Crop Productivity With Alternative Input Use And Cropping Diversity Strategies

S.A. Brandt[1], D. Ulrich[1], A.G. Thomas[2] and O.O. Olfert[2]

[1] Scott Research Farm, Scott Sask.
[2] Saskatoon Research Centre, Saskatoon Sask.

Introduction

Farmers on the Canadian prairies, are urged to become more diversified in what they produce and to reduce their reliance on fertilizers and pesticides. It is thought that these changes will address food safety and environmental concerns, while conserving the soil resource and providing adequate economic returns. These changes are being proposed in the belief that they will adequately address these issues. However, in most cases, dealing with one of these issues can involve tradeoffs with respect to others.

To date relatively few studies have ben conducted to develop an understanding of how crop production systems function. Most such studies have been based on crop rotations. To enhance our understanding of sustainability, additional system studies are clearly needed.

This research was initiated to investigate how alternative input use and cropping diversity strategies affect sustainability aver a 12 -18 year period.

Materials and Methods

The study was started in 1994 at the Scott Research Farm. AA detailed description of the treatments used and how they were applied is given in the preceding paper by Ulrich *et al.* That information is not repeated here, but a few related pieces of information are provided.

The study is based on three levels of cropping diversity and three levels of input use along with the 6 year cropping sequences as described previously (Table 1).

Table 1. Summary of cropping systems

Crop diversity	**Input level**	**Crop sequence**[1]
LOW (low diversity of annual grains)	High	F_T-W-W-F_T-C-W
	Reduced	L_{GM}-W-W-F_C-C-W
	Organic	L_{GM}-W-W-L_{GM}-C-W
DAG (diversified using annual grains)	High	C-R-P-B_M-F_X-W
	Reduced	C-R-P-B_M-F_X-W
	Organic	L_{GM}-W-P-B_M/S_C-S_{CGM}-C
DAP (diversified using annual grains and perennial forages)	High	C-W-B_F-O/B_R&A-H-H
	Reduced	C-W-B_F-O/B_R&A-H-H
	Organic	C-W-B_F-O/B_R&A-H-H

[1] F_T = tillage fallow, W = wheat, C = canola, L_{GM} = lentil green manure, F_C = chemical fallow, P = field pea, B_M = malt barley, B_F = feed barley, S_C = sweet clover, S_{CGM} = sweet clover green manure, R = fall rye, F_X = flax, O = oats, B_R&A = bromegrass-alfalfa, and H = hay.

Some additional information specific to this report is;

-gravimetric soil moisture was determined to 90 cm depth before seeding and after harvest.

- available soil N and P was determined to 60 cm depth on soil samples taken in late October of each year.
- weed biomass was determined on 2 m2 areas per plot at physiological maturity of the crop.
- grain yield was determined at crop maturity on a 1.2 x 40 m area per plot.
- forage yield was determined on a 1.0 x 40 m area per plot at soft dough stage of oats and 10% bloom of alfalfa.
- protein was determined by near infrared reflectrometry on grain samples and by wet chemistry (kjeldahl) on forages.

Although the treatments were initiated in 1995, they were all applied on barley stubble. For this reason, yield data from 1995 is not included in this report.

For the 5 year period, 1996-2000, 2 years, 1997 and 1998 had below normal growing season precipitation, while 1996 and 1999 were above normal (Table 2). 2000 was only slightly above normal, but soil moisture was relatively high in spring of 2000. There were similarities in relative performance of treatments during years that were drier than normal that differed from years that were wetter than normal. For that reason, results have been summarized across dry and wet years, dry years being 1997 and 1998, wet years being 1996, 1999 and 2000.

Table 2. Growing season precipitation (mm) at Scott during 1996-2000.

Month	1996	1997	1998	1999	2000	Long Term
May	32	27	5	46	24	36
June	41	60	105	43	33	60
July	106	26	16	78	94	59
August	43	26	14	54	52	45
TOTAL	221	138	140	221	203	200

Results and Discussion

At seeding, differences in soil moisture between input levels or cropping diversity treatments did exist when combined over years, however differences were small (Table 3). There were some significant cropping phase effects (data not shown), with treatments after chemical and tillage fallow having the greatest amounts of stored moisture. Treatments on green manure fallows were sometimes equal to tillage fallow, but on a few occasions they were lower. Treatments that had grown a grain or forage crop the previous year had the least soil moisture, with little difference between treatments.

