Tillage and Phosphorus Availability

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Background

It has been recognized for some time that adoption of the no-till system in Saskatchewan soils can increase the ability of the soil to supply available nitrogen through mineralization (Greer and Schoenau, 1992). This effect may be attributed to the enhancement in amounts and ease of decomposition of organic matter, but several years may be required to detect these benefits (Campbell et al., 1996). Compared to nitrogen, tillage system and its relationship to phosphorus availability have received less attention.

We would anticipate that reducing or eliminating tillage would increase phosphorus availability by reducing erosion, increasing soil moisture to allow phosphorus to move more easily to roots, and increasing biological activity. The greater mycorrhizal fungi colonization reported in no-till (Mozafar et al., 2000) that extends the root system would provide better plant access to soil phosphorus. However, another important consideration in how a cropping/tillage system can affect phosphorus fertility is the balance between P fertilizer addition and crop P removal. Regardless of the system employed, if more P is removed in crop harvest than what is replaced by fertilizer or manure, the P stores in the soil will be depleted. Therefore, the overall balance between P inputs and outputs will influence phosphorus fertility trends over time. Brandt (1992) observed no difference in soil extractable P levels between no-till and conventional till after nine years.

Changes in distribution of phosphorus in the soil may also arise. In long-term no-till systems, a phenomena commonly termed “stratification” is observed in the upper soil profile, in which high concentrations of immobile nutrients like P are found closer to the surface due to lack of mixing by tillage (Essington and Howard, 2000). Mixing by tillage can alleviate this stratification. Questions have arisen as to how the elimination of stratification through a tillage operation might affect phosphorus availability.

There is a need to address unresolved issues in the relationship between tillage and phosphorus availability in Saskatchewan soils. The objective of this paper is to provide further insight into how low disturbance direct seeding (no-till) system in Saskatchewan impacts phosphorus availability. This is accomplished by briefly reviewing research that addresses the initial stages (1 yr), short-term (5yr) versus long term (25 yr), and what happens to P availability when a long-term no-till soil receives a cycle of tillage.

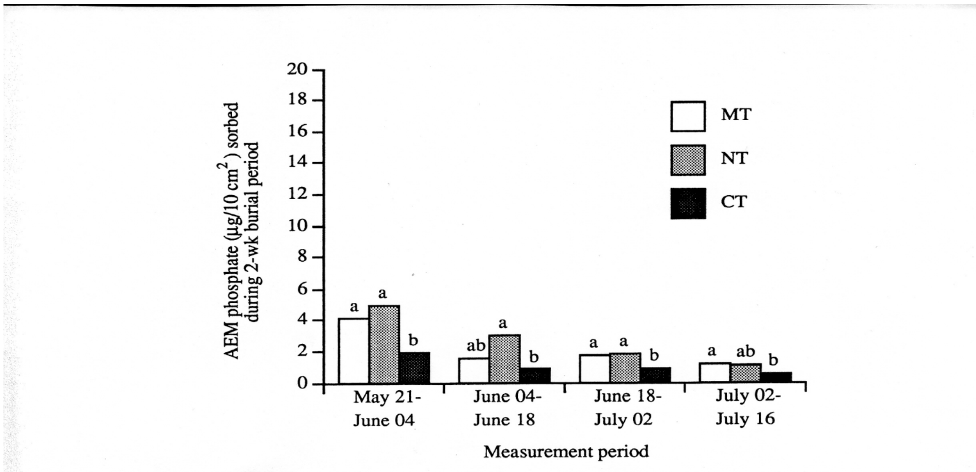
Switching to No-Till

Research in the 1990's by a graduate student at the University of Saskatchewan (Adderley, 1999) examined the effect of pre-seeding tillage with a heavy duty cultivator: fall + spring (CT); spring only (MT) and no-till (NT) on pea stubble in 1996 and 1997 at two sites: Brown soil zone (Central Butte) and Black soil zone (Melfort AAFC). The sites were under conventional tillage previously. In this study, supply rates of nitrate, phosphate and sulfate were measured using PRS anion exchange membrane (aem) probes placed in PVC cylinders in the field for two week intervals over approximately six weeks the following spring and summer in wheat seeded on the different tillage plots (Figure 1).

Figure 1. PRS probes placed in PVC cylinder in field in wheat crop.

In general for the two sites over the two years, the supply of available phosphorus as affected by tillage was: NT ≥ MT> CT as depicted in Figure 2.

