P concentration in drainage water. Phosphorus concentration was linearly correlated with soil Olsen P above this change point as depicted in Fig1.

Does phosphorus move in soil: Phosphorus is considered to be immobile in soil and highly mobile in plant system. Phosphorus like nitrogen is an anion, but is highly reactive with other cations especially Al, Fe, Ca etc in soil system and therefore becomes immobile in the soil as soon as added to the soil. In agriculture, P fertilizers are often applied in excess of immediate plant uptake. This often leads to accumulation of P in top soil layer, but excess P can transport to soil profile (Sims et al., 1998). The fate of applied P fertilizer depends upon soil type and soil properties like P sorption capacity and amount and rate of application. The translocation and distribution of P in the soil profile is important with respect to plant uptake and risk of P losses. The relation between extractable soil P concentration and dissolved P concentration of runoff is not unique and varies with soil type (Sharpley, 1995). Thus the risk assessment of P depends on two parameters viz., (i) intensity factor and (ii) capacity factor. The potential pathways of P movement in soil can be explained by its bidirectional flow. The rainfall contributes for the runoff of soil which carries the P along with it and causing the particulate and dissolves P and accumulates in the water bodies. On the other hand, the downward movement of water also carries P via infiltration resulting in leaching of P into deeper layers of soil profile. However the main loss of P is through runoff, but nowadays many countries have found that subsurface pathways of P loss has become common from agricultural land. The problem of leaching of P indicates the potential capacity of soil to desorb P, which is completely saturated with P or by additional factors like water, organic matters, preferential flow pathways etc.

From last few years presence of high phosphorus levels in water bodies affecting aquatic life forms in many western countries have raised concerns of researchers and policy makers. Earlier main source of P pollution was point sources (industrial, sewage plants etc.) and later steps were taken to address this problem, to remove most of the P from the effluents. But the problem persisted and attention was focused then on phosphorus from agricultural sources as these contribute a significant portion to phosphorus input in water bodies. Phosphorus lost from agricultural soils via surface and sub surface pathways depends upon the soil type, rate of P application, source of P (Hooda et
al., 1999), amount and intensity of rainfall (Edwards and Daniel, 1993), soil P status (Pote et al., 1996; Hooda et al., 1999) etc.

**Pathways of P transport in the soil:** Phosphorus is assumed to be adsorbed or fixed in soil after application. It is found that cations move seldom due to their adsorption on the exchange sites of soil colloids, while anions move faster through soil except phosphorus which undergoes chemical fixation with soil components. Most of the phosphorus added to soil as fertilizer and manure is rapidly bound by the soil minerals in chemical forms that are not subject to rapid release; thus, soil solution phosphorus concentrations are typically very low (Gregory Mullins, 2009). The fig 2 shows different transport mechanisms of phosphorus from agricultural fields. Models are used to predict P transport from fields by runoff in many countries using soil box data (Vadas et al., 2005).

![FIG 2: Processes responsible for phosphorus transport from agricultural field (Gregory Mullins, 2009)](image)

Phosphorus from two main sources enters in soil and later to aquatic bodies, namely point and non point sources. Point sources originate mostly from industrial operations, municipal waste water treatment plants, livestock, farms etc. These sources are mainly governed by the state laws and pollution boards. While non point sources include soil erosion and runoff mostly from agricultural lands, garden or lawns, forests, livestock pastures, etc. These sources enter water bodies either as dissolved or particulate forms.

Phosphorus is lost from the soil mainly by surface runoff and leaching. Although the latter mechanism of P loss is given more importance recently with increase P content in sub surface drain flow in watershed. In environment P may be in dissolved and particulate forms. Loss of P from surface runoff is much studied aspect wherein P is lost in two forms (i) soluble P (ii) particulate P (sediment P). The transport of soil P from agricultural land to surface waters depends on many factors including climate, soil type and hydrology, soil P content, agronomic practices, and landscape (Lemunyon and Gilbert, 1993). Recently applied fertilizer or manure are the large source of dissolved P. The particulate P is soil particle bound P or mineral containing aluminium, calcium, iron, organic materials which is resistant to degradation and is the dominant form of P in runoff. Many reports from western countries have reported about 70 to 90 percent of P lost as particulate form from croplands associated with eroded soil.

