Overseeding Clovers into Permanent Pastures

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ABSTRACT

Benefits of establishing legumes into permanent pastures have been well studied. Successful establishment of legumes in pastures can be challenging, however, and more information is needed about different seeding methods and variables that affect legume establishment. A pasture and a small plot experiment were conducted in Blacksburg, Va from 2009 to 2011to gain better understanding of how seeding method and management variables affected red clover *(Trifolium pratense* L.) and white clover (*Trifolium repens* L.) establishment into permanent cool season grass pasture and sod. In the pasture experiment, seedling density was measured two months after sowing and grass, white clover, red clover, and weed biomass were periodically measured during the experiment. Broadcast seeding treatment had 93% more clover seedlings than drill treatment (P = 0.1087) two months after sowing. No difference (P > 0.10) for clover biomass was observed between sowing treatments in any year and clover establishment was considered successful (over 25% of pasture composition) in both treatments. In the drill treatment, clover seedling density was negatively affected by the residual grass biomass at sowing (P = 0.0196). In the broadcast treatment, a quadratic relationship between clover seedling density and residual grass biomass at sowing was found (P = 0.0516). Clover seedling density in April 2009 determined the amount of clover biomass in August 2009 (P = 0.0008) and the 2010 clover biomass mean (P = 0.0249). Further exploration of the influence fertilization with P and K, grass biomass at sowing, and defoliation frequency on clover establishment were studied in a split-split plot study.

Fertilization with P and K was assigned to whole plots that were split in half and assigned a high or low grass biomass at sowing treatment, the subplots were split in and designated either a high or low cutting frequency. Prior to cutting, samples from each plot were sorted to grass, white clover, red clover, and weed. Plots with a low grass biomass at sowing (232 seedlings m^{-2}) had a higher seedling density ($P < 0.0001$) compared with plots with a high grass biomass at sowing plots (111 seedlings m^{-2}). Greater biomass of white and red clover depended both on having a low grass biomass at sowing and a high frequency of defoliation ($P = 0.0026$ and $P < 0.0001$, respectively). Red clover yield was also determined by interactions between fertilization and a high frequency of defoliation ($P < 0.0001$), as well as between fertilization and low grass biomass at sowing ($P = 0.0026$). Dry conditions resulted in low clover yields (6% of total herbage mass) with red clover producing four times the herbage mass of white clover. These data show that creating a favorable environment for seedlings to germinate and establish was more important than seeding method

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LIST OF ABBERVIATIONS:

WC	white clover
RC	red clover
BST	broadcast sowing treatment
Drill	no-till drill sowing treatmnent
NO	plots not fertilized with P and K
PK	Plots fertilized with P and K
Grass Bio	grass biomass at sowing
Cut Freq	cutting frequency
ADF	acid detergent frequency
NDF	neutral detergent frequency
CP	crude protein

CHAPTER ONE

GENERAL INTRODUCTION

Overall Hypothesis

Establishing clovers into permanent pastures has many benefits. The experiments in this thesis test how managerial decisions can effect clover establishment into permanent pasture. The factors tested were sowing method, fertilization with P and K, grass biomass at sowing, and cutting frequency. One hypothesis tested was that higher clover establishment would occur for no-till drilling treatments compared to broadcast seeded treatments. No-till drilling would create a better environment for clover seedling germination and establishment because of control of seeding depth and able to cut through grass sod to ensure good seed to soil contact.

Overall Objectives

I) To compare the effectiveness of broadcast to no-till drilling for overseeding red and white clovers.

II) Identify potential environmental variables that may help explain the success or failure of seeding methods.

III) To gain better understanding how grass biomass at sowing, defoliation frequency, and soil fertility influenced the establishment of overseeded clover into permanent sod.

Thesis Organization

This research is divided into four chapters in manuscript style for publication. The second chapter review literature pertaining to the benefits of overseeding clover into permanent pastures and factors that affect clover establishment. The third chapter examines a large plot grazing study conducted to look at the affect of sowing method on overseeded clovers. The fourth chapter examines a small plot study conducted to gain understanding on how management practices affect clover establishment. The final chapter provides a concluding summary.