Table 3. Influence of input and cropping diversity on available spring soil moisture (mm) to 90 cm depth (1996-2000 avg).

Input Level	Cropping Diversity Level		
	LOW	DAG	DAP
Organic	151abc	150ab	152abc
Reduced	158a	150abc	149c
High	155ab	149abc	145c

As expected, available soil N was lowest for the organic systems, reflecting that fertilizer N was not applied to these treatments (Table 4). Low soil N with reduced inputs was related to use of direct seeding, which likely reduced mineralization of N from soil organic matter. Rates of N application in reduced input systems were slightly lower than for high inputs, but would not fully account for the differences in soil N. The LOW diversity systems generally had higher soil N than DAG or DAP reflecting N mineralization in the fallow or green manure phases of these systems.

Table 4. Influence of input and cropping diversity on available N in fall (kg/ha) to 60 cm depth (1995-1999 avg).

Input Level	Cropping Diversity Level		
	LOW	DAG	DAP
Organic	49cde	46ef	41f
Reduced	56bc	51bcde	46ef
High	82a	57b	55bcd

Values followed by the same letter do not differ (P=0.05)

Weed biomass data was collected to provide an indication of the impact of weed competition on crop yield. A more comprehensive description of weed biomass results is provided by Ulrich *et al* in the poster section of this publication.

When averaged across years and systems, the organic systems had higher weed biomass than reduced or high systems (Table 5.) However, the differences were relatively small. The mean values are somewhat deceiving because several interactions occurred between years, input level and diversity level. The consequence of these interactions was that in several cases, weeds likely had a significant impact on organic yields, and in a few cases on reduced input yield. These are discussed in more detail along with yield responses.

Table 5. Influence of input and cropping diversity on weed biomass (kg/ha) at crop maturity (1996-2000 avg)

Input Level	Cropping Diversity Level		
	LOW	DAG	DAP
Organic	236b	568a	295b
Reduced	124c	139c	131c
High	68c	136c	73c

Wheat grown on fallow (including chem fallow and green manure) or wheat stubble and barley all showed similar trends when grouped over dry and wet years (Table 6). In all cases, the organic systems were lowest yielding, partly due to increased weed competition, but also largely due to reduced N supply. During dry years, reduced inputs provided yield that was similar to high inputs, but during wet years, high inputs yielded more.

Differences in weed competition between high and reduced systems were relatively small. The observed yield differences would be consistent with differences in available N. In years of below normal moisture, the demand for N was lower, and yields were similar. In wet years when crop demand was greater the reduced systems with less N failed to reach the same yield levels as the high input systems.

Yield of organic barley was only about half that of reduced and high input barley in dry years. It was anticipated that organic barley would perform well due to the reportedly greater weed competitiveness of barley than other crops. However in the organic DAG system, the crop was under sown to sweet clover, and this likely competed with the crop reducing yield. In the organic DAP system, barley was grown 3 years after an N fixing legume, which may have further reduced available N, particularly N mineralized during the growing season. Such differences would not be readily detected by conventional soil testing in late fall.

Where wheat was grown on canola stubble a somewhat different trend appeared. In dry years, yield was quite low for the high input wheat. It is likely that residues of Edge applied for weed control in the preceding canola crop were causing damage. This damage was only evident in dry years, and only in high input wheat, although the same herbicide treatment was applied to canola in the reduced input system. Portions of some wheat rows showed considerable symptoms while others showed none. Thus this damage may be a result of uneven herbicide distribution due to tillage being applied in one direction only.

In wet years relative yields for the 3 input systems followed a similar pattern to yield on wheat stubble, although the reduced system was still at least equal to high inputs.