Phosphorus transport in subsurface pathways occurs either through the movement of solvent through the profile or by preferential flow pathways (Stamm et al., 1998). Preferential flow pathway transports relatively large amount of water through a small portion of soil volume. Under natural conditions such flow tends to occur to a greater extent in fine textured soil as compared to coarse textured soil because of high clay content in fine textured soil and hence greater chance of cracking (Li and Ghodrati, 1994). Soil P may also be transported in natural preferential subsurface pathways, especially through macropores, soil cracks and fissures (Heathwaite, 1997; Stamm et al., 1998). Both coarse and fine textured soils may be particularly prone to P transfer by preferential flow through artificial tile drainage and the natural macropore network. Phosphorus form and concentration in drainage water is influenced by soil texture, tillage intensity, cropping system and seasonal variability (Simard et al., 2000). Many studies have illustrated P leaching from the soils amended with manures. The risk of P leaching from manure-amended soil is especially great if the soil already has a high readily available P content. P leaching through subsurface pathways was illustrated in long term experiment carried out in Broadbalk (Heckrath et al., 1995). The mechanism could either be preferential flow or rapid transport of P in forms less susceptible to sorption and most of P form were dissolved reactive P (DRP) in drainage water. The results suggest enhanced P losses through subsurface runoff on heavy soils, once a certain plough layer concentration of Olsen-P is exceeded. In India such reports from Punjab illustrated significant amount
of Olsen P below plough layer in long term experiments.

**Phosphorus and environmental quality:** An annual loss of 8 M t plant nutrients has been mentioned through 5.3 billion of soil lost by water erosion (Prasad and Biswas, 2000). The transport of P can occur by surface runoff and subsurface flow. In reality, these are very dynamic processes. For example, surface or overland flow can infiltrate into a soil during movement down a slope, move laterally as interflow, and reappear as surface flow. Generally P loss in surface runoff is much greater than in subsurface flow and is dependent on the rate, time, and method of P application; form of fertilizer or manure applied; amount and time of rainfall after application; and land cover (Andraski et al., 2003; Sharpley and Rekolainen, 1997). However, P loss by leaching can occur in sandy, organic, or peaty soils with low P adsorption capacities; and in soils with substantial preferential flow pathways (Djodjic et al., 2004; Sims et al., 1998; Van Es et al., 2004). Even so, P losses are often agronomically small (generally < 2 kg P ha\(^{-1}\)), representing a minor proportion of applied fertilizer or manure P (generally < 5%). Phosphorus uptake and harvest removal by crops ranges from 10 to 30% of applied P (on average 20%), due to the rapid and only slowing reversible sorption of P to Al, Fe, and Ca compounds in soil. Many studies indicate lake water concentrations above 0.025 mg L\(^{-1}\) P generally accelerate eutrophication. These values are an order of magnitude lower than P concentrations in soil solution critical for plant growth (0.2 to 0.3 mg L\(^{-1}\)), emphasizing the disparity between critical lake and soil P concentrations. It is essential to maintain a critical level of P to benefit crop yield at the same time to minimize loss of P via erosion, surface runoff and leaching pathways from cultivated plots (Higgs et al., 2000). The loss of P from soil causing eutrophication may be as low as 0.01 mg/L P, which may not be of economic importance from farmer point of view (Fig 3), but high and unaccounted soil erosion cause significant losses of P to water bodies.

Phosphorus management strategies: Phosphorus loss from soil to water is an important issue as it results in limiting the nutrient from agriculture soil system. The major contributor of P to water bodies is from sewage effluents, industrial plants, agriculture etc causing eutrophication. Recent reports from Long Term Fertilizer Experiment (LTFE) of Punjab soils considered to be rich agricultural production
belt concerns have come up whether in future, loss of P from agricultural soil polluting the water table can become a serious issue or not? If loss of phosphorus occurs soon after application of manure and fertilizer, the loss can be as high as 100 times greater than runoff losses. In India movement of phosphorus through different pathways is yet to be studied. Although, most of the research work on phosphorus is emphasized on the P status, its efficient utilisation for crop yield, fractionation, chemistry and its availability in the soil. Now the time has come to identify the soils of high P build up, its movement through soil matrix. Under intensively cultivated area of India continuous addition of fertilizer and manure in excess of crop requirement will result in increased phosphorus content in the surface soil, contributing to accelerated P losses from soil system.

Most important thing to understand is that soil P tests are designed to measure available P and identify yield responsive soils. The Soil Test Phosphorus (STP) gives no indication of the potential for transport or relation of P in erosion, runoff or drainage, the two components that probably play a major role in determining environmental concerns for excessive soil P. The existing soil P test methods like Olsen, Mehlich 3, Bray, acetic acid etc are designed as per crop requirement and available soil P status. The approach based upon STP therefore cannot give the real picture of P loss. But for environmental purpose, with less research and theoretical background dataset is not available. Therefore the chemical extractant used for soil test P cannot be used best to predict the critical levels of P for environmental pollution. Soil test P measure the P concentration in soil solution and not measure the potential or retention, transport factors of P in erosion, runoff or drainage which plays important role in determining environmental P levels hence STP must be accompanied by a measure of desirability of P from soil system and the effect of other cations on P release (Beauchmin et al., 1996). The P sorption reactions have been extensively used for both agronomic (Ozanne and Shaw 1967, Fox and Kamprath 1970) and environmental purpose (Zhang et al., 2005). It is therefore necessary to develop a more appropriate technique to know the actual potential of soil contributing to the non point source of P pollution. The two approaches like degree of P saturation and P index have been widely accepted and used as per situation in different parts of the world with high P levels in soil system.