CHAPTER TWO

LITERATURE REVIEW:

A review of literature pertaining to forage legumes and their establishment is given below. The aim of this chapter is to give the reader a better understanding of forage legumes overall with a focus on clover establishment into permanent pastures. The first section will give a brief description and overview of white clover and red clover. The second section will discuss the benefits of incorporating forage legumes into temperate pasturelands. The third section will discuss forage legume establishment. The literature review will end with a discussion comparing broadcasting and no-till drilling seeding methods for establishing forage legumes into permanent pastureland

Species Overview

In this section, I will provide a brief overview of the forage legume species that were used in my thesis research – red and white clover.

Triflorium pratenses L. is commonly known as red clover. The follow description of red clover was obtained from the book 'The Genus Trifolium' by Zohary and Heller (1984). Red clover is a perennial with fusiform root and short stock that has many stems that arise from basal leaves. Stems are simple or branched and are hollow and pubescent. Bottom leafs have long petioles while medium and high leafs have short petioles. Red clover has ovate-lanceolate stipules, that are membranous with green or red veins. Leaflets are very short, mostly 1.5-3 x 0.7-1.5 cm, obovate to obvate-oblong or broadly elliptical. Leaflets are also almost toothless, and hairy on both faces or only beneath. Heads are terminal and are solitary or in pairs, globular or ovoid, and mostly located on the peduncle or reduced leaves, but are rarely pedunculate. Flowers are many, usually

1.5-1.8 cm long and dense. Corolla is reddish-purple to pink. Each pod contains one seed and is oblong-ovoid, and is yellow, brownish, or violet in color.

The origin and distribution of red clover is reported by Allen and Allen (1981). They state that red clover originated in the Mediterranean and Red Sea region and now is widely distributed throughout the northern hemisphere. Perhaps the mostly widely grown of the true clovers, its introduction into Europe, according to the authors, had a greater affect on civilization than the potato or any other introduced forage plant. Introduction date into the United States in not known, but could be as early as 1652.

The following information was found in the book "Forage Legumes for Temperate Grasslands" section on red clover (Frame, 2005b) unless otherwise noted. Optimum temperature for red clover growth is 20 to 25°C, with a range of 7 to40°C. Optimum pH for nodulation is 6.0 to 6.5 but, red clover will grow in soil with pH 5.0 to 6.0. Red clover is drought tolerant compared to most forage species due to a deep taproot and provides high forage production that has a high acceptability and nutritive value as a forage. Red clover can yield 13,000 to 18,000 kg ha^{-1}, and is used typically in beef cow-calf and stocker operations, grown for hay, silage, pasture, and soil improvement (Duiker and Curran, 2009; Caddel and Redmon,1995). Red clover can fix about 125 to 220 kg N ha^{-1} a year (Smith et al., 1985).

Trifolium repens L. is commonly known as white clover. White clover is a perennial with rhizomatous, prostrate stems which are creeping and has rooting from nodes (Zohary and Heller, 1984). White clover is widely distributed throughout the world. It can be found from the Arctic Circle to temperate sites on tropical mountains. White clover grows best in temperate zones with cool moist seasons and is found throughout Europe, North America, South America, Australasia, and Mediterranean (Gibson and Cope, 1985).

White clover is primarily used as a pasture crop and is adapted to soils with fine to medium texture that are well to poorly drained. Due to stolon growth, white clover can colonize bare space and niches in grass-clover swards (Frame 2007). White clover can tolerate acid to moderately alkaline conditions but requires moderate fertility (Moore, 2003). White clover can fix as much as146 kg N ha^{-1} year and can produce 5,000 to15,000 kg dm ha^{-1} a year (Smith, 2002). Protein and mineral rich, white clover retains digestibility due to continual generation of leaves and has a high acceptability by animals (Sooegaard, 1993). White clover is most commonly utilized for grazing due to low growth habit, but varieties such as ladino can grow taller and have suitable use as a hay crop (Justice, 2005).

