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Risks of phosphorus runoff losses from five Chinese paddy soils under conventional management practices

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A B S T R A C T

Phosphorus (P) runoff from arable land is a major cause for eutrophication of many surface waters. However, relatively little research has been conducted on managing P in rice (*Oryza sativa* L.) production systems, where farming practices differ from those of upland cropping systems due to water ponding on the soil surface (field ponding water; FPW). Because FPW is a direct source of surface runoff, identifying the main source of P and the critical period of high P concentrations in the FPW provide important insights to mitigating P runoff losses. In this study, field monitoring and laboratory incubation experiments were combined to evaluate how soil P content and conventional P fertilizer application affected FPW P concentrations in rice–wheat (*Triticum aestivum* L.) rotation systems of five Chinese rice producing regions. All soils had Olsen-P concentrations (10.1–20.5 mg kg^{-1}) well below the critical levels (30–172 mg kg^{-1}) for promoted risks of P loss. However, conventional P application rate significantly elevated FPW P concentrations compared to no P application, and P fertilizer contributed 47–92% of total P (TP) and 59–97% of total dissolved P (TDP) in the FPW. Temporarily, both TP and TDP concentrations peaked one day after P application (0.15–8.90 mg TP L^{-1} and 0.16–4.49 mg TDP L^{-1}), then decreased rapidly and stabilized five days later. We conclude that fertilizer is the major source of P loss in Chinese rice production systems, and that P fertilizer rate should be optimized to reduce P concentrations in the effluent water in the first week following P application.

1. Introduction

Today, eutrophication of surface water has become a worldwide environmental problem. In most of the freshwater ecosystems limited by phosphorus (P), agricultural sources of P have been identified as one primary contributor (King et al., 2015; Sharpley et al., 2015). In China, agriculture is estimated to contribute over 60% of the annual gross P loads to surface waters (Chen, 2007). This proportion of P load is predicted to even increase with the continuing intensification of agricultural production as driven by the national food security. In particular, national concerns have arisen over unreasonable use of P in agricultural production (Li et al., 2015), stressing the great need of evaluating the impacts of agricultural P management strategies on water quality (Sharpley et al., 2016).

Surface runoff plays a predominant role in P loss from most of the upland soils (Schroeder et al., 2004; Smith et al., 2007; Wallace et al., 2013) and the flooded soils (Liu et al., 2016). Commonly, P in surface runoff consists of both fertilizer P recently added to the soil and the soil P in the established pools (Withers et al., 2003; Liu et al., 2012). The P recently applied becomes instantly mobile after interaction with rainfall, and it constitutes a short-term source of P loss (Withers et al., 2003; Susumu et al., 2016). Depending on the type of P compounds and the presence of sorptive materials (e.g., edges of pedogenic phyllosilicates or sesquioxides that constitute the majority of pH-dependent charges in soils mineral components), water solubility of P fertilizers and potential of P loss may differ greatly. In a paired catchment study, for instance, McDowell et al. (2010) found that application of reactive phosphate rock reduced filterable reactive P by 58% and total P by 38% compared to application of superphosphate.

When fertilizer is overused, the surplus of P exceeding crop needs is

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