University of Alberta

Legume-grass forage mixes for maximizing yield and competitiveness against weeds in early establishment

by

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I dedicate this thesis to Charlie Kaufmann, whose love and supported helped me complete this project.

"A weed is no more than a flower in disguise" – James Russell Lowell

"A flower is an educated weed" – Luther Burbank

"To forget how to dig the earth and to tend the soil is to forget ourselves" – Mohandas K. Gandhi

"*There are two spiritual dangers in not owning a farm. One is the danger of supposing that breakfast comes from the grocery and the other that heat comes from the furnace" – Aldo Leopold*

Abstract

A field experiment from 2003 to 2005 at two sites examined the impacts of forage species and legume proportion on forage sward production. Grasses generally established rapidly and out-yielded swards high in legume content, although legumes did improve forage quality. Alfalfa was retained at greater relative biomass in mixed swards than swards containing clover. Legume persistence also varied depending on neighbouring grass species.

A greenhouse study examined competitive interactions between Canada thistle (a common pasture weed), white clover and Kentucky bluegrass during establishment. Although thistle was most susceptible to intra-specific competition, and strongly affected forage yield, the latter also influenced weed biomass. Competitiveness of forages depended directly on soil medium, emphasizing the importance of abiotic factors on vegetation dynamics in mixed swards.

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List of Abbreviations

ADF – Acid Detergent Fibre
ADSY – Acid Detergent Soluble Yield
CP – Crude Protein
CPY – Crude Protein Yield
E1 – Ellerslie 1 study location (established 2003)
E2 – Ellerslie 2 study location (established 2004)
N - Nitrogen
TCPY – Total Crude Protein Yield
W240 – West 240 study location at the Edmonton Research Station

Chapter 1. Introduction

1.1. Background

Legumes are known to benefit the forage sward, both through a positive contribution to yield and/or improved forage quality (Barnett and Posler 1983, Sleugh *et al*. 2000, Papadopoulos *et al*. 2001). This benefit could be caused by the diversity created by adding legumes into a grass sward, which may allow for the utilization of soil resources not used by neighboring grasses. Overyielding is the phenomena that occurs when the benefits of combining two or more species of plants with complementary growth forms outweighs the cost of increasing competition, and subsequently produces greater yields than each individual species grown alone (Gokkus *et al*. 1999, Posler *et al*. 1993). The addition of legumes however, does not guarantee that overyielding will occur (Sengul 2003).

More importantly, legumes are beneficial due to the symbiotic relationship they have with nitrogen (N) fixing bacteria. Alfalfa, white clover and alsike clover can provide up to 258 (Burity *et al*. 1989), 545 (Elgersma and Hassink 1997) and 86 (Fairey 1986) kg N ha^{-1}, respectively to a forage sward, and can negate the requirement for N addition to maximize productivity, even of the grass component. The addition of atmospheric N reduces the need for the addition of fertilizer, thereby reducing establishment costs, energy consumption, and the potential for N loss (i.e. through leaching or runoff). The addition of legume to swards at seeding is a common practice due to widespread acceptance of its benefits to forage yield and quality (Elgersma and Hassink 1997), and animal production (Bertlisson and Murphy 2003, Dewhurst *et al.* 2003) compared to grass grown alone.

The addition of legumes to a forage stand can provide benefits to the sward (Kunelius *et al*. 2006, Sleugh *et al*. 2000), but the proportion of legume required to optimize these benefits has not been delineated. Plant species and growth forms may also change the positive impacts of legumes on grass growth, as well as overall sward yield. To date, little is known about how mixing different root growth forms of grasses (i.e. bunchgrasses vs. rhizomatous sod-grasses) or legumes (i.e. shallow rooted clovers vs. tap-rooted alfalfa) may impact overall production and quality of a sward. The different root systems of grasses (i.e. fibrous vs. rhizomatous) may influence the ability of a plant to obtain resources when grown along side legumes. This may have a significant impact on their ability to achieve overyielding based on differences in growth and associated forage biomass and/or quality. Finally, information on the optimal proportion of legumes relative to grasses within seeding mixtures is needed to consistently achieve maximum forage production in a single cut hay system. In Alberta, this is particularly important as forage shortages have been increasing in recent years, and represent one of the greatest limitations to expansion of the beef industry.

