DEPLETION OF PHOSPHORUS RESERVES, A BIG THREAT TO AGRICULTURE: CHALLENGES AND OPPORTUNITIES

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ABSTRACT: *Phosphorus (P) is considered as a second most vital plant nutrient as well as second most deficient about 90% in agricultural soils of Pakistan following the nitrogen which boosts and insures bumper crop yield. Hence, P is widely used in crop production. Without this element, the higher productivity is not possible and its role cannot be replaced due to no any substituent, since it is an essential element. Farmers have belief that profitability is only associated with an enormous rate, So, they greatly rely on pivotal nutrient P, which is a finite and in this way its consumption increasing demand causing the decline of its reserves due to rapid excavation. Many scientists are threathening that within 50 to 100 years phosphorus will be completely depleted and P from peak can occurs for a period of only 2030 or 2033. According to some surveys, world has 71 billion tons of P reserves and mine production is about 0.19 billion tons, some research analyst has perception that, the threat is not closer, as its propaganda. But increasing fertilizer demands per day may doublet or triplet or meet the level soon up-to 1.00 billion tons of production. Then decline can take place around 71 years (71÷1.00). From this microscopic angle, the danger can be observed most closely. Agriculture cannot afford such condition in the future and huge crises can be raised. Therefore, well organized agronomic strategy must be applied in this mean time, number of crop cultivation practices are available, they can minimize P use along with improve yield and can save P and extend the threat to several hundred years. This planning should be adopted together new reserves also discovered. Currently, it is need of time, a call ought to be given from the Food and Agriculture Organization (FAO) with them to ''Reduce P use and Save P'' for sustainability of agriculture. This paper is well elaborating and indicating in detail, the threats to agriculture, challenges and providing possible remedies for food security under small bracket. Furthermore, paper identifying depletion of P reserves as a true story.*

Key words: Phosphorus, Depletion, Threat, Agriculture, FAO

INTRODUCTION

Phosphorus is an essential macro plant nutrient required in larger quantity as compare to other elements followed by nitrogen. It is an anion in nature (compound with negatively charge) and does not leach down from soil readily. P is a mobile and available to plants in the form of orthophosphate ions $H_2PO_4^-$ and HPO_4^{-2} [1]. Naturally, it is not free accruing element and is extremely reactive. It is obtained by processing of phosphate rocks that is used in inorganic farming while crud form utilized in organic farms. Most common P fertilizers are used includes diammonium phosphate (DAP), monoammonium phosphate (MAP), single super phosphate (SSP) and triple super phosphate (TSP) [2]. These fertilizers are frequently applied to soil for fertility with the aim of the greatest yield. Generally, in agricultural soils, P is a major insufficient inorganic nutrient [3]. Same time, it has uncounted importance, It is a constituent of nucleic acid, proteins and phospholipids [4] and become crucial for the reproductive part and necessary component of majority of enzymes. They are great importance in the transportation of energy in carbohydrates, metabolism, in fats and also respiration in plant. P develops as well as enhance photosynthesis rate [5]. P help to stimulate early root growth and development and thus gives rapid and vigorous start to plants as well as straighten straw and decreases lodging tendency, brings early maturity of the crop, particularly cereals. It also stimulates flowering and aids in seed formation, increase ratio of grain/seed [6] along with improves quality of seed in legumes and involves by enhancing of root nodules [7]. P strengthens the stem and influence on weakness, If plant growing under stressful period. P encourages other nutrients uptake and maximizes water use ability of the plant. It is act as assistance in genetic traits transfer from generation to generation [8]. The efficiency of P mostly occurs in the seedlings and young plants. P supply must be adequate to the plant, deficiency of P significantly disorder the growth and plant shows symptoms of browning in foliages (above ground parts of plants), thin stem, short lateral bud, loss of lower leaves immediately and slower rate of flowering and causes suppression of leaf maturation [9,10,11]. The optimum need of fertilizer should be achieved through efficient utilization of available P in crop production with minimum rates. Crops like, *Oryza sativa* L.), sunflower (*Halinthus anus* L.), potato (*Solanum tuberosum* L.), peas (*Pisum sativum* L.), broccoli (*Brassica oleracea* L.), peanut (*Arachis hypogaea* L.) must be cultivated with proper fertilization, because, they are major source of P for health of human compare to other crops, where levels of P should be lowered. P is a non renewable, thus misses or over use avoided strictly and role obtained on the basis of where it is more valuable. From human health point of view, P is beneficial for body, improve and maintain the bones, teeth, repairs cell, power the muscle, keeps kidney healthy, enhance brain functioning, involves in metabolism process and enable utilization of different minerals [12]. So, P is seriously needed to plant. Improved crop yield and its quality is directly associated with P supplement which is recommended to all crops by various doses. Agriculture has several advantages of phosphorus and its balanced use can save the P and feed the globe.

