Impact of Tillage System, Preceding Crops, and P Fertilizer on Economic Performance of Flax Production

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Abstract

Conservation farming is a system approach that considers all factors that affect production. Reduced tillage is one of the methods of conservation farming and is becoming increasingly popular on the prairie. This will impact directly on nutrient availability and on fertilizer and other chemical management decisions. Phosphorus (P) supply, and its availability in early stages of plant growth, is critical to the determination of optimum crop yield. Producers frequently avoid P application in flax and increase the P supply in the preceding crops since flax is very sensitive to seed-placed applications of monoammonium phosphate. Along with supplying residual P, a preceding crop such as wheat and canola may also have different impacts on yield and performance of flax depending upon its association with mycorrhizae. Since flax is a highly mycorrhizal crop, it is possible that mycorrhizal associations could be responsible for part of the positive response that flax shows in zero-till systems and the limited P response observed in recent studies. If so then P fertility requirements in flax could be greatly affected by the tillage system and by whether the preceding crop was mycorrhizal or not. Phosphorus fertilization could possibly be reduced or eliminated in flax grown in zero-till following a mycorrhizal crop and optimized in flax grown under conventional tillage management. By more clearly defining the P requirements of flax, canola and wheat grown under different management systems, it is possible to reduce inputs while maintaining or improving crop yield and quality. While many research studies have evaluated the economic impact of tillage systems on N fertility requirements, there has been very limited information available on the economic impact of tillage management and P phytoavailability or on the impact of the tillage system and past phosphorus fertilizer management on phosphorus response of crops. The objective of this study is to evaluate the economic impact of flax on tillage system, P fertilizer application, preceding crop, and level of P fertilizer applied in preceding crop.

Introduction

The sustainability of any farming system depends on its agronomic and economic performance while reducing negative effects on environment by more efficient use of inputs. Conservation farming is a system approach that considers all factors that affect production. Reduced tillage is one of the methods of conservation farming system and is becoming increasingly popular on the prairie to conserve soil and water resources, sustain high and satisfactory returns, minimize degradation of soil and environment (Lal et al., 1990). Compared to conventional tillage, reduced tillage will change moisture relations, distribution of plant nutrients in the soil profile, deposition of organic residues and the type and activity of soil micro-organism activities. This will impact directly on nutrient availability and on fertilizer and other chemical management decisions. While many research studies have evaluated economic impact of tillage systems on N fertility requirements, there has been very little information available on the economic impact of tillage management and P phytoavailability.

Although canola and wheat are the two major annual crops in the Canadian prairies, flax is also becoming very important. Flax and wheat tend to respond very well to reduced tillage systems, frequently producing higher yields under zero-till as compared to conventional till. Canola, on the other hand, may not respond as beneficially to zero-till management as cereal crops or flax. While flax production is lower than that of canola and wheat, it is likely to expand in the future.

Canola and wheat have a high demand for plant nutrients, including phosphorus. Deficiencies of P are common and frequently limit crop yield. Therefore, proper P fertilization is important in optimising crop yield. 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. Unlike canola and wheat, phosphorus fertilization of flax is 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 done under conventional tillage. This study will examine the economic impact of reduced tillage system on P fertilizer response of canola, wheat, and flax and determine the net return of flax to the level of P fertilization in preceding crop.

Materials and Methods

In 1999, the researchers at the Brandon Research Center, Agriculture and Agri-Food Canada (AAFC) initiated a field research with canola and wheat grown under zero tillage (ZT) and conventional tillage (CT) with three levels of P fertilizer at two locations north of Brandon. Both were on Newdale clay loam soils, one with history of zero till at the Manitoba Zero Tillage Research Association farm (MZTRA) and one with history of conventional tillage at the Philips Brandon Research Centre farm (BRC). The study involves 12 treatments under two different tillage systems, and with different levels of P fertilizer, different preceding crops and different levels of P fertilizer on preceding crops (Table 1). In year 1 of the study, no-till and conventionally tilled canola (nonmycorrhizal crop) and wheat (mycorrhizal crop) were established in a split plot design, with tillage system as the main plot and crop type and fertilizer level as subplots. Plot size was 4m by 5m for wheat and canola and 2m by 5m for flax, and each treatment was replicated four times. Crops were seeded early to mid-May at 2.5 cm or less. Phosphorus fertilizer at 0, 25 and 50 kg P_2O_5 per ha was side-banded with the canola and wheat, randomized within the tillage systems. In 2000, flax was sown on the canola and wheat, with and without P fertilizer, while the canola and wheat plots were repeated at another location. In 2001, durum wheat was seeded on the flax, flax was seeded on the canola and wheat, and the canola and wheat plots were repeated at a new location. In 2002, durum wheat was seeded on the plots sown to flax in 2001 and flax was seeded on the plots sown to canola and wheat. In 2003, durum wheat was again seeded on the plots sown to flax in 2002. Durum wheat was excluded from our treatment analysis since 2003 data were not available yet. Statistical analysis was conducted using Proc Mixed of SAS to investigate the impact of preceding crops, P fertilizer, and tillage system on yield and net income of flax.

