# Characterizing soil phosphorus supply on aggrading and degrading management regimes.

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## ABSTRACT:

Practical concerns regarding P fertility usually focus on crop maturity and quality. However, on highly degraded soils P supply can be so low as to limit grain yield. A study of soils treated with conservation and conventional tillage methods indicated that mineralizable fractions of organic N and S were enhanced under conservation managements. Increased soil organic matter quality on these managements may also increase organic P supply. However, assessing the importance of organic P using soil incubations is of little value because mineralized P is quickly fixed as insoluble forms. In this study, we investigate the supply of P on aggraded and degraded soils, using a sequential chemical fractionation which has been operationally linked to plant uptake and net P supply. We also quantify the size of these P fractions on severely degraded and manure amended soils in an attempt to link visual P deficiency and sufficiency to soil P levels. Total and organic P differ little among tillage regimes. Native grassland contains the least mass of P in the 10 cm surface layer, which indicates the importance of fertilizer additions and mixing of mineral soil. Available P fractions are 1.5 to 2.5 times higher in the aggraded conservation managements, reflecting the input of fertilizer P. Trends in available Pi for cultivated soils confirm previous soil quality rankings based on N and S supply. The chemical fractionation of available inorganic P (Pi) clearly delineates the sufficiency of P supply to durum wheat plants. Severely degraded soils showing visual P deficiencies, have 88 % less available Pi than the aggraded manure amended soil, while total and organic P differed by less than 25 %. Therefore, sequential chemical fractionation is a more sensitive indicator of P supplying power than is total or organic P.

**Key words:** Phosphorus, plant available, potential P supply, management, manure.

## INTRODUCTION:

Phosphorus (P) is supplied to plants from the mineralization of organic P, release of sorbed inorganic P, and the very slow release of P from minerals or humus-P complexes. The effect of conservation tillage systems on improving N and S supply is well documented (Carter et al., 1982). However, less is known about their impact on P dynamics and availability. Managements which aggrade soil organic matter (SOM) and add significant proportions of P fertilizers will increase soil P supply. Conversely, degrading managements should limit P supply through the removal of SOM, inclusion of P fixing minerals, and, typically, lower levels of fertilizer.

Hedley et al. (1982) described a fractionation sequence which proved useful in assessing the readily plant available and slowly available sources of P. They also found that changes in the chemical fractions corroborated plant uptake amounts. Others have used this procedure to characterize changes in soil P resulting from soil development and longterm crop management (O'Halloran et al., 1987; Schoenau et al, 1989; Mckenzie, 1989).

In this study a sequential chemical fractionation of soil phosphorus was undertaken to determine the effect of conservation managements on P availability. Severely degraded and manure amended soils were also fractionated in an attempt to verify the link between sequentially extracted P fractions and plant P concentration.

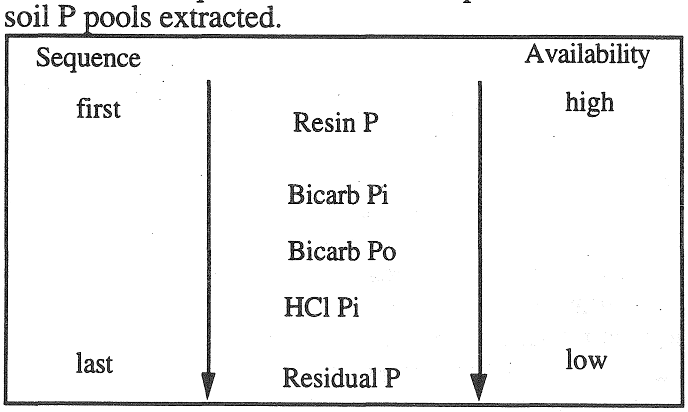
## MATERIALS AND METHODS:

Soil samples were collected in the fall of 1990 from four differently managed Oxbow loam soils near Indian Head, Sk (Greer and Schoenau, 1992). The fields provided a wide contrast in the degree of tillage, residue additions and fertilizer applications. A field managed as summerfallow-spring wheat (fallow-wheat) returned the least residues, had little fertilizer added and was most intensively tilled. A second field was sampled after seven years of brome grass seed production. A third field was sampled after direct seeding to a spring cereal-oilseed rotation for 13 years. The control site for site study was chosen from a nearby prairie site.

Severely eroded (Haverhill association) soils with and without manure amendment were sampled in the fall of 1992. The entire site was eroded in the early 1960's and later manured in spots at approximately 40 - 50 Mg $ha^{-1}$. Five replicate manure amended spots were sampled to 15 cm along with adjacent unmanured areas. Mature wheat plants were also taken to determine tissue P concentrations.

Soil P fractions were determined by sequentially extracting the soil according to the method of Tiessen and Moir (1993). A schematic view of the procedure showing order of extraction and relative degree of P availability is given in Figure 1.

Figure 1. Overview of the sequential fractionation procedure and relative availability of soil P pools extracted.




Statistical analysis was performed in STATWORKS® as a completely randomized design. Replication of treatments was not performed within each field sampled. Therefore randomly selected cores were used as replicates.

## RESULTS AND DISCUSSION:

Cultivated soils contained significantly more Total P (Pt) than did the same rooting volume in the native site (Table 1). Sampling only the top 10 cm of the native site could reduce the contribution of P-bearing minerals as a larger proportion of the low bulk density thatch is included in the sample from the native site. However, fertilizer P additions to the cultivated soils is likely the major cause for the apparent difference in total P. Among the cultivated fields,the fallow-wheat rotation which received little fertilizer contained as much Pt as the other fields. Export of P as grain can have a large impact on soil P levels (Barber, 1979). The direct seed continuous cropping field sustained much higher cropping frequency than did the fallow-wheat field, while the field managed for brome grass seed would have the least P removed as grain.