A . Central Butte (Brown) site



B. Melfort (Black) site

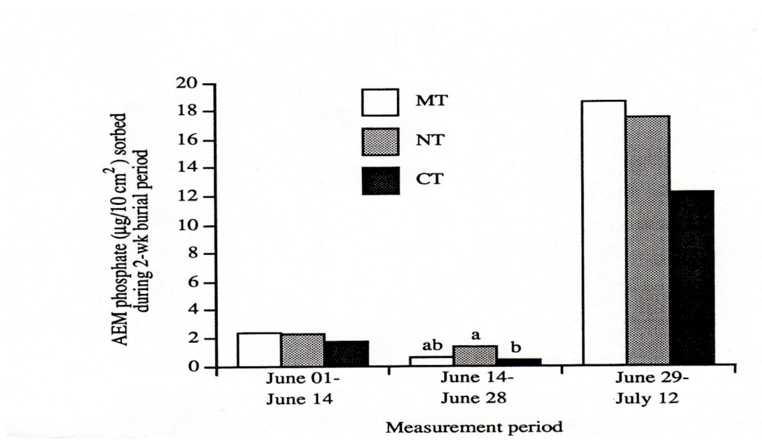


Figure 2. Mean soil phosphate supply rates under minimum (MT), no-till (NT) and conventional till (CT) of pea stubble at A. Central Butte (Brown) and B. Melfort (Black) sites (Adderley, 1999). For each measurement period, treatment means with different letters are significantly different at P<0.10).

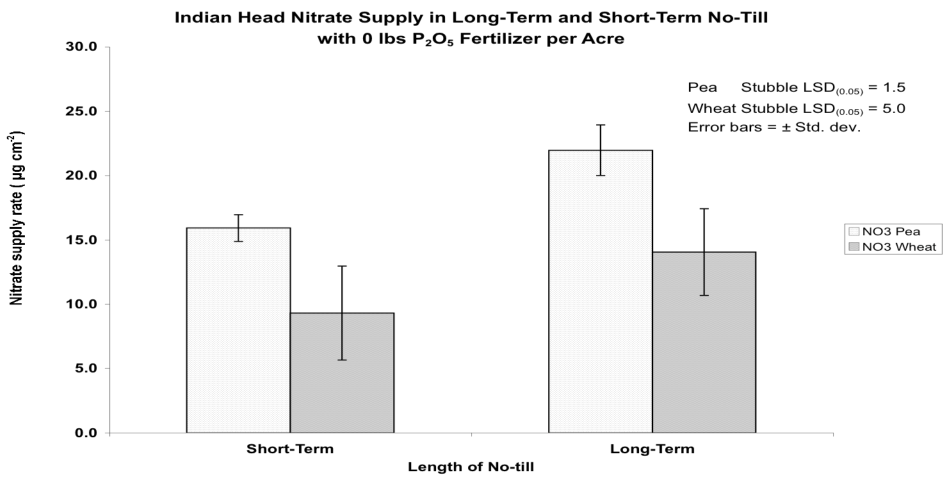
Since this was the first year of the tillage treatments, the higher supplies of soil phosphorus were attributed to higher soil moisture content under no-till that enhanced the ability of P to move by diffusion in the soil. The effect of moisture on P mobility is evident at the Melfort site, where the large increase in soil P supply rate in the June 29-July 12 period was associated with 52 mm of rain received over the same time period. Higher soil supplies of phosphate measured under no-till may also reflect greater release of P from surface residues than when incorporated, as was observed by Sharpley and Smith (1989).

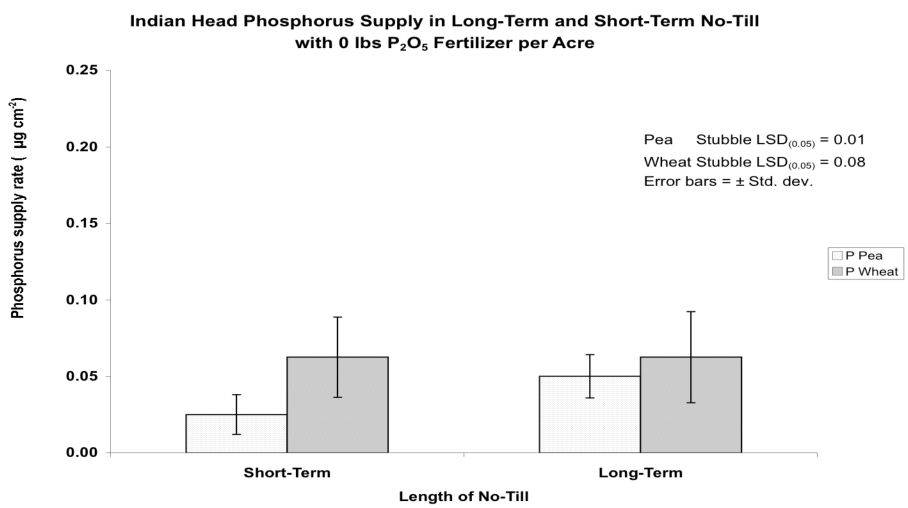
Short term (5 years) versus Long term (25 years) of No-Till

To reveal the effects of adopting low disturbance direct seeding on P availability over a longer time frame, in early spring of 2006 we sampled five year (short-term) and twenty-five year (long-term) no-till plots. Treatments sampled included two stubble types (pea and wheat) with three different P fertilizer treatments (0, 20 and 40 kg P_20_5/ha). Intact 0-15 cm soil cores were removed from each plot and incubated for two weeks in the laboratory. The supply rates of available phosphorus and nitrogen in the soil cores were measured over the two-week period using PRS probes (Figure 3).