Uses and Values of Clovers

There are several uses for clover in pasture settings. This section is divided into three parts. The first part will discuss the ability of clover and legumes to supply nitrogen to forage systems. A comparison of clover ability to fulfill a pastures nitrogen need compared to inorganic nitrogen fertilizer will be discussed. The second part will discuss how clover can increase forage quality and positively influence animal performance. Special attention will be given to the dilution of fescue toxicity. The third part will discuss clover's effect on total forage biomass, distribution of forage biomass throughout the growing season, and drought tolerance.

Nitrogen Transfer form legumes

Legumes fix atmospheric N into mineral form and can transfer this mineral N to grasses or other neighboring plants. Various factors affect the amount of N transferred from legumes to grass. Six to 79% of the total N in grass has been reported to come from neighboring legumes at distances over 20 cm (Gylfadóttir et al., 2007; Brophy et al., 1987). Nitrogen transfer from legumes to grass is affected by; interspecies distance and legume/grass ratio (Brophy et al., 1987), season (Ledgard, 1991), legume and grass species (Ta and Faris, 1987), dry matter accumulation between the donating and receiving species, and overall root turnover (Rasmussen et al., 2007). Dahlin et al. (2010) found that cutting had no effect on the percentage of N ryegrass obtained from red clover. They did find mulching of cut material allowed for a greater percentage of ryegrass N to come from the associated red clover (57%), compared to if the material was removed (30%).

Nitrogen is transferred from legumes to associated grasses by aboveground and below ground processes. Aboveground N transfer occurs through the senescence and decomposition of stems and leaves and through grazing animals. Five to 20% of N ingested by grazing is utilized by the animal. The rest is excreted with the majority of the N excreted in the urine (Decau et al., 2003). Urine N is 80% urea-N with the rest is a mixture is amino acids, peptides, and ammonium. A single urination event can deposit 600 to 1,000 kg N ha^{-1} for cattle (Zaman and Blennerhassett, 2010) and 500 kg N ha^{-1} for sheep (Singh et al., 2009).

Belowground transfer occurs via rhizodeposition and mycorrhizal connection between plants. Mycrorhyzial connections between plants have been shown to increase transfer of below ground nitrogen, though the process is not fully understood (Haystead et al., 1988; Johansen and Jensen, 1996). Pathways for rhizodeposition include; senescence and decay of root nodules and root, exudation of soluble compounds from roots, sloughing off of root border cells, and secretion if mucilage (Fustec et al., 2010). The decomposition of plant material, either above ground or below ground, is how the majority of N is transferred between legumes and associated grass (Russelle et al., 1994). The senescence and decomposition of root nodules and roots is the major pathway of N transfer (Dubach and Russelle, 1994). Nitrogen transfer through exudation occurs at lower amounts. Paynel et al. (2001) found that ammonium is the most common form of nitrogen exudates from plants roots. They also found, amino acids such as serine and glycine, can be exuded from clover roots.

Several experiments found the ability of legumes to supply N to grass in pastures settings. Vines at al. (2006) conducted a six year experiment in which tall fescue (*Festuca arundinacea* Schreb.) was grown in a mixture with red clover, alfalfa (*Medicago sativa* L.), or fertilized with 89 kg N ha^{-1}. The study found that tall fescue-red clover and –alfalfa mixes had soil NH_4 concentrations, aboveground N, and total herbage mass comparable to tall fescue pastures being fertilized with 179 kg N ha^{-1}. Hoveland et al. (1991) found that alfalfa grown with tall fescue could produce more biomass than tall fescue fertilized with 168 kg N ha^{-1}. Carter and Scholl (1964) found that orchardgrass (*Dactylis glomerata* L.) or bromegrass (*Bromus inermis* Leyss) monocultures would have to be fertilized with 268 kg N ha^{-1} to produce the same amount of biomass as orchard grass or bromegrass grown in a mixture with alfalfa or red clover.

Forage Quality and Animal Performance

A benefit of adding clovers and other legumes to grass pastures is increased forage quality and increased animal intake. These two factors can lead to greater animal performance over grass monocultures. Clovers also can dilute the toxic effects of endophyte infected tall fescue, which is of concern in the Mid-Atlantic region.

