EVALUATING THE FEASIBILITY OF SHORT-TERM ALFALFA STANDS IN CEREAL-BASED ROTATIONS

Progress Report to PPI and FAR

Submitted on Jan. 23, 1992 by:

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Introduction

This is a multidisciplinary research project that is investigating the effect of short-term alfalfa stands on soil and crop parameters. The work plan for this project will not be reviewed here since it was described in detail in the original proposal.

This project involves two staff members from the Dept. of Plant Science (Martin Entz and Kevin Vessey), and a graduate student (Mr. Dave Kelner). Other researchers from the U of Manitoba involved in this project are Dr. Scott Jeffrey (Ag. Economics) and Dr. Jane Yeomans (Soil Science).

The specific research objectives of this project were outlined in the original research proposal. In this progress report, I will outline the progress to date for each objective.

SPECIFIC RESEARCH OBJECTIVES

1. How many years does alfalfa have to be included in the crop rotation before significantly reducing weed populations (ie., to the point that herbicide use in the following crop can be significantly reduced)?

Progress to date:

In 1991, weed populations were compared in wheat after one year of alfalfa with wheat after barley. (Note: Herbicides were applied in 1990 to both alfalfa and barley crops). Populations of green foxtail in unsprayed plots averaged 40 plants m2 in wheat after alfalfa and 354 m2 in wheat after barley. Wild oats averaged 8.5 plants m2 in wheat after alfalfa and 40 m2 in wheat after barley. Red root pigweed populations averaged 6 m2 in wheat after alfalfa and 28 m2 in wheat following one year of alfalfa.

These results appear to confirm research in the 1940's (Agriculture Canada; Brandon, MB) that short-term alfalfa stands can significantly reduce annual weed populations in subsequent crops. Suppression of weeds with crop rotations is important, especially where herbicide resistant weed populations are prevalent.

2. How many years does alfalfa have to be included in the rotation to extract deep-leached nutrients?

Progress to date:

The Winnipeg site has very high levels of N to a depth of 240 cm, and therefore provides a unique opportunity to evaluate the ability of different crops to extract soil N. In the year of alfalfa establishment (1990), alfalfa and barley extracted significant ($P<0.05$) amounts of N to a depth of 120 cm (see Figure 1a; attachment 1). In the second year, wheat following barley only extracted significant amounts of soil N to a depth of 90 cm, however, the alfalfa extracted significant ($P<0.05$) amounts of N to a depth of 180 cm (Figure 1b; attachment 1). **For more detail on N and water extraction by the different rotation crops, see attachment 1.**

One important question that will have to be addressed in this study, is whether or not the biologically fixed N will be released to the soil once the alfalfa stand is worked into the soil. A recent review by Peterson and Russelle (1991; J. Soil Water Cons. 46:229-235) pointed out that significant release of N from the alfalfa residue can "recontaminate" the soil. Results in the next 2 or 3 years should hopefully allow us to answer this question.

Extraction of other nutrients has also been measured and analysis of these results in currently under way.

Mass Balance: Data of nutrient removal by crops will be used to calculate a simple mass balance, and to calculate yield/nutrient consumption ratios. This analysis should be completed by March 31, 1992.

3. How many years can alfalfa be included in the rotation before causing a water shortage in the next annual crop?

Progress to date:

With the exception of significantly ($P<0.05$) deeper soil water extraction by the alfalfa compared with the annual crops (Figure 2; attachment 1), few differences in soil water level between treatments were observed at either location in this study. Therefore, to date, there has been no evidence to suggest an imminent water shortage in the annual crop following alfalfa. Precipitation in 1990 and 1991 was between 110% and 120% of the long-term average.

4. How many years does alfalfa have to be included in the rotation before reducing nitrogen fertilizer requirements in subsequent crops?

Progress to date:

The nitrogen contribution of alfalfa to subsequent annual crops is being monitored by N uptake into cereal crops and by N15 analysis. Lab analysis is currently underway, and should be completed by early February. In 1992, wheat after barley (no N fertilizer) yielded 2475 kg/ha (averaged over two sites) while wheat following one year of alfalfa (alfalfa had been cut twice in establishment year) yielded 3105 kg/ha. Yields of wheat following barley (fertilized to soil test recomm.) averaged 3089 kg/ha, while wheat following alfalfa fertilized with the same amount of N yielded 2970 kg/ha.

5. What are the economics of including short-term alfalfa stands in rotation with annual crops?

Progress to date:

Economic analysis is currently underway. In order to predict the optimum alfalfa stand length in economic terms, Dr. Jeffrey is using information from the rotation study as well as long-term alfalfa and grain crop yields for the Black soil zone of the prairies. The model that is being used to conduct this analysis also considers weather conditions. A preliminary report on the economic analysis will be published in March, 1992.