Table 1. Field management effect on the mass of Total and Organic P in the surface layers of an Oxbow loam, Indian Head, Sk.

| Treatment | Total P | Organic P |
|---|---|---|
| | ($g\ m^{-2}$) | |
| fallow-wheat | 82 | 33 |
| direct seed continuous | 76 | 33 |
| brome | 89 | 31 |
| native | 56 | 23 |
| LSD | 7 | 5 |

Organic P (Po) was also lowest on the native site, but not significantly different among the cultivated soils. This trend in organic P parallels that found for the organic N and S (Greer and Schoenau, 1992). As with N and S, the mass of organic and inorganic P per 10 cm rooting volume shows little difference between managements.

Sequential chemical extraction can separate soil P into readily available, slowly available and stable P forms. Anion exchange resin P has been found to contribute more than half of the P taken up by plants on calcareous soils (Bowman et al., 1978). Sodium bicarbonate and hydroxide extractable P also contributes to plant available P (Hedley et al., 1982). These three P fractions can be summed to represent the 'available' inorganic P. The organic P extracted with sodium bicarbonate and hydroxide are considered a potential source of mineralizable P. The remaining extractable amounts are recalcitrant or slowly available P sources and organic pools which account for net P immobilized (Hedley et al., 1982).

Managements with reduced soil mixing, higher fertilization, and residue additions had the highest levels of inorganic P in available forms (Table 2). Trends in available Pi across the cultivated soils correspond closely with the soil N supplying power, although for differing reasons. Crop removal of P as grain was least in the brome grass field, which received some fertilizer to optimize seed yields. Direct seed continuous cropping and fallow-wheat fields have less available Pi, with the differences largely reflecting the balance between P removed as crop and added as fertilizer.

Table 2. Field management effect on the mass of Available, Labile and Recalcitrant P in the surface layers of an Oxbow loam, Indian Head, Sk.

| Treatment | Available Pi | Labile Po | Recalcitrant Pt |
|---|---|---|---|
| | ($g\ m^{-2}$) to 10 cm depth | | |
| fallow-wheat | 5.5 | 17 | 62 |
| direct seed continuous | 8.3 | 18 | 50 |
| brome | 13.3 | 17 | 59 |
| native | 5.5 | 12 | 35 |
| LSD | 2.0 | ns | 8 |

Available P was lowest in the fallow-wheat and native soils. Virgin Chernozemic soils are typically low in available inorganic P fractions (Tiessen, 1981). However, in the fallow-wheat field, degradation due to sparse fertilization and frequent tillage probably combine to limit the amount of available Pi. Longterm unfertilized research plots have also shown similarly low amounts of available Pi (Mckenzie, 1989).

Labile forms of organic P found in the bicarbonate and hydroxide fractions are thought to be sources for microbial respiration and P release. This P fraction was not different among the fields, suggesting that potential supply of P from organic sources was not affected by management.

Resistant (recalcitrant Pt) fractions, which contain mainly calcium-fixed P, was highest in the fallow-wheat field and lower in the fields where tillage and mixing was less frequent. This is consistent with increased mixing and dilution of the A horizon with more calcareous subsurface layers which occurs in intensively tilled fields.

Discussing the soil quality in terms of potential P supplying status is only as meaningful as the relation between chemical extractant and plant P availability. Linking the P fractions with plant availability was conducted on a severely eroded site showing spots of severe P deficiency. Phosphorus in the plant tissue from the eroded area was below the 0.15% critical level (Table 3). Manure amended spots contained twice as much P per weight of plant tissue and did not show any visual P deficiency symptoms.

Table 3. Phosphorus concentration in plant tissue and associated soil fractions from manure amended and unamended sites.

| Treatment | Plant tissue | Total P | Organic P | Available Pi | Labile Po | Recalcitrant Pt |
|---|---|---|---|---|---|---|
| | (%) | $g\ m^{-2}$ | | | | |
| Unmanured | 0.10 | 119.2 | 16.8 | 3.7 | 4.5 | 115.0 |
| Manured | 0.20 | 156.0 | 21.0 | 30.5 | 6.8 | 122.0 |
| P>F | 0.001 | 0.003 | 0.079 | 0.002 | 0.005 | ns |

Soil P analysis indicated 31% more total and 20 % more organic P was present in the manure amended sites. However, available Pi fractions were 8 times higher than those found in the unamended site. Labile Po was somewhat higher in the manure amended soil, however the difference was not as great. Therefore, chemically extracted P fractions which reflect the easily desorbed inorganic P sources are more sensitive indicators of P sufficiency than are labile organic P forms.

## CONCLUSIONS:

Phosphorus fertility was greatly affected by aggrading and degrading managements. Differences in total P reflected the impacts of fertilizer addition and crop removal of P in different management systems. Conservation managements did not lead to a build up of organic P or labile organic P in the top 10 cm of the rooting volume, but accumulations of plant available inorganic P were observed where additions as fertilizer or manure exceeded the removal of P as crop. Tillage which causes mixing of less weathered calcareous subsoil into the upper rooting layers appears to increase recalcitrant P and decreased available P forms.

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