



Prairie Experiences with Reduced Input Crop Production

Martin H. Entz, Orla M. Nazarko, Rene C. Van Acker and Allison Schoofs
Department of Plant Science, University of Manitoba
Winnipeg, Manitoba, Canada R3T 2N2 Email: m_entz@umanitoba.ca

Summary

Interest in reducing crop inputs is driven by a desire to reduce input costs, though other benefits are widely recognized. Since pesticides and fertilizer account for approximately one-half of all variable crop input costs in prairie grain production, the main focus of this paper is on plant-based solutions for pesticide and fertilizer use reduction. Frameworks that provide a market incentive for reduced input production (e.g., organic, IPM) are reviewed. Three management strategies to achieve input use reduction are discussed: increasing input use efficiency, input substitution and preventative management. Examples of these three plant-based management strategies for reducing crop inputs are given: One from a University field trial (The Glenlea long-term rotation) and one from an on-farm pilot project (Pesticide Free Production (PFP) program) in Manitoba, Canada. The long-term study at Glenlea clearly demonstrates the feasibility of sustainable crop input reduction, but only if robust cropping systems with careful consideration of long-term soil fertility are employed. PFP program results showed that farmers who were successful in producing pesticide free crops differed from conventional farmers mostly in terms of their attitudes, though some differences in crop rotation and seeding management were also observed. Technology transfer to facilitate crop input use reduction requires a different approach than that based on the diffusion of innovation model.

Introduction

Cost of crop production, along with net return and income variability, is a major economic factor in crop production. The estimated cost of production for wheat in Manitoba in 2003, is \$122 (Cdn)/acre (Table 1). Approximately 50% of these costs are accounted for by pesticides and fertilizer. For an economic perspective on the question of input cost reduction, readers are referred to Zentner et al.'s 2002 review paper. The present paper considers plant-based management strategies and tactics for reducing pesticide and fertilizer inputs.

Reducing input costs involves much more than not spraying. Simply eliminating fertilizers or herbicides, without a plan or forward preparation, usually results in lower net returns for farmers. The "plan" and the "forward preparation" involve agronomy. This agronomy must emphasize preventative and alternative strategies for pest control and soil fertility maintenance. The degree to which farmers and researchers can design and implement such systems will dictate how far crop input reduction can proceed. Organic farmers use a wide range of crop production practices because they have gone all the way – that is, they have eliminated the use of most off-farm crop inputs. The Cubans have, out of necessity, adapted their crop production system to require fewer off-farm crop inputs as well (Rosset and Benjamin, 1994). So, it can be done.

The objective of this paper is to review frameworks for input use reduction; to discuss management options for input use reduction; to highlight Canadian prairie research on the subject; and to introduce concepts of technology transfer for reduced input crop production.



TABLE 1. Guidelines for Estimating 2003 Crop Production Costs (Canadian dollars). Source: Manitoba Agriculture and Food.

Operating cost	Wheat	Canola	Sunflowers	Peas	Navy Beans (row crop)
Seed and treatment	17.00	23.38	31.35	39.00	38.16
Fertilizer	29.50	36.35	36.30	18.30	32.00
Herbicide	21.00	26.00	50.00	20.00	74.50
Fungicide	10.00	25.25	0.00	0.00	30.00
Insecticide	0.00	0.00	17.00	0.00	0.00
Fuel	11.50	11.50	12.00	13.00	13.81
Machinery operating	10.00	10.00	11.00	10.50	11.00
Crop Insurance	5.36	8.20	5.14	4.89	9.80
Crop Insurance	7.50	7.50	8.00	8.00	8.00
Land taxes	6.50	6.50	6.50	6.50	8.00
Drying costs	0.00	0.00	6.00	0.00	0.00
Interest on operating	3.55	4.64	5.50	3.61	6.76
Total operating	121.91	156.32	188.79	123.80	232.03

Frameworks for Reducing Crop Inputs

Some input cost reduction systems are based on lower yields, but higher market value for the produce. This philosophy is based on a belief that consumers will pay more for agricultural products that are produced with fewer farm chemicals (Magnusson, 2002).