Nutritive Value

Compared to grasses, forage legumes generally have higher contents of protein, pectin lignin, carotene and vitamins, and have lower contents of water soluble carbohydrates, cellulose and hemicelluloses (Frame, 2005a). Zemenchik et al. (2002) found that legumes can increase the crude protein content of forage when grown in mixtures of grasses compared grass monocultures fertilized with inorganic nitrogen at low and medium levels. Furthermore, Zemenchik et al. (2002) found that legumes increase crude protein and lower acid detergent fiber and neutral detergent fiber of grass stands, and this is related to the amount of clover in grass stands. Another benefit of clovers is that with increased maturity clover digestibility remains fairly constant, but grass digestibility decreases (Weisbjerg and Soegaard, 2007).

Intake and Animal Performance

Greater legume intake and utilization by ruminants over grasses is due to differences in physical and chemical structure of the legume plant. Forage legume cell structure leads to smaller particle size and lower retention time in the rumen (Dewhurst et al., 2009). Wilman (1996) found that sheep had higher intake for vein structure associated with forage legumes over vein structure associated with grass. Increased synthesis of microbial nitrogen form protein-rich legume forage leads to more non-ammonia nitrogen reaching the small intestines of ruminants (Frame, 2005a). Animal preference for legumes over grasses has been well established. Rutter (2004) found that dairy cow intake was 63% white clover in a plot that was 25% white clover by composition. Higher intake for silage legumes over silage grasses of the same or even lower digestibility has been reported (Dewhurst et al., 2003). Greater voluntary intake, nutritive value, and nutrient availability of forage legumes compared to grass, leads to greater animal performance (Dewhurst et al., 2009). Greater animal performance also has been linked to greater quantity of clover in a pasture (Mourino et al., 2003). Hoveland et al. (1991) reported that steers grazing tall fescue-legume mixes had a higher average daily gain than on tall fescue supplied with 134 kg ha^{-1} or inorganic nitrogen fertilizer. In another example, lambs grazing alfalfa or red clover stands had higher live weight gain, shorter days to slaughter, higher cold carcass weights, and higher killing percentage than lambs grazing annual rye grass stands (Fraser et al., 2004; Speijers et al., 2004).

Dilution of Fescue Toxins

Tall fescue plants infected with a fungal endophyte can lead to production problems in cattle including; fescue foot, bovine fat necrosis, and fescue toxicosis (Schmidt and Osborn, 1993). Fescue toxicosis may cost the beef cattle industry $600 million annually in decreased profitability (Paterson et al., 1995). Consumption of other feeds and forages by livestock can dilute the detrimental effects of tall fescue toxicity on animal performance (Ball, 1997). Diluting tall fescue pastures can be achieved by interseeding legumes (McMurphy et al., 1990). Thompson et al. (1993) performed a combined analysis on 12 independent studies conducted in the southeast. They found that animals preformed better at all levels of infection rate of tall fescue when clovers where present then when clovers were not present. The authors concluded that the presence of 10 to 25% clover can alleviate the effect of fescue toxicity. Hoveland et al. (1997) found an increase in average daily gain in steers grazing endophyte infected tall fescue with as little as 6% alfalfa present.

Effects on Forage Biomass Production

Benefits of adding forage legumes to pasture are increased forage yield, increased days grazing and better seasonal distribution of forage (Johnson et al., 2007). The positive influence of multispecies mixtures for increased biomass production has been found (Tracy and Faulkner, 2006). Increased biomass per production area for several grass-legume combinations is attributed to higher biomass per plant of grasses and legumes when grown in association of each other (Aberg et al., 1943). Usually as one species plant biomass increases the associated species biomass decreases, though (Roberts and Olson, 1942). Taylor and Allison (1983) found that tall fescue yielded 37% less when grown in monoculture compared to mixture with forage legume. When planted with timothy (*Phleum pretense* L.) and bromegrass, legumes where able to increase yield by 125 and 98% respectively. The ability of forage legumes to improve the seasonal distribution of cool-season grass swards has been reported (Sleugh et al., 2000; Vines et al., 2006). Forage legumes created a more even distribution of biomass production in warm-season grass pastures in Texas (Evers, 1985). In addition to extending biomass production legumes increased biomass yield in warm-season grasses by 15% or 1700 kg ha^{-1} (Bartholomew and Williams, 2010).