Plots cropped using CT management practices received two tillage operations in the fall and for residue management and weed control, plus two tillage operations in spring to prepare the seedbed. The main tillage implement were either a heavy duty cultivator with harrows or a light cultivator with harrows. However, there was no cultivation of any kind on the Zero Till Blocks.

Side-banded monoammonium phosphate at 0 and 25 kg P_2O_5 ha^{-1} was applied to the flax. Ammonium nitrate at 70 kg N ha^{-1} with the flax and 100 kg N ha^{-1} with the canola, and wheat applied as a pre-plant band prior to seeding. Wheat and Canola also received 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 was balanced in the pre-plant N application. Pre-plant burn-off application of paraquat and glyphosate was used only in the first year of the study on both wheat and canola plots and in-crop applications of a variety of recommended herbicides were used as required for control of different weed species.

Table 1. Treatments

	Yr 1			Yr 2 flax
Treatments	tillage	crop	P_2O_5	P_2O_5
1&2	conventional	wheat	0	0 or 25
3&4	conventional	wheat	25	0 or 25
5&6	conventional	wheat	50	0 or 25
7&8	conventional	canola	0	0 or 25
9&10	conventional	canola	25	0 or 25
11&12	conventional	canola	50	0 or 25
1&2	Zero till	wheat	0	0 or 25
3&4	Zero till	wheat	25	0 or 25
5&6	Zero till	wheat	50	0 or 25
7&8	Zero till	canola	0	0 or 25
9&10	Zero till	canola	25	0 or 25
11&12	Zero till	canola	50	0 or 25

Economic Analysis:

The economic performance of the 12 treatments under two different tillage systems was determined using standard budgeting techniques by computing annual net income of each treatment by subtracting production and all input expenses from gross revenue as described by Zentner et al. (2002). For this purpose, we first developed a database using Econometric View

(E-view Version 4.1) software and, then, an appropriate command file was written in E-view syntax to evaluate each system in regard to costs of production, gross return, and net income. Net income was defined as the income remaining above cash costs (i.e., seed, fertilizer, chemical, fuel and oil, repairs, crop insurance premium, miscellaneous, land taxes, and interest cost on variable inputs), ownership costs (depreciation, interest on investment, and insurance and housing) for machinery and grain storage, and labor. The labor costs used for machinery and farm operations were calculated according to the machinery work rate per hectare (Saskatchewan Agriculture and Food, 2002). All annual inputs used in each phase of rotation for each management treatment, the type and frequency of field operation, year and replicate including pre-plant activities, tillage, fertilization, planting, insects and pests control, harvesting, storage, and transportation were included in the analysis. Coefficient of variation (CV) was used to measure relative variability of net income of each treatment. The research plot data were extrapolated to the farm-level using a 907-ha representative farm, with a typical complement of machinery and labor supply for each treatment. The cost of inputs was held constant at their 2001 levels. The use of constant prices facilitates to compare net income of crops between years without inflationary effect.

Results and Discussion

This section discusses the yield, net income and cost incurred on different treatments in the experiment. We start with the analysis of treatments and then discuss the impacts of P and tillage system on each individual crop.

Analysis of Treatments:

Net income was not significantly increased by P application; however, it was affected by preceding crops at both locations (Fig. 1 and 2). Generally speaking, ZT system generated higher net income compare to Conventional system.