Canola was usually low yielding in the organic systems. Weed competition was relatively high in the organic systems, partly because canola would not tolerate post emerge harrowing, a practice that was used extensively in larger seeded organic crops. In addition, organic canola was seeded later as part of the weed control strategy, and *B.rapa* varieties were used, as opposed to *B. napus* in reduced and high systems.

In dry years, high input canola was low yielding, mainly because crop establishment was poor. This was most probably due to the seed bed drying out as a consequence of pre seeding tillage used with high inputs.

Table 6. Yield (kg/ha) of crops in individual cropping phases as influenced by input level during dry (1997 and 1998) and wet (1996,1999,2000) years.

Cropping Phase	Input Level	Dry Years	Wet Years
Wheat on fallow	Organic	1402b	2637c
	Reduced	2035a	3399b
	High	2076a	3962a
Wheat on wheat stubble	Organic	1084b	1779c
	Reduced	1518a	2726b
	High	1461a	3266a
Barley	Organic	900b	2352c
	Reduced	1829a	3758b
	High	1781a	3976a
Wheat on canola stubble	Organic	1296b	1866c
	Reduced	1808a	2808b
	High	1296b	3156a
Pea	Organic	828b	2742b
	Reduced	1943a	3325a
	High	2200a	2729b
Canola	Organic	534b	821c
	Reduced	1179a	1496b
	High	700b	1862a
Flax	Reduced	643a	1306a
	High	554a	1292a
Fall Rye	Reduced	1700a	2062a
	High	1555a	1987a
All Forages	Organic	980	1282
	Reduced	1346	1693
	High	1281	1716

Yields for the same cropping phase in the same column followed by the same letter do not differ (P=0.05)

Because pea was able to fix N to meet most of it's needs, it behaved quite differently than other crops. In dry years, high input was highest yielding. Lower pea yield with organic in dry years was associated with delayed seeding, which resulted in the crop flowering during periods of greater climatic stress.

Reduced input pea may have been adversely affected by winter annual weed and volunteer rye growth, that was allowed to remain until just prior to seeding in 1998. This did reduce seedbed moisture, and reduced pea emergence in that one case. During 1997, organic pea was quite weedy because post emerge harrowing was not sufficiently aggressive.

Under wet conditions, reduced input pea was higher yielding than either high or organic input pea, and organic pea equaled yield with high inputs. It is worth noting that pea can be seeded quite deep. This allowed organic pea to tolerate rather aggressive post emerge harrowing. The result was that weed control in organic pea was almost equal to high or reduced inputs with the one exception as noted above.

Results with pea raise an interesting question regarding whether we would be able to boost yield of other crops in reduced input systems simply by increasing N application rates.

Flax was not grown in any of the organic systems. Flax yield did not differ significantly between reduced or high inputs during either dry or wet years (data not shown).

Fall rye was grown on canola stubble in the high and reduced input systems. If residues from Edge affected yield of high input wheat on canola stubble, it is likely that it had at least as large an impact where fall rye was grown. This is a possible explanation for slightly higher yield with reduced than high inputs and both dry and wet conditions although the differences were not statistically significant(data not shown).

Forage yield was highly variable because forages failed to establish adequately in several years. For this reason, it was difficult to distinguish any trends.

Yields for each of the input and diversity systems reflect the composite of individual crop responses. Under dry conditions, the reduced input systems tended to be favored with all diversity systems (Figure 1a). Yield with reduced and high inputs was highest for DAG and lowest for LOW diversity. With organic inputs, DAP was highest yielding and DAG lowest. In wet years, yield increased in the order DAP>DAG>LOW for organic, but for reduced and high inputs the relationship was DAG>DAP>LOW (Figure 1b). The general trend for high inputs to provide higher yield than reduced inputs was maintained for LOW and DAP. However with DAG these 2 input systems provided similar yields. This reflects the presence of several crops in the DAG system that performed relatively well with reduced inputs in wet years.

