SOIL PHOSPHORUS AVAILABILITY DIFFERENCES BETWEEN SPRINKLER AND FURROW IRRIGATION

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ABSTRACT

Water flowing in irrigation furrows detaches and transports soil particles and subsequently nutrients such as phosphorus (P). To reduce the risk of erosion and offsite P transport, producers in south-central Idaho have been converting from furrow to sprinkler irrigation. We completed research on soil P dynamics in furrow versus sprinkler irrigated soils from four paired-fields in the region. Surface soils (0-2.5 inches) were obtained from fields in September following barley harvest. Furrow irrigated soils contained 38 parts per million (ppm) of plant-available P (i.e. Olsen-extractable), on average, as compared to 20 ppm under sprinkler irrigation. These results are important as 20 ppm extractable P can be construed as the point where soil P is considered low to medium in soil testing; extractable P values over 40 ppm limit sites to P application based on crop uptake only. These soils were also analyzed using a sequential extraction technique, and total and amorphous Fe were determined to identify inorganic P pools. Soils under furrow irrigation had greater concentrations of inorganic P in the soluble/Al-bound/Fe-bound and occluded phases, and in the amorphous Fe phases. Phosphorus concentrations in all other soil phases were similar between the two irrigation practices. Findings suggest that Fe redox chemistry plays a large role in P release under furrow irrigation, even in aridic systems. In terms of soil P, results support the use of sprinkler irrigation as a best management and conservation practice.

INTRODUCTION

Nutrient (e.g. P) enrichment of surface water runoff associated with anthropogenic activities is a serious problem in the United States (USEPA, 1996). The primary pathway for P loss from agricultural soils is through surface runoff (Vadas et al., 2004). Once in irrigation return flow waters, P may be transported distances greater than 11 miles (Ippolito and Nelson, 2013). Thus, managing irrigation practices may help influence runoff and reduce P losses from agricultural systems.

Two major irrigation practices utilized in production agriculture are furrow and sprinkler irrigation. Sprinkler irrigation has been shown to improve irrigation use efficiency as compared to furrow irrigation (Al-Jamal et al., 2001), making sprinkler irrigation an attractive water conservation practice. Conservation efforts also typically suggest increasing sprinkler and reducing furrow irrigation will reduce sediment and thus P loss. For example, the 200,000 ac Twin Falls irrigation tract in south central Idaho realized a decrease in net suspended sediment losses from 400 lbs/acre in the early 1970s to 9 lbs/acre in the mid 2000s by implementing several management techniques including replacing furrow with sprinkler irrigation (Bjorneberg et al., 2008). The obvious benefit of converting from furrow to sprinkler irrigation is eliminating furrow irrigation runoff. Changes in soil nutrient status could also occur due to the difference is soil wetting that occurs between the two irrigation methods. To that end, we investigated the change irrigation practice has on soil P dynamics.

METHODS

Fields from four southern Idaho producers were identified; each producer grew barley on relatively adjacent fields using either furrow or sprinkler irrigation. Following barley harvest, three surface soils (0-2 inch depth) were collected from the top (inflow end) and bottom of each field, composited, and then air dried and ground to pass a 0.079-inch sieve. Soil analysis included Olsen extractable P (Olsen et al., 1954), a modified Hedley sequential extraction for a) soluble+Al+Fe-bound P, b) Fe-coated (i.e. occluded) P, and c) Ca-bound P (Kuo, 1996), total free Al and Fe (Loeppert and Inskeep, 1996), and amorphous Al and Fe phases (Loeppert and Inskeep, 1996). T-tests were performed between the top and bottom of fields for either furrow or sprinkler irrigation sites, or between furrow and sprinkler irrigated sites. Significant differences were determined at an α of 0.05.

RESULTS AND DISCUSSION

Soil sampling at the top as compared to the bottom of the field, in either furrow or sprinkler irrigated sites, had no effect on Olsen-extractable P concentration (Figure 1A). Overall, furrow irrigated soils contained greater Olsen-extractable P as compared to sprinkler irrigated soils (Figure 1B). This information suggests that switching from furrow irrigation to sprinkler irrigation will reduce available soil P. This could be construed as a positive result in systems, such as presented here, where available P content approaches 40 ppm and P fertilizer application becomes limited to crop removal only as outlined in the Idaho Nutrient Management Plan (State of Idaho, 2001). However, to fully understand why differences were present between furrow and sprinkler irrigation, more information is required. Thus, a sequential inorganic P extraction was performed.