Organic Farming

Organic farming is the most widely recognized form of reduced input agriculture. Its main feature is its requirement that no synthetic pesticides or fertilizers are used. Organic food markets are increasing by about 20% per year and in Canada there are currently 3100 organic farmers and 0.5% of arable land in Canada is certified organic (AAFC, 2002). Most certifying agencies require the whole farm to be converted to organic over a certain time period, restricting farmers ability to grow crops organically on just one field (Wallace, 2001). European Union standards will soon require that only organically-produced seed be used.

While organic farming reduces input costs, net returns range from less than conventional production to equal to or greater than conventional production (Hoepfner, 2001). Dobbs (1992) working in South Dakota, found that while net returns were lower (\$42/acre) in an organic system compared with a conventional system (\$65/acre), financial and market risk was lower for the organic system.

Non-organic reduced input initiatives

Several authors have suggested that adoption of sustainable agriculture is most likely if the system is compatible with an existing system. Modest chemical input use may be more promising than organic production in terms of productivity and profitability. There is also evidence that food products intermediate between organic and conventional have a niche in the food market (Magnusson, 2002).

Integrated Pest Management

There are over 60 definitions of Integrated Pest Management; however, two features are most important: use of multiple pest control tactics and the integration of pest biology knowledge (Nazarko et al., 2003c). Kogan (1988-in Nazarko et al., 2003c) reviewed IPM's 30 year history and argued that its development is still in its infancy primarily because IPM programs still rely on pesticides as the principle pest management tool. Nazarko



et al. (2003c) argue that low adoption of IPM is due to a lack of connection between the goals of academic researchers and those of farmers.

Other reduced input systems

Several systems intermediate to organic and conventional have been proposed with over 150 such food eco-labelling initiatives in the US alone (Nazarko et al., 2003c). In Quebec, an initiative called Healthy Grain has successfully marketed grain produced for one year without pesticides or fertilizer (Douglas, 2002). A similar program in Manitoba, Pesticide-Free Production, demonstrates that farmers can implement such intermediate systems with satisfactory results (Nazarko et al., 2003a; 2003b).

Use of wildlife-friendly cropping systems is increasing. For example, programs to maintain and enhance nesting sites for migrated waterfowl through production of winter cereals and perennial forage crops have been promoted in the Northern Great Plains region for some time. In California, Lundberg Farms have branded "Nutrafarmed" rice, a production system that maximizes benefits to migrating waterfowl (see www.lundberg.com, verified May 15, 2003).

Management for Reducing Crop Inputs

Strategies for reducing chemical input use can be placed on a continuum of increasing cropping system management: 1) efficiency in input use; 2) substitution of off-farm inputs with on-farm and knowledge/management inputs; and 3) redesign of the cropping system to reduce reliance on inputs.

Efficiency of inputs

Strategies to maximize efficiency of crop inputs include reduced tillage; reduced pesticide rates, using economic thresholds for pests, site-specific pest and soil management, use of models to predict pest occurrence and soil nutrient supplying power, and maximizing interactions between soil and crop management.

Tillage reduction has provided significant savings in input costs, though it has also meant greater investment in seeding equipment (Zentner et al., 2002). In wetter areas of the Canadian prairies, such as the Black and Gray soil zones, tillage intensity is high and so no-till is less expensive compared with conventional tillage (Zentner et al., 2002). In the drier Brown and Dark Brown soil zones, however, no-till is more expensive than tilled systems due to low tillage intensity in conventional systems (Zentner et al., 2002).

Economic thresholds (ET) were originally developed as tools for insect pest management and have subsequently been applied to weeds and diseases. The ET concept has been criticized on several grounds:

ET's oversimplify the causes of yield loss (e.g., relative time of emergence of weed and crop not considered); most ET's only consider one pest-one crop interaction; ET's consider the impact of the pest for one year only; ET's consider only a apply/do not apply choice with no opportunity for reduced rate or alternative control measure; and ET's deal exclusively with direct pest management and therefore encourage reactive rather than proactive approaches (Nazarko et al., 2003c).

Weeds are the primary target for pesticide use in Canada, with herbicide accounting for 80% of pesticide sales in western Canada in 2001. Herbicide use has been shown to be reduced using reduced herbicide rates, band application, using knowledge of weed emergence periodicity to optimize herbicide use (Nazarko et al., 2003c), and site-specific management (Faechner et al., 2002).

Efficiency of fertilizer use can be maximized by greater knowledge of indigenous soil nutrient content (i.e., soil testing), better knowledge of N credits from legumes in rotation, and site-specific management.



