Do Different Tillage Systems and Crop Rotations Affect Nitrogen Fixation in Lentil and Pea?

A. Matus, D.A. Derksen and C. van Kessel
[1] Department of Soil Science, University of Saskatchewan, Saskatoon, SK., S7N 5A8
[2] Agriculture Canada, Brandon Research Center, MB., R7Y 5Y3

Introduction

In western Canada, the proportion of arable land seeded under zero-tillage has increased considerably in recent years. Some research has been conducted on the effects of tillage systems on the grain yield of crop legumes (Lafond et al., 1992). However, no information exists on the effects of tillage systems and crop rotations on nitrogen fixation in crop legumes. Stevenson et al., 1995) reported that inorganic soil nitrogen and soil water content are the primary controls of nitrogen fixation in pea (Pisum ***sativum*** L.). Percent nitrogen derived from atmosphere by pea was higher in areas of the landscape with high soil moisture content and low inorganic soil nitrogen. Research shows that zero-tillage soils have lower amounts of soil nitrate compared with soils in conventional-tillage (Doran, 1980). Reduced amounts of soil nitrate in a zero-tillage soil increased soybean ***(Glycine max*** L.) nitrogen fixation (Hughes and Hex-ridge, 1989; Wheatley et al., 1995). Zero-tillage systems increased soil moisture content (Lafond et al., 1992) and this reduction in water stress may increase nitrogen fixation in crop legumes (Bennet and Albretch, 1984). Similarly, Bremer et al. (1988) reported reduced nitrogen fixation with a decline in water use by lentil (Lens ***culinaris*** Medikus).

Another factor that needs attention is the effect of diversifying crop rotations. For example, a highly diversified crop rotations may affect nitrogen fixation differently than less diversified crop rotations. Therefore, the objectives of this study were to detect: 1) the effects of zero- and conventional-tillage on nitrogen fixation in lentil and pea and, 2) the effect of two highly diversified and four less diversified crop rotations on nitrogen fixation in lentil.

Materials and Methods

Nitrogen fixation in lentil and pea was measured in a long-term rotation experiment established in 1991 by Drs. D.A. Derksen and H.A. Loeppky at the Indian Head Experimental Farm, Indian Head, Saskatchewan. The soil was a silty clay with 3% organic matter and a pH of 8.0. Research plots were on a field that had been under zero-tillage management practices since 1987.

In zero-tillage, crops were seeded directly into standing stubble. Conventional-tillage plots were cultivated in the fall and spring. The experimental design was a split-plot with the tillage systems as the main plots and the crop rotations as the subplots. Crop rotations were replicated four times. All six rotations were based on the following series of crop: cereal [spring wheat ***(Triticum aestivum L.)*** or canaryseed ***(Phalaris canariensis*** L.)], oilseed [canola ***(Brassica naps*** L.), except rotation 4 that had pea in the second phase], cereal (spring wheat or canaryseed), and pulse (lentil) (Table 1).

Wheat was fertilized with 183 kg ha^{-1} of urea and 49 kg ha^{-1} of monoammonium phosphate in rotations 1, 2, 3, 5, and 6, and with 91 kg ha^{-1} of urea and 25 kg ha^{-1} of momoammonium phosphate in rotation 4. Lentil was fertilized with 55 kg ha^{-1} of urea and 39 kg ha^{-1} of monoammonium phosphate in rotations 1, 2, 3, 5, and 6, and with 28 kg ha^{-1} of urea and 20 kg ha^{-1} of monoammonium phosphate in rotation 4. Comparisons among means were made using orthogonal contrasts.

Lentil and pea were inoculated with seed applied *Rhizobium leguminosarum* type C and *R. leguminosarum* biovar *viceae*, respectively. To estimate nitrogen fixation by the A-value approach (Rennie and Rennie, 1983) ^{15}N-microplots (lm x lm) were installed at the center of each plot and fertilized with 10 kg ha^{-1} $K\text{-}^{15}NO_3$ enriched at 10.5 % atom ^{15}N excess. Wheat was chosen as the reference crop to calculate nitrogen fixation in lentil and pea.