Summary

Organic Inputs

Comparisons at the system level indicated that the organic input systems were consistently lower yielding than reduced or high inputs. However within individual phases of the systems, organic inputs occasionally equaled yield for high inputs. Increased weed competition and a reduced supply of N were major factors affecting yield of organic systems. Other yield limiting factors in organic systems included delayed seeding and use of *B rapa* canola. Where weeds were adequately controlled, and the N limitation overcome by fixation with pea, organic yield was similar to high inputs. Where crop stands were reduced in high input wheat or canola, organic systems also provided equivalent yield.

To date, only one crop failure has occurred with the organic systems. That involved canola where stand establishment was poor in combination with high weed densities. In general, organic weed control improved over years, mainly as a result of increased experience with techniques used. This would suggest that organic systems may increase relative to other systems if further improvements can be made to weed control methods, particularly if they permit earlier seeding. The impact of N deficiency on organic crops suggests that N fixing legumes are critical to long term viability of such systems, and that improving N supply may require a considerable number of years. Other methods of supplying N for organic crops like manures or composts have not been investigated to date, but are planned for the next cycle of the study.

Reduced Inputs

Reduced input systems performed well, particularly in drier than normal years. Nitrogen restricted yield responses in years of more favorable moisture. Earlier control of weeds before seeding in some cases may improve these systems, as would strategies to improve N supply. These could include some tillage where residues warrant, or increased rates of N.

High inputs

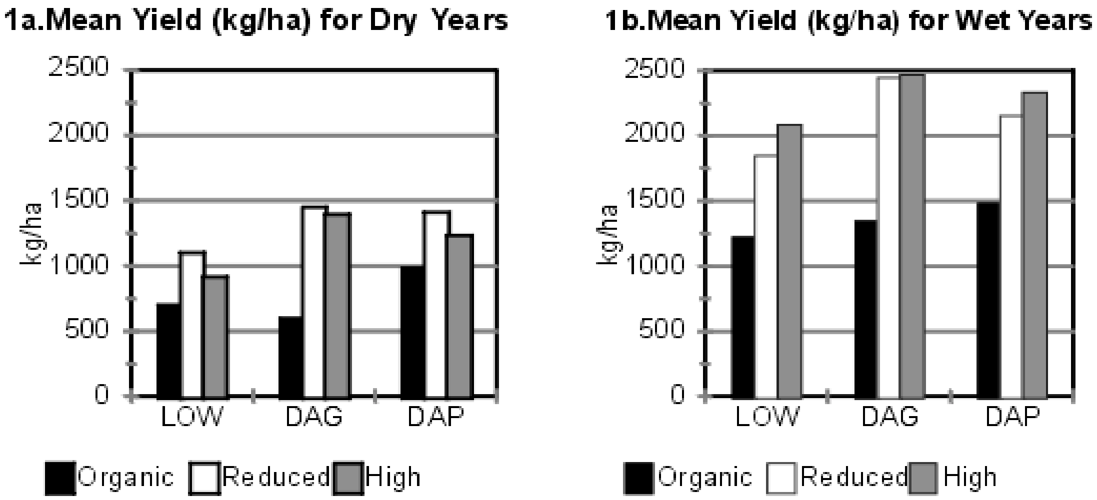
High input systems sometimes performed less well in dry years. To some extent this was related to pre-seeding tillage. Restricting tillage may aid in improving crop stands in dry years.

Diversity Systems

The LOW diversity systems were generally the simplest to manage, and performed relatively well in dry years. Systems with a high frequency of fallow were developed as part of a drought strategy. The compromise is that they can be less productive in wet years, and fallow has been demonstrated to be a major factor contributing to soil degradation.

The DAG systems performed well in all years. A possible weakness is the fall rye crop which consistently provided disappointing yields, particularly since the crop has such a low economic value. However, it may be possible to improve it’s performance.

Frequent failure of the forages in these systems were a major weakness. Many of the problems associated with forage establishment are due to the use of a nurse crop. Changing how the forages are seeded could substantially improve their performance.



1a.Mean Yield (kg/ha) for Dry Years

1b.Mean Yield (kg/ha) for Wet Years

Figure 1. Mean yield for 6 phases of 3 input systems and 3 levels of cropping diversity during dry (a,1997 and 1998) and wet (b, 1996,1999, and 2000) years.