POSSIBLE AGRICULTURAL CHALLENGES

Crop productivity relies on major NPK fertilizers. They sustain the maximum yield season by season. Current agricultural trend moved to application of a higher rate of P (Non renewable natural resource). In other hand depletion of P reserves are continuing, around 50 to 100 years they may be stopped providing P [14,15]. It is predication that P from peak can only occurs till 2030 [16] or 2033 [17]. In addition, the need of phosphatic fertilizers in the agriculture are day by day increasing due to increased demand of more food production [18, 19] and exactly world is working, 40 new unites developed in 10 different countries [20]. This is one angle of the story, where production of P augmented according to interest for farming and supply of world P is being accomplished, however in left hand, something happening non positive, the assets are being minimized. Lessening in earth's P reserves can bring about emergencies in future agribusiness. The threat can be observed from up-high of fertilizer prices, plus the quality is also being reducing [21,22]. During 2014 in USA P excavation reduced from 31.1 million tons to 27.1 million tons [23]. United States Geological Survey during 2012 declared world has an estimate seventy one (71) billion tons of P reserves and 0.19 billion tons were mining production [24]. With 100mt production of phosphate, China ranking at 1st , Morocco+Western Shara ranking at 2nd with 30mt, United State produces 27.1 and ranking at 3rd , Russia contributes 10mt, Brazil 6.75mt, Egypt 6mt, Jordon 6mt, Tunisia 5mt and ranking at 4th, 5th, 6th, 8th, and 9th respectively. While, Austerlia and Peru producing very minimal P (Fig. 03,04)

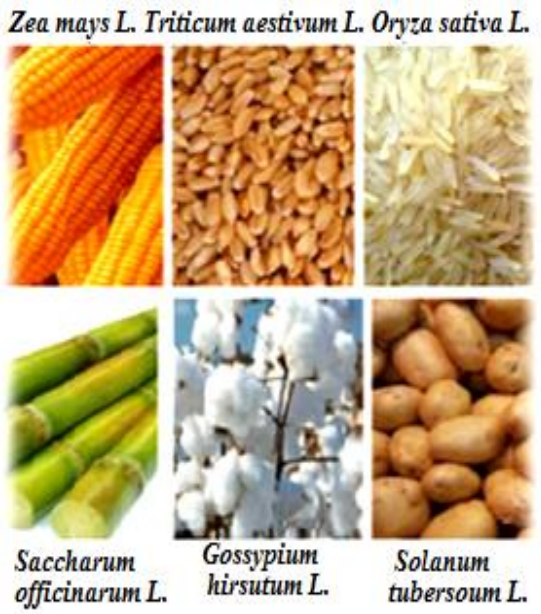

Fig. 01: Some major crops of the world where, P is generally applied in highest rate [13]

