Strategies for Improving Soil Fertility in Mature Alfalfa Stands

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Key Words: soil fertility, phosphorous, nitrogen, alfalfa

Abstract

Declining soil fertility is one of the main causes for decreased yields in mature alfalfa stands. Nitrogen, phosphorous, and sulphur are three nutrients that are often found to be limiting in prairie soils. In this study we applied nitrogen, sulphur, and phosphorous fertilizers as well as *Sinorhizobium meliloti* and *Penicilium bilaiae* inoculants to mature alfalfa stands to determine how these different treatments affected biomass yield and nutrient content. The experimental plots were established in the spring of 2004 and yield data from this seasonis presented. In season 2 (2005) we will be monitoring the experimental plots for residual responses from the treatments.

Introduction

Alfalfa (*Medicago sativa* L.) is one of the most widely grown forage crops produced in western Canada. In 2001, Statistics Canada reported that over 1.1 million ha in Saskatchewan alone was used for alfalfa and mixed alfalfa production. Its high yield potential, excellent nutritive value, and N_2 fixation ability make it the preferred legume forage crop (Howarth, 1988).

Alfalfa producers are often faced with reduced productivity in mature stands. The decline in productivity can be attributed to a combination of both biotic and abiotic agents, which act together to produce a cumulative stress load on the stand (Leath, 1989). Decreased nutrient availability is often one of the main factors that leads to a decline in productivity.

Harvesting alfalfa for forage involves removing all of the above-ground biomass from the field, in many cases two, three, or even four times a year. This can lead to the depletion of important soil nutrient reserves as large amounts of nutrients are exported from the field with the plant biomass. In this study we evaluate some methods for improving soil fertility in mature alfalfa stands through applications of fertilizers and/ or microbial inoculants. The main nutrients that our study focuses on are nitrogen and phosphorous, however sulphur is considered to a lesser extent.

Materials and Methods

A field study was initiated in the summer of 2004 at three different sites to compare how different treatments affected dry matter production in mature alfalfa stands. The three sites chosen for this study were mature, pure stand alfalfa fields located in the major dryland alfalfa producing area of Saskatchewan. The experiment was set up in a randomized complete block design in which there were 14 treatments replicated six times.

The trials were established in early May 2004. A small plot seeder was used to band in the inoculants, gypsum, and the P fertilizer to a depth of 4-cm. The seeder was equipped with Flexi-

Coil narrow row disc openers with on row-row press wheel packing; row spacing was 30-cm. This system caused minimal soil disturbance and therefore did very little damage to the alfalfa stands.

All treatments except the undisturbed control and one mechanical disturbance received the equivalence 7.4 kg S ha^{-1} as a gypsum based granule. This was done because the inoculant carrier is gypsum based so at high rates of inoculant application it was possible that there could be an S response. All treatments were applied the same amount of gypsum. Table 1 includes all of the treatments in the study as well as the application method for that treatment.

Treatment	Application Method
1. 100 kg N ha^{-1} ammonium nitrate (34-0-0)	broadcast
2. 100 kg N ha^{-1} urea (46-0-0)	broadcast
3. 100 kg N ha^{-1} urea (46-0-0) + Agrotain® (5.2 L MT^{-1})	broadcast
4. 100 kg N ha^{-1} Agrium ESN ® (44-0-0)	broadcast
5. 20 kg N – 22.6 kg S ha^{-1} ammonium sulphate (21-0-0-24)	broadcast
6. 4 kg ha^{-1} N-Prove® granular (*S. meliloti*)	coulter
7. 40 kg ha^{-1} N-Prove® granular (*S. meliloti*)	coulter
8. 40 kg ha-1 TagTeam® granular (*S. meliloti* + *P. bilaiae*)	coulter
9. 40 kg P_2O_5 ha^{-1} triple super phosphate (0-45-0)	coulter
10. 40 kg ha^{-1} JumpStart® granular (*P. bilaiae*)	coulter
11. 40 kg ha^{-1} JumpStart® + 20 kg P_2O_5 ha^{-1} (0-45-0)	coulter
12. Mechanical disturbance*	coulter
13. Mechanical disturbance + 40 kg gypsum ha^{-1}	coulter
14. Control (undisturbed)*	

* Did not receive any gypsum

Soil Sampling

Soil samples were taken from the six undisturbed controls at each site. Composite samples from three randomized points in each control plot were taken at depths of 0-15 cm, 15-30 cm, and 30-60 cm. The soils have been analyzed for N, P, K, S, organic carbon and total carbon content, pH, EC, texture, and bulk density. This was done to characterize f the soils and to try to determine any possible spatial variability in the soils. Table 2 includes selected soil properties determined from the three field sites.

