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FORAGE TECHNICAL BULLETIN

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Impact of alfalfa and fertilizer on pastures: Soil Fertility and Nutrient Cycling

Introduction

Soil fertility plays a major role in the productivity of your pasture and your livestock. Even small changes in the nutrient composition can affect the ratio of grass and legumes present. Therefore, it is very important to understand the cycling process of nutrients through the soil, plants, and animals. To date, there has been little research under Manitoba conditions on how adding alfalfa or fertilizer to pastures affects nitrogen fixation and the cycling of nitrogen (N) and other nutrients. This study investigates the role of alfalfa and fertilizer on nutrient cycling in pastures.

Nutrients can become concentrated in specific areas of a pasture (e.g. near water, shade and supplement feeders) or during certain times of the year. If nutrient concentrations are too high to be used efficiently by pasture plants, they can potentially be lost from the system. For example, soil nitrogen can be converted into a gas and lost into the atmosphere through processes known as volatilization and denitrification. Environmental problems due to leaching and runoff of nutrients may also occur. High levels of nitrogen and phosphorus in runoff may end up in streams and lakes, causing algal blooms that use up the oxygen in the water, resulting in "dead zones" that harm aquatic life.

Research Study

A study was conducted at the Agriculture and Agri-Food Canada Research Centre in Brandon, MB from 1994-1999. In the spring of 1994, pastures were established on a Souris fine sandy loam. The study used rotational grazing on four combinations of pasture type and fertilizer management. There were two different pasture types (100% grass or mixed alfalfa/grass) and two different fertilizer treatments (no fertilizer, or spring fertilization to full soil test recommendation levels). This resulted in a total of four treatments, shown in Table 1.

Table 1. Pasture Types and Fertilizer Treatments used in the Study

1) Meadow bromegrass No added fertilizer	3) Meadow bromegrass + Alfalfa (40-50% of biomass) No added fertilizer
2) Meadow bromegrass + Fertilizer	4) Meadow bromegrass + Alfalfa (40-50% of biomass) + Fertilizer

The grass-only pastures were seeded with 10 lb/acre 'Paddock' meadow bromegrass. The mixed alfalfa-grass pastures were seeded with 7 lb/acre 'Paddock' meadow bromegrass and 3 lb/acre 'Spredor II' alfalfa. Starting in 1995, fertilizer was applied as a surface-applied dry blend prior to grazing each spring. The concentration of each nutrient in the blend was based on soil samples collected the previous fall.

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Each pasture in the study was 9.1 acres and was divided into five paddocks that were rotationally grazed by cow-calf pairs. Stocking rates were adjusted so that the amount of forage remaining after the grazing period was equal in each pasture. In order to estimate the amount of N fixed by alfalfa, fertilizer enriched with a special form of nitrogen (the ^{15}N isotope) was applied. Use of that form of N allowed it to be traced in the plant material and soil samples collected from each pasture.

To determine the movement of nutrients in the soil, samples were taken at different depths throughout the grazing season. Different areas (zones) of the paddocks were also sampled separately to determine if the nutrient concentration changed with the distance from water sources or fence lines.

Study Results

Effect of Fertilizer on N Fixation by Alfalfa

The amount of fertilizer applied to each type of fertilized pasture is shown in Table 2. The application of phosphorus (P), potassium (K), and sulphur (S) is important to the long-term productivity and persistence of legumes. However, P or S fertilizers usually also contain some N. In mixed legume/grass stands, the grasses are able to use applied N fertilizer more effectively than the legumes and thus become more competitive against them. In addition, N fertilization reduces nodulation of legumes, decreasing their ability to fix N. Applying too much N fertilizer to mixed pastures can decrease the legume component of the stand compared to unfertilized mixed pastures.

Phosphorus fertilizer management did not affect the amount of N fixed by alfalfa. The amount of N fixed by alfalfa in the mixed alfalfa-grass pastures was similar in both the fertilized and unfertilized treatments.