Input substitution

The first strategy for input substitution involves using on-farm instead of purchased inputs. A classical example is the use of farm-saved seed. Farm-saved seed can often provide the same level of seedling vigor and crop yield as certified seed if grain farmers use correct techniques in seed production, harvesting and handling (Moes et al., 1992). A second strategy involves substituting knowledge and management inputs for chemical inputs.

Substituting cultural and biological pest control strategies for pesticides can be very successful (Nazarko et al., 2003c). However, substituting alternative nutrient sources for inorganic fertilizers is less clear cut. It is very important to recognize that nutrient substitution is fundamentally different from pest control substitution. The distinction stems from the fact that fertilizers are a “yield-building” input while pesticides are a “yield-protecting” input.

Prasad and the late James Power wrote “The use of chemical fertilizers along with organic manures is probably the best way to keep food production level with or ahead of the increase in the population” and “..conjunctive use wherein a mixture of organic and inorganic nitrogen sources are used gives better nitrogen-use efficiency than using either source alone” (Prasad and Power, 1997).

Preventative management

Preventative management is based on the idea that long-term management of the cropping system will maintain pests at low levels and maximize soil biological fertility, and in this way input costs can be reduced. Nazarko et al. (2003c) discuss two critical components of a preventative system: 1) synergistic interaction between individual components and 2) redundancy in components to compensate for inevitable failures of some system components.



Crop Management

Weed management strategies in a reduced input system include competitive crops, competitive cultivars, manipulating seeding dates, seeding at higher rates, choosing cultivars with enhanced mycorrhizal dependency, nutrient management, growing allelopathic plants and using in-crop tillage instead of herbicides to control weeds (see reviews by Frick, 2000 and Nazarko et al., 2003c). Management strategies to reduce disease problems were recently reviewed by Krupinsky et al. (2002). They point out the importance of integrated approaches plus the value of record-keeping and field scouting.

Cultivar mixtures have recently been tested and found to provide significant benefits for disease management (e.g., the now famous rice example; Zhu et al., 2000). Wheat cultivar mixtures are now being used in northeastern Oregon and southeastern Washington (Mundt 1994) for stripe rust suppression and yield stabilization. "In 1998, 10% of soft white winter wheat and 76% of club wheat fields in this region were sown to cultivar mixtures. In Kansas, wheat variety blends occupied 7% of fields in 2000, with yield stabilization viewed as the most significant benefit received from mixture deployment" (Bowden et al. 2001). Barley cultivar mixtures were used widely (>90% of fields) in the former East Germany in the 1980's to control powdery mildew (Wolfe, 1997), however since unification, this system has been replaced by susceptible cultivars and fungicide use. In Alberta, Jedel et al. (1998) reported that mixtures of barley were more effective in capturing resources than monocrops.

Redesigning the Cropping System

A complementary longer-term strategy for preventative management involves redesigning the cropping system. The aim is to design cropping systems that can function effectively with fewer off-farm inputs. Since cropping systems are site-specific, it follows that design changes must also be site-specific.

Among preventative strategies, crop rotation is one of the most important. Rotation of crops with varied planting dates, growth habits and fertility requirements will minimize the likelihood that pest will adapt to the cropping systems and proliferate (Nazarko et al., 2003c). Crop rotation also enhances soil biological activity and fertility (Ingham, 2003). Among prairie crops, perennial forages, winter annual cereals and grain legumes provide unique benefits that complement spring seeded cereal and oilseed crops. Organic farmers rely heavily on crop rotation to maintain cropping system function, including management of weeds and maintenance of soil fertility (Entz et al., 2001; Wallace, 2001).

The combination of no-till and a robust crop rotation has proven to be particularly important in enhancing system productivity and reducing crop input requirements. For example, Matus et al. (1997) demonstrated an interaction between tillage and crop rotation for biological N fixation of pea and lentil. Legume N fixation was higher under no-till compared with the tilled treatment and this increase was greatest in a diversified compared with a simple crop rotation. The role of crop rotation in reducing problems of weeds (Derksen et al., 2002; Nazarko et al., 2003c), diseases (Krupinsky et al., 2002) and in enhancing soil nutrient status (Prasad and Power, 1997) have been reviewed.