Results and Discussion

a) Effects of Tillage Systems on Nitrogen Fixation in Lentil and Pea

Nitrogen fixation in lentil grown under zero-tillage was 10% higher than under conventional-tillage, while nitrogen fixation in pea was 31% higher. Similarly, Herridge and Holland (1992) observed that soybean grown using zero-tillage had increased nitrogen fixation compared with soybean grown using conventional-tillage. These higher levels of nitrogen fixation observed using zero-tillage may result from the reduced soil nitrate found in zero-tillage. Hughes and Herridge (1989) concluded that reduced soil nitrate in zero-tillage soils increased nitrogen fixation in soybean. Whereas, increased levels of soil nitrate decreased nitrogen fixation (Cowie et al., 1990). The zero-tillage system retains the residues from the previous crop on the soil surface during the fallow, which reduces mineralization of the nitrogen in the stubble. Conversely, soil cultivation stimulates mineralization of soil organic matter and results in higher nitrate concentrations in cultivated soils as compared with zero-tillage soils (Doran, 1980).

Soil moisture under zero-tillage was greater than under conventional-tillage (Lafond et al., 1992). This water stress under conventional-tillage has been observed to decrease nitrogen fixation in soybean (Weisz et al., 1985). Therefore, decreased soil moisture under conventional-tillage may have caused reduced nitrogen fixation in lentil and pea in the present study.

b) Effects of Crop Rotations on Nitrogen Fixation in Lentil

Grain yield of lentil grown using highly diversified rotations (Rotations 5+6) was higher than when they were grown using less diversified rotations (Rotations 1+2+3+4) under zero- and when averaged across tillage systems (Table 3). Nitrogen fixation in lentil grown using highly diversified rotations (Rotations 5+6) was higher than when less diversified rotations were used (Rotations 1+2+3+4) under conventional- and when averaged across tillage systems (Table 3). Highly diversified rotations included three different crop species before seeding lentil (Table 1). In less diversified rotations wheat occupied 50% of the rotation. The percentage of wheat in the rotation probably affected nitrogen fixation and grain yields of lentil.

Summary

Nitrogen fixation in lentil and pea was higher in the zero-tillage system. This suggests that zero-tillage has the potential to increase the residual nitrogen benefits of legume crops to a subsequent crop. Lentil grown in a highly diversified rotation had higher levels of nitrogen fixation than lentil grown in a less diversified rotation, in conventional- and when averaged across tillage systems. However, rotations did not affect the nitrogen fixation of lentil grown under zero-tillage. Some research has been conducted to determine the effects of tillage systems on legume grain yields in western Canada, while no research has been done to learn the effects of crop rotations on nitrogen fixation in crop legumes. Therefore, more research is needed to confirm the results observed in the current study.

Acknowledgments

The authors acknowledge the support of the Agriculture Canada Research Branch, Indian Head Saskatchewan, especially the technical support provided by Mr. K. Schiffer, and the Department of Soil Science of the University of Saskatchewan. The technical assistance of Mr. G. R. Parry in determining the isotopic composition of the plant samples and the comments on the manuscript by M. A. Matus are highly appreciated.

References Cited

Bennet, J.M., and S.L. Albretch. 1984. Drought and flooding effects on N_2 fixation, water relations, and diffusive resistance of soybean. Agron. J. 76;735-740.

Bremer, E., R.J. Rennie, and D.A. Rennie. 1988. Dinitrogen fixation of lentil, field pea and fababean under dryland conditions. Can. J. Soil Sci. 68:553-562.

Cowie, A.L., R.S. Jessop, and D.A. MacLeod 1990. Effect of soil nitrate on the growth and nodulation of winter crop legumes. Aust. J. Exp. Agric. 30:65 l-654.

Doran, J.W. 1980. Soil microbial and biochemical changes associated with reduced tillage. Soil Sci. Soc. Am. J. 44:765-771.

Her-ridge, D.F., and J.F. Holland. 1992. Production of summer crops in northern New South Wales. I. Effects of tillage and double cropping on growth, grain and N yields of six crops. Aust. J. Agric. Res. 43:105-122.

Hughes, J.F., and D.F. Herridge. 1989. Effect of tillage on yield, nodulation and nitrogen fixation of soybean in far north-coastal New South Wales. Aust. J. Exp. Agric. 29:671-677.

Lafond, G.P., H. Loeppky, and D.A. Derksen. 1992. The effects of tillage systems and crop rotations on soil water conservation, seeding establishment and crop yield. Can. J. Plant Sci. 72:103-125.

