SHORT COMMUNICATION

Legume cover crops with winter cereals in southern Manitoba: Fertilizer replacement values for oat

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Department of Plant Science, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2. *Received 5 July 2004, accepted 21 December 2004.*

Thiessen Martens, J. R., Entz, M. H. and Hoeppner, J. W. 2005. **Legume cover crops with winter cereals in southern Manitoba: Fertilizer replacement values for oat**. Can. J. Plant Sci. **85**: 645–648. Yield benefits of legume cover crops in winter/spring cereal systems have not been well documented in the Canadian prairies. The objective of this study was to evaluate the fertilizer replacement values (FRV) of relay-cropped alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.) and double-cropped chickling vetch (*Lathryus sativus* L.) and black lentil (*Lens culinaris* Medik. subsp. *culinaris*) to a subsequent oat (*Avena sativa* L.) crop. Field experiments were conducted in Manitoba on a clay soil at Winnipeg and a sandy loam at Carman. Alfalfa provided the highest FRV at Winnipeg (51–62 kg N ha^{-1}), followed by chickling vetch (29–43 kg N ha^{-1}), lentil (23–39 kg N ha^{-1}), and red clover (24–26 kg N ha^{-1}). FRV could not be established at Carman, where course-textured soil and low rainfall limited legume growth.

Key words: Relay cropping, double cropping, cover crops

Thiessen Martens, J. R., Entz, M. H. et Hoeppner, J. W. 2005. **Culture-abri de légumineuses dans les champs de céréales d'hiver du sud du Manitoba : utilité comme engrais de substitution pour la culture de l'avoine**. Can. J. Plant Sci. **85**: 645–648. On connaît mal l'incidence des cultures-abris de légumineuses sur le rendement des céréales d'hiver ou de printemps dans les Prairies canadiennes. L'étude devait déterminer l'utilité, comme engrais de substitution, de cultures intercalaires de luzerne (*Medicago sativa* L.) et de trèfle rouge (*Trifolium pratense* L.) ainsi que d'une double culture de gesse commune (*Lathyrus sativus* L.) et de lentille noire (*Lens culinaris* Medik. ssp. *culinaris*) pour une culture subséquente d'avoine (*Avena sativa* L.). Les expériences au champ se sont déroulées sur un sol argileux à Winnipeg et sur un loam sablonneux à Carman, au Manitoba. La luzerne est la plus utile comme engrais de substitution à Winnipeg (de 51 à 62 kg de N par hectare), suivie par la gesse commune (de 29 à 43 kg de N par hectare), la lentille (de 23 à 39 kg de N par hectare) et le trèfle rouge (de 24 à 26 kg de N par hectare). On n'a pu établir la valeur de ces cultures comme engrais de substitution à Carman, car la nature grossière du sol et la faible pluviosité ont nui à la croissance des légumineuses.

Mots clés: Cultures intercalaires, double culture, cultures-abris

Forage legumes are well recognized for their beneficial role in sustainable cropping systems, even when grown in a single season (Kelner and Vessey 1995). However, even single-year systems may not be an attractive option to many producers who have found continuous grain cropping to be feasible in their climate and soil type.

Relay- and double-cropping systems have been shown to have potential for incorporating the benefits of legume cover crops into continuous annual grain-cropping systems, without sacrificing a year of grain production. Relay cropping involves a legume cover crop undersown with the main crop and allowed to grow after main crop harvest, while double cropping involves a legume cover crop planted after main crop harvest. These systems, more common in longer growing season areas, are being adapted to the shorter growing seasons of the northern Great Plains (Stute and Posner 1993). In previously published work, we have shown that both relay and double cropping systems are agronomically feasible in southern Manitoba (Thiessen Martens et al. 2001).