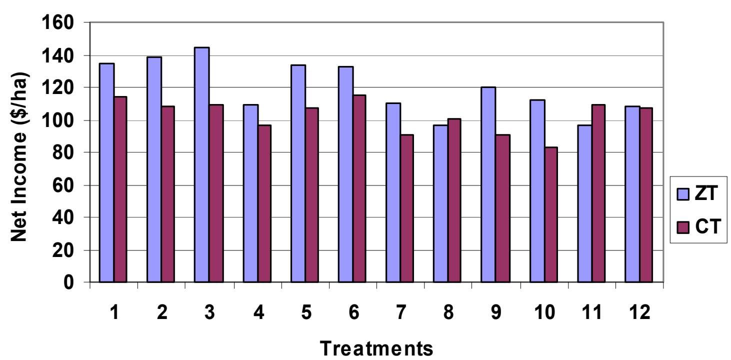

Figure 1. Average net income for all crops at the MZTRA farm ($/ha).

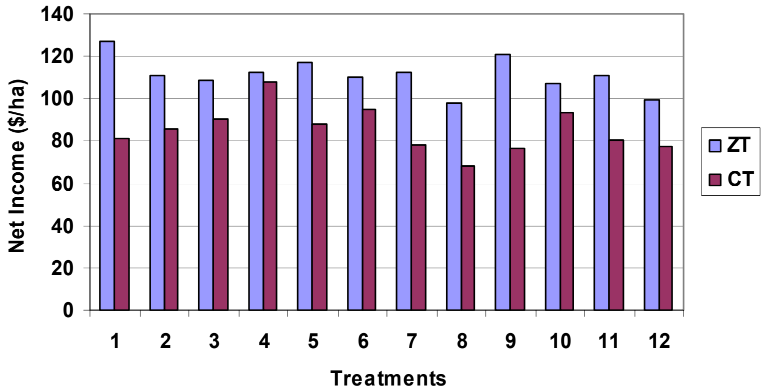

Figure 2. Average net income for all crops at the BRC location ($/ha).

Coefficient of variation (CV) was used to measure relative variability of net income or relative riskiness of each treatment. CV measures the scatter in the data relative to the mean or the relative size of the "average spread around the mean" to the mean. The CV computed for net income of each treatment indicated that generally there was lower income variability associated with treatments under ZT system and when wheat was preceding crop compare to the treatments under CT and canola as preceding crop (Fig. 3 and 4). The relative variation in net income is mainly attributed to the change input use or variation in yield and not input or output prices because we assumed a constant price for inputs and outputs. The constant price of inputs and outputs was determined as the average price of inputs and outputs, respectively, for the duration of project.

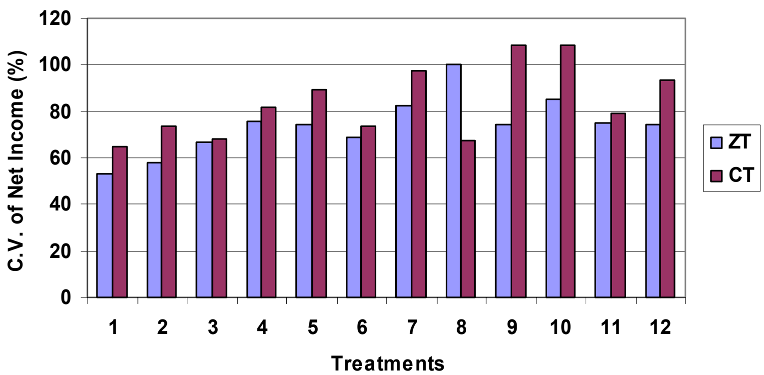

Figure 3. Coefficient of variation of net income at the MZTRA farm.

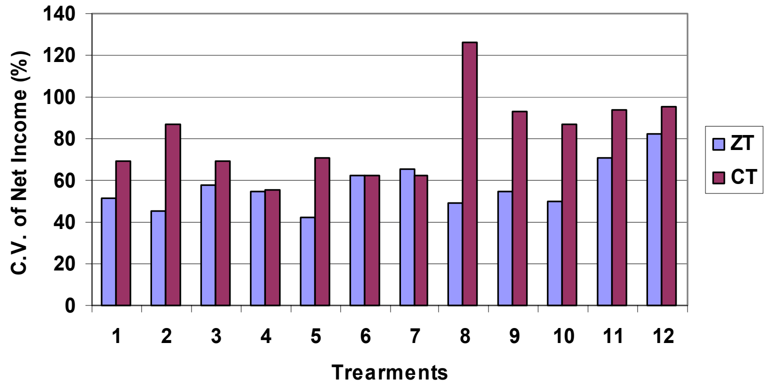

Figure 4. Coefficient of variation of net income at the BRC location.