Intercropping diversifies the cropping system spatially and can reduce weeds (Szumigalski et al., 2002) and diseases and insects (Holliday, pers comm). Prospects for harvesting of intercrops in which both species are grain crops may improve through development of the McLeod Harvest system which allows for on-farm separation of grain of different crops (www.mcleodharvest.com; verified 14 May, 2003).

Cover crops are living ground cover planted into or after a main crop and are grown for their soil-conserving and weed suppressing abilities. Thiessen Martens and Entz (2001) concluded that relay and double cropping with winter cereals is feasible in the eastern and southern parts of the Canadian prairies. Hoepfner (2001) determined that late-season cover crops in Manitoba provided an average fertilizer N replacement value of 25 kg/ha (range – 20 to 75 kg/ha). In Alberta, Moyer et al. (2000) reported that the use of fall rye cover crops



during the fallow year effectively suppressed weed biomass. Fall-planted fall rye cover crops reduced herbicide needs of solid-seeded Navy beans in Manitoba (Duval and Entz, unpublished) and soybeans in northern Minnesota (Porter, pers comm).

Rosset and Benjamin (1994) introduced the term successional cropping, which incorporates elements of both crop rotation and intercropping. Successional systems use permanent regenerating understory crops in combination with harvested grain crops. Understory crops regenerate either vegetatively or by seed. Successional cropping is most popular in small-holder agriculture however examples can also be found in industrialized agriculture. For example, Australians are currently experimented with cereal and oilseeds cropped over top of perennial alfalfa, where the alfalfa regenerates vegetatively (Latta, pers. comm.). Braul and Entz (2003) demonstrated the ability of Black medic to regenerate from seed in continuous cropping systems in Manitoba with significant benefits to the cropping system in terms of N additions. Medics have been used on a North Dakota farm since 1992 and N benefits have been observed (Braul and Entz, 2003).

No-till is a form of successional cropping since no-till systems allow for maintenance of the soil food web "between crops" (Ingham, 2003). It can be argued that no-till provides a level of "between crop biological activity" that is well suited to semi-arid zones; an area where cover crop plants cannot be sustained due to lack of water. In wetter zones, adding a cover crop to the no-till system simply adds biological activity to the system and increases the intensity of the successional cropping system.

Reducing Crop Inputs: Research Examples from the Prairies

1. The Glenlea Long-Term Rotation

Established in 1992, Glenlea is the longest running organic research trial in Canada. Individual 1 ha mainplots contain three crop rotations: 1) wheat-pea-wheat-flax, 2) wheat-clover-wheat-flax, 3) wheat- alfalfa (two years)-flax; flax is the "test crop" at the end of each four year rotation cycle. Each of these mainplots are managed using organic, conventional and low-input (data not shown) techniques. Measurements include crop yield and quality, soil quality, economics, energy use, weeds, diseases and insects. The experimental area covers 11 ha and includes 3 replicates.

On the basis of energy efficiency, weeds, crop yield under organic conditions, cost of production (input cost) and net income, the best overall performance was recorded for the alfalfa-containing cropping system (Table 2). Clearly, reducing inputs in the robust alfalfa-containing rotation did not result in negative agronomic or economic effects. In fact, this was the most profitable system. Reducing inputs in the "grain only" rotation (rotation 1), however, did not work as well. Most indicators were significantly reduced in the organic compared with the conventional system in rotation 1 (Table 2). It was interesting to note that cropping systems that contained the most weeds also had the highest ground beetle numbers. When used as an indicator of ecosystem health, this suggests that plant diversity is important for beetle diversity and hence a healthy soil food web.



TABLE 2. Performance indicators for cropping systems tested in the Glenlea long-term crop rotation in 1995 and 1999.