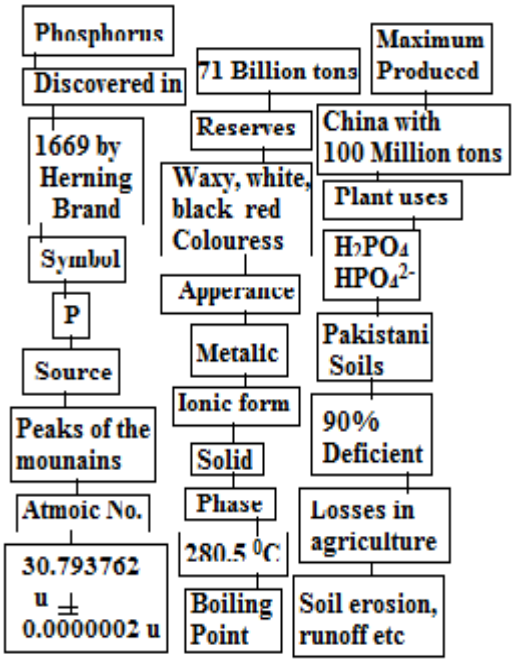

Fig. 02: Profile of nutrient phosphorus [36]

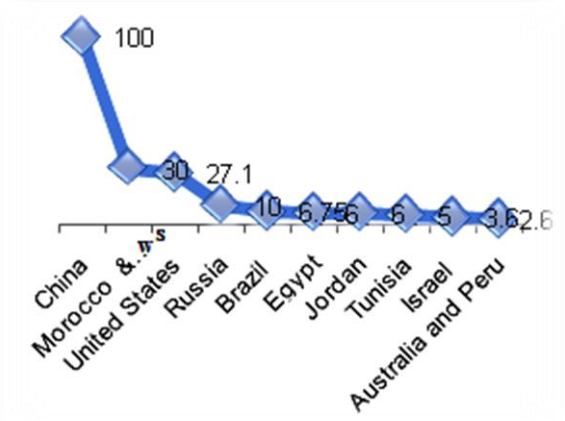

Fig. 03: Phosphate production million tons in different countries of the world [23]

Fig. 04: Ranking of countries on the basis of phosphate rock production [6]

[23]. P reserves are also in Canada, Algeria, Saudi Arabia, Senegal, Syria, South Africa and Togo. Among them, some countries improving the P_2O_5 production, near future, it may reach up-to 0.25 billion tons, then P reserves may occur till 284 years and this figure favoring to prediction of Sutton and his team [25] they said that threat is not closer. But if world doublet P production up-to 0.50 billion tons, then reserves can remain continue only till 142 years and with 1 billion tons, the reserves can only remain for 71 years, by dividation of production with one million ton, from this view the danger to agriculture is looking very closely and alarming.

Researchers those saying P reserves will deplete within time of just 35 years, they additionally proposing new survey ought to be conducted, and thus this step should be taken promptly and a world class new study begin with engagement of farming nations. Furthermore, for sustainable development of agriculture, advanced measures are necessary for food security. P is the supplement extraordinarily utilized in every crop. From aggregate P_2O_5 of rock phosphate, around 82% used in agriculture through fertilizers and 18% are used as a part of other industrial purposes. There are various points of interest of P in agribusiness and shortage can cause dire difficulties, therefor urgent steps should be taken [26] and available P must be efficiently utilized long as long possible .

Integrated use of P fertilizers with other nutrients can minimize requirements of plant for P. In further, crop nutrient management extensively relayed on major organic sources like compost, farm yard manure, and poultry manures etc and also P recycled through valid procedures. Many researchers and scientists around the world who are dealing with the issue of P depletion, suggests recycling of P from human urine. A scientist Warren McLaren reported that P reserves may deplete within some years. To withstand the situation urine is utilized. It is rich in P. A man estimate discharges 500L y^{-1} and commonly ‘’Struvite’’ fertilizer is prepared from human urine. Simply known as MAP, stands for magnesium ammonium phosphate hexahydrate, slowly releases the nutrients. Analysis proved ‘’Struvite’’ enriched with 5.7% of N, 12.6% P by weight and the phosphate is completely citrate-solvent [27,28]. However, this type recommendations are not valid in the Muslim world as well as many other countries due to moderately difficulty, socio-cultural acceptability and Haram (forbidden or Use is habituated religiously). Islamic world cannot use human urine and bath wastes for plant nutrition purposes those latterly eaten. Foliar application of urine made fertilizers on vegetable crops is prohibited. Even common peoples do not use vegetables cultivated near to city/urban areas and they prefer rural farming harvested vegetables, because of city side grown vegetable are mostly cultivated through city drainage water and they said Haram. Plant nutrition cannot be achieved in Islamic countries from those sources which are a clear indicator of Haram. Perhaps, such methods of plant nutrient management can be practiced in forestry and gardening. There are many other ways can be for recycling of nutrients, like collection of vegetable and fruit wastes from different shops. City wastes can be collected in thousand tons in good form from big cities such as Karachi and Lahore in Pakistan.

