AMERICAN JOURNALS
Open Access, Peer Reviewed Journals

American Journal of Technology and Applied Sciences
ISSN (E): 2832-1766| Volume 18, | November, 2023

MECHANISMS OF PLANT ADAPTATION TO PHOSPHORUS

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ABSTRACT

Phosphorus is one of the seventeen essential nutrients required for plant growth. Despite its importance, it is limiting crop yield on more than 40% of the world's arable land. Moreover, global P reserves are being depleted at a higher rate and according to some estimates, there will be no soil P reserve by the year 2050. This is a potential threat to sustainable crop production. Most of the P applied in the form of fertilizers may be adsorbed by the soil and is not available for plants lacking specific adaptations.

KEYWORDS

adaptation mechanism, nutrient stress, phosphorus efficiency, soil phosphorus management.

Introduction

Phosphorus is one of the seventeen essential nutrients required for plant growth. It is the second most important macronutrient next to nitrogen in limiting crop growth [1]. Plant dry weight may contain up to 0.5% phosphorus and this nutrient is involved in an array of processes in plants such as photosynthesis, respiration, energy generation, nucleic acid biosynthesis and as an integral component of several plant structures such as phospholipids [2]. Despite its importance in plant growth and metabolism, phosphorus is the least accessible macro-nutrient and hence most frequently deficient nutrient in most agricultural soils because of its low availability and its poor recovery from the applied fertilizers. The low availability of phosphorus is because it readily forms insoluble complexes with cations such as aluminium and iron under acidic soil conditions and with calcium and magnesium under alkaline soil conditions whereas the poor P fertilizer recovery is due to the fact that the P applied in the form of fertilizers is mainly adsorbed by the soil, and is not available for plants lacking specific adaptations [3]. Moreover, global P reserves are being depleted at a higher rate and according to some estimates, there will be no soil P reserve by the year 2050 [4].

The Main Part

More than 40% of the world's soils are deficient in phosphorus and the acid-weathered soils of tropical and subtropical regions of the world are particularly prone to P deficiency. [6] On the other hand, in order to cope with the ever-increasing world population agricultural production and productivity need to parallel increase with the increasing population. [7] One option to enhance soil P availability and hence crop yield is to apply P-containing fertilizers. However, there is scarcity, particularly of chemical fertilizers, in tropical and subtropical regions where most of the earth's population is concentrated. [8] Moreover, lack of fertilizer infrastructures, financial constraints by farmers, and poor transportation facilities in the rural areas all make P fertilization unattainable for these areas. Sustainable management of P in agriculture requires that professionals in the area of crop sciences discover mechanisms that either enhance plant P acquisition ability and/or efficient P utilization ability and further exploit these adaptations to make plants more efficient to thrive under P-limiting conditions.

Status and availability of phosphorus in plants

Despite its importance for normal plant growth and metabolism, P is one of the least accessible nutrients. Many soils are inherently poor in available phosphorus content although the total amount of P in soil may still be high. This is evident from the extremely low soil solution P concentration (<1 μM) in sandy soils, alkaline soils and highly weathered soils of the tropics and sub-tropics. Moreover, a large fraction of total soil P is in organic form in many soils and these forms are not directly available to plants. Many of the agricultural soils in developing countries, in particular, are P-deficient and have an unfavourable condition for P availability. It is estimated that crop productivity is limited by P deficiency on more than 40% of the world's arable lands. Additionally, the world's resources of P are limited. [9,10] Phosphorus is commonly bound to iron and aluminium oxides and hydroxides through chemical precipitation or physical adsorption. [11] As a result of adsorption, precipitation and conversion to organic forms, only 10-30% of the applied phosphate mineral fertilizer can be recovered by the crop grown after the fertilization [12]. The rest stays in the soil and may be used by crops in the following years [13]. Because of low P solubility and desorption, only a small proportion of phosphate ions exist in the soil solution for plant uptake even under optimum P fertilization making P fertilizer recovery lower compared to other nutrient-containing fertilizers [14]. This suggests that chemical fertilizer application alone is not a cost-effective way of increasing crop production in many P-limiting soils [15]. Therefore, the use of genotypes/cultivars with improved root traits able to unlock and absorb P from bound P resources and/or effectively utilise the absorbed P is of paramount importance for enhancing the efficiency of P fertilization [16].

Mechanism of Phosphorus efficiency in plants

Phosphorus efficiency is a term that generally describes the ability of crop species/genotypes of a given plant species to give higher yield under P-limiting conditions. Plant species as well as genotypes within the same species may differ in P efficiency. The ability of a crop/genotype to give higher yield under P-limiting conditions may be related to the ability to take up more P from the soil under P-limiting conditions (uptake efficiency) or the ability to produce higher dry matter per unit of P in the plant tissue (utilization efficiency) or a combination of both [17].

Conclusions

Global P reserves are rapidly being depleted. Moreover, agrciultural soils especially of tropical and subtropical regions of the world are inherently poor in available P content thus ultimately affecting crop yield. This problem is further aggravated in the aforementioned regions by the absence or sub-optimal application of P fertilizers due lack of financial resources and lack of access to P fertilizers by the farmers making the available soil P content in these regions far below the optimum amount that can sustain higher crop yield. Therefore, maintenance of soil P at a target value through either of the following ways: application of P fertilizers, periodic incorporation of crop residue, and application of organic manures would be essential for sustainably higher crop yield. Under conditions where all these soil P management options might not be possible, the use of P-efficient crops or crop genotypes, having desirable traits that enable them to have better performance under P stress conditions, might serve as an alternate option for sustainable crop production.[18]

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