Rennie, R.J., and D.A. Rennie. 1983. Techniques for quantifying N2 fixation in association with nonlegumes under field and greenhouse conditions. Can. J. Microbiol. 29: 1022-1035.

Stevenson, F.C., J.D. Knight, and C. van Kessel. 1995. Dinitrogen fixation in pea: controls at the landscape- and micro-scale. Soil Sci. Soc. Am. J. 59: 1603- 16 11.

Weisz, P.R., R.F. Denison, and T.R. Sinclair. 1985. Response to drought stress of nitrogen fixation (acetylene reduction) rates by fieldgrown soybeans. Plant Physiol. 78:525-530.

Wheatley, D.M., D.A. Macleod, and R.S. Jessop. 1992. Effects of zero tillage practices on soybean yield and soil cover. pp. 302-305. In Proc. of the Six Australian Agronomy Conference (K.J. Hutchinson and P.J. Vickery, Eds.), Australian Society of Agronomy, Vic.

Table 1. Crop rotations for the nitrogen fixation study in lentil and pea at Indianhead in 1995.

Crop rotations	Cereal	Oilseed	Cereal	Pulse
R1 Post-emergence herbicides	Spring wheat	Canola	Spring wheat	Lentil
R2 Pre-emergence herbicides	Spring wheat	Canola	Spring wheat	Lentil
R3 Low-input herbicides'	Spring Wheat	Canola	Spring wheat	Lentil
R4 Low-input herbicides and fertilizer[b]	Spring wheat	Pea	Spring wheat	Lentil
R5 Highly diversified I	Canaryseed	Sunola	Spring wheat	Lentil
R6 Highly diversified II	Spring wheat	Mustard	Canaryseed	Lentil

a In this rotation grassy weeds are not controlled in the spring wheat phases and reduced herbicide levels are used for broadleaf weed control.
b This rotation uses the same herbicide approach as R3 and the rates of fertilizer used for all crops is half that applied in the other rotations (i.e., one half soil test recommendations).
Note: Each of these rotations is present in zero- and conventional-tillage systems with all phases of the rotation present each year.

Table 2. Means for grain yield and percent nitrogen derived from atmosphere of lentil and pea grown at Indianhead in 1995.

Grain Yield (t ha“)

Crops	**Zero-tillage (ZT)**	**Conventional-tillage (CT)**	**Mean**
Lentil	1.15	1.12	1.14
Pea	1.40	1.36	1.38
Contrasts	***Probability level***		
Lentil vs. pea	NS	NS	NS
ZT vs. CT	–	--	NS

Percent nitrogen derived from atmosphere

Crops	**Zero-tillage (ZT)**	**Conventional-tillage (CT)**	**Mean**
Lentil	***72***	***62***	***67***
Pea	**79**	**48**	**64**
Contrasts	***Probability level***		
Lentil vs. pea	*	NS	NS
ZT vs. CT	–	–	**

*, ** Significant at the 0.05 and 0.01 level, respectively.

Table 3. Means for grain yield and percent nitrogen derived from atmosphere of lentil grown at Indianhead in 1995.

Grain yield (t ha^{-1})

Crop rotations	Zero-tillage	Conventional-tillage	Mean
R1 Post-emergence herbicides	1.32	1.29	1.31
R2 Pre-emergence herbicides	1.08	1.33	1.21
R3 Low-input herbicides	1.10	0.99	1.05
R4 Low-input herbicides and fertilizers	1.15	1.12	1.14
R5 Highly diversified I	1.46	1.21	1.34
R6 Highly diversified II	1.49	1.07	1.28
Mean	1.27	1.17	1.22
Contrast	***Probability level***		
(R5+R6) vs. (R1+R2+R3+R4)	**	NS	**
Zero- vs. Conventional-tillage	--	--	NS

Percent nitrogen derived from atmosphere

Crop rotations	Zero-tillage	Conventional-tillage	Mean
R1 Post-emergence herbicides	68	47	58
R2 Pre-emergence herbicides	63	50	57
R3 Low-input herbicides	65	52	59
R4 Low-input herbicides and fertilizers	72	62	67
R5 Highly diversified I	75	68	72
R6 Highly diversified II	72	70	71
Mean	69	58	64
Contrast	*Probability level*		
(R5+R6) vs. (R1+R2+R3+R4)	NS	**	**
Zero- vs. Conventional-tillage	–	--	**

** Significant at the 0.01 probability level.