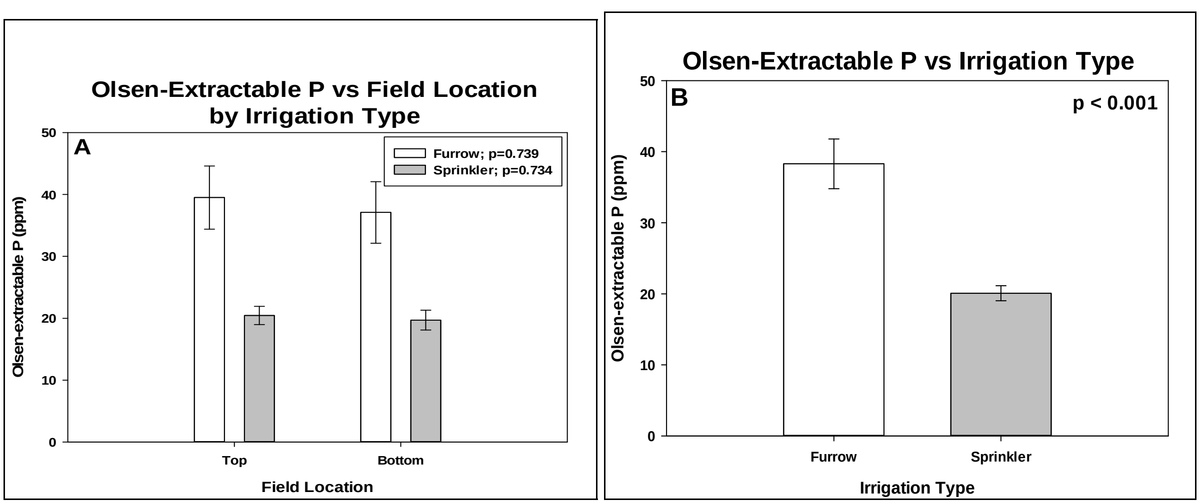

Figure 1. Olsen-extractable phosphorus as affected by A) field location within furrow or sprinkler irrigation and by B) irrigation type.

Results from the sequential extraction showed greater P concentrations present in the soluble+Al+Fe-bound and the occluded phases (i.e. Fe-coated) for furrow as compared to sprinkler irrigated soils (Figures 2A and B). No differences were present between furrow and sprinkler irrigation for the Ca-bound P phase (Figure 2C) likely because these soils are aridic and dominated by $CaCO_3$ (~10% $CaCO_3$ by wt as determined by a pressure calcimeter method; Sherrod et al., 2002). Furrow irrigated soils likely contained greater P concentrations associated with Al and Fe phases, as these phases have been shown to dominate over the soluble P phase (Ippolito et al., 2007). Thus, total free and amorphous Al and Fe phases were measured.