Rot	System	Weeds density m ⁻²		Beetles no. per trap		Flax Yield kg ha ⁻¹		Energy Use Efficiency, Output/input	Soil P kg ha ⁻¹	Net Income \$ ha ⁻¹ yr ⁻¹ (input cost)
		1995	1999	1995	1999	1995	1999	1992-1999	2003	1992-1999
1	Conven'l	16	189	19.3	63	1877	1378	7.1d	41.3	251 (104)
	Organic	12	532	18.7	76	961	606	13.0c	29.3	235 (43)
2	Conven'l	15	91	18.7	32	1809	1827	NA	21.0	NA
	Organic	6	128	18.7	75	1023	993	NA	32.6	NA
3	Conven'l	4	40	12.7	33	1712	1454	19.8b	21.3	360 (71)
	Organic	6	110	17.7	37	1373	1379	38.9a	<10	350 (36)
	Prairie	NA	5	18.7	15	NA	NA	NA	NA	NA
Rotation		**	**	NS	**	*	*	***	NA	NA
System		NS	***	**	***	***	***	**	NA	NA
RxS		NS	***	NS	***	NS	NS	**	NA	NA

*, **, *** denotes significance at p<0.10, p<0.05, p<0.01 respectively; NS - Not Significant; NA - Not Available

The main drawback of using alfalfa hay crops to facilitate crop input reduction in this study was soil P “mining”. Recent soil test results (Table 2) show extremely low soil P levels in the organic system where alfalfa has been used in 50% of the rotation. Similar observations of low available soil P were made on Manitoba farms where organic management had been practiced for several decades (Entz et al., 2001). The long-term effects of organic management on available soil P levels are not well understood. It is important to note that about 50% of P in prairie soils resides in the organic pool, and is not accounted for in traditional soil tests (Prasad and Power, 1997).

Results from Glenlea show that by including soil-building crops such as alfalfa and sweetclover in rotations, inputs can be reduced without significant yield reductions in some instances. Clearly, an integrated ruminant-grain farm would be in the best position to capture these rotational benefits. Limitations to organic production include phosphorous mining in the alfalfa-based rotation and an increase in wild mustard in all rotations.

2. Pesticide-Free Production (PFP)

A participatory, on-farm study was conducted to assess the potential of PFP to be implemented on typical farms, and the level of success farmers experienced with PFP. PFP prohibits the use of in-crop pesticide and seed treatment during one crop year, as well as prior use of residual pesticides. Synthetic fertilizer use is permitted, as are pre-emergent applications of non-residual pesticides.

A total of 71 farmers, representing 120 fields and 11 crops participated in the study. Fields and farmers were grouped based on whether or not fields 1) achieved PFP certification and 2) were in transition to organic. Certification was achieved for 83% of the participating farmers. Spring cereals were the most likely crops to achieve PFP certification. Yields in all groups were slightly lower than conventional averages in Manitoba, but were not significant among groups. Weed densities were higher (P=0.065) in non-certifiable fields than in certifiable fields. Most farmers reported manageable weed densities the year following PFP. Soil conservation practices were used on a high proportion of PFP fields.



TABLE 3. Agronomic characteristics of fields on which Pesticide-Free Production (PFP) was attempted in 2000 and 2001. (Adapted from Nazarko et al., 2003).

Management tactic used	Non-certifiable fields	Certifiable, non-transitional fields	Certifiable, transitional fields	P-value for group effect
Forage underseeded in PFP crop	5.4b	21.8a	28.6a	0.038
Forage in rotation history	24.2	29.4	37.7	0.33
Forage year before PFP attempt	9.4b	13.2ab	28.6a	0.048
Fallow year before PFP attempt	12.5	13.2	21.4	0.59
Reduced tillage	64.7a	47.2	18.5b	0.0004
Preseed herbicide	42.2a	32.1	0.0b	0.0003
In-crop tillage	12.1a	0.0b	17.9a	0.0026
Higher seeding rate	27.3b	49.0a	57.1a	0.02
Narrow row spacing	34.4	51.9	53.9	0.12
Certified seed	62.5	40.0	60.7	0.78
Weed patch treatment	6.1	13.2	0.0	0.13
Seeding date rel. to area average	-6.0	-8.1	-6.7	0.88

Management practice associated with PFP are shown in Table 3. Results indicate that forages in rotation played an important role in the success of PFP, and that transitional farmers relied more heavily on forages than conventional farmers. Success of PFP was also associated with use of higher seeding rates, however no differences in row spacing were noted. All three groups tended to seed earlier than the area average, indicating no tendency for study participants to delay seeding for weed control purposes.