Table 2. Soil properties from three field sites.

Site	Texture	pH (0-15 cm)	Nutrients N	P	K	S
			kg ha^{-1} (0-60 cm)			
Smeaton	Loam	5.8	33	13	102	2.7
Crooked River	Clay Loam	6.4	40	14	140	3.3
Star City	Sandy Clay Loam	6.8	36	16	86	1.7

Plant Sampling

Plants from the P treatments were sampled at an early vegetative stage to be analyzed for P content. As plants mature the percentage of P in the plant tissue declines. Therefore, any differences in plant P content between the different treatments are easier to detect in young plants.

Plants were sampled again at the 10% bloom stage and analyzed for biomass yield and N content. A 1-m^2 sample was cut at a 4-cm height from each plot and dried at 40°C to a constant mass and then weighed. A second cut was also taken at the 10% bloom stage from the Smeaton and Crooked River sites. The Star City site was only harvested once because there was not sufficient re-growth to be able to take a second cut.

Results and Discussion

The yield data from each site for 2004 is presented in the following figures (Fig. 1, 2 and 3). To date no statistical analysis has been performed, therefore the data is limited to the mean and standard deviation of each treatment. When comparing the controls with the mechanical disturbance treatments at each site, there is very little difference between the two. This means that the yields did not seem to be effected by the coultering operation. However, the application of gypsum did affect yield, most notably at the Star City site (Fig.3). Thus the mechanical disturbance that received the gypsum (M.D. + Granule) will be used as the control against which the different treatments will be compared.

The responses from the different treatments seemed to be somewhat site specific. Overall the Smeaton site had the highest yields while the Star City site, where only one cut was taken, had the lowest yields. The four N fertilizer treatments did not vary much within each site and only resulted in slightly higher yields than the control treatments. The Smeaton site had the most notable response to the N fertilizers. The 40 kg *S. meliloti* inoculant treatment compared well with the N fertilizer treatments. However the 4 kg *S. meliloti* inoculant treatment only resulted in a better yield than the M.D. + Granule control at the Crooked River site (Fig. 2). This may mean that the higher population of *S. meliloti* introduced to the field, with the 40 kg ha^{-} application, resulted in greater nodulation and higher N_2 fixation.

Overall the 40 kg P_2O_5 ha^{-1} treatment seemed to induce the highest yield responses at all of the sites indicating that these sites were more deficient in P than they were in N. The Star City site also had a very notable response to the 21-0-0-24 treatment indicating that it had a severe S deficiency (Fig. 3). The *P. bilaiae* treatments were, for the most part, unsuccessful at increasing biomass productivity; in some cases they seemed to have a negative impact on yield. However, at the Crooked River site the *P. bilaiae* + 20 kg P_2O_5 treatment did lead to a positive increase in yield (Fig. 2).

These sites will be monitored in 2005 to test for residual responses to the treatments.