Drought Resistance

Forage legumes can benefit a grass sward in droughty conditions for several reasons. Legumes generally have a better water use efficiency compared to cool season grasses in droughty conditions (Fairbourn, 1982). White clover, generally considered drought intolerant, showed a greater ability to tolerate drought stress and recoup after the stress was gone than perennial ryegrass (*Lolium perenne* L.) and tall fescue (Karsten and MacAdam, 2001). The root system of white clover allows for better performance than *Phalaris* (Liu and Kemp, 1992) and rye grass (Grieu et al., 2001) under drought stress. This is due to a greater plasticity in being able to balance root and shoot growth in response to water stress (Skinner and Comas, 2010). The ability of a forage legume to perform under and recover after moisture deficit is species and cultivar specific (Apariciotejo et al., 1980). Drought stress can actually improve forage quality of legumes, by delaying maturity, increasing leaf:stem weight ratio, and increasing the quality of the leaf and stem (Peterson et al., 1992).

Establishing Clovers in Pasture

Factors that affect clover establishment will be reviewed. Descriptions of direct drilling and broadcasting will be given, as well as literature pertaining to them. There are several factors that affect the successful establishment of forage legumes into grass swards. These include, competition/suppression of grass, nutrients, seeding date, effect of innoculant, cutting regime, insect suppression, and seeding depth.

Suppression of Grass

Hill and Hoveland (1993) found that competition from endophyte free tall fescue affected establishment more than moisture or defoliation stress on white clover, caucasian clover (*Trifolium ambiguum* M. Bieb), and birdsfoot trefoil (*Lotus corniculatus* L.).

They also found cutting frequencies that suppressed grass growth favor white clover establishment. Grass suppression through the use of herbicide has led to favorable forage legume establishment (Cuomo et al., 2001). Herbicides effect on suppressing grass swards for legume establishment is effected by season (Mueller and Chamblee, 1984), and herbicide type, and herbicide rate (Koch et al., 1987). Grass suppression by light tillage (Taylor et al., 1969), grazing animals, and mechanical cutting (Seguin et al., 2001) are also effective. Grass and legume species (Taylor and Allinson, 1983), and high application of nitrogen fertilizer (West et al., 1980) can favor grass competiveness.

Nutrients

Nutrients, primarily nitrogen and phosphorous, can have an effect on forage legume establishment in grass swards. Phosphorous is a key nutrient for clover seedlings (Frame 1992). Baker (1980) found that phosphorous was the most important factor relating to emergence and yield. The effectiveness of phosphorous fertilization was influenced by soil type and liming. High seeding rates with phosphorous fertilization enhanced burr medic (*Medicago polymorpha* L.) establishment in Texas (Muir et al., 2001). Nitrogen fertilization had a positive effect on forage legume establishment in cool-season grass swards (Laberge et al., 2005). West et al. (1980) found nitrogen fertilization follows a quadratic curve, with low to medium levels being beneficial to clover establishment. High levels of nitrogen fertilization makes grass more competitive, however, so the grass sward should be suppressed before applying nitrogen fertilizer. Effect of nitrogen fertilization is affected by soil organic matter and soil nitrogen levels (Seguin et al., 2001). Woodman et al. (1997) found that placement of nitrogen and phosphorous influence forage legumes response to fertilization. They found that phosphorous was more effective when it was drilled with the seed rather than placed below seed, while nitrogen was more effective when it was placed 2.0 cm below the seed.

Seeding Date

Seeding of forage legumes should be timed to coincide with adequate moisture and temperature to ensure successful stand establishment, normally in early spring or late summer in temperate regions (Cosgrove and Collins 2003). Taylor et al. (1969) found that for using a drill, spring sowing of legumes into bluegrass swards was the most effective, followed by late summer, with mid-summer sowing having the poorest establishment. For broadcast sowing February was more effective than March sowing (Mueller and Chamblee, 1984). Spring sowing is better than fall seeding, though fall seeding is effective if plants are given enough time to establish and grow to the point of being tolerant of freezing (Laidlaw and McBride, 1992). Fall seeding is most effective when sown in October than September, due to less moisture and insect stress (Rogers et al., 1983).