6. Based on the agronomic and economic implications of including alfalfa in rotation with annual grain crops, what is the optimum annual/perennial crop rotation for producers to use?

A prediction on the optimum stand length will not be attempted until 1993.

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EXTRACTION OF DEEP-LEACHED NITRATE-N BY SHORT-TERM ALFALFA STANDS

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ATTACHMENT 1.

INTRODUCTION

Certain dryland cropping practices can lead to leaching of nitrate-N below the root zone of annual crops (Campbell et al. 1975; Schepers 1988). This deep-leached N is unavailable to most crops, and may contaminate groundwater.

Several investigators have concluded that alfalfa can effectively extract nitrate-N from deep in the soil profile (Schertz and Miller 1972; McGill 1991), and could help clean up sites contaminated by nitrates (Schumann and Elliot 1978; Peterson and Russelle 1991). It is known that alfalfa absorbs water (Kohl and Kolar 1976) and nutrients (Lipps et al. 1957) throughout the entire rooting zone, however, little quantitative information is available.

Root systems of alfalfa cultivars range from highly branched to strongly tap-rooted (Barnes 1983). Therefore, genetic variation in the ability of alfalfa to extract deep-leached nitrate-N may exist.

The objectives of this study are:

1) To measure soil nitrate-N and water extraction by annual and perennial crops.
2) To determine the length of time alfalfa would have to remain in a rotation to significantly reduce nitrate-N.
3) To measure variation in soil water extraction among alfalfa cultivars in the establishment year.
4) To determine to what extent alfalfa may contribute to nitrate-N concentration after being incorporated in the soil. (This objective will not be discussed here).

METHODOLOGY

The research site is located in Manitoba's Red River Valley on an Osborne clay soil (see Photographs). This area has been in a crop-summerfallow rotation for several decades, and as a result, soil nitrate-N levels to 240 cm are very high (>8 ppm).

Rotations under investigation include: 1) spring wheat (cv. Roblin) -- field pea (cv. Victoria) -- barley (cv. Heartland), 2) alfalfa for 1 to 10 years (cv. OAC Minto) -- spring wheat -- field pea -- barley, and 3) a non-crop treatment. All 12 treatments are replicated 4 times. This crop rotation study was established in 1990 and will continue until 2005. Crops are grown using recommended practices. Alfalfa was established without a companion crop, and was cut for hay in 1990 (1 cut) and 1991 (3 cuts). A second site is located at Portage la Prairie, MB (data not shown).

Samples for soil nitrate-N determination were taken in late October in 1990 and 1991 using a Giddings soil corer. The soil was sampled at 30 cm increments to a depth of 240 cm. Two areas in each plot were sampled. Soil was air dried and analyzed for nitrate-N using standard methods (MB soil testing lab and Norwest Labs, Wpg.). Nitrate-N extraction was determined by comparing soil nitrate-N levels in the annual crop and alfalfa-containing rotations with the non-crop area, and by monitoring the change in soil nitrate-N within treatments over years.

A 240 cm neutron access tube was installed in the centre of each plot. Soil moisture level was determined at intervals during the growing season using a Troxler model 4330 soil moisture gauge. Volumetric surface soil moisture (0 to 10 cm) was determined gravimetrically.

A second field experiment was established in 1991 to measure establishment year water extraction of a number of different alfalfa cultivars. This experiment was located approximately 100 m from the crop rotation trial. Alfalfa cultivars included Legend, Excaliber, Rangelander, Alfa-Graze, Wilson, and Nitro.

RESULTS AND DISCUSSION

NITROGEN AND WATER EXTRACTION

Nitrate-N levels in the top 120 of soil in 1990 were significantly lower following barley and one year of alfalfa than in the non-crop area (Figure 1a). It was concluded that both crops extracted nitrate-N to 120 cm. The similarity of nitrate extraction patterns for alfalfa and barley was attributed to the very dry conditions in late-summer and fall in 1990, which severely limited alfalfa regrowth after the first cut. By the end of the second growing season, the alfalfa crop had extracted nitrate-N to a depth of 180 cm, while the cereal containing rotation

(wheat following barley) only extracted N to a depth of 90 cm (Figure 1b).

Results of the first two years indicate that alfalfa has the ability to extract deep-leached nitrate-N. At the present time it is unclear how deep the alfalfa roots will grow, or whether the present rate of growth can be sustained in future years. However, at half the present growth rate, the total amount of time required for the alfalfa crop to "clean up" the top 240 cm of soil would be four years.

The distribution of soil nitrate-N and soil water in the fall of 1991 were similar for the respective treatments (Figure 1b and Figure 2), indicating that nitrate extraction was closely associated with soil water extraction.

