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Changes in grain transportation policy, rising input costs, favorable weather. and increasing concerns about environmental degradation are causing producers throughout western Canada to extend and diversify their cropping systems. In the Brown soil zone of southwestern Saskatchewan, there has been significant expansion in the areas planted to lentil, pea, and canola, at the expense of summerfallow and wheat. Producers are being told that extended and diversified cropping systems offcr many potential benefit. including: i) reduced requirements for N fertilizer, particularly for systems that include Icgumes, ii) reduced problems with crop pests, iii) higher grain yields and improved grain quality of subsequent cereal crops, iv) improved soil fertility and soil quality characteristics, and v) higher economic returns.

A long-term crop rotation experiment being conducted at the Agriculture and Agri-Food Canada Research Ccntre at Swift Current provides an opportunity to examine some of these claims. This experiment was initiated in 1967 and involves 12 crop rotations; however, for this paper only 4 systems are considered using data for the 1979-96 period. The rotations include, Fallow-Wheat (F-W), Fallow-Wheat-Wheat (F-W-W), Continuous Wheat (W), and Wheat-Lentil (W-L), all fertilized with recommended rates of N and P. Tillage, during the summerfailow period and for seedbed preparation, was used sparingly to conserve surface crop residues.

Soil Nitrates, N Fertilizer Requirements, and N Leaching Losses

- Soil test nitrates (NO_3 in the top 2 feet of soil) measured in spring on land that was previously seeded to grain lentil averaged 60 lb/ac compared with 39 lb/ac under monoculture stubble wheat. These compare to soil N levels of 70 lb/ac normally found in soils that were fallowed. The higher level of soil N found in the W-L rotation has resulted in an average N fertilizer savings of 9 lb/ac for the subsequent wheat crop.
- Soil N levels found below the rooting depth of wheat (i.e., below 4 feet) were lower under W-L than W. The relatively low N losses under the W-L system reflects the greater synchrony between N release from decomposed lentil residues and N uptake by the wheat plants (compared to wheat stubble). N leaching losses were greatest under the fallow-containing rotations.

Soil Water Conservation and Water Use Efficiency

- inclusion of lentil in the rotation had no effect on over-winter soil water recharge. The shorter and less dense lentil stubble (for snow trapping) did not result in less over-winter soil water recharge compared to that found under wheat stubble. Soil water reserves measured in spring, just prior to planting wheat, averaged 7.7 inches in the top 4 feet of soil under lentil stubble compared 7.8 inches under wheat stubble. Spring soil water reserves under stubble conditions averaged 1.7 inches less than under fallow. By harvest time, all crops (whether grown on fallow or stubble) extracted all available water in the 4 foot depth leaving an average 5.8 inches in this depth. The lower limit of plant available water for this soil is 5.7 inches.
- Water use efficiency (based on conserved spring soil water plus May to July precipitation) has averaged 2.6 bu/ac/inch for fallow-seeded wheat and 2.2 bu/ac/inch for stubble-seeded wheat.

Leaf Diseases

- Tan spot data collected over the 1994-96 period showed that wheat grown after lentil was as severely infected as wheat grown after wheat, but both were significantly less severely diseased than wheat grown after fallow. This reflects the higher density of infective leaf spotting fungal structures found on older as compared to newer wheat residues and the fact that tillage was minimized so as to conserve surface residues.
- So far, ascochyta blight in lentil has not been a problem during the 18 years of this study. despite several moist years in the 1990s. However, the recommended practice for disease prevention is to grow a pulse crop only once every four years.