The value of relay- and double-cropped legumes in annual grain-cropping systems depends on the benefits that the legumes provide to the following crop, the most important of which is nitrogen (N). Although the effective growing season of relay and double crops is short, various legume cover crops, including alfalfa, red clover, and chickling vetch, have been observed to produce satisfactory amounts of dry matter (DM) with limited moisture and heat resources (Biederbeck et al. 1993; Stute and Posner 1993; Thiessen Martens et al. 2001). Based on aboveground DM production of 190 to 1800 kg ha^{-1}, estimated N contributions of relay and double-cropped legumes ranged from 6 to 54 kg N ha^{-1} in a study carried out by Thiessen Martens et al. (2001). Aboveground DM production is not a true measure of the N contribution of legume cover crops, nor does it take into account non-N yield benefits or costs such as weed suppres-

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Abbreviations: **DM**, dry matter; **FRV**, fertilizer replacement values sion or soil moisture depletion. Therefore it is important to directly measure the yield benefits of the cover crops to a subsequent crop.

The benefit of a legume to a following crop is often described in terms of a N fertilizer replacement value (FRV), which is defined as the quantity of fertilizer N required to produce a yield in a crop that does not follow a legume that is identical to that produced by incorporation of a legume (Hesterman 1988). The objective of this study was to determine FRV of relay cropped perennial legumes and double-cropped annual green manure legumes to a subsequent oat crop.

FRV trials were conducted in 1997–1999 at Winnipeg, MB (Black Lake clay, Cumulic Regosol) and Carman MB (Hochfeld fine sandy loam, Orthic Black Chernozem) as part of a larger study evaluating legume cover crops in relay- and double-cropping systems (Thiessen Martens et al. 2001). Experimental design was a split-plot with four replications. Main plots were winter wheat (*Triticum aestivum* L. 'CDC Kestrel') and fall rye (*Secale cereale* L. 'Prima'). Subplots were N source, in the form of a relay crop, a double crop, or inorganic N fertilizer. Relay crops were alfalfa (cv. Nitro) and red clover (cv. common), while double crops were black lentil (cv. Indianhead) and chickling vetch (cv. AC Greenfix). Subplots were 2 m × 6 m. Oats (cv. OT288) were grown on all plots in the year after the cover crop to evaluate the FRV of the legume cover crops.

Winter cereals were established in September 1997 and legume cover crops were established in 1998. Management of crops in these years is described by Thiessen Martens et al. (2001). In May 1999, plots were sprayed with 1780 g a.i. ha^{-1} glyphosate [isopropylamine salt of N-(phosphonomethyl)glycine] and 500 g a.i. ha^{-1} 2,4-D (2,4-dichlorophenoxyacetic acid) to terminate alfalfa and red clover and to control weeds. Oats were direct seeded into all plots at a rate of 92 kg ha^{-1} on 1999 May 26 at Carman and on 1999 May 28 at Winnipeg. Triple super phosphate fertilizer (0-46-0) was placed with the seed at a rate of 55 kg P_2O_5 ha^{-1}. Plots not containing legumes during the previous growing season received broadcast fertilizer applications of ammonium nitrate (34-0-0) at rates of 0, 40, 80, and 120 kg N ha^{-1} on 1999 Jun. 07 at Carman and 1999 Jun. 08 at Winnipeg. The oats at Carman were sprayed on 1999 Jun. 17 with 400 g a.i. ha^{-1} propanil (3′,4′-dichloropropionanilide), 100 g a.i. ha^{-1} thiensulfuron {Methyl 3-[[[[4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]-sulfonyl]-2-thiophenecarboxylate} and 50 g a.i. ha^{-1} tribenuron {Methyl 2-[[[[N-(4-methoxy-5-methyl-1,3,5-triazin-2-yl)methylamino]carbonyl]amino]-sulfonyl]benzoate} to control broadleaved weeds. Oats were harvested from a known area using a plot combine on 1999 Sep. 17 at Carman and 1999 Sep. 19 at Winnipeg. Harvested samples were cleaned and weighed and used to calculate yield per hectare.