Net income of treatments was higher when flax was grown after wheat than after canola at both locations under both tillage systems (Fig. 5 and 6). This may be well explained by greater mycorrhizal formation after wheat than canola, which may have enhanced P nutrition and crop yield. This may also reflect early season weed competition from the volunteer canola.

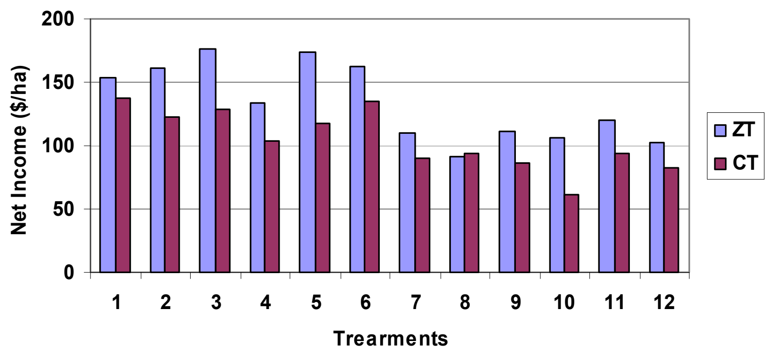

Figure 5. Net income for flax at the MZTRA farm ($/ha).

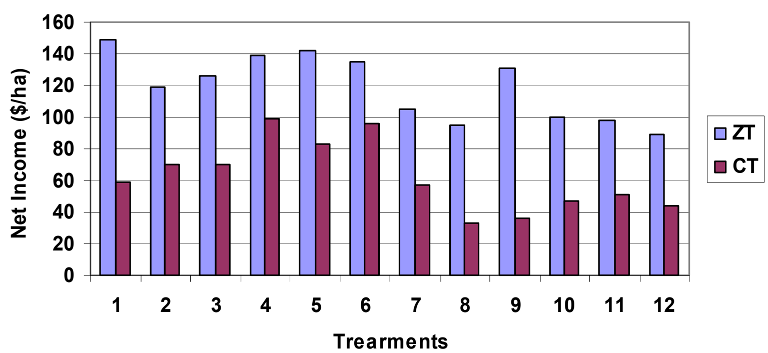

Figure 6. Net income for flax at the BRC location ($/ha).

Yield and Net Income Analysis for Flax:

Seed yield of flax was not influenced by P application in the MZTRA location except in year 2002 and it was similar, more or less, for both ZT and CT systems (Table 2). Seed yield of flax, however, was higher and strongly significant when grown after wheat than canola. There was also year to year effect depending on the locations. For example, in year 2000, P residual and interaction of P residual and preceding crop were significant in MZTRA but not in BRC. In 2001, interaction of P residual, preceding crop, and tillage was significant in BRC but not in MZTRA. In 2002, P on flax was significant in BRC only and interaction of P residual and tillage in MZTRA (data not presented).

Generally, similar pattern with lesser magnitude was observed for Research Centre site as for zero-till farm. Flax yield was higher with wheat as preceding crop and tillage system and P application having no or minor impact on flax yield though higher yield observed as P increased when wheat was preceding crop.

Table 2. Statistical Analysis Using Proc Mixed for Effects of Phosphorus Fertilizer and Tillage System on the Seed Yield of Flax at both Sites in 2000-2002.

		Seed Yield			
Source	DF	Research Centre		MZTRA	
		P-value	SE	P-value	SE
P (Flax)	1	0.0352		ns	
Preceding Crop	1	0.0001		0.0001	
P (Flax)*Preceding Crop	1	ns		ns	
P (Residual)	1	ns		ns	
P (Residual)* P (Flax)	2	ns		ns	
P (Residual) * Preceding Crop	2	ns		ns	
P (Residual) * Preceding Crop * P (Flax)	2	ns		ns	
Tillage	1	ns		ns	
P(Flax) * Tillage	1	0.0774		ns	
Preceding Crop * Tillage	1	ns		0.0834	
Preceding Crop * P (Flax) * Tillage	1	ns		ns	
P (Residual) * Tillage	2	ns		ns	
P (Residual) * P (Flax) * Tillage	2	ns		ns	
P (Residual) * Preceding Crop * Tillage	2	ns		ns	
P (Residual) * Preceding Crop * P (Flax) *Tillage	2	ns		ns	

Relative to the mean, there was less yield variability when preceding crop was wheat than canola though CV of yield for all treatments was generally high (Fig. 7). P application or tillage systems have not caused significant change in the relative size of yield variability. The change in the size of yield variability has mainly been caused by preceding crop.

