Crop Sequence Economics in Dynamic Cropping Systems

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Introduction

No-till production systems allow more intensified and diversified production in the northern Great Plains. While diversified cropping systems have the potential to increase profitability by increasing crop productivity and decreasing production costs, there is an increased need for information on improving economic returns through crop sequence selection.

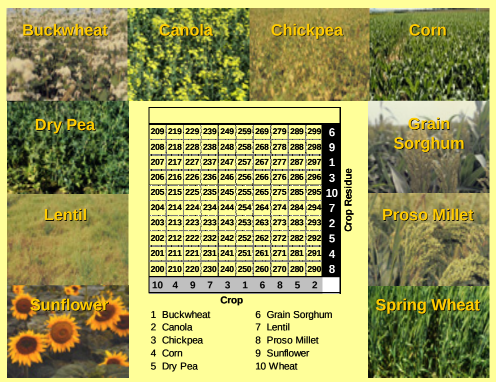

Figure 1. Diagram of one replicate of the crop x crop residue matrix used to evaluate the influences of crop sequence on crop production. During the first year 10 crops were no-till seeded into a uniform crop residue. During the second year, the same 10 crops were no-till seeded perpendicular over the residue of the previous year's crops.

Table 1. 1999-2006 Average crop prices including government loan deficiency payments.

Crop	Price ($ kg^{-1})
Buckwheat[3]	0.25
Canola[1]	0.22
Chickpea[2]	0.35
Corn[1]	0.08
Dry pea[1]	0.14
Grain sorghum[1]	0.08
Lentil[1]	0.27
Proso millet[1]	0.08
Spring wheat[1]	0.12
Sunflower[1]	0.24

[1]USDA-NASS
[2]USDA-AMS
[3]Agriculture and Agri-Food Canada
Note: Buckwheat price data are Canadian average prices; grain sorghum and proso millet are South Dakota average prices; chickpea are U.S. average prices; all others are North Dakota average prices.

Methods and Materials

Field research was conducted on the Area IV Soil Conservation District/ARS Cooperative Research Farm located 6 km southwest of Mandan ND to determine the influences of previous crops and crop residues on seed production of buckwheat (*Fagopyrum esculentum*), canola (*Brassica napus*), chickpea (*Cicer arietinum*), corn (*Zea mays* L.), dry pea (*Pisum sativum* L.), grain sorghum (*Sorghum bicolor* L.), lentil (*Lens culinaris*), proso millet (*Panicum miliaceum* L.), sunflower (*Helianthus annus* L.), and spring wheat (*Triticum aestivum* L.). Research began in 2002 by seeding the 10 crops in adjacent strips. The following year the same 10 crops were seeded perpendicular to the original strips creating a 10-by-10 crop x crop residue matrix (Figure 1). In 2003, a second site was initiated so each crop sequence would be present for 2 years (2003 and 2004). Crops were arranged using a randomized complete block experimental design with strip-block treatments and four replicates. Further details of the field study may be found in Tanaka et al. (2007).

Enterprise budgets were constructed for each crop based on the field operations and inputs used. Production activities and inputs used for each crop were consistent across all crop residue treatments within a year. Net returns for each crop sequence were calculated based on the estimated costs and observed yields, and using 1999-2006 average prices adjusted to include average government loan deficiency payments (Table 1). Net returns within each crop residue treatment are presented as net return differences from the average of all 10 crops to facilitate relative comparisons among crops. Net returns within each crop are presented as net return differences from each crop grown on its own crop residue to quantify the economic value of the "rotation effect" for each crop.

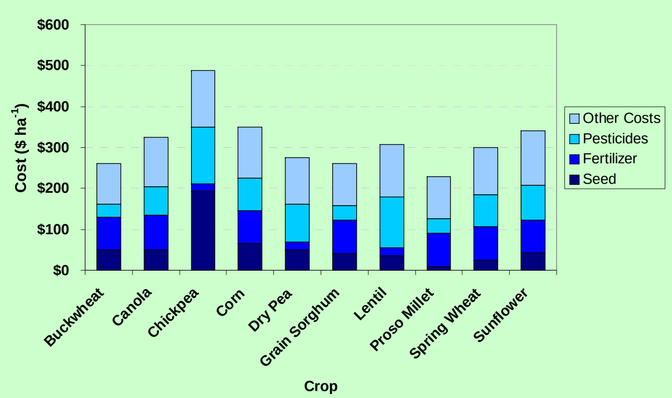

Figure 2. Production costs for each crop. Other costs include machinery operating and ownership costs, labor, and interest on operating costs.

Planning the current season: Given the previous crop, what will likely be the most profitable crop this season?