Figure 3. Collection of intact soil cores at the Indian Head site and incubation in the laboratory.

This comparison revealed significantly higher supplies of available nitrogen as nitrate and also higher supplies of available phosphorus after 25 years of no-till compared to 5 years (Figure 4). The effect of stubble type was most evident for nitrogen, with greater nitrate supply rates on pea stubble than wheat. The impact of added P fertilizer on increasing P supply was greatest on the long-term no-till soil. This perhaps suggests greater fixation of P fertilizer into less soluble forms on the short-term no-till compared to the long term.





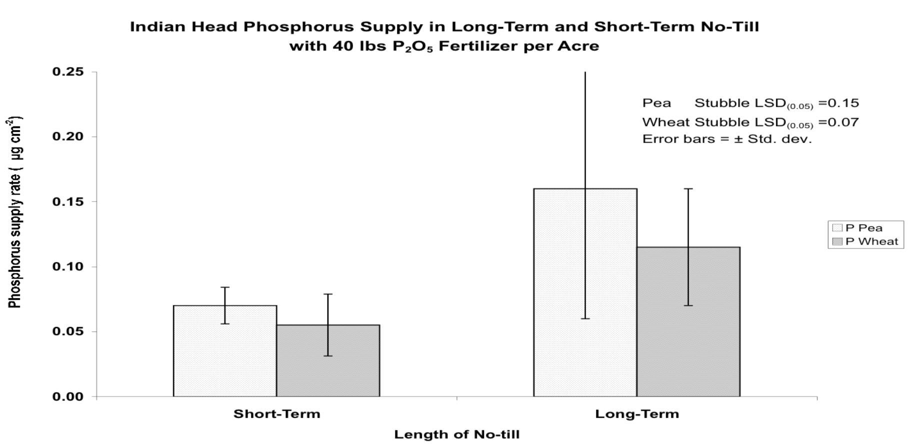


Figure 4. Nitrate and phosphate supply rates in Indian Head soils.

The results of the soil P supply measurements were consistent with observations at this site that crops grown on the long-term no-till soil were not as responsive to added P fertilizer.

Imposing a Cycle of Tillage on a Long term No-till Soil

Phosphorus stratification at the surface in no-till appears to have little impact on P availability based on results of research work conducted in 2005 by a graduate student at the University of Saskatchewan (Baan 2007). In this work, a cycle of tillage was imposed on long-term (10 yrs +) no-till soils at sites in the Brown (Central Butte), Black (Rosthern) and Gray (Tisdale) soil zones. Tillage treatments were no-till (NT), spring till with heavy duty cultivator with sweeps (MT), fall + spring till (CT), and fall + spring till with cultivator plus tandem disk (MXT). Cores of soil 0-15 cm were taken from each plot and segmented into 0-5 cm, 5-10 cm and 10-15 cm depth increments and extractable (modified Kelowna) P concentrations determined. Grain yield and P uptake in the crop were also assessed. As shown in results from the Tisdale site (Table 1), the mixing by the tillage operation reduced the stratification. However, as shown in crop P uptake data from all three sites, there was no large effect on P availability as shown by similar crop P uptake among treatments (Table 2).

Table 1. Modified Kelowna extractable P concentration measured in intact segmented cores taken after imposition of tillage treatments at Tisdale site (Baan, 2007).

Treatment	***0-5cm***	***5-10cm***	***10-15cm***
	---------------mg P / kg ----------------		
NT	45	25	10
MT	39	31	12
CT	33	23	11
MXT	35	21	15

Table 2. Crop P uptake (grain+ straw) in 2005 at the three tillage sites (Baan, 2007).

Treatment	***Crop P Uptake (kg P/ha)***		
	Central Butte	Rosthern	Tisdale
NT	11.3	15.4	15.3
MT	11.0	15.4	11.5
CT	11.3	14.5	13.9
MXT	10.8	16.0	14.3
Lsd (0.10)	NS	NS	2.0

More uniform distribution of P might result in more uniform distribution of roots in the topsoil as reported by Drew (1975). However, mixing by tillage may also increase the contact between fertilizer band and soil constituents responsible for fixation. Reduced crop P uptake in the Tisdale site tillage treatments was attributed to reduced yield and P demand as a result of immobilization of available nitrogen from incorporation of large amounts of surface straw and chaff in the tillage operation.

Conclusion

The no-till systems that were evaluated appeared to generally have a positive effect on soil P availability in the short and long-term, with benefits that accrue over time. Stratification of P as a factor affecting P availability does not appear to be an issue, and tillage to address this does not seem warranted based on the results. Identification of different soil P forms using chemical fractionation and synchrotron spectroscopy may provide additional insight into the relationship between tillage system and soil P fertility.

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