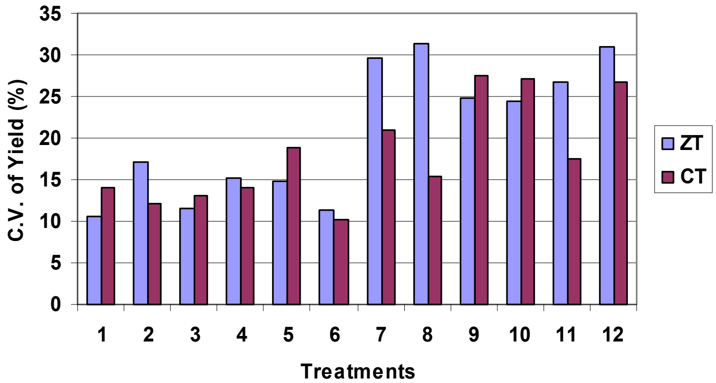

Figure 7. Coefficient of variation of flax yield at the MZTRA farm

Tillage system and the preceding crop both influenced the net income of flax (Table 3). The general practice has been to work the Conventional Tilled Blocks two tillage operations in the fall and two tillage operations in the spring. A heavy duty cultivator was used for two passes in the fall and either a heavy duty cultivator with harrows or a light cultivator with harrows was used for two passes in the spring. However, there was no cultivation of any kind on the Zero Till Blocks. So, when the costs of cultivations (machinery and labor) are incorporated into cost calculation of each treatment, the net income of flax was higher under the ZT system compared to CT system. Recall that seed yield of flax was only influenced by preceding crop but this is not true for its net income as it is influenced by both tillage system and preceding crop. As for CV of flax net income, a similar pattern was observed as for CV of flax yield. That is, there is less income variability to the mean for the treatments under ZT system and wheat as preceding crop. Finally, flax net income at this site was not changed as P application increased, indicating this variable was not significant in variation of net income.

Net income of flax per hectare was higher for the treatments with ZT system and wheat as preceding crop.

Table 3. Statistical Analysis Using Proc Mixed for Effects ff Phosphorus Fertilizer and Tillage System on the Net Income of Flax at both Sites in 2000-2002.

		Seed Yield			
Source	DF	Research Centre		MZTRA	
		P-value	SE	P-value	SE
P (Flax)	1	ns		0.0261	
Preceding Crop	1	0.0001		0.0001	
P (Flax)*Preceding Crop	1	ns		ns	
P (Residual)	1	ns		ns	
P (Residual)* P (Flax)	2	ns		ns	
P (Residual) * Preceding Crop	2	ns		ns	
P (Residual) * Preceding Crop * P (Flax)	2	ns		ns	
Tillage	1	0.0016		0.0097	
P(Flax) * Tillage	1	0.0937		ns	
Preceding Crop * Tillage	1	ns		ns	

Preceding Crop * P (Flax) * Tillage	1	ns	ns
P (Residual) * Tillage	2	ns	ns
P (Residual) * P (Flax) * Tillage	2	ns	ns
P (Residual) * Preceding Crop * Tillage	2	ns	ns
P (Residual) * Preceding Crop * P (Flax) *Tillage	2	ns	ns

Generally speaking, since the flax yield was similar for both tillage systems and P application had no significant impact on flax yield, when increase costs of cultivation for machinery and labor and increased cost of P fertilizer are incorporated into the total cost, the ZT system with lesser use of P application became economical.

Yield and Net Income Analysis for Wheat:

Seed yield of wheat was higher under CT than ZT, with the effect being greater on the Research Centre Farm than on the MZTRA (Fig. 8 and 9). Opposite to flax crop, wheat yield was significantly higher under CT system and increased as P application increased (but not significant except in year 2000 and only in MZTRA). The highest wheat yield in MZTRA is obtained under CT with 50 kg/ha of P and in BRC under CT but only 25 kg/ha.