**Degree of phosphorus saturation:** Although in the many western countries continuous application of animal manure and fertilizers in excess of crop uptake resulted in high build up of soil P polluting the nearby water sources. There is a need to determine the high P build up areas of intensive cropping system for a better understanding of P dynamics in Indian soils. So the existing soil test methods for P determination only assess the crop response to the nutrient. It is therefore necessary to develop a more appropriate technique to know the actual potential of soil contributing to the non point source of P pollution. Degree of Phosphorus Saturation (DPS) has been widely used and accepted method of determine P saturation capacity of the soil (specific to Al and Fe) in many countries. DPS measure the potential of the soil to release P in excess which even can pollute the water bodies. In many western countries DPS had been used in relation to Fe and Al as this plays an important role in fixing P in the soil. Even the P sorption maxima and other cations also determine the adsorption of P hence this technique can be tried with respect to the different conditions of the soil. The Degree of Phosphorus Saturation (DPS) is an index developed earlier in Netherland for environmental and manure management policies (Breeuwsma et al. 1995). This approach assumes that the ratio between P, Al and Fe concentration can be used as an indicator of soil’s potential to release P (Nair and Harris, 2004). The Degree of Phosphorus Saturation (DPS) is an index of the proportion of a soils P retention capacity that is already filled by P. This index was developed in order to account for the effect of soil type on the relationship between STP and water soluble P.

Phosphorus sorption saturation provides insight into a soil’s ability to release P to solution as well as its remaining capacity to bind added P and can be given as:

\[ P_{\text{sat}} = \frac{\text{Sorbed P}}{\text{P sorption capacity}} \]

The most common measure of P_{\text{saturation}} employs P, Fe and Al extracted by acid ammonium oxalate and given as

\[ P_{\text{sat}} = \frac{P_{\text{ox}}}{(Fe_{\text{ox}} + A_{\text{ox}})} \]

where, \( P_{\text{ox}} = \) ammonium oxalate extractable P content in mmol/kg.
Alox = ammonium oxalate extractable Al content in mmol/kg
Feox = ammonium oxalate extractable Fe content in mmol/kg

The degree of P saturation is measured indirectly by P isotherm that includes all P sorption and binding sites which varies with soil type and land use. Therefore degree of P saturation can also be measured from water soluble P (WSP) as a routine soil test from agricultural farms as well as from precision farming systems (Pothig et al., 2010).

Under intensively cultivated area of India a continuous addition of fertilizer and manure in excess of crop requirement will result in increase in phosphorus content in the surface soil, contributing to accelerated P losses from soil system. Under those areas this approach can be utilised to evaluate the phosphorus saturation trend in the soils. The soil P test developed originally for agronomic purpose (e.g. Bray and Krutz, Olsen, Mehlich-3), for environmental purpose (e.g. water extractable P [WEP]). The soil testing methods are less appropriate for environmental aspect.

The DPS is an improvement over the STP method in that it accounts for differences in P holding capacities of different soil types and therefore gives a better correlation with runoff dissolved P concentration across soil types. However, it does not assess the risk of water leaving the field and reaching surface waters or groundwater and as a result, on its own, cannot predict Dissolved P load losses (Sibbesen and Sharpley 1997). The Langmuir sorption maxima has been recommended as the best estimate of Phosphorus Sorption Capacity (PSC) for a wide range of soils, but is too expensive to be practical (Sharpley 1995). Estimation of PSC from oxalate extractable Fe and Al is effective for acid soils (Hughes et al. 2000).

**P Index:** National Committee of Soil Scientists in USA developed the P index in the early 1990’s (Lemunyon and Gilbert 1993) for the states of New York, Virginia, Alberta, Delaware, Wisconsin, Minnesota etc. Phosphorus index had been developed in many countries based upon the environmental concerns. P index is defined as transport and source factors controlling P loss in surface runoff (Sharpley et al., 1999).

**Management to reduce P transport:** Phosphorus transport from agriculture can be reduced by controlling the loss through erosion, runoff etc by conservation tillage approaches that leave little crop cover and protect the bare surface being exposed to runoff water. Total P loss via runoff can be reduced by six fold by using mould board plough despite higher STP values of the field (Hansen 2002). The runoff water routed through vegetative barrier can reduce as much as 90% P loss via runoff (Chaubey et al. 1995).