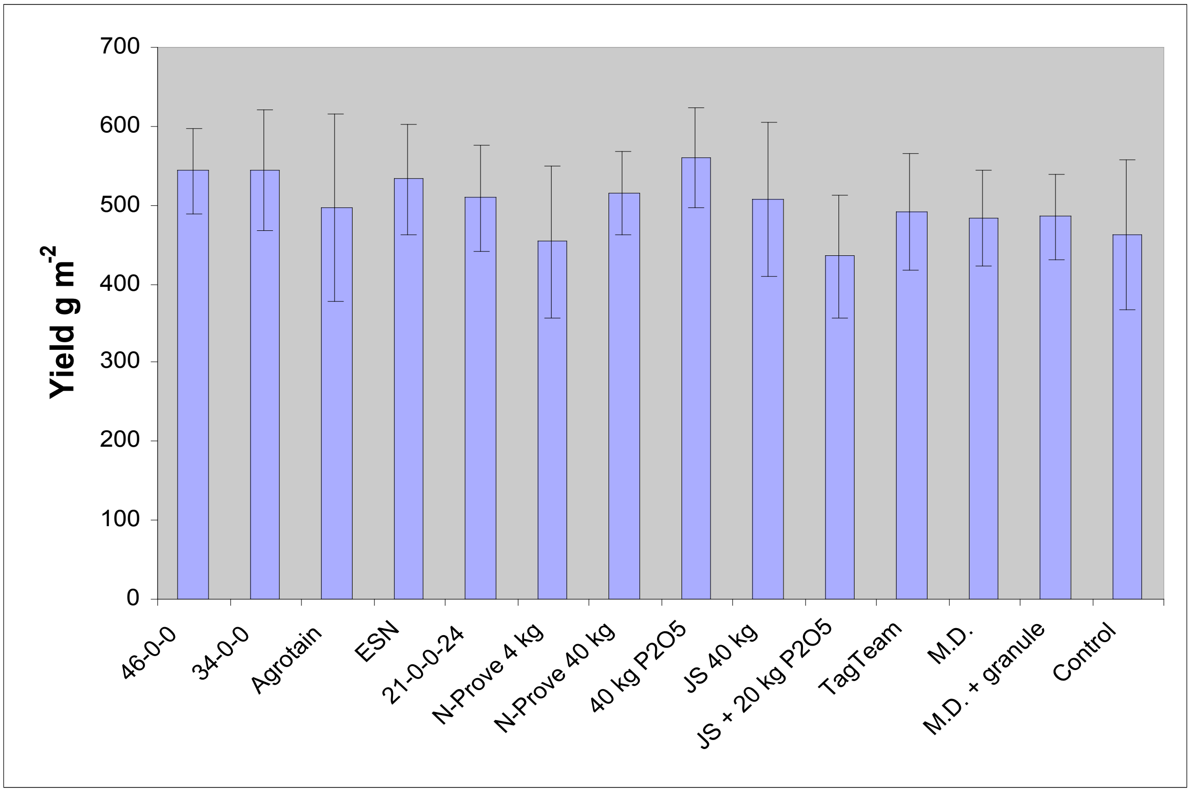

Figure 1. Alfalfa biomass yields (g m^{-2}) at Smeaton site in 2004.