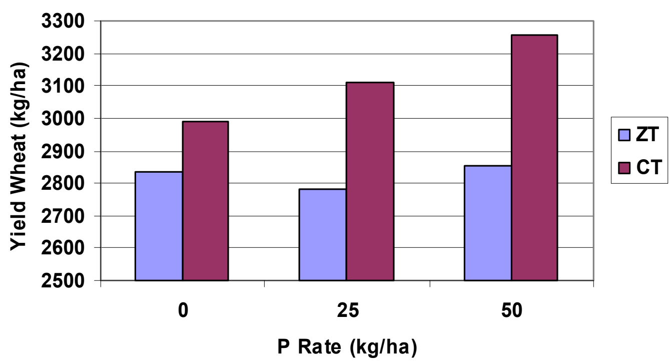

Figure 8. Wheat yield and P rates at the MZTRA (kg/ha).

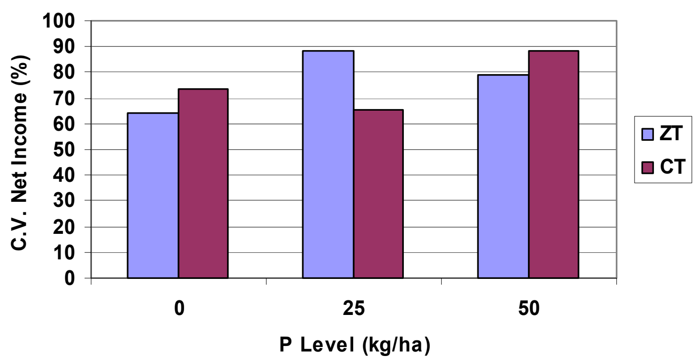

Figure 9. Coefficient of variation of net income for wheat at the BRC site.

No tillage by P interactions occurred, indicating that P response patterns were similar under zero-till and conventional till (Table 4).

Table 4. Statistical Analysis Using Proc Mixed for Effects of Phosphorus Fertilizer and Tillage System on Grain of Canola and Wheat at both Sites in 2000-2001.

		Canola				Wheat			
Source	DF	Research Centre		MZTRA		Research Centre		MZTRA	
		P-value	SE	P-value	SE	P-value	SE	P-value	SE
Phosphorus	2	0.0617	249.6	0.0074	265.5	0.0780	77.2	ns(0.1536)	761.7
Tillage	1	0.0241	257.2	0.0053	265.5	0.0810	98.8	0.0032	761.2
Phosphorus*Tillage	2	ns	261.3	0.0459	269.4	ns	109.2	ns	763.7

CT system also provided more stability in terms of yield variability. However, when we incorporated cultivation and P fertilizer costs to estimate the net income there was generally no significant differences between ZT and CT systems in MZTRA; however, there was a tendency for the net income to be higher under CT system in Research centre spatially when 25 kg of P fertilizer was applied per hectare (Fig. 10 and 11). Recall that MZTRA was long under ZT system and zero-tilled system in BRC was only in the duration of study.

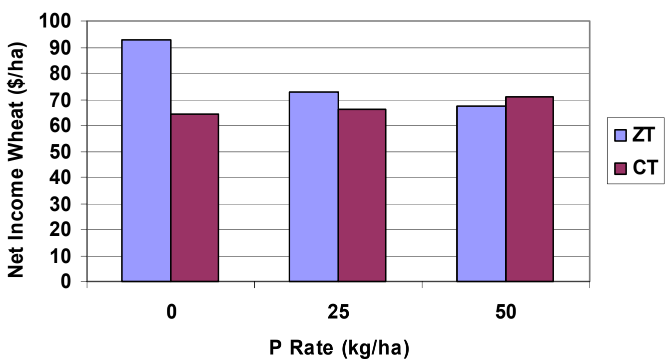

Figure 10. Net income for wheat at the MZTRA Farm ($/ha).

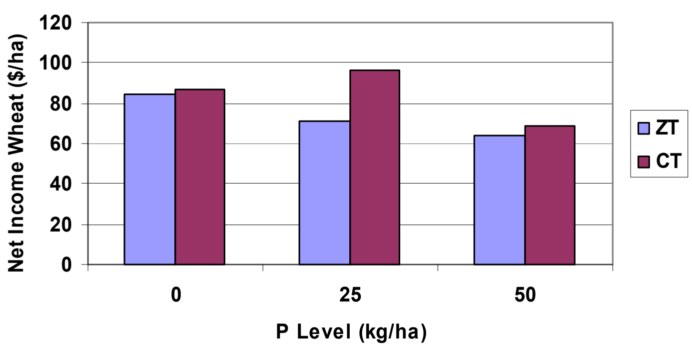

Figure 11. Net income for wheat at the BRC Farm ($/ha).