A second study was conducted to determine if the demographic and attitudinal characteristics of farms and farmers participating in a PFP pilot project varied depending on the level of PFP implementation. Results are given in Table 4. Fields and farms on which PFP was implemented were relatively large. There were few demographic differences among groups. Demographic characteristics of participating farmers were typical for Manitoba (data not shown). Attitudinal orientation (adherence to a conventional versus an alternative agricultural paradigm) of participants who were not in transition to organic production were similar to a random sample of Manitoba farmers (data not shown). However, attitudes for certifiable, transition farmers were significantly different than attitudes among the non-certifiable group. Therefore, the main conclusion of this study is that attitude was the most important factor affecting success of PFP on Manitoba farms.



TABLE 4. Demographic characteristics of farms on which Pesticide-Free Production was attempted. Adapted from Nazarko et al. (2004).

Demographic Characteristic	Non-certifiable fields	Certifiable, non-transitional fields	Certifiable, transitional fields	P-value for group effect
Mean farm size (ha)	669	655	528	0.51
Mean field size (ha)	31.3	25.5	38.6	0.065
Pedigreed seed farms (%)	20.0	21.4	34.8	0.26
Livestock farms (%)	46.7	42.9	43.5	0.87
Sustainable organization member (%)	12.5	29.6	30.4	0.38
PFM was financially beneficial (%)	-	90	90	NA
Expect increase in future pesticides (%)	-	6.0	0.0	NA
More tolerant to weeds (%)	28.6	30.0	54.6	0.36
Net farm income >\$25,000 (%)	83.3	52.0	66.7	0.61
Post-secondary education (%)	76.9	65.4	50.0	0.10
Mean ACAP* score	88.0a	92.2ab	97.9b	0.046

*ACAP – Alternative-Conventional Agricultural Paradigm Scale; score range from 24 to 120 with lower scores indicating adherence to a conventional paradigm (Beus and Dunlop, 1991).

Technology Adoption for Reducing Crop Inputs

In order to ensure that research related to input use reduction strategies is effective, we must understand the adoption of new agricultural practices. The traditional theory of technology adoption has been based on the diffusion of innovations model (Nazarko et al., 2003c). This theory has usually been applied to commercialized, simple innovations, such as the use of a new type of machinery. The effectiveness of this theory in predicting adoption of complex, non-commercial innovations has been criticized, especially in the case of innovations related to environmental protection (de Buck et al. 2001). These are referred to as "environmental innovations". There are many reasons for the distinction between environmental innovations and traditional agricultural technology. Innovations under the traditional model are generally simple and require no major reworking of farm structure. Innovations such as cropping system redesign are complex packages of methods, and are not universally applicable (different practices are appropriate for different farms). In addition, the benefits of environmental innovations do not necessarily accrue to the adopters, but rather to society as a whole (e.g. the protection of water supplies). Therefore short-term direct economic gain to the farmer may not be obvious (Saltiel et al. 1994; Nazarko et al., 2003c).

Characteristics of farmers adopting sustainable practices include farmers’ information sources, structural conditions of the farm (e.g., cropping system; integration of livestock) and especially farmers’ attitudes or beliefs (Nazarko et al., 2003b). These factors should be given due consideration when planning education and extension programs as well as agricultural policy.

Conclusions

Industrialized farming systems that reduce crop inputs through strategies of input substitution and cropping system redesign are in their infancy. Organic farmers have made the most progress to date. Farmers who use diverse crop rotations, especially in combination with reduced tillage, also have incorporated regenerative processes and ecological continuity into their farming systems.

Integrated cropping systems that employ a combination of chemical inputs and management/knowledge intensive approaches are likely to be the most sustainable systems in the long term. Policy and market incentives for adopting such systems in the Canadian prairie region are also in their infancy, however this is changing.



Also, there are examples of where reducing off-farm inputs through strategies outlined in this paper result in higher net returns. Results of the on-farm pesticide reduction pilot program clearly demonstrate that farmer attitude is crucial to the success of reduced pesticide use systems.

Acknowledgements

Funding from the Manitoba Rural Adaptation Council, Covering New Ground and the Natural Sciences and Engineering Research Council of Canada is also gratefully acknowledged.