Effects of Inoculants

Legumes ability to interact with rhizobial to form nitrogen fixing nodules and these are important for establishment and to compete with grass (Wurst and van Beersum, 2009). Forage legumes with no rhizobia reduced the ability for legumes to compete with associates grass (Wurst et al., 2010). Laberge et al. (2005) showed that kura clover (*Trifolium ambiguum* Bieb) with no nitrogen or nodulation died within six weeks after emergence. Furthermore they showed that kura clover inoculated with native inoculum produced more root dry matter (dm), foliage dm, and total dm. If the seed is not inoculated with enough rhizobial seeding survival will be reduced (Patrick and Lowther, 1995). If enough rhizobial are present for the plant to nodulate fully, more inoculm will not enhance plant performance (West et al., 1980). Innoculating with more than one rhizobial species is increases nodulation and plant performance (Heichel and Vance, 1979). The presence of certain arbuscular mycorrhiza fungi also increases nodulation and plant performance (Mishra et al., 2009). Rhizobia are generally species specific (Beauregard et al., 2004). Low pH effects rhizobia ability to nodulate as well as root hair growth (Staley, 2003). However, forage legumes ability to nodulate is not always the cause for poor establishment as competition from grasses effects root growth by creating physical barriers and impairing photosynthesis (Staley and Belesky, 2004).

Cutting

Defoliation of the sward is desirable to bring light into the bottom of the sward to stimulate legume growing points (Frame, 2005a). Frequent defoliation increased the competitiveness of establishing white clover over associated grasses (Boatman and Haggar, 1985). Frequent cutting of tall fescue-legume swards took away the competitive edge of endophyte fungus and allowed legumes to successfully establish (Hoveland et al., 1999). In ryegrass-white clover swards clipping can reduce competition between ryegrass and white clover (Wen and Jiang, 2005). Effect of cutting frequency on biomass is species and cultivar specific (Hill and Hoveland, 1993; Swift et al., 1992). Cutting follows a quadratic curve, with medium levels being the best for DM production (Elgersma and Schlepers, 1997). If establishing clover is defoliated too young or defoliation too intense, clover establishment will be adversely affected (Hayes and Williams, 1995). Rotational grazing is better than continuous stocking for clover establishment and persistence (Brink and Pederson, 1993). Rotation management should be based on sward condition and used to open up the sward (Sheldrick et al., 1987).

Insect suppression

Control of invertebrates can be critical in establishing a competitive forage legume stand (Green and Martin, 1995). Several studies have shown that pesticides allowed for better establishment of forage legumes (Bryan, 1985; Byers and Templeton, 1988; James et al., 1980). The effectiveness of pesticides is based on pest present, pesticide type, clover species, and clover maturity (Mowat and Shakeel, 1988a, b). Invertebrate preference for different cultivars are based on anti-herbivory compounds within the cultivar, such as the cyanogenic levels in different cultivars of white clover (Mowat and Shakeel, 1989). Mollusks can be an important pest in the establishment of alfalfa (Dowling and Linscott, 1983). Williams (1984) found that plots that were not treated with mulluscicides, slugs caused a 70% reduction of seedlings, which lead to failure of establishment and thus overall biomass. Pesticide can be applied via seed coat though care should be taken as some pesticides can decrease rhizobium viability and hurt germination (Barratt et al., 1995). Invertebrates are usually seasonal and insecticides are only effective in months when insect population are active (Rogers et al., 1983).