Yield and Net Income Analysis for Canola:

Seed yield of canola was higher under CT than ZT, with the effect being greater on the Research Centre Farm than on the MZTRA (statistically significant in year 2000 only in BRC) (Fig. 12 and 13). There was also a general trend toward higher yield as P application increased. Tillage by P interactions occurred only in MZTRA in year 2001, indicating that P response patterns were not similar under two tillage systems. As for wheat, canola yield provided more stability in terms of yield variability under CT with the effect being significantly greater at the Research Centre Farm. When tillage costs were incorporated and net income was estimated, at the MZTRA Farm, CT system with 50 kg/ha of P generated significantly higher net income than other treatments (Fig. 14). For Research Centre Farm, the highest net income was obtained under CT system with only 25 kg/ha of P application (Fig. 15). Statistically, the effect of tillage on net income of canola was significant only in year 2001 and only in BRC (data not presented).

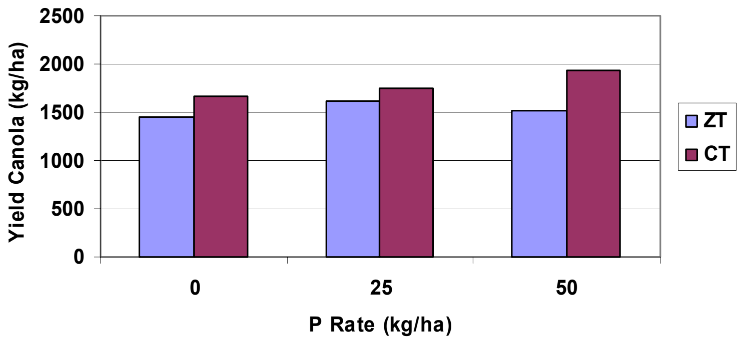

Figure 12. Canola yield and P rates at the MZTRA (kg/ha).

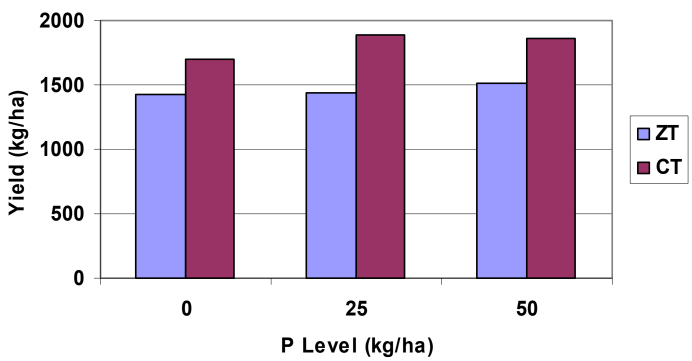

Figure 13. Canola yield and P rates at the BRC (kg/ha).

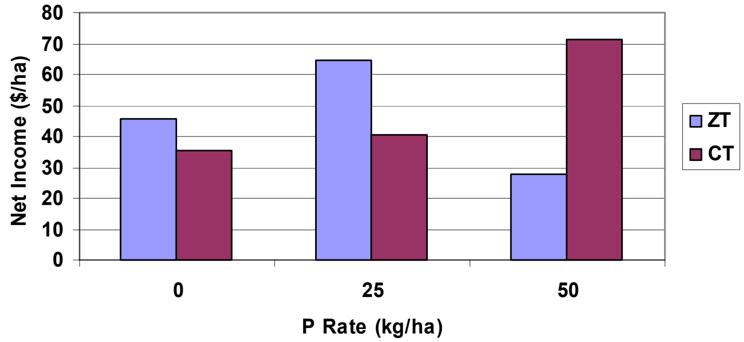

Figure 14. Net income for canola at the MZTRA Farm ($/ha).

