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THE EFFECT OF TILLAGE SYSTEM AND PRECEDING CROP ON PHOSPHORUS RESPONSE OF FLAX

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Introduction

Reduced tillage systems are becoming increasingly popular on the prairies, to conserve soil moisture, increase crop yield potential, improve soil quality and reduce time, labour and equipment costs in farming operations. Reducing tillage also has important implications for nutrient management. With reduced tillage, moisture relations, distribution of nutrients in the profile, deposition of organic residues and the type and activity of soil micro-organisms will change as compared to a conventional tillage system (Grant and Bailey 1993). This will impact directly on nutrient availability and on fertilizer management decisions. While many research studies have evaluated impact of tillage systems on N fertility requirements, there has been little information collected on the impact of tillage management on P phytoavailability.

Early season P supply is critical to determination of optimum crop yield. Withholding P during early plant growth will limit crop production and cause a restriction in crop growth from which the plant may not recover. Phosphorus limitation later in the season has a much lower impact on crop production than limitations experienced early in growth. No-till systems reduce early season soil moisture and can increase soil compaction (Grant and Lafond 1994), which may reduce the availability of phosphorus during early growth. Low P supply and slow root growth may combine to cause severe P stress early in the season when plant demand for P will outstrip the soils ability to supply the nutrient. This may occur more frequently under reduced tillage, where the soil is slightly slower to warm up in the spring and where bulk densities in the soil surface may be increased to some extent (Grant and Lafond 1994). However, it may be that in soils with a history of phosphorus fertilization, as most of our soils have now, starter phosphorus to optimize crop yield may be less important than in the past, if management practices encourage availability of residual phosphorus from the soil. Information on the impact of tillage system and past phosphorus fertilizer management on phosphorus response of crops is limited.

Canola and wheat are the two major annual crops in the Canadian prairies, while flax is also important. Flax and wheat tend to respond very well to reduced tillage systems, frequently producing higher yields under no-till as compared to conventional till management (Lafond et al. 1993). According to both research trials (Lafond et al. 1993) and producer experience, canola may not respond as beneficially to no-till management as cereal crops or flax. If part of the reason for lower relative yield of canola under no-till is the change in nutrient dynamics, optimization of soil fertility could lead to significantly higher canola yields.

While flax production is lower than that of canola and wheat, it is likely to expand in the future. Production of flax was limited and prices volatile because of the size of the industrial oil market. While some flax is used for human consumption, the instability and short shelf life of the product reduced the widespread of linseed oil in the human diet. A plant breeding program has recently led to the development of Solin, a category of flax with oil characteristics similar to those of sunflower. Solin cultivars produce an oil that resists auto-oxidation and has a longer shelf life. These characteristics have made solin oil sought-after in the edible oil market. In addition, there is increasing movement of flaxseed into the health food market, because of reported beneficial effects on the nature and levels of blood cholesterol. The expanding market for flaxseed, combined with the current low prices for cereal crops, the removal of the Western Grain Transportation Subsidy, and the increasing incidence of fusarium head blight and wheat midge, point to an increase in future flax acreage in western Canada.

Canola and wheat have a high demand for crop nutrients, including phosphorus (Grant and Bailey 1993b). Deficiencies of P are common and frequently limit crop yield. Therefore, proper P fertilization is important in optimising crop production. Although canola requires a large amount of P for growth, maximum responses are often attained at lower rates of P than for wheat, corn or barley. Kalra and Soper (1968) evaluated the efficiency of a number of crops in absorbing soil and fertilizer phosphorus, under greenhouse conditions. Rapeseed and flax used about equal amounts of soil P, but rapeseed absorbed fertilizer P in large amounts. Rapeseed was much more effective than flax in extracting fertilizer P. This is because rapeseed, a nonmycorrhizal plant, could modify its root structure and root hair number, proliferating roots in fertilizer reaction zones and decreasing pH in the rhizosphere. However, rapeseed (canola) is sensitive to damage from seed-placed P and quantities of P required to optimize yield may lead to seedling damage.

Phosphorus fertilization of flax can be problematic, since flax is very sensitive to seed-placed applications of monoammonium phosphate (Nyborg and Hennig 1969). Banded applications of P fertilizer are not generally used effectively by flax unless they are positioned within 2.5 to 5.0 cm of the seed-row (Sadler 1980) and broadcast applications of P tend not to increase flax seed yield (Grant and Bailey 1993). Therefore, unless a producer has access to seeding equipment capable of side-banding fertilizer, P fertilization of flax is frequently ineffective. Most of the studies conducted on P fertilization of flax were conducted under conventional tillage. Cooperative studies being conducted by Agriculture and Agri-Food Canada, coordinated by Guy Lafond (Pers. Comm.), show responses of no-till flax to P fertilizer were generally quite low, in the order of 0 to 2 bu acre, which was generally not statistically significant. In 14 site years of research in Manitoba and Saskatchewan, the P response of the "best" treatment in the experiment exceeded 3 bu/acre in only 3 instances. Producers frequently avoid P application in flax and increase the P supply in the preceding crops, in order to supply residual P for use by the subsequent flax crop.