References

1. Agriculture and AgriFood Canada Market and Industry Services Branch. 2002. Organic Industry Factsheet. [Online]. Available at <http://ats-sea.agr.ca/supply/e3313.htm>. [1 May 2003].
2. Bowden, R., J. Shoyer, K. Roozeboom, M. Claasen, P. Evans, B. Gordon, B. Heer, K. Janssen, J. Long, J. Martin, A. Schlegel, R. Sears, and M. Witt. 2001. Performance of wheat variety blends in Kansas. Kansas State University Agric. Extension Bull. 128 (www.oznet.ksu.edu/library/crpsl2/SRL128.pdf) [13 May 2003]
3. Blackshaw, R.E. and L.J. Molnar. 2003. Nitrogen fertilizer timing and placement effect on weeds and spring wheat. Weed Sci. Soc. Am. Abstr. 43:56.
4. Bourgeois, L., J. Moes and E.H. Stobbe. 1996. Impact of threshing on hard red spring wheat seed vigour. Can. J Plant Sci. 76:215-221.



5. Braul, A.J. and M.H. Entz. 2003. Managing dormancy – the key to successful self-regenerating legume systems. Proc. Can. Soc. Agron. Montreal, QC (in press).
6. deBuck, A.J., I. Van Rijn, N.G. Roling and G.A.A. Wossink. 2001. Farmers' reasons for changing or not changing to more sustainable practices: an exploratory study of arable farming in the Netherlands. *J. Agr. Educ. Ext.* 7:153-166.
7. Derksen, D.A., R.L. Anderson, R.E. Blackshaw and B. Maxwell. 2002. Weed dynamics and management strategies for cropping systems in the Northern Great Plains. *Agron. J.* 94:174-185.
8. Dobbs. 1992. Northern Plains Sustainable Agriculture Society Newsletter. Jan., 1992.
9. Douglas, A. 2002. Earn premiums but keep your sprays. *Country Guide*. Jan. 2002. 26B-28B.
10. Entz, M.H., R. Guilford and R. Gulden. 2001. Productivity of organic crop production in the eastern region of the Northern Great Plains: a survey of 14 farms. *Can. J Plant Sci.* 81:351-354.
11. Entz, M.H., V.S. Baron, P.M. Carr, D.W. Meyer, S.R. Smith, Jr. and W.P. McCaughey. 2002. Potential of forages to diversify Northern Great Plains cropping systems. *Agron. J* 94:240-250.
12. Faechner, T., K. Norrena, A.G. Thomas and C.V. Deutsch. 2002. A risk-qualified approach to calculate locally varying herbicide application rates. *Weed Res.* 42:476-485.
13. Frick, B. 2000. Weed management. Pages 3-30. In *Back to basics: A manual for weed management on organic farms*. Organic Producers Association of Manitoba, Virden, MB.
14. Hoepfner, J.W. 2001. Energy dynamics of organic and conventional rotations across prairie Canada. M.Sc. thesis. Univ of Manitoba, Winnipeg, MB.
15. Ingham, E. R. 2003. http://soils.usda.gov/sqi/SoilBiology/soil_food_web.htm [Verified 14 May 2003]
16. Jedel, P.E., J.H. Helm and P.A. Burnett. 1998. Yield, quality and stress tolerance of barley mixtures in central Alberta. *Can. J Plant Sci.* 78:429-436.
17. Krupinsky, J.M., K.L. Bailey, M.P. McMullen, B.D. Gossen and T. K. Turkington. Managing plant disease risk in diversified cropping systems in the Northern Great Plains. *Agron. J.* 94:198-209.
18. Magnusson, E. 2002. Consumer interest in and willingness-to-pay for Pesticide Free Production food products: a probit analysis. M.Sc. Thesis, Univ of Manitoba, Winnipeg, MB. 178 pp.
19. Matus, A., D.A. Derksen, F.L. Walley, H.A. Loepky and C. van Kessel. 1997. The influence of tillage and crop rotation on nitrogen fixation in lentil and pea. *Can J Plant Sci.* 77:197-200.
20. Moyer, J.R., R.E. Blackshaw, E.G. Smith and S.M. McGinn. 2000. Cereal cover crops for weed suppression in a summerfallow-wheat cropping sequence. *Can J Plant Sci.* 80:441-449.
21. Mundt, C. C. 1994. Use of host genetic diversity to control cereal diseases: implications for rice blast. Pages 293-308 in: *Rice Blast Disease*, Zeigler, R. S., Leong, S. A., and Teng, P. S., eds. CAB International, London.
22. Nazarko, O.M., R.C. Van Acker, M.H. Entz, A. Schoofs and G. Martens. 2003. Pesticide Free Production of field crops: results of an on-farm pilot project. *Agron. J.* (in press).
23. Nazarko, O.M., R.C. Van Acker, M.H. Entz, A. Schoofs and G. Martens. 2004. Pesticide Free Production: characteristics of farms and farmers participating in a pesticide use reduction pilot project in Manitoba, Canada. *Am. J. Alt. Agric.* (in press).
24. Nazarko, O.M., R.C. Van Acker and M.H. Entz. 2003. Strategies and tactics for herbicide use reduction in field crops in Canada: a review. *Can J Plant Sci.* (in review).