Table 2. Spring Fertilizer Application on Alfalfa-grass and Grass-only Pastures (lb/ac)

	Grass-only				Alfalfa-grass			
Year	**N**	**P_2O_5**	**K_2O**	**S**	**N**	**P_2O_5**	**K_2O**	**S**
1994	0	0	45	0	10	45	69	0
1995	85	4	0	27	26	18	0	27
1996	98	20	0	0	8	38	0	0
1997	98	9	0	0	4	20	0	0
1998	61	20	19	0	39	28	14	9
Average lb/ac	69	11	12	5	18	29	17	7

Effect of Precipitation on N Fixation by Alfalfa

The major factor affecting the amount of N fixed by alfalfa was precipitation. Changes in alfalfa yield throughout the growing season were closely associated with rainfall levels. As alfalfa yields increased due to increased precipitation, N fixation also increased. Research in other dryland agricultural regions also supports this.

Comparing N Fixation by Alfalfa to N Fertilizer Inputs

There was no difference in the N content of the forage in the unfertilized alfalfa-grass pasture and the fertilized grass only pasture. This suggests that including alfalfa in pastures can provide enough plant protein for grazing animals through N fixation alone, without the need for additional fertilizer.

Soil Fertility and Nutrient Cycling

In the alfalfa-grass pastures, alfalfa fixed 54 pounds of N for every ton of above-ground alfalfa dry matter produced. Other research has found similar estimates of N fixation by alfalfa. This can be used as a rule-of-thumb to estimate the amount of N fixed by alfalfa in mixed alfalfa-grass pastures.

Effect of Soil Fertility on Livestock Productivity

Including alfalfa in unfertilized pastures improved carrying capacity and total calf gain. The unfertilized mixed alfalfa-grass pasture had a carrying capacity 27% higher than the unfertilized grass only pasture. Similarly, the total calf gain was 32% higher on the unfertilized alfalfa-grass pasture compared to the unfertilized grass only pasture.

For more information, see the other technical bulletins in the series produced from this research study: Cow-Calf Productivity and Pasture Carrying Capacity.

When fertilizer was applied, the carrying capacity and total calf gain were similar in both the grass only and mixed alfalfa-grass pastures. However, the average N fertilizer applied each year was much less for the mixed alfalfa-grass pasture. The grass only pasture received an average of 68 lb/acre N per year compared to only 17 lb/acre N per year for the mixed alfalfa-grass pasture. This greatly reduced the production costs for the pastures containing alfalfa.

N Cycling in Pastures

The N fixed by alfalfa eventually returns to the soil as the alfalfa litter and roots decompose. The N released by decomposition needs to be continuously taken up by plants in order to avoid leaching and to ensure efficient cycling of N through the pasture system.

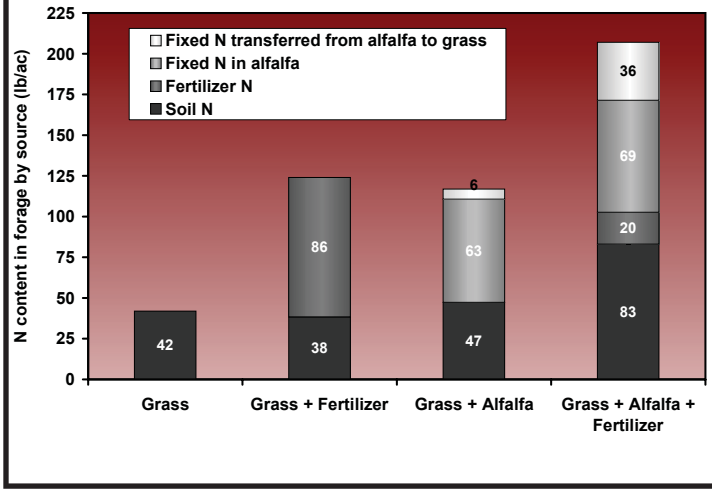
The presence of legumes in the mixed pasture also results in a higher N content in the plant material. This higher plant N content creates a lower carbon-to-nitrogen ratio (C:N ratio), which speeds up the decomposition of plant litter and roots. A faster rate of decomposition increases the soil mineral N supply, which is then converted to nitrate in the soil. Nitrate can be taken up by growing plants but is also prone to leaching into ground water or denitrification (conversion of N to gases that are lost into the atmosphere).