According to Hesterman et al. (1992), yield must be significantly higher following a legume than a nonlegume control, in order for a FRV to be valid. Therefore, oat yields following legume treatments and the control (0 kg N ha^{-1}) within each location were analyzed using analysis of variance (SAS Institute, Inc. 1985), in a split-plot design with preceding winter cereal as the main plot effect and legume as the subplot effect. Differences were considered significant at $P < 0.05$. Means were separated using a Fisher protected LSD test. When a significant crop response was observed, fertilizer response curves were generated by calculating quadratic regressions for each winter cereal system at each site using oat yield data for the N fertilizer treatments. Quadratic regressions were used because they provided the highest R^2 values. Oat yields from treatments including relay- and double-cropped legumes were plotted on the fertilizer response curve, using the equation generated by the slope of the curve, to calculate the FRV of the four legumes (Lory et al. 1995).

Air temperature and precipitation were monitored at both sites during the growing season months of the entire study period. In 1998, during the winter cereal-legume phase of the study, rainfall was considerably higher at Winnipeg (258 mm) than at Carman (171 mm) in May, June and July. Weather conditions in July, August and September 1998 were hotter and drier than the long-term average at both Carman and Winnipeg [Table 3 in Thiessen Martens et al. (2001)]. Rainfall was particularly low in August and September 1998 (59 mm at Carman and 29 mm at Winnipeg), during a key period of legume growth. It is possible that late-season soil moisture conditions remained more favorable at Winnipeg where soils were fine-textured clay, than at Carman where soils were coarse-textured sandy loam. In 1999, during the oat phase, growing season precipitation was slightly higher than average at both Carman and Winnipeg [Table 3 in Thiessen Martens et al. (2001)].

Oat yield for all treatments ranged from 1600 to 4500 kg ha^{-1} at Winnipeg (Fig. 1) and 3600 to 5300 kg ha^{-1} at Carman (data not shown). The high oat yields at Carman may be a result of residual effects of alfalfa production 4 yr before establishment of this field trial. Although results of a soil test performed in April 1998 did not detect any differences in nitrate N between the two sites, organic soil N levels may have been considerably higher at Carman. Hoyt (1990) reported yield benefits to wheat crops up to 13 yr after alfalfa production.

In both winter cereal systems at both sites, oat grain yield exhibited a positive response to increased rates of fertilizer N (Winnipeg data shown in Fig. 1; Carman data not shown); the response was weaker at Carman than at Winnipeg due to residual effects of alfalfa production, as discussed above.

Previous winter cereal type did not affect oat yield at either site (Table 1). Legume relay and double crops significantly increased yield above the control at Winnipeg, while at Carman, legumes did not have a significant effect on oat yield (Table 1). Therefore, FRV could not be established for the Carman site. The absence of a legume effect at Carman was most likely due to drought conditions in 1998 and the coarse soil texture at this site, limiting legume growth (Thiessen Martens et al. 2001) and possibly resulting in a soil moisture penalty to the oat crop in 1999. No significant winter cereal × cover crop interactions were observed (Table 1).

The FRV at Winnipeg ranged from 23 to 62 kg N ha^{-1} (Fig. 1). Models for quadratic regression equations were sig-

Table 1. Oat grain yield following relay- and double-cropped legumes, in two winter cereal systems at two experimental sites

	Oat grain yield	
	Winnipeg	Carman
	(kg ha^{-1})	
Cover crop		
Alfalfa	3210*a*	4120
Red clover	2550*c*	3630
Chickling vetch	2900*b*	4490
Lentil	2750*bc*	4290
Control	1580*d*	4080
LSD (0.05)	210	620
Previous winter cereal		
Winter wheat	2480	4090
Fall rye	2820	4160
LSD (0.05)	800	340
ANOVA	*P > F*	
Cover crop (CC)	<0.0001	NS
Previous winter cereal (WC)	NS	NS
CC × WC	NS	NS

a–d Means within columns followed by different letters are significantly different according to a Fisher protected LSD test ($P < 0.05$).

nificant ($P = 0.007$ for fall rye; $P = 0.069$ for winter wheat) for both winter cereal systems at Winnipeg.