Crop (columns) / Crop Residue (rows)

Crop Residue	Buck-wheat	Canola	Chick-pea	Corn	Dry Pea	Grain Sorghum	Lentil	Proso Millet	Spring Wheat	Sun-flower
Buck-wheat	***103***	-14	-102	-126	30	-20	60	79	73	-82
Canola	***96***	-66	-51	-94	6	-22	48	65	47	-30
Chick-pea	63	-60	-97	-43	25	0	-4	***71***	59	-15
Corn	***95***	-37	-89	-92	41	-56	57	52	52	-23
Dry Pea	***121***	-88	-45	-64	-28	-23	36	67	53	-29
Grain Sorghum	62	-43	-82	-54	28	-32	19	***65***	61	-23
Lentil	***72***	-86	-63	-56	28	3	7	67	62	-35
Proso Millet	54	-73	-28	-70	61	-91	***81***	37	44	-15
Spring Wheat	83	-106	-34	-75	30	-40	***97***	25	43	-23
Sun-flower	***97***	-63	-85	-81	77	-39	49	74	59	-88

Example: If the previous crop was Canola, Buckwheat net returns were $96 ha^{-1} *higher* and Corn net returns were $94 ha^{-1} *lower* than the average for all 10 crops.

Example: Regardless of the previous crop, Buckwheat would have produced net returns higher than the average for all 10 crops, and would have produced the highest net returns for 6 of the 10 crop residues.

Figure 3. 2003-2004 average departure of net returns ($ ha^{-1}) from the average across all crops within each crop residue. Blue denotes highest net returns within each row, red denotes lowest net returns within each row. Note: Net return departure values and relative rankings within rows are sensitive to price assumptions.

Looking ahead: What will be the effect of the crop grown this year on profitability next year?

Example: If considering growing Corn, following Dry Pea would have *increased* net returns by $88 ha^{-1} and following Buckwheat would have *decreased* net returns by $37 ha^{-1} relative to growing corn after corn.

Example: Following Dry Pea, net returns for all subsequent crops would have been higher than growing each crop on its own residue, and would have produced the highest net returns in 4 of the 10 subsequent crops.

Crop (columns) / Crop Residue (rows)

Crop Residue	Buck-wheat	Canola	Chick-pea	Corn	Dry Pea	Grain Sorghum	Lentil	Proso Millet	Spring Wheat	Sun-flower
Buck-wheat	0	***24***	-29	-37	-4	19	11	10	-27	10
Canola	20	0	49	24	0	44	27	25	-26	90
Chick-pea	-15	4	0	72	16	63	-27	28	-17	102
Corn	-5	4	-14	0	9	-15	12	-14	-45	72
Dry Pea	***80***	12	90	***88***	0	77	50	***61***	***15***	125
Grain Sorghum	-47	-11	-16	29	-13	0	-35	-10	-46	62
Lentil	10	-6	51	75	35	***83***	0	40	3	98
Proso Millet	-18	-4	76	51	***58***	-22	64	0	-25	108
Spring Wheat	38	-10	***96***	72	53	56	***106***	15	0	***126***
Sun-flower	-10	-28	-16	5	39	-5	-3	2	-45	0
Range:	127	52	125	125	71	105	142	74	60	126

Figure 4. Rotation effect on net returns. Within each crop, 2003-2004 average departure of net returns ($ ha^{-1}) from those obtained when growing that crop on its own residue. **Blue** denotes highest net returns within each column, red denotes lowest net returns within each column. The ranges in net returns for each column are shown at the bottom of each column, calculated as the difference between the highest and lowest net returns within each column. Note: While net return departure values are sensitive to price assumptions, the relative rankings within columns are not.

Results and Discussion

- ***Growing season precipitation*** - In 2003 and 2004 was below average, so the results reflect crop sequence effects under dry conditions. Results may have been substantially different under wet conditions.
- ***Production costs*** – Costs ranged from $228 ha^{-1} for proso millet to $488 ha^{-1} for chickpea (Figure 2).
- ***Current season profitability*** - Using long-term average prices, buckwheat had the highest net returns on 6 of the 10 crop residue treatments, while lentil and proso millet had the highest net returns on 2 treatments (Figure 3). Canola and corn had the lowest net returns on 3 of the 10 crop residue treatments, chickpea had the lowest net returns on 2 treatments, grain sorghum and sunflower had the lowest net returns on 1 treatment. Results are sensitive to the price assumptions, and may change dramatically with price changes. This illustrates an opportunity in dynamic cropping systems to improve short-term profitability by responding to changing market conditions.
- ***Rotation effect*** – Crop sequence can have a substantial impact on net returns as shown by the range in net returns across crop residues within each crop (Figure 4). Lentil, buckwheat, chickpea, corn and sunflower net returns were the most sensitive to crop sequence with lentil exhibiting a range in net returns of $142 ha^{-1} depending on crop sequence. Lowest lentil net returns were observed following grain sorghum and highest net returns following spring wheat.
- ***Planning for both the current season and the rotation effect*** – In order to maximize profitability, it is important to look beyond the current season. Even though buckwheat was generally the most profitable crop (Figure 3), the rotational effects of buckwheat were generally small and often negative (Figure 4). While spring wheat was not the most profitable crop, it always had net returns higher than the average for the 10 crops (Figure 3). Spring wheat also had a higher rotational benefit than buckwheat for all crops except canola, so looking at a 2-year sequence, wheat may provide higher net returns than buckwheat.

Conclusion

Crop sequence has a significant effect on cropping system net returns. A dynamic cropping systems approach may offer opportunities for producers to increase economic returns; however, understanding potential crop sequence effects will be critical to avoiding costly mistakes. Management of dynamic cropping systems will need to be based not only on single-year profit opportunities, but also on subsequent crop sequence effects.

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