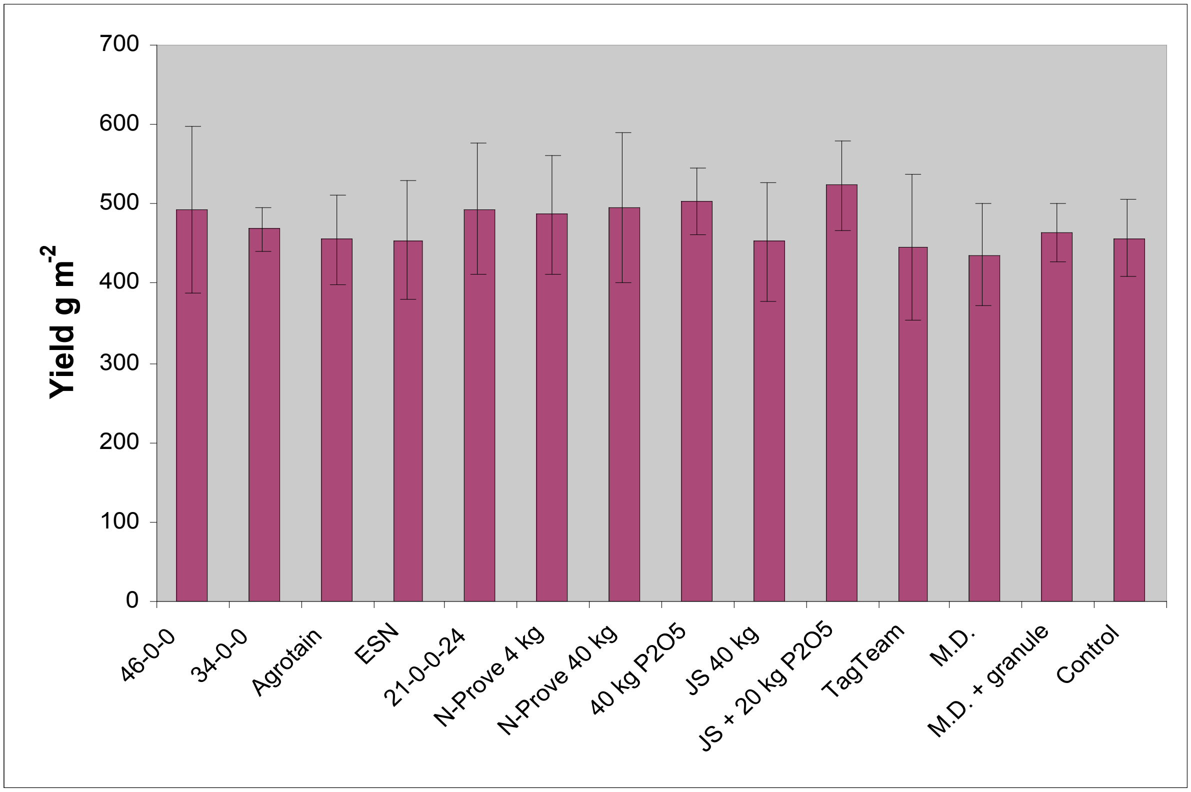

Figure 2. Alfalfa biomass yields (g m^{-2}) at Crooked River site in 2004.

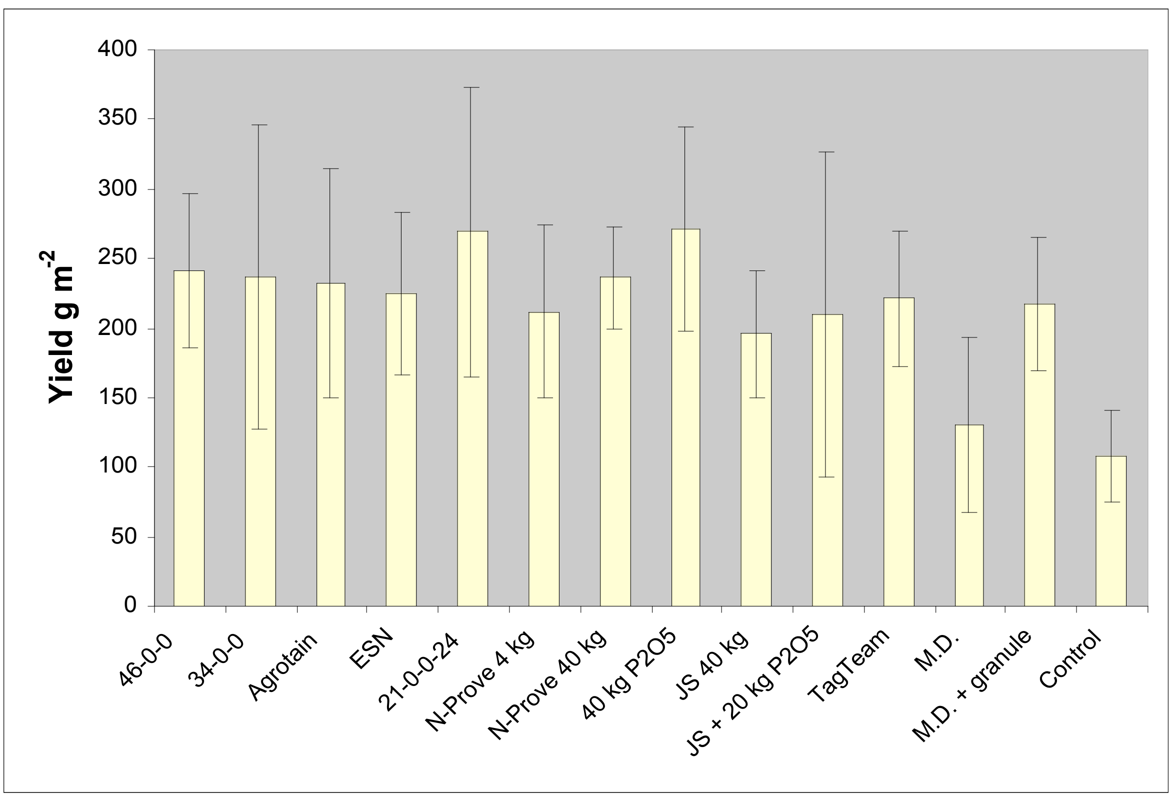

Figure 3. Alfalfa biomass yields (g m^{-2}) at Star City site in 2004.

Acknowledgements

The authors would like to thank the S.A.F.R.R.- Agricultural Development Fund for providing the funding for this study. They would also like to thank Philom Bios for their help with establishing the study.

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