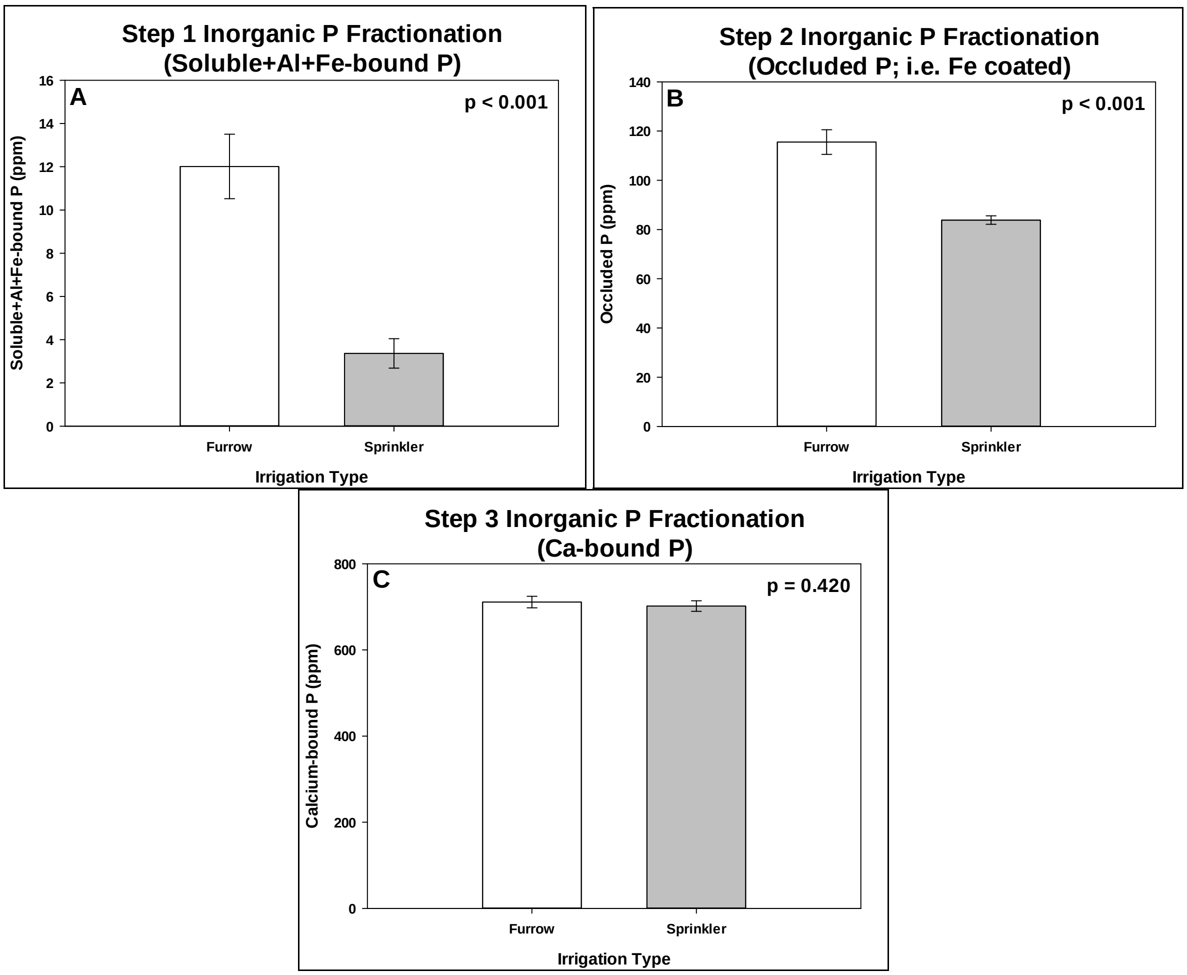

Figure 2. Sequentially extracted soil P concentrations associated with A) soluble+Al+Fe-bound, B) occluded (i.e. Fe-coated), and C) Ca-bound phases.

Total free soil Al and Fe content represent 100% of amorphous phases (non-crystalline) as well as a fraction of crystalline phases present (Van Bodegom et al., 2003) that may act as reaction sites for P sorption. Differences were not present for total free Al or Fe between furrow and sprinkler irrigated soils (Figures 3A and B). There was also no difference in amorphous soil Al content (Figure 4A); however, furrow irrigated soils contained greater concentrations of amorphous Fe as compared to sprinkler irrigated soils (Figure 4B).

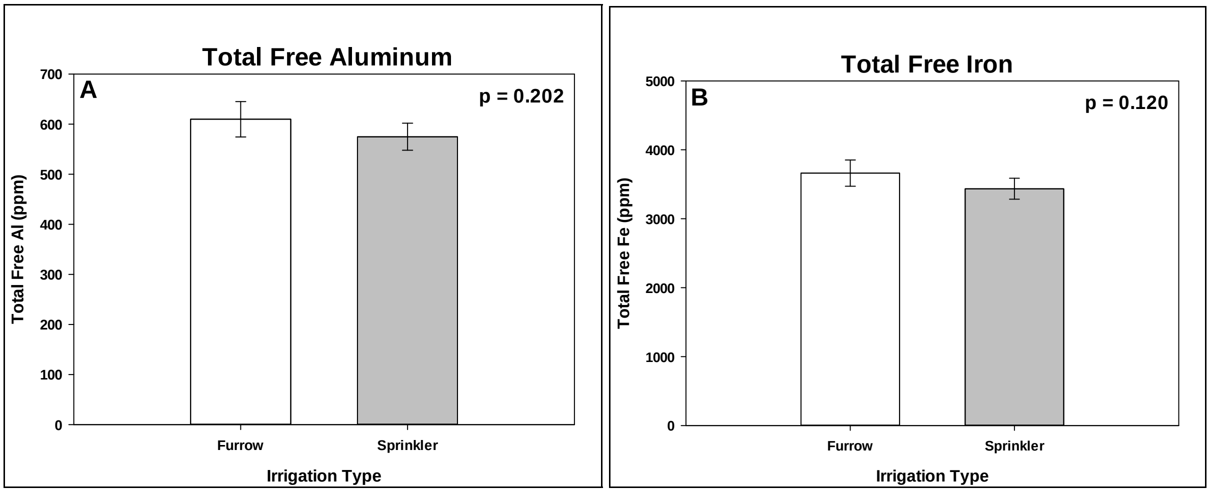

Figure 3. Total free soil A) aluminum and B) iron concentrations.