When weedy species invade an establishing forage sward managers must make decisions regarding their control. The risk of losing beneficial N fixing plants may prevent producers from spraying fields to remove weeds. While spraying herbicides at reduced rates may reduce mortality to legumes, it also results in reduced weed control (Mesbah and Miller 2005). Moreover, while the use of herbicides with residual properties may improve long-term weed control, it also prolongs the period before legume re-establishment can be undertaken.

Invasive weeds lead to production losses in agronomic systems, including range and pasture environments (Masters and Sheley 2001). Canada thistle is a widespread perennial weed impacting both annual and perennial crops, and is found in North America, Europe, and Asia (Donald 1990, Ang et al. 1994, Freidli and Bacher 2001). Across Canada, thistle is highly adaptable to a wide range of growing conditions. In the 1997 Western Canada Weed Survey, Canada thistle was found to be present in 53% of cereal, oilseed and pulse crops surveyed (Thomas *et al*. 1998). However, this report underestimates the weed's impact as it does not include perennial fields. In Alberta, 44 of 47 reporting counties indicated that they had moderate to high Canada thistle infestations (Agriculture and Rural Development 2009).

Intense competition from Canada thistle often leads to a reduction in plant production. Canada thistle is an aggressive plant that has been shown to reduce wheat (Mclennan *et al*. 1991) and canola (O'Sullivan *et al*. 1985) yields by up to 49% and 26%, respectively. In perennial crops such as forages, Canada thistle can lead to reduced seed production (Moyer et al. 1991) and biomass yield losses of up to 2 kg ha^{-1} of Canada thistle biomass present (Grekul and Bork 2004). In addition to reductions in yield the impact in pastures is intensified due to Canada thistle's ability to deter grazing, reducing grazing potential (Seefeldt *et al.* 2005). Recent research has begun to look at the impacts of Canada thistle on pasture and hay systems (Seefeldt *et al*. 2005, Grekul and Bork 2004), as well as the potential for using perennial plants to outcompete the weed (Wilson and Kachman 1999). However, these studies often focus on grasses and seldom address systems that include legumes.

Canadian provinces have legislation requiring the control of specific plants deemed a threat to both agronomic and native plant systems. In Alberta, the Weed Control Act (Government of Alberta,1980) classifies weeds of concern as either restricted, noxious or nuisance. Canada thistle is considered a noxious weed under this legislation, consistent with other western provinces, and as a result, control of this plant by the land owner is required to prevent its spread. Weed control methods available to producers include: chemical methods using herbicides, both selective and non-selective (Hodgson 1970, Bixler 1991, Grekul and Bork 2007), the addition of fertilizer to improve weed suppression through competition from increased forage (Grekul and Bork 2007), biological control methods using insects (Friedli and Bacher 2001) or livestock grazing (De Bruijn and Bork 2006), and mechanical means such as tilling (Lukashyk *et al*. 2008) or mowing (Schreiber 1967, Beck and Sebastian 2000). Several herbicides are approved for use on Canada thistle in both annual and perennial cropping systems (Alberta Agriculture and Rural Development 2009). While the application of herbicides has been shown to be effective for Canada thistle control, these chemicals may remove beneficial legumes from the plant community.

1.2. Research Objectives

By studying the impacts of different forage species, both on each other and on a weed (Canada thistle), we can begin to understand the complex competitive dynamics that regulate forage availability, as well as improve Canada thistle control by using the competitive influences of herbage. This research evaluates the role of legumes in optimizing forage production and quality within newly seeded swards. Additionally, this research assesses the inter-specific dynamics between a common legume (clover), a common pasture grass (Kentucky bluegrass), and Canada thistle during early forage establishment. Better information on the role of legumes in forage mixes, including their relation to Canada thistle abundance, will allow producers to make more informed decisions regarding herbicide application for weed control.

The specific objectives of this research include:

(1) Reviewing the benefits of legumes in forage swards, legume-grass sward dynamics, Canada thistle biology, and the potential interactions between Canada thistle and legume-grass mixed swards (Chapter 2).

(2) Evaluating the relative contribution of various amounts of legumes to total forage yield and quality, when established in mixtures with various perennial grasses (i.e. test of overyielding) (Chapter 3),

(3) Determining the specific competitive and facilitative trade-offs between a noxious weed (Canada thistle), a legume forage (white clover) and a common perennial grass (Kentucky bluegrass) grown in combination with one another in the greenhouse (Chapter 4),

(4) Develop recommendations for newly established mixtures so as to optimize forage availability (biomass and quality), as well as the ability of common forages to compete with Canada thistle (Chapter 5).

1.3. Literature Review

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