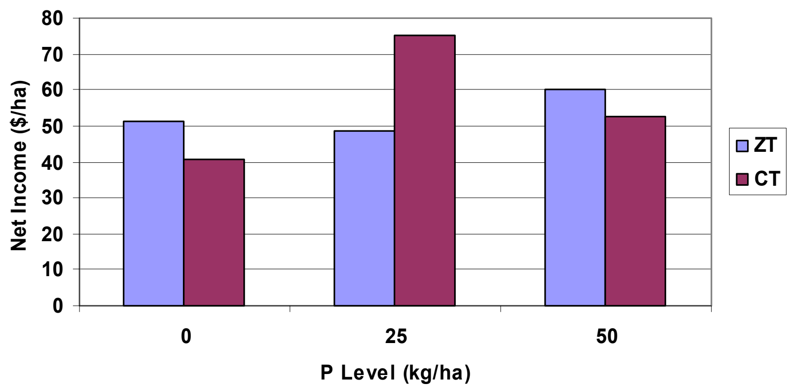

Figure 15. Net income for canola at the BRC Farm ($/ha).

Input Costs:
Comparison of input costs for the two tillage systems indicated that input costs are about $45 to $50 per ha higher for CT than ZT system. These higher costs are mainly due to higher machinery, fuel and oil, and labour costs for that system as shown in Fig. 16 and 17.

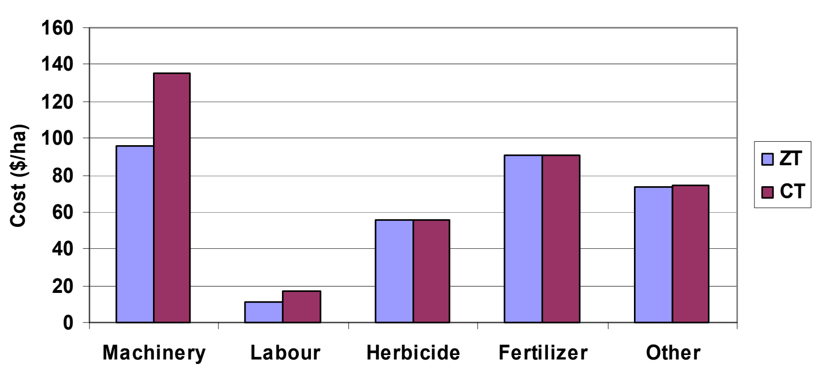

Figure 16. Input costs at the MZTRA farm under two different tillage systems ($/ha).

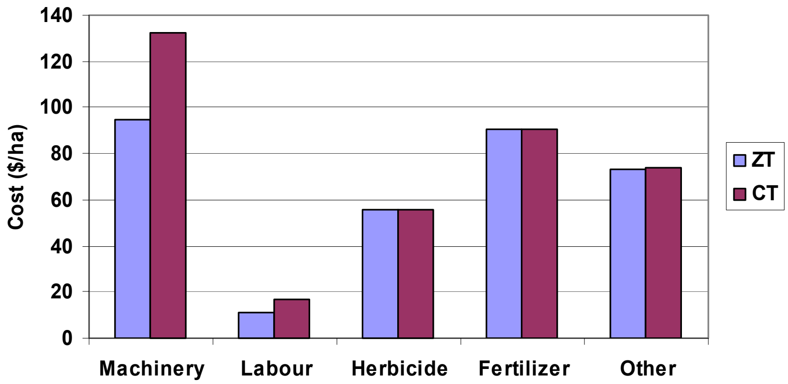

Figure 17. Input costs at the BRC farm under two different tillage systems ($/ha).

Conclusion

The objective of this study was to evaluate the economic impact of flax on tillage system, P fertilizer application, preceding crops of wheat and canola, and level of P fertilizer applied in preceding crop. Results indicated that net income was affected by preceding crops but not by P application and ZT system generated higher net income compare to CT system. Generally, there was lower net income variability associated with treatments under ZT system and when wheat was preceding crop. Net income of treatments was higher when flax was grown after wheat than after canola which may be well explained by greater mycorrhizal formation after wheat than canola. Seed yield of flax was influenced by the preceding crop but not by P application or the tillage system. The tillage system and preceding crop both, however, influenced the net income of flax. In addition, seed yield of wheat and canola was higher under CT system and increased as P application increased. Tillage and P interaction was not observed for wheat over period of the study, indicating that P response patterns were similar under both ZT and CT. Tillage and P interaction occurred for canola only in MZTRA in 2001. When costs were incorporated to estimate the net income, there was generally no significant differences between ZT and CT systems for wheat in MZTRA; however, there was a tendency for the net income to be higher under CT system in BRC. For canola, net income was significantly higher under CT system with 50 kg/ha of P at MZTRA and under CT system with 25 kg/ha of P at the BRC.

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