25. Prasad, R. and J.F. Power. 1997. Soil fertility management for sustainable agriculture. Lewis Publishers. New York.
26. Rosset, P. and M. Benjamin. 1994. The greening of the revolution. Ocean Press, Melbourne, Australia.
27. Saliel, J., J.W. Bauder and S. Palakovich. 1994. Adoption of sustainable agricultural practices: diffusion, farm structure and profitability. *Rural Sociol.* 59:333-349.
28. Szumigalski, A.R., R.C. Van Acker and M.H. Entz. 2002. Agronomic value of annual sole versus intercrops. *Proc. Canadian Weed Science Soc.*, Saskatoon, SK. (in press).
29. Thiessen Martens, J.R. and M.H. Entz. 2001. Availability of late-season heat and water resources for relay and double cropping with winter wheat in prairie Canada. *Can. J Plant Sci.* 81:273-276.
30. Wallace, J. (ed.) . 2001. Organic field crop handbook. 2nd edition. Canadian organic growers Inc. Ottawa, ON. 292 pp.
31. Wolfe M.S., 1997. Variety mixtures: concept and value. In: Variety Mixtures in theory and practice, Wolfe, M. S. (ed.). European Union Variety and Species Mixtures working group of COST Action 817. Online at: www.scri.sari.ac.uk/TiPP
32. Zentner, R.P., D.A. Wall, C.N. Nagey, E.G. Smith, D.L. Young, P.R. Miller, C.A. Campbell, B.G. McConkey, S.A. Brandt, G.P. Lafond, A.M. Johnston and D.A. Derksen. 2002. Economics of crop diversification and soil tillage opportunities in the Canadian Prairies. *Agron J.* 94:216-230.
33. Zhu, Y., H. Chen, J. Fan, Y. Wang, Y. Li, J. Chen, J. X. Fan, S. Yang, L. Hu, H. Leung, T. W. Mew, P. Teng, Z. Wang, and C. C. Mundt. 2000. Genetic diversity and disease control in rice. *Nature* 406: 718-722.

Systems Thinking in Crop Production

Martin H. Entz, Orla M. Nazarko, Rene C. Van Acker and Allison Schoofs
 Department of Plant Science, University of Manitoba
 Winnipeg, Manitoba, Canada R3T 2N2 Email: m_entz@umanitoba.ca

“In switching from one system to another, it is extremely important to remember that one is switching systems and not merely changing technologies”.

Fred Kirschenmann, a farmer from North Dakota, and current director of the Leopold Centre in Iowa stated that:

In this presentation, Martin Entz will challenge farmers to think of their farm as a system. Three main system components will be stressed: 1) technology, 2) uncertainty (weather and markets), and 3) on-farm management. The way in which these components are used by farmers must reflect their goals. The farming system includes factors that can be cThis system consists of technology, agronomic and System components will be Different parts of the system include of the review some of the processes farmers must go through to change the way on-farm

1. Increased knowledge of biological and ecological processes

In their 1984 book on organic farming, Bezdicsek and Power suggest that organic farming involves the substitution of biological mechanisms for chemical and mechanical inputs (Bezdicsek and Power, 1984). Many others have also argued for the incorporation of more natural ecological processes into crop production systems (e.g., Soule and Piper, 1992; Jackson and Jackson, 2002).



FarmTech 2004

Global Perspectives... Local Knowledge

Proceedings

Conventional crop production, which is increasingly about simplified systems involving only a few crops and high inputs of fertilizers and pesticides, has ignored many important biological and ecological processes. A whole generation of farmers and agronomists has been trained in these conventional crop production systems. As a result, few farmers and agronomists truly appreciate the importance of nature in crop production, and even fewer have the ecological knowledge to farm without chemical inputs.