Crop Rotation Benefits Of Annual Forages

Patrick M. Carr
North Dakota State University Dickinson Research Extension Center

This paper was presented during the 28h annual Manitoba - North Dakota Zero Tillage Workshop at Bismarck, ND, during 9-10 February, 2006.

Research Summary

Many grain and seed crops cannot be grown profitably in the prairie region of Canada or the northern USA. Incorporating forages into crop rotations can reduce fertilizer and herbicide inputs when growing wheat (*Triticum* spp.) or other grain crops, thereby enhancing cropping system economics. Soil water is conserved and cropping flexibility results when annual rather than perennial forages are grown, and some of the soil-N and pest control benefits that occur when growing perennial forages are maintained. Lack of knowledge and infrastructure are obstacles preventing the widespread incorporation of annual forages into cropping systems. New efforts are underway to develop cropping systems which maximize benefits offered by legume forages when used for grazed pasture in rotation with wheat and other grain crops.

Introduction

Spring wheat was planted on over 0.4 million ha (1.1 million acres) in southwestern North Dakota in 2005 (USDA-NASS, 2006). The expected returns to labor and management in 2006 are -\$45 ha^{-1} (-\$18 $acre^{-1}$) for hard red spring wheat and -\$30 ha^{-1} (-\$12 $acre^{-1}$) for durum wheat (Swenson and Haugen, 2005). The negative returns that are projected suggest that crops besides spring wheat should be grown for grain in 2006.

Barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.), and corn (*Zea mays* L.) were the second, third, and fourth most widely grown grain crops (after wheat) during 2004 in southwestern North Dakota, respectively. However, Swenson and Haugen (2005) project -\$15 ha^{-1} (-\$6 $acre^{-1}$) generated for malt barley production in 2006, -\$84 ha^{-1} (-\$34 $acre^{-1}$) for oat, and -\$67 ha^{-1} (-\$27 $acre^{-1}$) for grain corn. Swenson and Haugen (2005) also project negative returns for several seed crops in the region in 2006, including sunflower (*Helianthus annuus* L.; -\$12 ha^{-1} [-\$5 $acre^{-1}$]); canola (*Brassica napus* L. and *B. rapa* L.; -\$62 ha^{-1}[-\$25 $acre^{-1}$]), flax (*Linum usitatissinum* L.; -\$30 ha^{-1} [-\$12 $acre^{-1}$]), and field pea (*Pisum sativum* L. subsp. *sativum*; -\$32 ha^{-1} [-\$13 $acre^{-1}$]).

Not all seed crops are expected to generate negative returns in the region if grown in 2006. For example, chickpea (*Cicer arietinum* L.) is expected to return \$57 ha^{-1} (\$23 $acre^{-1}$), lentil (*Lens culinaris* Medik.) is expected to return \$44 ha^{-1} [\$18 $acre^{-1}$]), and mustard (*Brassica* spp.) is expected to return \$35 ha^{-1} (\$14 $acre^{-1}$). However, disease control continues to be a significant problem in chickpea, mustard production is constrained by a small market with limited growth potential, and lentil production has not been profitable consistently. For example, lentil returned an average of -\$80 ha^{-1} (-\$32 $acre^{-1}$) when grown within the region in 2002 (FinBin, 2005).

Alfalfa (*Medicago sativa* L.) was grown on over 80,000 ha (200,000 acres) in southwestern North Dakota in 2004. Swenson and Haugen (2005) did not consider the management of alfalfa for hay when developing crop budgets for 2006, but alfalfa hay production returned an average of \$41 ha^{-1} (\$17 $acre^{-1}$) to labor and management in 58 fields within southwestern North Dakota that are included in the most recent data set maintained in the Farm Financial Management Database at the University of Minnesota (FinBin, 2005). Growing alfalfa for hay has returned an average of \$65 ha^{-1} (\$26 $acre^{-1}$) over the past 10 years, making alfalfa hay production the most profitable crop enterprise in the region. The returns generated by alfalfa suggest that forages can be used to enhance cropping system profitability if inserted into rotations dominated by grain and seed crops.