**Phosphorus source management:** Managing the different sources of P is very much essential for reducing the risk of P loss from agricultural soil. The factors that effect P sources like rate of application, method of application, time of application, quantity and the type of P sources are important for soil P management. Direct application of heavy loads of manure or FYM in irrigated soil risks the easy loss of P from surface soils. The loss of P is also noticed from soil where the fertilizers or manure are not incorporated properly in the soil. Surface loss or runoff losses reduce when there is a good gap between the application time and the runoff (Sharpley, 1997). Thus, runoff losses can be managed or reduced by avoiding high application of fertilizers during high rainfall season as well as to reduce the application in high soil P build up sites. The runoff losses from manure can be reduced by decreasing P solubility. P loss can be reduced to three fold by treating the poultry manure with aluminium sulfate (Moore et al., 2000). In many countries Comprehensive Nutrient Management Plans (CNMPs) have been made an essential component in nutrient management strategies (Beegle et al., 2000). The example of Virginia P index is explained hereunder as:

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<th>Factors Description</th>
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<td>Phosphorus risk index = erosion risk factor + surface risk factor + subsurface risk factor</td>
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<tr>
<td>Erosion</td>
<td>Edge of field soil loss (tons/acre), Sediment delivery factor, Sediment total P factor (ppm), Runoff from field (inches), Runoff from P delivery factor, Runoff Dissolved Reactive Phosphorus (DRP) Factor (ppm), Applied fertilizer DRP factor</td>
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<td>Percolation (inches), Soil texture / drainage factor, Subsurface DRP factor</td>
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Based upon the description, values are calculated and fitted in the equation to calculate P index for a given watershed. Such a modified version of the P index (Sharpley et al., 1999) can be explained by an example. A P index value of < 8 has a low potential for P loss under current management practices. A value of 8 to 14 has a medium potential for P loss and some changes should be made to protect surface waters. A value of 15 to 32 has a high potential for P loss and adverse impacts on surface waters. Finally, a P index of > 32 indicates a very high potential of P loss and adverse impacts on surface waters. Thus many softwares are now available to determine the P index values of a particular site.

The original P index used a simple weighted matrix to integrate agronomic STP with other criteria that quantify soil erosion and runoff, as well as P fertilizer/manure rate, method and timing of application. Higher the P index the greater the risk of P loss. Almost all states of USA had already developed their P index values viz, Alberta, Wisconsin, Quebec, Minnesota, etc. The Phosphorus Index is a simple field-based planning tool to assess the risk of phosphorus (P) movement from agriculture to water. Many versions of the P index exist and are in varying stages of evolution due to differing regional and geographic conditions. Much research done to identify P sensitive watersheds, expand and improve on P indices, and to develop best management practices (BMPs) to reduce agricultural P losses to water. The P index is an assessment tool developed in Iowa and other states to estimate the relative contribution of various sources and transport factors to assign a risk rating to a field or management area (Lemunyon and Gilbert, 1993; Mallarino et al., 2002). Such index can be popularised at the field scale along with the soil loss calculations in watersheds of India which will give an idea of P being lost from agricultural soil and its accumulation in the water bodies.

CONCLUSIONS

With large pressure of population on the land for food production high intensive cropping is gaining importance day by day which has direct dependence on the present phosphate reserves, and strategies should be made for efficient utilisation of the resources and minimise its loss from soil. Phosphorus application, accumulation, management and transfer in intensive cropping systems have increased concern worldwide. Even though much research on P has been done in the last few decades, still information regarding agricultural production and environmental quality is less. The areas which have already high phosphorus build up should adopt appropriate nutrient management strategies and prevent the loss of phosphorus from being transported via runoff or sub surface flow. India, where the phosphate fertilizers are imported totally, should address the present situation of phosphorus level in soil and environment sooner. Experiments carried out in long term fertilizer experiment in Punjab has already revealed the movement of P through soil profile, which indirectly hints high P build up in Indian soils. Although presently we lack data on high P build up status of Indian soils, but reports have illustrated from many experiments that soon will have many such water bodies. To address the concern soil testing P for environmental risk assessment, pathways of P transport and strategies to manage P should be attempted at country level. The approach using both quantity and intensity parameter like DPS can definitely play an important role in estimating the potential capacity of our soils over periodical basis. Soil testing alone cannot give the answers related to the issues of P under sub surface pathways and its accountability of loss. The DPS can be used in areas with high accumulation of P by fertilizer and manure and further can be used as an index in determining the environmental concerns related to the issues of using P fertilizers.

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