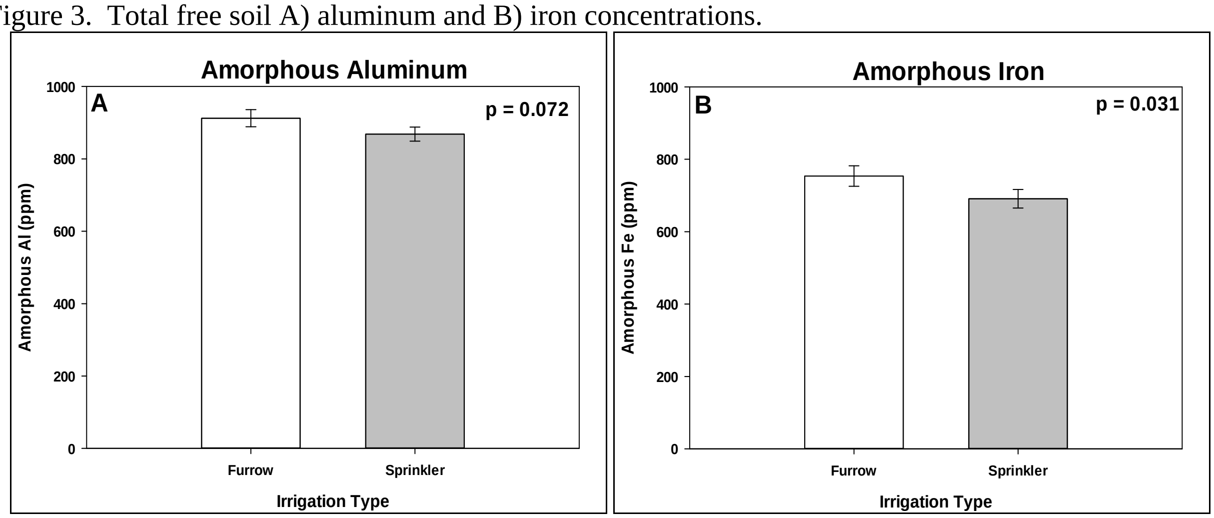

Figure 4. Amorphous soil A) aluminum and B) iron concentrations.

Furrow irrigated soils undergo periods of saturation, likely causing a reduction in Fe from the 3+ to 2+ state. Under initial reduced conditions, ferric-bearing mineral phases dissociate and release P to the soil solution, with some P sorbed by $CaCO_3$; thus the increase in Olsen-extractable P under furrow as compared to sprinkler irrigation (Figure 1B). In addition to the initial P release, when soil Fe mineral phases undergo further reduction their crystallinity decreases (i.e. they become amorphous) with a concomitant increase in surface area. Increasing surface area leads reduced Fe to sorb greater quantities of P and was likely the cause of the increased P concentrations in the soluble+Al+Fe-bound and occluded sequential extraction steps (Figures 2A and B).

In calcareous-dominated soils it is typically believed that $CaCO_3$ greatly influences P precipitation and that calcium phosphate mineral phases control P availability. Yet this obviously may not be the case if calcareous systems contain other P-reactive constituents such as Fe oxides (Ryan et al., 1985b), similar to our study. In further support of this contention, Holford and Mattingly (1975a) studied 24 calcareous soils and observed that high-energy P sorption was closely related to total free Fe. It should be noted that the total free Fe extraction procedure also removes 100% of the amorphous Fe phases, thus Holford and Mattingly's (1975a) data may actually be describing P sorption onto these phases. Unfortunately the researchers did not perform an amorphous extraction procedure. However, Ryan et al. (1985a) studied 20 calcareous soils, performed an amorphous Fe extraction test, and showed that P sorption was strongly related to amorphous Fe oxides instead of $CaCO_3$.

Furthermore, calcium phases may not entirely control P availability in calcareous soils periodically experiencing reduced conditions (e.g. saturation during furrow irrigation), leading to an increase in Fe mineral phase(s) surface area. In calcareous soils, differences in P sorption between $CaCO_3$ and amorphous Fe mineral phases are likely a function of surface area and not total quantity present. Holford and Mattingly (1975b) found that the surface area of $CaCO_3$ in calcareous soils ranged from 1.0 to 1.5 $m^2\ g^{-1}$ and was inversely related to degree of weathering. Crystalline and amorphous Fe oxide surface areas, on the other hand, range from 17 to 280 $m^2\ g^{-1}$ (Sparks, 2003; McLaughlin et al., 1981) and thus their P sorption capacity is greater than that of $CaCO_3$. More importantly, it has been shown that amorphous Fe phases can sorb up to 10 times more P than their crystalline counterparts (McLaughlin et al., 1981), supporting the increase in P associated with these phases in furrow versus sprinkler irrigation.

SUMMARY

Greater soil test P concentrations existed in furrow as compared to sprinkler irrigated soils. Furrow irrigated sites underwent longer periods of soil saturation, likely leading to reduced conditions. Ferric-bearing mineral phases likely dissociated and released P to the soil solution, which was partially sorbed by $CaCO_3$ and led to the increase in Olsen-extractable P. Under furrow irrigation, increasing available soil P content could potentially lead to greater offsite movement. In comparison, sprinkler irrigated soils contained less available P yet the quantity would still be considered sufficient for crop growth. Results support the use of sprinkler irrigation as a best management and conservation practice.

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