Rotational Benefits of Forages

Impact on Yield

Several research studies suggest that grain and seed yield increases result in subsequent crops when forages are inserted into crop rotations. Entz et al. (2002) summarized results of research in North Dakota and the Canadian Prairie Provinces indicating grain yield increases in some instances of 50% or more when spring wheat followed alfalfa compared with wheat, corn, or some other non-legume grain or seed crop. Entz et al. (1995) cited other studies where grain yield increases for wheat were similar following a mixture of alfalfa and bromegrass (*Bromus inermis* L.) and alfalfa alone. These research results are corroborated by producer experience; over 60% of 253 producers surveyed in Manitoba and Saskatchewan indicated that grain yields were enhanced when wheat and other crops followed legume forages in a rotation (Entz et al., 1995).

Much of the rotation yield benefit to grain and seed crops following alfalfa is attributed to the biological N_2-fixing ability of the legume species. Fertilizer replacement values in excess of 100 kg ha^{-1} (90 lb $acre^{-1}$) are possible for alfalfa and some other legume forages even after removing a hay crop, if regrowth is plowed under (Entz et al, 2002). The impact of alfalfa and other legumes on the soil N pool may even be greater when these forage species are grazed and not hayed, since there is considerable recycling of nutrients.

There are some rotational yield benefits provided by alfalfa and other forages that result from non-N factors. Many of these non-N benefits are attributed to improvements in soil quality. For example, larger and more stable aggregates occurred in soils where perennial forages were grown compared with grain crops in several studies summarized in the review paper by Entz et al. (2002). Other research discussed by these same authors indicated that soil microbial activity also was greater in soils where perennial forages were grown, even in semiarid regions.

Pest Suppression

Reports of weed suppression provided by forages are widespread in the scientific literature. In their review paper, Entz et al. (2002) cited several studies where weed production was significantly less in rotations that included forage crops compared with those which did not. In one study, wild oat (*Avena fatua* L.) dockage was <1% of the grain produced in forage-containing rotations compared with 15% in continuous wheat or wheat-fallow systems.

Research identifying weed suppression resulting after incorporating forages into rotations with grain crops is supported by on-farm observations. Over 80% of commercial grain and forage producers surveyed in Manitoba and Saskatchewan indicated that weed growth was reduced following forage crops (Entz et al., 1995). Thirty-three percent of respondents in that same survey indicated that the weed suppression benefits provided by forages continued for more than two years after forage growth was terminated. Weeds that were controlled included annuals like wild oat and green foxtail [*Setaria viridis* (L.) Beauv.], but also perennials like *Canada thistle* [Cirsium arvense (L.) Scop.].

The impact of forages on reducing pests is not limited to weeds. For example, common root rot (*Helminthosporium* and *Fusarium* spp.) infection in wheat was suppressed when red clover (*Trifolium pretense* L.) was grown between two wheat crops in a red clover-spring wheat-canola-spring wheat rotation compared with a continuous wheat monoculture (Clayton et al., 1997). Likewise, common root rot was suppressed only when a 3-yr hay crop was included among several rotations in a separate study described by Entz et al. (2002).

Economic Returns

Few economic studies have compared the impact of forages on crop rotation profitability. Zentner et al. (1986) did compare the economic returns generated by forage-based cropping systems to rotations that consisted only of grain and seed crops. The forage-based cropping systems had lower production costs and more stable net returns than the continuous grain production systems. The greater income stability associated with the forage-based cropping systems lowered the risk associated with field crop production in the northern Great Plains. Entz et al. (2002) pointed out in their review of this research that forage-based cropping systems offered a biological option for minimizing risk that may be superior to government programs.

Shortcomings of Perennial Forages

Drought-Induced Yield Suppression

Yield benefits do not always result when alfalfa and other perennial forages are inserted into rotations with grain and seed crops. Rather, yield reductions oftentimes occur in semiarid regions in the northern Great Plains. For example, a Canadian study cited by Entz et al. (2002) indicated that grain yield was depressed following alfalfa compared with fallow, even after a full year of summer fallow between alfalfa termination and a subsequent wheat crop. Likewise, wheat yields were reduced following alfalfa, birdsfoot trefoil (*Lotus corniculatus* L.) and sainfoin (*Onobrychis viciifolis* Scop.) compared with fallow in southwestern North Dakota during some years, even when favorable amounts of precipitation were received during the growing season (Carr et al., 2005a).