Between the 1990 and 1991 sampling dates, the level of nitrate-N below 120 cm (rooting zone of most annual crops) increased by an average 2.1 ppm in the cereal rotation, and 2.7 ppm in the non-crop plots (Figures 1a and 1b). This increase in the level of deep nitrate was attributed to the above average precipitation in the summer of 1991. These results indicate that the cereal crops were ineffective in halting the deep-leaching process in this trial.

WATER EXTRACTION IN ESTABLISHMENT YEAR: CULTIVAR EFFECT

In this experiment, the majority of establishment year water extraction occurred in the top 150 cm of soil (Figure 3). These results suggest that under very favourable moisture conditions (such as in 1991), alfalfa could extract soil nutrients to a depth of 150 cm in the year of establishment. While few differences in water extraction between cultivars occurred in the top 150 cm of soil, Legend extracted significantly ($P<0.05$) more water than Nitro at lower depths (Figure 3).

ACKNOWLEDGEMENTS

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REFERENCES

Campbell, C.A., W. Nicholaichuk, and F.G. Warder. 1975. Can. J. Soil Sci. 55:279-286.

Barnes, D.K. 1983. p. 127-136. In: Limitations to Efficient Water Use in Crop Production. ASA Publ.

Kohl, R.A. and J.J. Kolar. 1976 Agron. J. 68:536-538.

Lipps, R.C., R.L. Fox, and F.E. Kohler. 1957. Soil Sci. 84:195-204.

McGill, K.S. 1991. p.115-136. In: Proc. Manitoba Society of Soil Science Annual Meeting, Jan. 7 and 8, Wpg.

Peterson, T.A. and M.P. Russelle. 1991. J. Soil Water Conserv. 46:229-235.

Schepers, J.S. 1988. p.167-178. In: Cropping Strategies for Efficient Use of Water and Nitrogen. ASA Special Publication No. 51.

Schertz, D.L. and D.A. Miller. 1972. Agron. J. 64:660-664.

Schumann, G.E. and L.F. Elliot. 1978. Soil Sci. 126:237-243.

Figure 1a. Influence of crop rotation on soil NO_3^--N concentration (0 - 240 cm) in October, 1990 at Winnipeg. (*, **, significant at 0.05 and 0.01 probability levels, respectively; NS, non-significant)

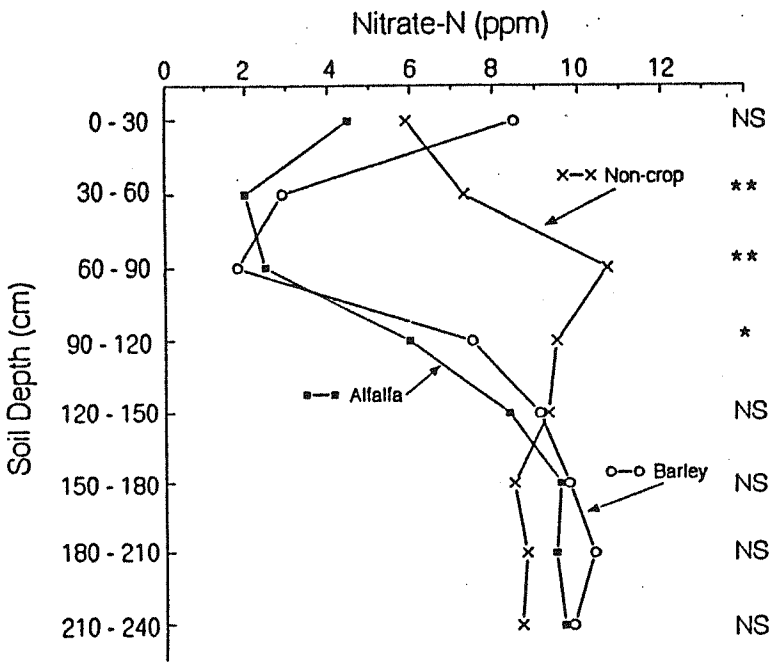


Figure 1b. Influence of crop rotation on soil NO_3^--N concentration (0 - 240 cm) in October, 1991 at Winnipeg. (*, **, significant at 0.05 and 0.01 probability levels, respectively; NS, non-significant)

