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Can deficit irrigation techniques be used to enhance phosphorus and water use efficiency and benefit crop yields?

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Soil drying and rewetting (DRW) affects the forms and availability of phosphorus (P). Water soluble P has been reported to increase 1.8- to 19-fold after air-drying with the majority of the increase (56-100%) attributable to organic P. Similarly, in two contrasting soil types DRW increased concentrations of total P and reactive P in leachate, likely due to enhanced P mineralisation and physiochemical processes causing detachment of soil colloids, with faster rewetting rates related to higher concentrations of P. The intensity of drying as well as the rate of rewetting influences organic and inorganic P cycling. How these dynamics are driven by soil water status, and impact crop P acquisition and growth, remains unclear.

Improving P and water use efficiencies and crop yields is globally important as both P and water resources become increasingly scarce, whilst demand for food increases. Irrigation supply below the water requirement for full crop evapotranspiration is employed by agricultural practitioners where water supply is limited. Regulated deficit irrigation describes the scheduling of water supply to correspond to the times of highest crop demand. Alternate wetting and drying (AWD) is applied in lowland irrigated rice production to avoid flooding at certain times of crop development, and has benefited P nutrition and yields. This research aims to optimise the benefits of P availability and uptake achieved by DRW by guiding deficit irrigation management strategies. Further determination of underlying processes driving P cycling at fluctuating soil moisture status is required.

Presented here is a summary of the literature on DRW effects on soil P availability and plant P uptake and partitioning, in a range of soil types and cropping systems, with emphasis on alternate wetting and drying irrigation (AWD) compared to continuous flooding in lowland irrigated rice production. Soil water contents and matric potentials, and effects on P dynamics, are highly variable across studies (at laboratory, greenhouse and field scales). Aiming to understand this variation, two sets of results are presented. Firstly, the effects of soil type on responses to DRW, and relationships between soil gravimetric water content and matric potential and thresholds at which DRW increases P availability, are shown and physiological implications suggested (from laboratory experiments). Further evidence is given for the role of the microbial biomass in elevated P availability, and P increased in soil that was partially air-dried and maintained above -1.5 MPa, the permanent wilting point. Secondly, effects of DRW on soil P availability, plant P nutrition, water use and physiology in pot-grown plants are shown (from glasshouse experiments). Soil P availability has been quantified by water and sodium bicarbonate extracts, and plant P concentrations via ICP-OES. Further understanding the effects of soil water status on P cycling is needed to improve irrigation and other management strategies to optimise P and water use efficiencies and crop yields. Thus, future experiments will investigate how different sources of P (organic and inorganic) respond to DRW regimes (including field experiments).