Results of studies indicating that grain and seed yields are depressed following perennial forages is not unexpected in semiarid regions. Soil water reserves oftentimes are depleted following perennial forages and must be at least partially replenished to avoid drought-induced yield depression in subsequent grain or seed crops. A study cited by Entz et al. (2002) in western Saskatchewan demonstrated that less soil water was stored following a 2-yr alfalfa crop than annual grain crops. Likewise, less soil water occurred following forage legumes than fallow in rotations with wheat in North Dakota (Badaruddin and Meyer, 1989). These two researchers reported that soil water depletion was most severe when legume growth continued into late summer and fall.

Rotational Inflexibility

The benefits provided by diverse rotations in suppressing pests in the northern Great Plains have been summarized in papers written by scientists both in Canada and the USA (Turkington et al., 2003; Kuprinsky et al., 2004). The advantages in pest suppression presumably result from susceptible plant hosts being grown for no more than two successive seasons before being rotated with non-susceptible species. The inclusion of non-susceptible break crops generally prevents large pest populations and disease infestations from developing. Many perennial forage stands are maintained for several years after first being established, even though research indicates that most of the benefits provided to subsequent grain and seed crops occur within the first few years following establishment. For example, Entz et al. (1995) summarized results of several studies indicating that optimum N accumulation and weed suppression occurs within three years of alfalfa stand establishment. However, these researchers reported that the average stand duration for alfalfa was 8 years in semiarid portions of the northern Great Plains. This hesitancy to terminate alfalfa occurs because of difficulties encountered when attempting to establish and terminate perennial plant species in dry conditions (Bullied and Entz, 1994; Kilcher and Heinrichs, 1960). Unfortunately, maintaining perennial crops in long-lived stands provides opportunities for pest infestations to develop.

Extent and Potential of Annual Forages

Present Use

Annual forages are an important contributor to the feed supply in the northern Great Plains. For example, small-grains were harvested for forage (primarily as hay) from over 0.25 million ha (0.6 million acres) across Montana, North Dakota, and South Dakota in 1997 (Carr et al., 2002). Barley in Canada and corn in North Dakota are important ensiled forage crops in the region. Triticale (× *Triticosecale* Wittmack) is a newer cereal that has performed better than traditional small-grain forages both in semiarid regions of western Canada and Montana in research cited by Entz et al. (2002). Emmer (*Triticum turgidum* L.), spelt (*T. aestivum* L.), and even rye (*Secale cereale* L.) are other small-grain crops that can be grown successfully for forage in the northern Great Plains (unpub. data).

Cereal crops can be grown alone or in mixtures for forage. While forage yield may not increase (Baron et al., 1992), seasonal distribution often improves when cereals mixtures are grown. Research cited by Entz et al. (2002) demonstrated that mixtures of spring and winter cereals provide earlier grazing than winter cereals alone, but later grazing than spring cereals alone. Unpublished data collected at Dickinson, ND, produced similar results and demonstrate the ability of cereal mixtures to extend the grazing period beyond that provided using a traditional method of cereal forage management.

Mixtures of barley or oat and field pea are grown in the northern Great Plains to enhance the forage quality compared with growing cereal crops alone. The crude protein concentration of forage generally is increased from 1% to 2%, and even more, as a result of intercropping (Carr et al., 1998; 2002). Forage yield may not be increased from intercropping cereals with pea compared with growing cereals alone in high soil-N environments or when N fertilizer is applied (Carr et al., 1998), but more dry matter is produced when grown in low soil-N environments (Carr et al., 2002).

Perennial pastures generally are believed to be the least expensive feed sources for beef cattle (Entz et al., 2002). However, annual forages can be used to extend the grazing season when perennial species cannot or should not be grazed. A common practice is to pasture animals on crop residue and regrowth following grain and seed harvest during fall and winter months. Alternatively, annual crop mixtures can be used to extend the grazing system, as has already been mentioned. Finally, cereals can be swathed and then grazed by cattle during winter months. All these strategies can reduce beef cattle production costs by lowering or even eliminating the need to overwinter cattle in confinement systems.

Rotational Benefit of Annual Crops

Substituting annual for perennial forages solves some of the problems that exist when perennial species are inserted into rotations with grain and seed crops. Annual forages have a shallower root system and generally extract less water than long-lived perennial species like alfalfa. As a result, drought-induced yield depression in subsequent grain and seed crops is less likely following annual forages because soil water recharge can occur. Soil water content may even be greater following annual forages than grain and seed crops since forage generally is harvested earlier. As a result, a wider window exists for soil water reserves to be recharged before the next crop is grown.

