

SOIL PHOSPHORUS DYNAMICS UNDER SPRINKLER AND FURROW IRRIGATION

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ABSTRACT

Furrow irrigation detaches and transports soil particles and subsequently nutrients such as phosphorus (P). To reduce the risk of erosion and offsite P movement, producers can convert from furrow to sprinkler irrigation. We completed research on soil P dynamics in furrow versus sprinkler irrigated soils from four paired fields in south central Idaho. Surface soils (0-2.5 inches) were obtained from fields in the fall following 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 Olsen-extractable P may be considered the concentration 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, based on the Idaho One Plan. Soils were additionally analyzed using a sequential extraction to identify inorganic soil P pools, and an amorphous Al and Fe technique was used to help further explain differences in extractable soil P under furrow and sprinkler irrigation. Soils under furrow irrigation had greater concentrations of inorganic P in the soluble/Al-bound/Fe-bound and occluded Fe phases (i.e. Fe coated P), and in the amorphous Fe phases. These findings suggest that Fe reduction chemistry plays a large role in P availability under furrow irrigation, even in calcareous soil systems.

INTRODUCTION

Surface water enrichment of nutrients (e.g. P), due to anthropogenic activities such as production agriculture, 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 production systems.

Production agriculture utilizes two major irrigation practices: furrow and sprinkler. 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 suggest that 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 suspended sediment losses from 400 lbs/acre in the early 1970s to 9 lbs/acre in the mid 2000s by implementing several management techniques which included replacing furrow with sprinkler irrigation (Bjorneberg et al., 2008). Changes in soil P dynamics may also occur due to the difference in soil water status between the two irrigation methods. Thus, we investigated how irrigation practices alter soil P chemistry.

MATERIALS AND METHODS

Fields from four southern Idaho producers were identified; each producer grew barley on relatively adjacent fields using either furrow or sprinkler irrigation. All producers used somewhat

similar prior cropping rotations which included alfalfa, dry beans, corn, winter wheat, sugarbeets, and barley, and similar soil management techniques such as disking and roller harrowing. 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), 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). However, 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 can 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 (i.e. under furrow irrigation) and P fertilizer application becomes limited based on crop removal 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 detailed soil chemical information is required.

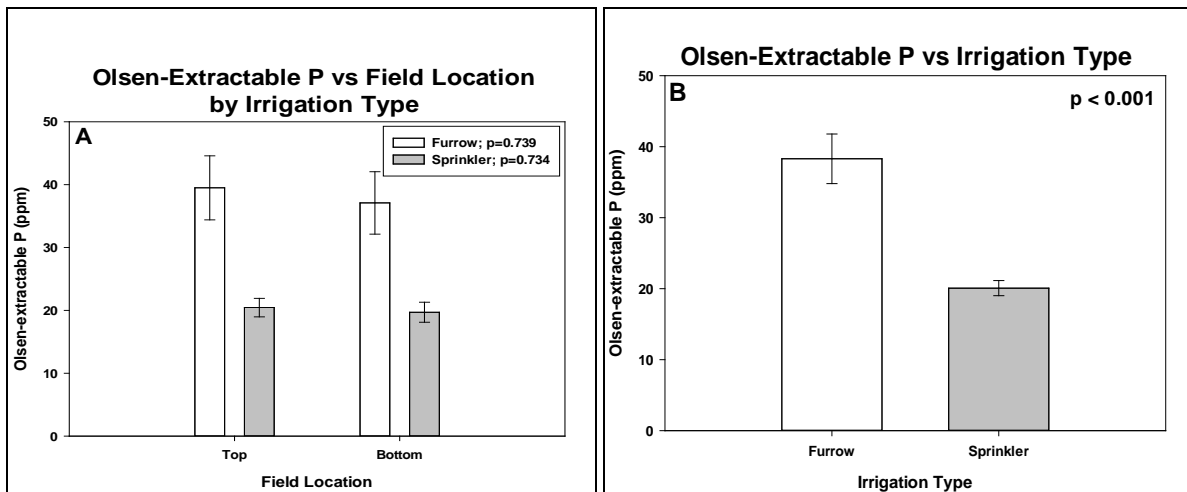


Figure 1. Olsen-extractable phosphorus as affected by A) field location within furrow or sprinkler irrigation and by B) irrigation type.