Grain Yields and Protein

- Yields of wheat grown after lentil were similar to yields of wheat grown after wheat in most years. Wheat after lentil yielded significantly more than wheat after wheat (i.e., more than 4.1 bu/ac higher) in only 4 of 18 yr, but yielded significantly less in 4 other years. The average yield of wheat grown after lentil was 23.4 bu/ac which compares with 23.5 bu/ac for wheat grown on wheat stubble.
- When expressed on a rotation basis (reflecting that there is no yield obtained during the fallow phase), total annual wheat production was highest for W (23.4 bu/ac/yr), intermediate for F-W-W (19.2 bu/ac/yr), and lowest for F-W (16.6 bu/ac/yr).
- The 18-yr average yield of lentil was 840 lb/ac; however, since 1989 when pre-emergence trifluralin was used for grassy weed control. and weather conditions were more favorable, lentil yield has averaged 1264 lb/ac.
- Annual yield variability was about 3 1% lower for crops grown on fallow than on stubble because of the higher soil water reserves in fallow which reduces the crop's dcpendancy on growing season precipitation.
- In contrast to grain yield, protein levels in wheat grown after lentil were higher in 12 of 17 years, by an average of 1.2 percentage points compared to wheat grown on wheat stubble. The average protein level in wheat grown on lentil stubble was 15.7% compared with 14.5% and 14.9% for wheat grown on wheat stubble and on fallow, respectively.

Soil Organic Matter and Soil Quality

- Soil organic matter levels have increased under well-fertilized W and W-L, and have remained constant under fallow-containing systems.
- Total organic C (tons/ac) in the O-6 inch soil depth was highest in W-L (16.1) > W (15.4) > F-W-W (14.6) > F-W (14.3).
- The improvements in soil organic matter have increased the rate at which N is released from the soil for use by plants. Potentially mineralizable N (or N supplying power) is highest for W (index=lOO) and W-L (index=87), intermediate for F-W-W (index=74), and lowest for F-W (index=62).
- Extending the rotation length increases the stability of soil aggregates or soil clods (stability index=40 for W, 34 for W-L, 23 for F-W-W, and 16 for F-W), thereby lessening the potential risk of erosion by wind or water.

Nonrenewable Energy Use and Efficiency

- Total input of nonrenewable energy (e.g., fuel, fertilizer, herbicides, machine manufacture and repair), expressed in diesel fuel equivalents, increased with cropping intensity (25.6 L/ac for F-W, 35.7 L/ac for F-W-W, 42.5 L/ac for W-L, and 55.8 L/ac for W).
- Fertilizer N is the major energy input of extended cropping systems. Including lentil in the rotation provided significant energy savings because of N fixation by the legume meeting most of its own needs plus providing additional N benefits to subsequent wheat crops. Consequently, carbon dioxide emissions are reduced with the W-L system (index=l61) compared to W (index=l99); however, both are still substantially higher than for F-W-W (index=1 33) and F-W (index= 100).
- The ratio of energy output to energy input (energy efficiency) has averaged 5.4 for F-W, 4.6 for F-W-W, 3.5 for W-L, and 3.4 for W.

Economic Returns and Riskiness

- **Costs** of production per unit of land area increased with cropping intensity. Total costs **($/ac)** for the complete rotation systems (baaed on 1996 input costs, but excluding land investment) averaged $63/ac for F-W, $76 for F-W-W. $103 for W, and $110 for W-L.
- Including lentil in the rotation was profitable when lentil price exceeded $O.l6/lb (the 1996 price for lentil was about $0.20/lb). At lentil prices below this breakeven value, lentil production was less profitable than wheat.
- F-W was the most profitable cropping system when wheat price was below $3.50/bu (net price). At wheat prices between $3.50 and $4.35/bu, F-W and F-W-W provided the highest and about equal net return. When wheat price was between $4.35 and $6.00/bu, F-W-W performed best. W performed best when wheat price was greater than $6.00/bu.

- Extending the rotation length requires acceptance of a trade-off between increases in net return and increases in income variability (or risk). Income variability was lowest for F-W (index=lOO), intermediate for F-W-W (index=1 13). and highest for W-L (index=l76) and W (index=23 1). All-risk crop insurance reduces the higher financial risk associated with more intensive cropping systems; however, income variability still remains higher than for F-W.

Conclusion

- Our findings confirm the current trends in land use practices by producers, and clearly show that extending and diversifying rotations by including pulse crops can be expected to enhance crop production, contribute to greater farm income, and maintain or improve the physical and biological quality (or sustainability) of the soils in southwestern Saskatchewan.