Annual forages provide flexibility for changing crops in diverse rotations that is not available when long-lived perennial species are grown. The biological diversity that may result from rotating annual grain, seed, and forage crops can be used to control pests. Cereals and certain dicotyledonous plant species also give producers the choice of harvesting the crop for forage or for grain, depending on economic, environmental, and other factors.

Weed suppression can occur when annual forages are inserted into rotations with grain and seed crops, even though the weed control benefits offered by perennial forages may be greater. Wild oat populations were significantly lower following triticale that was hayed compared with spring wheat that was harvested for grain (Schoofs and Entz, 2000). Fewer wild oat plants occurred following the triticale forage crop even when a grass herbicide (tralkoxydim) was applied in the wheat grain crop to control wild oat. Annual forages have reduced weed populations in other studies cited by these two researchers.

The N benefits of forage legumes are not restricted to alfalfa and other perennial species. Annual legumes including various medic (*Medicago* spp.) and clover species have been used successfully for decades to supply part if not all of the N needs for subsequent wheat crops (Puckridge and French, 1983). Grain yield increases of up to 50% along with increases in grain protein of 1% to 2% for wheat resulted from substituting fallow with annual legume pasture in that country. The enhancements in grain yield and quality are attributed largely to the biological N_2-fixing ability of the annual legume species.

Challenges Faced When Incorporating Annual Forages into Rotations

Obstacles exist which inhibit the widespread incorporation of annual forages into rotations with grain and seed crops. A trend has existed for decades in agriculture to specialize, so many farms that formerly contained both crop and livestock enterprises have maintained one and eliminated the other. As a result, much of the familiarity and knowledge regarding forage crop production no longer exist on many farms where grain and seed crops presently are grown.

Much of the infrastructure that once supported integrated crop-livestock enterprises has been dismantled. Krall and Schuman (1996) pointed out that watering systems and fences would need to be improved or installed if forages were grown and grazed on many farms where grain and seed crops presently are grown. Haying rather than grazing an option, but nearby markets for locally grown hay may not exist.

Carr and Poland (2003) pointed out that the reintroduction of forages into cropping systems is contrary to the belief that production efficiency is optimized by specialization. Beliefs can be difficult to change even when there is ample evidence to the contrary. These two researchers pointed out that the economic and environmental inefficiencies of the crop-fallow system were well documented decades before alternative systems were adopted in subhumid regions of North Dakota.

Future Directions

Work is underway to develop cropping systems where legume forages are rotated with grain and seed crops to reduce reliance on N fertilizer and pesticide inputs while, at the same time, maintain or enhance grain crop yield. This effort, patterned after an Australian farming method described in detail by Puckridge and French (1983), presently is centered in North Dakota and Wyoming. Much of the success of this project rests on the ability of researchers to identify legume species that regenerate naturally from the soil seed bank following a grain or seed crop, and produce adequate amounts of forage during a pasture phase. Grazing rather than haying the legume species is essential so nutrient cycling and weed control benefits of the system can be optimized. Promising legume forage species have been identified both in North Dakota (Carr et al., 2005 a, b) and Wyoming (Walsh et al., 2002). Research also is underway to identify self-regenerating legume species that are adapted to growing conditions in Manitoba (M.H. Entz, personal communication, 2005).

Conclusions

This review paper has briefly identified some of the advantages provided by forages if incorporated into rotations with grain and seed crops. A much more thorough evaluation of the benefits offered by forages if incorporated into crop rotations is provided by Entz et al. (2002). An additional paper by some of the same authors which describes the benefits of integrated crop-livestock systems in semiarid and subhumid regions should be published in Agronomy Journal in 2006 or 2007.

References

Badaruddin, M., and D.W. Meyer. 1989. Water use by legumes and its effect on soil water status. Crop Sci. 29:1212-1216.

Baron, V.S., H.G. Najda, D.F. Salmon, and A.C. Dick. 1992. Post-flowering forage potential of spring and winter cereal mixtures. Can. J. Plant Sci. 72:137-145.

Bullied, W.J., and M.H. Entz. 1999. No-till alfalfa stand termination strategies: Alfalfa control and wheat and barley production. Can. J. Plant Sci. 79:71-83.

Carr, P.M., R.D. Horsley, and W.W. Poland, 2002. Barley, oat, and cereal-pea mixtures as dryland forages in the northern Great Plains. Agron. J. 96:677-684.

Carr, P.M., G.B. Martin, J.S. Caton, and W.W. Poland. 1998. Forage and nitrogen yield of barley-pea and oat-pea intercrops. Agron. J. 90:79-84.

