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Requirements for Future ICRISAT Research on the Phosphorus Nutrition of Legumes

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In these concluding comments, it is appropriate to place the recent work on phosphorus in pulses at ICRISAT into perspective, both in terms of ICRISAT's broad research objectives and the ways that these are achieved, and to indicate the research that appears to be needed in the future. The Institute's first two mandates direct us to collect and enhance the germplasm of five crops of the semi-arid tropics—pearl millet, sorghum, pigeonpea, chickpea, and groundnut—and to determine the best ways of using the resources, crops, and environment of the zone. Germplasm collection and enhancement is mainly conducted within our Genetic Resources Program and our two crop improvement programs—Legumes and Cereals. Optimum utilization of resources is the aim of our Resource Management Program. As will be seen shortly, the recent research on the P nutrition of pigeonpea and chickpea has implications for both germplasm and resource management research in the future.

The earlier research at ICRISAT by Sheldrake, Narayanan, and Saxena provided a good physiological characterization of pigeonpea and chickpea. This and subsequent work by several disciplines in the Legumes and Resource Management Programs indicated clearly that pigeonpea and chickpea are phosphorus-efficient crops. What was not clearly understood was the mechanisms or crop traits that resulted in this efficiency. For chickpea, the solubilizing action of acidic root exudates (organic acids) had been identified as one possible mechanism, but no such specific solubilizing compounds were known for pigeonpea. Research in the Government of Japan Special Project has provided an invaluable lead, in the discovery that piscidic acid is exuded by pigeonpea and that this compound enhances pigeonpea's ability to take up phosphorus from iron phosphates in the soil. This research is an excellent example of the advantages of associations between ICRISAT and mentor institutes; in this case, scientists in Japan who provided expert techniques and in-depth knowledge to help investigate a specific problem that had been identified by more generally based research in the Institute.

At this stage, it is appropriate to consider the direction of future research for these two legumes. First, by considering the whole plant, it is apparent that much more basic research is needed on their nutrition. In this respect, there is a need to separate clearly the different aspects of the uptake and utilization of phosphorus in the plant. The questions that need to be addressed are the following.

- Has the internal requirement for P been adequately characterized for each crop species; for example, are the critical limits for tissue P concentration well known?
- Have all possible uptake mechanisms been explored? And how do these uptake mechanisms relate to the supply of phosphorus in the soil, both that in solution or in different solid species (iron phosphate being a specific example)?
- And, relevant to the above point, are critical limits now well established for any soil test?

Clearly, despite the advances made by this project on one mechanism for P uptake by pigeonpea, there is need for much more research into the various other factors that contribute to P uptake. We need to know the role of the morphology of the root systems, especially in relation to appropriate soil moisture status for absorbing P, the role of mycorrhiza (*in the field*), and the critical level of the P in the soil solution in

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ICRISAT Conference Paper no. 678.

(International Crops Research Institute for the Semi-Arid Tropics). 1991. Phosphorus nutrition of grain legumes in the semi-arid tropics (Johansen, C., Lee, K.K., and Sahrawat, K.L., eds.). Patancheru, A.P. 502 324, India: ICRISAT.

contact with the root. These factors all merit serious consideration because it is clear that—in contrast to most temperate legumes—pigeonpea and chickpea have evolved to be efficient at survival in low-P, droughty soils. The traits responsible for this P efficiency should be understood, so that they are not lost in subsequent breeding efforts to improve yield, especially as the breeding process is commonly carried out on soils of research stations with adequate to high P levels. It is clear that such further research will involve a combination of both germplasm and resource management disciplines.