Alfalfa provided the highest FRV in both winter cereal systems (Fig. 1), with values similar to those reported by Hesterman et al. (1992) using forage legumes relay cropped with winter wheat on a fine-loamy soil in north-central USA. Chickling vetch ranked second, followed by lentil and red clover (Fig. 1). The FRV from double-cropped chickling vetch and lentil at this site were similar to those reported by Biederbeck et al. (1996), who used these green manure legumes as spring-seeded summer fallow substitutes on a silt loam in semiarid Saskatchewan.

The FRV from red clover were approximately 50% that of alfalfa, and considerably lower than reported by Hesterman et al. (1992). It is interesting to note that red clover provided the lowest FRV of the four legumes tested, in spite of producing the most aboveground DM in the previous year (Thiessen Martens et al. 2001). Red clover has been observed in some cases to have lower N benefits in a rotation than alfalfa (Bullied et al. 2001). In addition, negative effects such as soil water depletion may have counteracted the N benefit of red clover, resulting in a lower-than-expected FRV. Previous research indicates that soil moisture depletion by the legume may reduce yield of the following crop when soil moisture levels are low (Hesterman et al. 1992). Peterson et al. (1992) observed that red clover yield is affected by drought more strongly than alfalfa.

Relay and double cropped legumes provided considerable FRV to a subsequent oat crop at Winnipeg. FRV could not be established at Carman, where legumes did not result in increased oat yield. This supports previous conclusions that relay- and double-cropping systems are better suited to sites with fine-textured soils that have a high water-holding capacity, making them less reliant on late-season precipitation (Thiessen Martens et al. 2001).

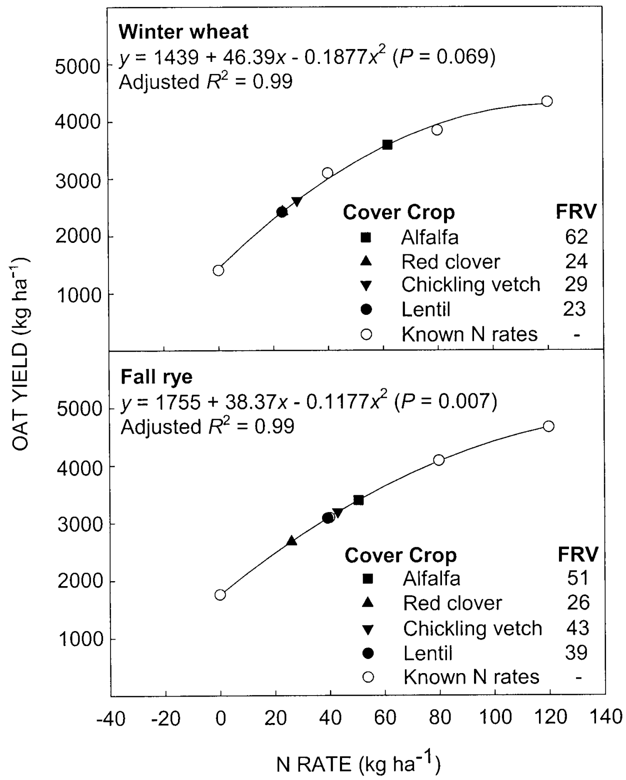

Fig. 1. Oat grain yield response curves and fertilizer replacement values (kg N ha^{-1}) of four relay- and double-cropped legumes following winter wheat and fall rye at Winnipeg. In the winter wheat system, the symbols for red clover and lentil are partially obscuring one another.

Of the two perennial legumes, alfalfa showed the most potential for relay-cropping systems, providing the highest FRV of the four legumes tested. Of the two annual green manure legumes, chickling vetch showed the most potential for double- cropping systems, ranking second of the four legumes. Indianhead lentil ranked third, while red clover provided the lowest FRV in spite of producing the most aboveground DM. More field testing is required to establish specific recommendations for N fertilization practices.

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