In the mixed pasture, the amount of N taken up by meadow bromegrass was enough to offset most of the N fixed by alfalfa. In addition, by the end of the grazing season, soil nitrate levels at a depth of one metre were low. This is an important finding, as it means that deep-rooted perennial grasses such as meadow bromegrass are able to effectively use the N fixed by alfalfa. As a result, the amount of N lost through leaching is minimized and there is more efficient cycling of N.

Figure 1 shows the total amount of N (lb/acre) in the forage for each combination of pasture type and fertilizer treatment. It also shows the origin of the N, whether it was from the soil, fertilizer, fixed N from alfalfa, or fixed N transferred from alfalfa to grass after alfalfa root and litter decomposition.

The alfalfa content in the mixed pasture in this study was 40-50% of biomass. Research conducted at the Brandon Research Centre has shown that this

Figure 1. Source of Nitrogen in Forage (lb/ac)



is the optimum alfalfa content for mixed alfalfa-grass pastures to be economically and environmentally sustainable. However, caution should be used when grazing pastures with a legume content higher than 50% because of the increased risk of bloat, as well as the increase in soil nitrate that occurs. If nitrate builds up during times when the pasture plants are not actively growing, they cannot effectively take it up. As a result, there is a higher risk that N will be lost either through leaching or denitrification. Also, high-legume content pastures could increase the proportion of N in the diet that is excreted in urine. A large percentage of the N in urine (over 80%) is lost through volatilization and denitrification.

In all four pasture systems, approximately 10% of the N in plants consumed by the grazing animals was retained in cow and calf gains. The remainder (approximately 90%) of N consumed was returned to the pastures through urine and feces. For nutrient cycling to be efficient, better management to minimize losses of nutrients in urine and feces is needed.

Nutrient Distribution in Different Areas of Paddocks

In this study, there was little difference in the concentration of nutrients near watering sites or fence lines compared to other areas of the paddock. This may be partly due to the small paddock size used in the study (each paddock was 1.8 acres). However, it does suggest that rotational grazing with short grazing periods can be a useful management tool to evenly distribute the nutrients excreted in feces in urine.

Conclusion

Adding alfalfa to grass-based pastures resulted in pasture productivity comparable to adding N fertilizer, but with much lower input costs.

Based on these results, it is crucial to maintain 40-50% alfalfa (by weight) in pastures to ensure long-term sustainability and productivity.

Better management practices are still needed to improve the use of N added to pastures, as well as the efficiency of N cycling through the soil–plant–animal system. In particular, mixed alfalfa-grass pastures tend to have increased levels of soil nitrate during the summer, increasing the risk of N losses to the environment. Managing pastures to improve the uptake of N by pasture plants will minimize these losses.

Benefits of adding alfalfa to grass-based pastures:

- The study found that alfalfa-grass pastures require much less fertilizer to meet the full soil test recommendations than the grass-only pastures.
- Alfalfa reduces the need for fertilizer because alfalfa (in mixed pastures) can fix approximately 54 pounds of N per ton of above-ground alfalfa dry matter.
- Fertilizer production is a very energy-intensive process. By reducing the need for fertilizer, adding alfalfa reduces the overall energy input required to produce forage. Compared to grass-only pastures, adding alfalfa reduces the energy required to fertilize to full soil test recommendations by 72%.
- Adding alfalfa to unfertilized grass-based pastures increased forage yield by 54% and calf weight gain per acre by 23%. This increase in production was achieved without any fertilizer cost.
- Of the four pasture management strategies, adding alfalfa to meadow bromegrass pastures at the time of seeding (without fertilizer) was the only strategy that produced a net profit. Net profit was determined for the entire 10-year study period using 2007 production costs.

Soil Fertility and Nutrient Cycling

TIPS to improve N cycling and to minimize losses:

- Maintain a balance with grasses and legumes (40-50% legumes).
- Use deep-rooted perennial grasses.
- Manage grazing to evenly distribute urine and feces and prevent a build up of nutrients.
- Sample the pasture in numerous zones to determine if different fertilizer rates are required.

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