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Biotechnology Advances 23 (2005) 501–513
BIOTECHNOLOGY ADVANCES
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Research review paper

Enhancing plant phosphorus use efficiency for sustainable cropping

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Received 22 November 2004; accepted 10 January 2005
Available online 2 September 2005

Abstract

Phosphorus (P) is one of the least available mineral nutrients to the plants in many cropping environments. Sub-optimal P nutrition can lead to yield losses in the range of 10% to 15% of the maximal yields. P deficiency is more critical in highly withered soils as well as in calcareous and alkaline soils. Amelioration attempts by addition of phosphatic fertilizers are economically and ecologically unsound as the efficiency of added phosphatic fertilizers is very low. Inoculation with the mineral phosphate solubilizing microbes has not helped much due to inconsistent performance of the inoculants under field conditions. These factors have led to examine the opportunities for developing genetically enhanced plants with better P use efficiency (PUE) through efficient P absorption, transportation and internal utilization. In order to improve the PUE in crop plants, it is important to explore genetic variation for all its associated traits. Inter- and intra-specific variations for these traits are known to exist and are shown to be under genetic and physiological controls, but modified by the plant–environment interactions. A more comprehensive understanding of the molecular and physiological basis of P uptake, transportation and utilization is leading to formulation of strategies aimed at developing better P efficient cultivars suited for sustainable cropping with less P fertilizer inputs. Issues relating to enhancing PUE through genetic manipulations of crop cultivar parameters are discussed.
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Keywords: P acquisition; P transporters; P utilization; Mycorrhizae; Metabolic engineering; GM crops

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0734-9750/$ - see front matter © 2005 Published by Elsevier Inc.
doi:10.1016/j.biotechadv.2005.01.004

Contents

1. Introduction

Phosphorous (P) is one of the least available, least mobile, mineral nutrient to the plants in many cropping environments, based on its contribution to the biomass as a macronutrient (Goldstein et al., 1988). Many soils have large reserves of total P, often hundred-time more than the P available to the crops (Al-Abbas and Barber, 1964). P is needed in metabolic processes such as energy transfer, signal transduction, macro-molecular biosynthesis, photosynthesis, respiration, etc. Therefore, direct availability of P determines the plant growth. Sub-optimal levels of P can lead to yield losses to the tune of 5% to 15% of the maximal yields. P deficiency is more critical in highly withered soils of tropics and subtropics, as well as calcareous/alkaline soils of Mediterranean basin (Hinsinger, 2001). Attempts at amelioration of this situation by additional P fertilizing is becoming an increasingly uneconomical and ecologically unsound practice, as the efficiency of the added P fertilizer is as low as about 10% (Werft and Dekkers, 1996). This has led to a search for more environment-friendly and economically feasible strategies for improving crop production in low P soils. In ideal situations, such strategies should enable the efficient use of P already present in the soil, by the cultivars.

Attempts to improve mineral phosphate solubilization (MPS) by enhancing capabilities of MPS rhizospheric bacteria have not been particularly successful because of limitations such as poor ecological fitness, low metabolite production, variability in inoculant-delivery systems, and inconsistent performance in field applications (Mark et al., 2003). An alternate strategy is to enhance the P use efficiency (PUE) of the plants. The latter strategy necessitates identification and deployment of plant traits that limit or enhance the uptake and utilization of P (Narang et al., 2000).

Plants that are efficient in absorption and utilization of the absorbed nutrients greatly enhance the efficiency of applied fertilizers. A more comprehensive understanding of the molecular and physiological basis of mineral nutrient uptake and utilization in plants is leading to strategies for development of better nutrient-efficient cultivars suited for optimal

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