Mycorrhizae are fungi which form associations with certain crops under low-P situations, enhancing the uptake of P by the crop. Tillage disrupts the mycorrhizal network. Research at Guelph (Miller 1998) and Agassiz (Bittman et al. 1998) showed that corn produced on summer fallow or under intense tillage was restricted in its ability to access P, while corn which followed a mycorrhizal crop, particularly under no-till, showed improved early season P nutrition. The greater P absorption is largely a result of the undisrupted mycelium present in an undisturbed soil. The mycelium remains viable over extended periods in frozen soil and so can acquire P from the soil and deliver it to the plant immediately upon becoming connected to a newly developing root system in the spring. Phosphorus status of the crop in the first 4-6 weeks of growth has a major impact on final crop yield. Flax is a highly mycorrhizal crop. It is possible mycorrhizal associations could be responsible both for part of the positive response that flax shows in no-till systems and for the limited P response observed in recent studies. If so, P fertility requirements in flax could be greatly affected by tillage system and by whether the preceding crop was mycorrhizal or not. Phosphorus fertilization could possibly be reduced or eliminated in flax grown in no-till following a mycorrhizal crop and optimized in flax grown on summer fallow, after a non-mycorrhizal crop, or under conventional tillage management. By more clearly defining the P requirements of flax, canola and wheat grown under different management systems, we may be able to reduce inputs while maintaining or improving crop yield and quality.

While effect of P on crop yield are important, it is also important to consider effects on crop quality. Cadmium (Cd) is a heavy metal present in soils, crops and phosphate fertilizers. Concern about food-chain transfer of Cd has resulted in (a) the World Health Organization setting a maximum provisional tolerable intake limit for an adult at 60 to 70 μg Cd per day (World Health Organization 1972) and (b) the Codex Alimentarius Commission of FAO/WHO proposing a limit on the concentration of Cd in cereal grains and oilseeds traded on the international markets. Although oilseed flax is generally grown for industrial purposes, a portion of the crop is used for human consumption. Cadmium levels in flaxseed can exceed 300 mg kg^{-1} (Marquard et al. 1990). Promotion of flax as a health food may increase the amount of flax in the human diet. Therefore, the relatively high level of Cd in flaxseed is of concern.

Phosphate fertilizers usually contain Cd in varying concentrations, reflecting the Cd content of the rock from which the fertilizer was derived. Phosphorus fertilizer may also influence Cd availability through its effects on soil pH, ionic strength, Zn concentration and plant growth. Preceding crop (Oliver et al. 1993) and tillage system (Brown 1998) may also influence Cd concentration of crops. However, information on the interactive effects of tillage system, preceding crop and P management on Cd content of crops is lacking. It may be possible to reduce the Cd content of flax while maintaining P sufficiency and crop yield by supplying P for flax by high applications in the preceding crop.

Objectives

1) To determine the impact of tillage system on P fertilizer response of canola and wheat.
2) To determine the yield response of flax to P fertilizer application, as influenced by preceding crop and tillage system and level of P fertilization in preceding crop.
3) To determine the effect of tillage system, preceding crop and P fertilizer management on Cd content of flax.
4) To determine the degree of mycorrhizal activity in flax, as affected by preceding crop and tillage system
5) To determine the early season accumulation of P by flax as influenced by preceding crop and tillage system

Materials and Methods

In year 1 of the study, no-till and conventionally tilled canola (nonmycorrhizal crop) and wheat (mycorrhizal crop) will be established in a randomized complete block design, with 4 replications. Phosphorus fertilizer at 0, 25 and 50 kg P_2O_5 per ha will beside-banded with the canola and wheat, randomized within the tillage systems. Two additional blocks of land equivalent in size will be no-till seeded to barley and wheat, fertilizer with 25 kg P_2O_5 per ha in preparation for the following years of study. In year 2, flax will be seeded with a SeedHawk plot seeder on 2m x 5 m plots on canola and wheat treatments, using no-till management on the no-till blocks and conventional till management on the conventional till blocks. In addition, blocks of canola and wheat will be produced on the barley block as described in year 1 and barley will be seeded on the wheat block for the following year's study. In year 3, flax will be sown on the prepared canola and wheat blocks and canola and wheat will be produced on the barley block. If funding is available, wheat may be sown on the flax stubble to determine residual effects of P application in year 3. In year 4, flax will be sown on the prepared canola and wheat blocks and possibly wheat on the flax plots.

Side-banded monoammonium phosphate at 0 and 25 kg P_2O_5 ha^{-1} will be applied to the flax. Ammonium nitrate at 70 kg N ha^{-1} with the flax and 100 kg N ha^{-1} with the canola, wheat and barley will be applied as a pre-plant band prior to seeding. Canola should also receive an overall application of 20 kg S ha^{-1} as ammonium sulphate in the pre-plant band. The amount of N in the monoammonium phosphate and ammonium sulphate will be balanced in the pre-plant N application.