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 dominated by CaCO_3 (~10% CaCO_3 , by weight, 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, amorphous Al and Fe phases were measured.

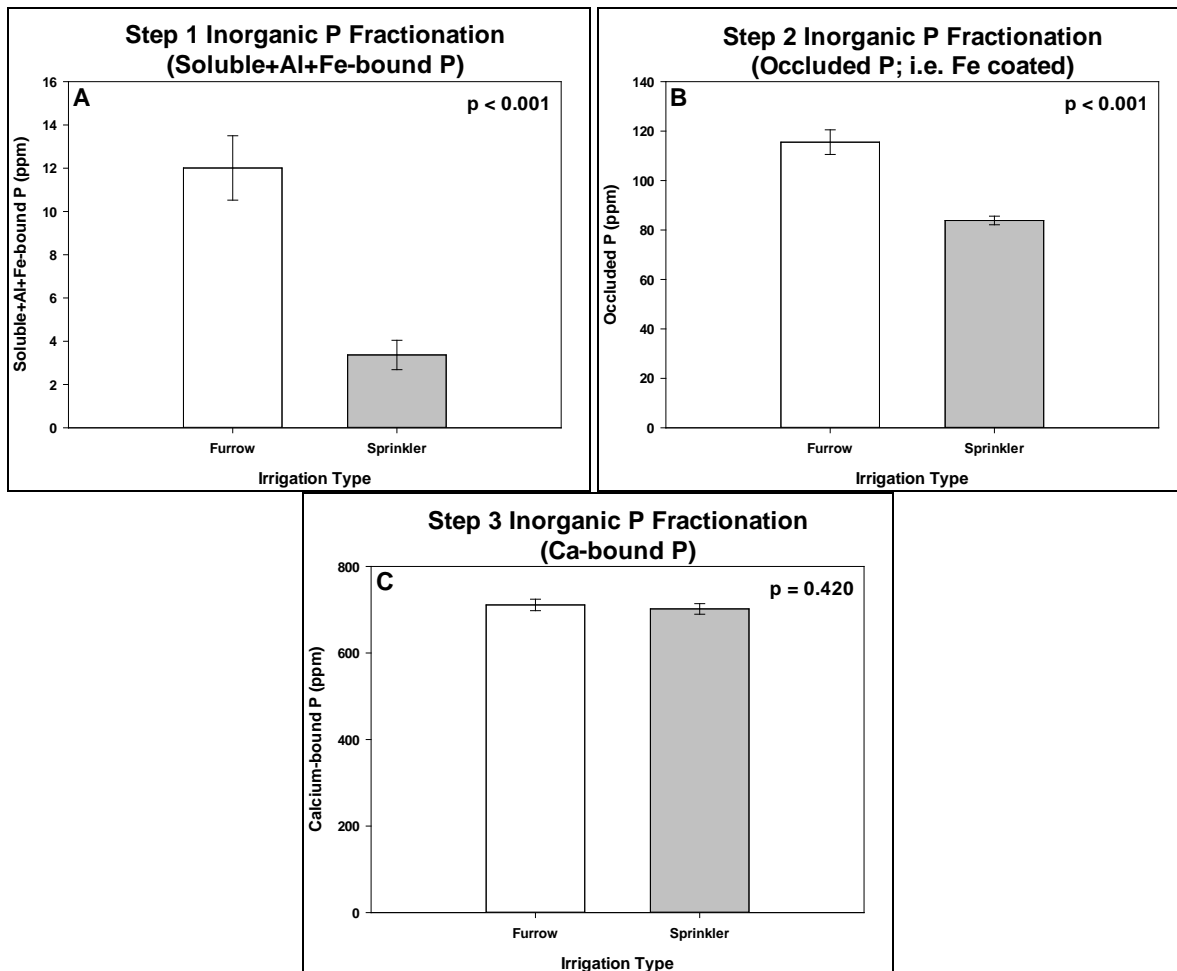


Figure 2. Sequentially extracted soil P concentrations associated with A) soluble+Al+Fe-bound, B) occluded (i.e. Fe-coated), and C) Ca-bound phases.