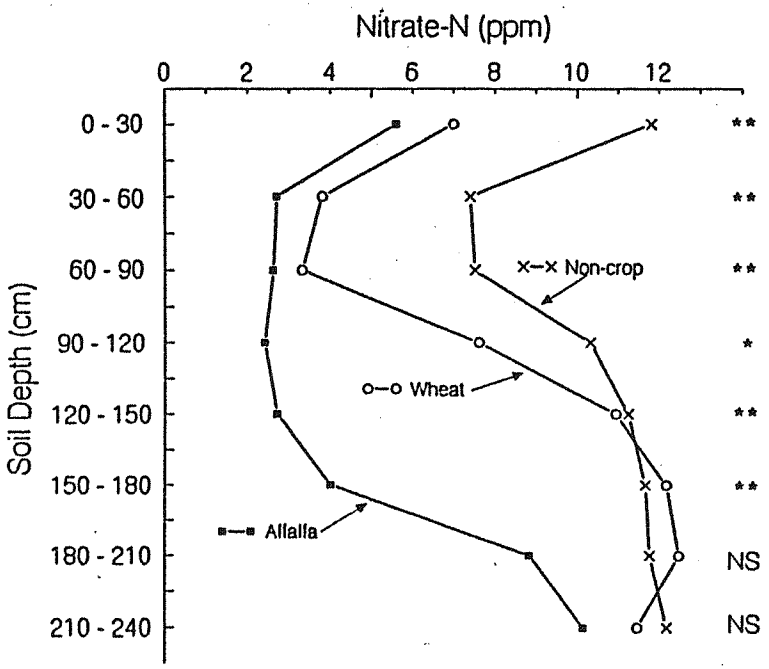
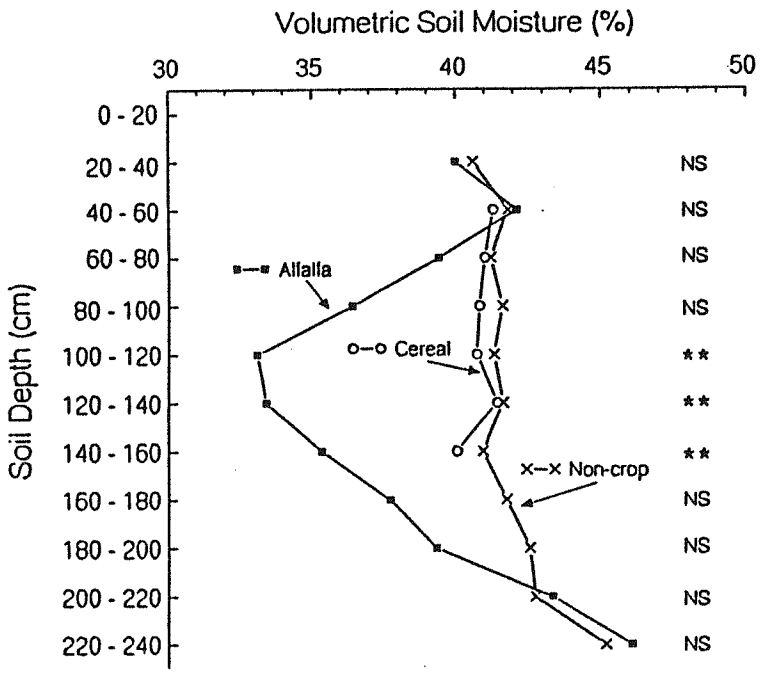


Figure 2. Influence of crop rotation on total soil water content (cm^3/cm^3) at fall freeze-up (Nov.) at Winnipeg in 1991 (**, significant at 0.01 probability level; NS, not significant).



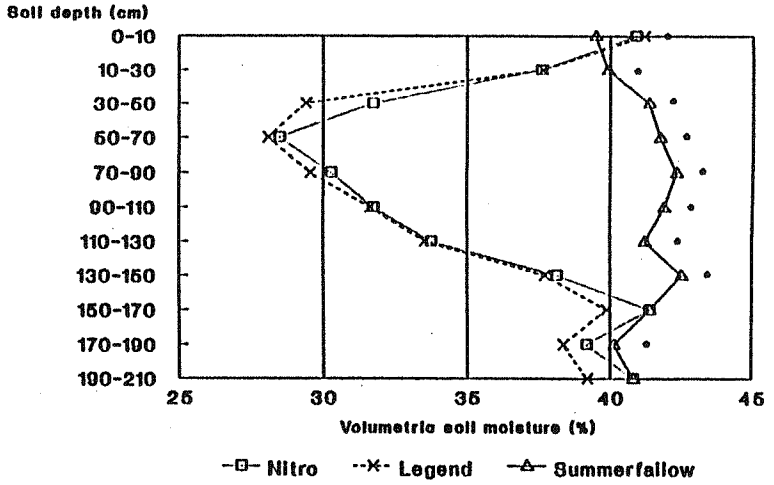


Figure #3. Growing Season Soil Water Extraction by Two Alfalfa Cultivars in the Year of Establishment, Winnipeg, 1991.