Yr 1			Yr 2 flax	Yr 3 wheat
tillage	crop	P_2O_5	P_2O_5	P_2O_5
conventional	wheat	0	0 or 25	0
conventional	wheat	25	0 or 25	0
conventional	wheat	50	0 or 25	0
conventional	canola	0	0 or 25	0
conventional	canola	25	0 or 25	0
conventional	canola	50	0 or 25	0
Zero till	wheat	0	0 or 25	0
Zero till	wheat	25	0 or 25	0
Zero till	wheat	50	0 or 25	0
Zero till	canola	0	0 or 25	0
Zero till	canola	25	0 or 25	0
Zero till	canola	50	0 or 25	0

Locations: two clay loam soils, low in P (one with history of zero till and one with history of conventional till i.e. Zero Till Farm and New Farm)
Plot Number: 3 treatments by 2 crops by 2 tillage systems by 4 reps = 48 plots at each location = 96 plots in total year 1. In years 2 to 4, 6 treatments by 4 reps by 4 preceding year's management (NT canola, CT canola, NT wheat, CT wheat) = 96 treatment plots per year at each location = 192 plots per year in flax plus the 96 plots in total for canola and wheat. Non-treated blocks of land will also be seeded in years 1 to 3, for site preparation.
Plot Size: Canola and wheat plots will be 4 m by 5 m. Flax plots will be 2 m by 5 m.

Seeding depth: 2.5 cm or less
Date of seeding: Early to mid-May
Pre-seeding weed control: Round-up just prior to seeding
In-crop weed control: As required for weed spectrum present
Measurements:
1) Soil nutrient status to 60 cm in spring or fall, by crop and tillage system
2) Spring moisture
3) Biomass yield at 5 weeks after emergence
4) P concentration of biomass at 5 weeks after emergence
5) Mycorrhizal infection at 5 weeks after emergence (Marcia Monreal)
6) Disease incidence (Debbie McLaren)
7) Weed populations(Doug Derksen?)
8) Flax seed yield
9) Cd concentration of the flax seed
10) Cd concentration of canola and wheat straw

Time Line for Project Completion

1999-2000: Select sites and establish P fertilizer treatments in no-till and conventional till canola and wheat. Seed large blocks of barley and wheat for following years trials. Determine background levels of nutrients, cadmium, weeds, diseases and mycorrhizae at each location. This has been completed.

2000-2001: Seed flax with and without P fertilizer treatments on fertility trial. Establish canola, wheat and fallow blocks for following years study. Seed large blocks of barley for following years trials. Determine mycorrhizal infection. Analyse plant and soil samples. Conduct statistical analysis of data and prepare reports for funding agency.

2001-2002: Conduct second year of flax fertility trial. Establish canola, wheat and fallow blocks for following years study. Determine mycorrhizal infection. Analyse plant and soil samples. Conduct statistical analysis of data and prepare reports for funding agency. If clear differences are becoming apparent, preliminary results may be presented at technology transfer meetings.

2002-2003: Conduct final year of flax fertility trial. Determine mycorrhizal infection. Analyse plant and soil samples. Conduct statistical analysis of data and prepare final reports for funding agency. Present results at technology transfer meetings. Post results on web pages and prepare technology transfer releases. Initiate preparation of manuscripts for peer-reviewed scientific journals. Prepare and defend graduate thesis (if graduate student is funded).

Technology Transfer Plan

Information from this project will be presented for producers at technology transfer meetings and provided to regional soil testing laboratories for use in modifying soil fertility recommendations for flax. Information will also be made available in written form to provincial agricultural departments for use by Agricultural Representatives and Soil Fertility Specialists and to agronomists working in private industry in the area of soil fertility. A report will be included on the Brandon Research Centre Web page. The data will also be published in peer-reviewed scientific journals.

Budget

	1999	2000	2001	2002	Total
Labour	7000	20000	20000	20000	67000
Graduate Student or technical	0	17500	17500	17500	52500
Materials and Supplies	1200	3000	3000	3000	10200
Chemical Analyses	5000	13000	13000	13000	44000
Mycorrhizal Analyses	1000	5000	5000	5000	16000
Travel	1000	1500	1500	1500	5500
Land Rental	1000	1000	750	500	3250
Library, computer and support services	1800	4900	4900	4900	16500
Total	18000	65900	65650	65400	214950

Funding for this project will be sought from both industry and government sources to attain the required total budget. Currently, funding commitments have been attained from the Potash and Phosphate Institute and Westco. Matching funding will be applied for under the Matching Investment Initiative program of Agriculture and Agri-Food Canada.

If complete funding is not attained, the degree of data collection will be reduced to meet the available funding.

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