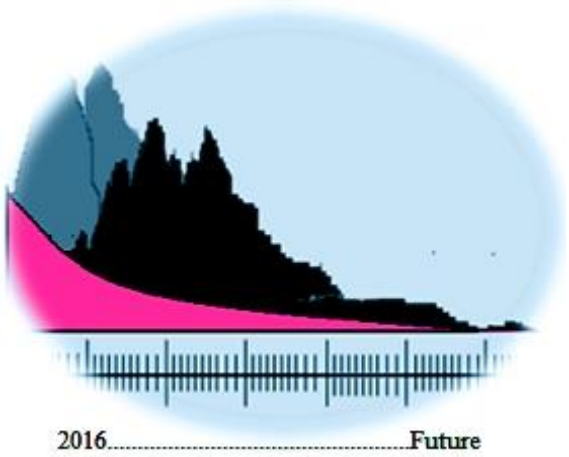

Fig. 05: An estimate the near future condition of P reserves [16,17,37]

BETTER CROPPING

Crop cultivation practices has direct effect on yield, efficient sowing to harvesting minimizes the loss of P due to runoff (leach down of nutrient with the fast fellow of water) and erosion (loss of upper fertile layer of soil by the water fellow or wind velocity). Additionally misuses and over uses of P fertilizers must be avoided in keeping point of view natural reserves of P are limited. Some soils like acidic (<7.0 pH) where P is not useful, application of P in such soils is equal to the waste of fertilizers which cannot produce productive results. Better is to supply of P should be associated with soil analysis tests and measures taken to balance the soil pH, then decided the rate, timing and method fertilizer application according to soil, what are soil conditions and what quantity should be applied? Another factor is over the use of P fertilizers that is also avoided.

Weed control: Weeds are also plants, they have need of P, similar as like crop for completion of life cycle. Weeds grow in the crop plant take part of P and also compete with the crop for greatest share of food [29,30], they are dominant due to mostly C_4 nature and having strong genetic characteristics. Proper removal of weeds, decrease demands of nutrition of the cropped field. Application of half dose of P in to the weed-free field can produce alternative results compare to weed-attacked field where may full rate of P if apply. Package of phosphorus conservation also must contain weed control technology.

Development of P stress tolerant varieties: Verities like drought tolerance can survive on low availability of irrigation and provides good results in term of yield, same as P insufficiency tolerant cultivars should be introduced, and those can grow, develop and yield high at limited level of P application by mitigating P stress. Such genetically modified varieties should be de**ve**loped in all field crops. It is better then only reliance on P and maximum yield can be obtained [31,32].

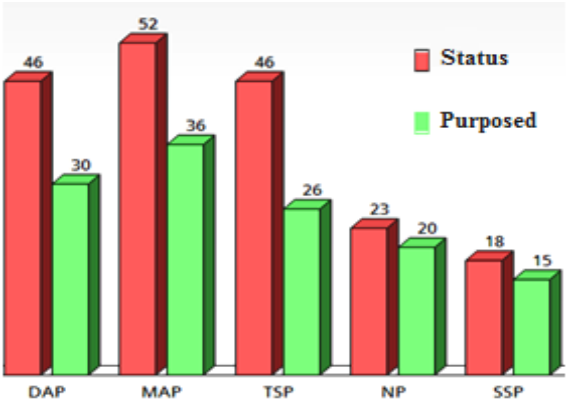

Fig. 06: Commonly used phosphorus fertilizers with P_2O_5% status and suggested reduction in %.