Carr., P.M., W.W. Poland, and L.J. Tisor. 2005a. Natural reseeding by forage legumes following wheat in western North Dakota. Agron. J. 97:1270-1277.

Carr, P.M., W.W. Poland, and L.J. Tisor. 2005b. Forage legume regeneration from the soil seed bank in western North Dakota. Agron J. 97:505-513.

Carr, P.M., and W.W. Poland. 2003. p. 124-132. *In* J.D. Hanson and J.M. Krupinsky (ed), Proc. from Dynamic Cropping Sys. Symp.: Principles, processes, and challenges. Bismarck, ND. 4-7 Aug., 2003.

Clayton, G.W., Rice, W.A., Lupwayi, N.Z., Turkington, T.K. 1997. Sustainability of legume-based conservation tillage systems. Final Technical Rep. on CAESA Project no. 9415 Sep. 1997.

Entz, M.H., V.S. Baron, P.M. Carr, D.W. Meyer, S. R. Smith, and W. P. McCaughey. 2002. Potential of forages to diversity cropping systems in the northern Great Plains. Agron. J. 94:240-250.

Entz, M.H., W.J Bullied, and F. Katepa-Mupondwa. 1995. Rotational benefits of forage crops in Canadian prairie cropping systems. J. Prod. Agric. 8:521:529.

Farm Financial Management Database (FinBin). 2005. Crop enterprise analyses for hay, alfalfa., sunflower, and lentils. North Dakota Farm and Range Business Management – Western Slope region. http://www.finbin.umn.edu//CropEnterprise / Analysis/ [verified 01 Feb., 2005)

Kilcher, M.R., and D.H. Heinrichs. 1960. The use of cereal grains as companion crops in dryland forage crop establishment. Can. J. Plant Sci. 40:81-93.

Krall, J.M., and G.E. Schuman. 1996. Integrated dryland crop and livestock production systems on the Great Plains: extent and outlook. J. Prod. Agric. 9:187-191.

Krupinsky, J.M., Tanaka, D.L., Lares, M.T. 2004. Leaf spot diseases of barley and spring wheat as influenced by previous crops. Agron. J. 96:259-266.

Puckridge, D.W., and R.J. French. 1983. the annual legume pasture in cereal-ley farming systems in southern Australia: A review. Agric., Ecosystem and Environ. 9:229-267.

Schoofs, A., and MH. Entz. 2000. Influence of annual forages on weed dynamics in a cropping system. Can. J. Plant Sci. 80:187-198.

Swenson, A., and R. Haugen. 2004. Projected 2005 crop budgets. Southwest North Dakota. ND Coop. Ext. Serv. Farm Management Planning Guide. Sec. 6., Reg. 4. Fargo.

Turkington, T.K., Hartman, M., Krupinsky, J.M., Kutcher, H.R., McMullen, M.P., Tewari, J.P., Xi, K. Plant disease management and diversity. p. 37-59. *In* J.D. Hanson and J.M. Krupinsky (ed), Proc. from Dynamic Cropping Sys. Symp.: Principles, processes, and challenges. Bismarck, ND. 4-7 Aug., 2003.

United States Dep. Agric., National Agric. Stat. Serv. (USDA-NASS). 2006. 2004 Durum and other spring wheat planted acres in the Southwest Crop Reporting Disctrict in North Dakota. Available online at http://www.nass.usda.gov/ Data_and_Statistics/Quick_Stats/index.asp . (Verified on 21 Jan., 2006).

USDA-NASS. 1999. 1997 Census of agriculture. Available online at http://www.nass. usda.gov/ . Verified on 07 Sep., 2000).

Walsh, M.J., R.H. Delaney, R.W. Groose, and J.M. Krall. 2001. Performance of annual medic (*Medicago* spp.) in southeastern Wyoming. Agron. J. 93:1249-1256.

Zentner, R.P., C.A. Campbell, S.A. Brandt, K.E. Bowren, and E.D. Spratt. 1986. Economics of crop rotations in western Canada. p. 254-317. *In* A.E. Slinkard and D.B. Fowler (ed.) Wheat production in Canada – a review. Proc. Can. Wheat Prod. Symp., Saskatoon, SK. 3-5 Mar. 1986. Div. of Ext. and Community Relations, Univ. of Saskatchewan, Saskatoon.