The surface area of amorphous Al and Fe minerals can be an order of magnitude greater than crystalline minerals (McLaughlin et al., 1981). Thus, amorphous Al and Fe minerals have greater reactivity for elements such as P. Figure 3 illustrates the differences in amorphous Al and Fe content between furrow and sprinkler irrigated soils. There was no difference in amorphous soil Al content (Figure 3A); however, furrow irrigated soils contained greater concentrations of amorphous Fe as compared to sprinkler irrigated soils (Figure 3B). As compared to sprinkler irrigated soils, furrow irrigated soils undergo longer saturation periods, likely causing a reduction in Fe from the 3+ (i.e. ferric) to 2+ (i.e. ferrous) state. Under initial reduced conditions, ferric-bearing mineral phases dissociate and release P to the soil solution, with some P likely 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 allowed the

amorphous Fe to sorb greater quantities of P. This was likely the cause of the increased P concentrations in the soluble+Al+Fe-bound and occluded sequential extraction steps (Figures 2A and B).

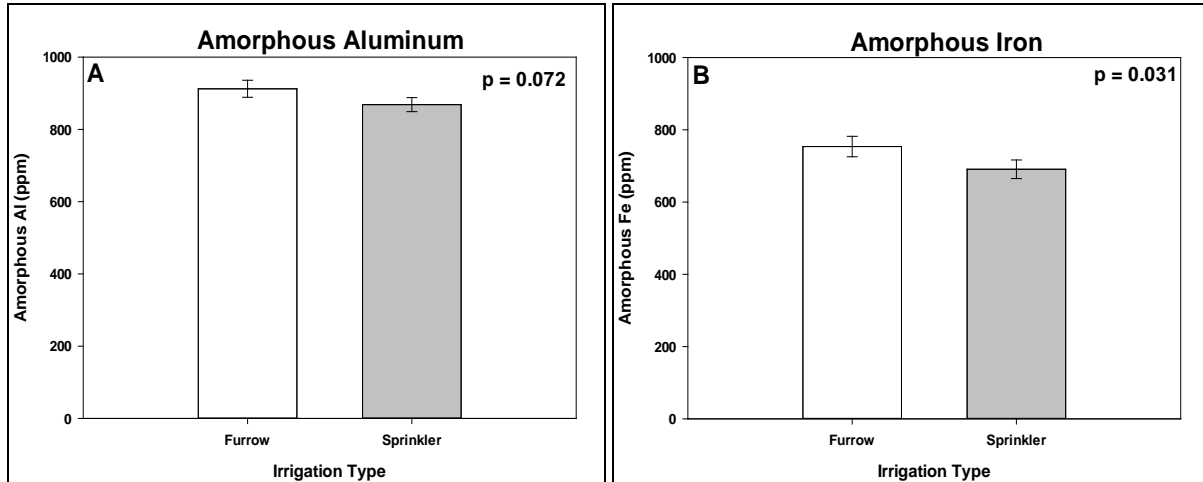


Figure 3. Amorphous soil A) aluminum and B) iron concentrations.

In calcareous-dominated soils, such as those found in south-central Idaho, it is typically believed that CaCO_3 greatly influences P precipitation and that calcium phosphate soil minerals control P availability. Yet this is obviously not the case if calcareous systems contain other P-reactive constituents such as Fe oxides (Ryan et al., 1985b). Supporting this contention, Ryan et al. (1985a) performed an amorphous Fe extraction test on 20 calcareous soils, showing that P sorption was strongly related to amorphous Fe oxides instead of CaCO_3 . Furthermore, soil Ca minerals 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 $\text{m}^2 \text{g}^{-1}$. Crystalline and amorphous Fe oxide surface areas, on the other hand, range from 17 to 280 $\text{m}^2 \text{g}^{-1}$ (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 (Figure 2A).

CONCLUSIONS

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. Under reduced conditions, ferric-bearing mineral phases 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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