Reduction in recommended dose: The recommended doses of P in various crops of Pakistan are 60 to 100kg ha^{-1} for irrigated wheat, 75kg ha^{-1} for rainfed wheat and 134 to 180, 120 to 170, 200 to 300, 90 to 120 and 90 to 121kg ha^{-1} for paddy, cotton, sugar cane, maize and pulses respectively [33], but province wise it varies some. If, 15-20% recommended dose reduced with nutrient stress tolarnt varieties then, it will not minize yield at economic level. This type planning should be developed in all around the world.

Manufacturing of improved fertilizer: New fertilizers should be manufactured which contains various essential elements and organic+inorganic source of nutrients can be combined, prepared organic-chemical (OC) fertilizer [34] along with nutrient % of P should be lessened in the existing fertilizers like DAP, MAP etc those contain high percentage of P (Fig. 04). In these fertilizers, the N percentage should be increased. DAP contains 46% of P and 18% N and MAP has 52% of P and 11% of N only. Lowering percentage of P in these fertilizers helps to P conservation.

Low rely on phosphorus: Organic sources of nutrients like farm yard manure (FYM), poultry manures, crop residues, compost, green manures, press mud, filter cakes, slaughter house wastes, home kitchen wastes, and sewage sludge are advantageous for plants and continuously being used. Higher or less all these manures contain various food substances. As knowledge, estimated 1.5 tons of nutrients are available in Pakistan, P accounts 191 thousand tons, about 50% dung remains uncollected, whereas out of collected animal dung, estimate 50% used as fuel in the form of dry decay. The slaughter house waste like, blood meal contains 2.0, fish meal 6, raw bone meal 22.5 and steamed bone meal has 27.5% of P. Analysis study of oil cakes shows cotton, castor, coconut, groundnut, linseed, safflower, rapeseed and seasum has 2.9, 1.8, 1.9, 1.5, 1.4, 2.2, 1.8 and 2.0 percentage of P respectively. However, compost (NPK%=0.5-0.15-05), FYM (NPK%=0.5-0.2-0.5%) and poultry (NPK%=3.03-2.63-1.4) manures are major sources for plant nutrition in the agriculture [35,36]. Latest research reported P is greatest in sewage sludge. In Belgium, the NuReSys and In Canada, the Ostara are companies producing fertilizer from sewage sludge. They extract the P enriched material struvite. It can also be prepared by the addition of Mn in to the wastes. Historically, bird guano (dung) is also an important source of P with NPK 12-10-2.5 % content, it is effective manure [37] specially for vegetables. Combination of organic manures with application P fertilizers greatly enhances the crop yield. Multi nutrient manures increases soil fertility, soil microbial activity, improves the soil structure, texture, aeration, water holding capacity and its use ability and ultimately increase P use efficiency in plants.

About several elements are essential plant nutrients, they are nitrogen (NO_3^-, NH_4^+), phosphorus (HPO_4^{2-}, $H_2PO_4^-$), potassium (K^+), calcium (Ca^{2+}, magnesium (Mg^{2+}), sulfur (SO_4^-), boron (BO_3^-, $H_3BO_3^-$), copper (Cu^{2+}), Iron (Fe^{2+}, Fe^{3+}), manganese (Mn^{2+}), zinc (Zn^{2+}), molybdenum (MoO_4^-), chlorine (Cl^-), cobalt (Co^{2}+) and nickel (Ni^{2+}). Generally NPK, Zn, manganese and boron nutrients are used in crop production of Pakistan, while, other nutrients are neglected, this condition perhaps also in the world, therefore farmers should be educated and acquainted with all necessary nutrients and their contribution to yield. Use of macro element P minimized that is a non renewable, along with the advantage of all nutrients obtained. Integrated plant nutrient management (IPN) includes chemical and non chemical source of nutrient must be adopted in every part of the world. Furthermore, fertilizer application methods are most important. So, farmers must be trained, and awareness should be raised about merits of fertilizer application methods. P fertilizers are traditionally used through broadcasting in Pakistan, broadcasting application usually requires high rate of fertilizer, utilization of nutrients become minimal due to drop out of material at wrong place or away from root zone, weeds are also fertilized along with crop, laterally negatively affect on crop growth, yield and deteriorate its quality [29], but broadcasting is easy to use and useful in dense growing crops, some farmers using P fertilizer during irrigation with flow of water, it is only alternative of broadcasting method, while placement of fertilizer is a best method in which small amount of fertilizer used, it is practicable in horticultuhral crops. Application of P fertilizer with placement method highly improve and enhance nutrient use efficiency, weeds do not fertilized, thus crop plant takes full benefits. Other methods include ‘’starter’’ (foliar and fertigation). Starter is known as a solution of 1:2:1 of NPK applied to plant during transplantation.

Similarly solution of NPK is applied to plant by foliar on plant foliages through sprayer and fertigation in the fellow of water. Both methods are gaining importance among farmers in modern cropping system. These fertilizer application practices produce maximal growth and yield. In these methods, small amount of fertilizer needed and comparatively same results can be obtained contrast to the excessive dose of fertilizer. Choosing of the best technique of application of P fertilizers not just can provide most yield but also help to reduce P demand that ultimately lower depletion of reserves.

Seed treatment with phosphorus: Seed treatments such as priming and mixing phosphorus in the form of dust, can act extraordinary for normal germination and seedling establishment. This requires a small amount of P fertilizer. While commonly basal dose of P requires huge fertilizer. Basal application of P is used for vigorous start of plant, it can also be obtained from P-treatment. This strategy can also be useful for reduction of P use in crop production.

Use of tillage and irrigation: Optimum depth of tillage operation helps to reduce chance of nutrient leaching, soils where is high risk of erosion, there minimum tillage practices

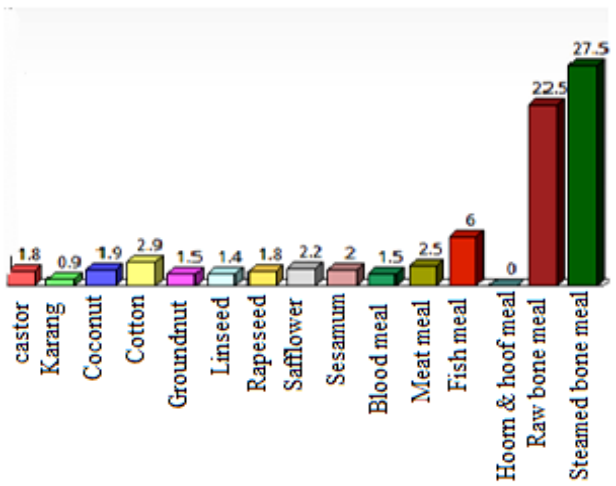

Fig. 07: Percentage of P in various organic manures and oil cakes [35]

should be applied while well prepared soils helps to plant's root system to grow and uptake nutrients. Moist soil condition should be remain continue till applied phosphorus completely utilized by the plant. Drought conditions adversely affect on P-Plant utilization relationship. It has been seen farmers irrigates the field appropriately during supply of fertilizer, but next irrigation they do not supply irrigation properly or even creates drought by extend the irrigation for a few days. These things rigidly avoided in crop production.

CONCLUSION AND SUGGESTIONS

It is concluded that depletion of phosphorus reserves is a true story. Therefore sustainability of phosphorus should be started immediately for food security before agriculture turn out to be near the critical conditions. Following suggestions can be advantageous.

- Lesser uses of P in crop production.
- Reduction of P % in different famous fertilizers (e.g., DAP, MAP, TSP).
- Integration of different source of nutrients (organic with P).
- P only utilized on most economic and human health beneficial crops.
- Relay on compost, for that farmers should be trained with modern compost preparation techniques.
- New genetically improved low P depending varieties should be developed.
- Misuse and over used avoided strictly and soil test conducted before applications.
- Losses due to runoff, leaching and erosion must be controlled effectively.
- Application level of other most essential nutrients increased.
- Farmers meetings should be conducted and awareness created about P depletion.
- Limit should be given to high P user countries and no more fertilizer supplied.
- P recycled through advanced technology and methods.
- Prices can be raised due to implementation of these suggestions, so, rates controlled through rigid and efficient legislation.
- Global based research should be started for the alternative of P. where all world universities involved at single platform with equal opportunities.

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