Seeding depth

Forage legumes are small and have a limited amount of energy to emerge and different soil types affect the depth at which they can be planted (Cosgrove and Collings 2003). Planting at 0.5 to 1.5 cm depending on species, is the depth recommended for most legumes (Roberts and Gerrish 2001). Temperature has an effect on the time and amount of seeds that emerge when sown at different depths (Charles et al. 1991)

Planting Methods

The three most common methods of planting legumes are; surface sowing without disturbance (broadcast), drilling of seed through undisturbed sod and residue (direct drilling), and sowing in tilled seedbeds (Pearson and Ison, 1997). Factors such as equipment availability, time, field slope, soil type, and likely weed pressure should be considered when selecting a seeding method (Cosgrove and Collins, 2003). In a review of sowing methods by Cook (1980), oversowing is defined as establishing new pasture species into an already existing sward. The swards can be live, chemically killed, or partly disturbed. The two methods of oversowing are direct drilling and broadcasting. Cook (1980) also states that conventional sowing, when tillage is used to create a seedbed, is seen as more reliable than oversowing. The advantages of oversowing are that it is inexpensive, more land per time unit can be sowed, and there is smaller hazard of soil erosion. Oversowing has great importance due to the recommendation of sowing clover every two years in order to keep a healthy stand (Hoveland et al., 1991).

Direct sowing is a more precise method of seeding. More control is given over depth of the seed, and can lead to better soil to seed contact. The effectiveness of a drill is based on moisture retention of the groove created by the drill (Baker, 1976), ability to open ground and cut through residue while placing seed at proper depth (Waddington, 1992), and soil bulk density and compaction of soil below seed placement (Munkholm et al., 2003). Direct drilling over conventional sowing has produced higher biomass and smaller population of root-lesion nematodes (Kunelius et al., 1988).

Broadcasting, is a method in which seed is spread over the ground surface. Broadcasting is down by hand, a mechanical spreader, aerial, and animal. Frost seeding is commonly practiced in the United States. Seed is broadcast on to the ground and incorporated into the soil by the freezing and thawing of the ground (Cumming, 2011). Broadcasting seed followed by soil covering equipment can lead to better clover establishment (Kankanen et al., 2001).

Comparison of Broadcast and Drilling Methods

Experiments comparing broadcasting vs. drilling for establishing clover have found varying results. The difference in results is mainly due to environmental conditions. Seed to soil contact is important for allowing moisture to reach the seed and allow the seed to successfully germinate and establish. Byers and Templeton (1988) found that drilling produced more legume dry matter over broadcasting. Though in year one broadcasting was more effective than drilling when planted in early spring. They concluded this was due to less moisture stress that year. Mueller and Chamblee (1984) also found that broadcasting benefitted from an early spring, late winter sowing. In alfalfa no difference was found between broadcasting and drilling when sowed in February. Broadcast red clover preformed better when sown in February, though overall drilling produced 2 to 4 times as much legume biomass as broadcasting overall in the establishment year. Though after two years, satisfactory stands where found in both sowing methods. Coumo et al. (2005) found no difference between drilling and broadcasting in terms of establishment across several forage legumes. They found that the main factor leading to successful legume establishment was the suppression of grass species. This is in contrast to Taylor et al (1969), who found that the most consistent single factor contributing to successful establishment was drilling seed. The authors points out the extreme moisture and temperature fluxes on the soil surface as cause of poor establishment via broadcasting. Surface seeding can be successful if seeding rate is doubled (Taylor et al., 1972).

Conclusions

Literature comparing broadcast to direct drilling is existing swards is limited. To further the understanding the influence sowing method on clover establishment into existing cool season grass swards a grazing experiment was conducted from 2009 to 2011. A second experiment was conducted in 2010 to better understand the influence of soil fertility, grass biomass at sowing, and defoliation frequency on clover establishment. The goal of these experiments was to find factors that lead to better establishment of clover in permanent pastures. Literature regarding clover establishment in existing cool season pasture in for the temperate climate of the mid Atlantic is especially limited. But the importance of legume establishment is high due to importance of forage systems, low input nature of those systems and cool season grasses being the base of those forage systems.

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CHAPTER THREE

The Effect of Sowing Method on Establishment of Clover into Permanent Pasture.

ABSTRACT: Establishing legumes into permanent pastures has many benefits. To gain understanding of how sowing method affects establishment of clovers into permanent cool-season grass pastures a study using four 1.1 ha pastures was conducted from 2009 to 2011 near Blacksburg, VA. Pastures were split in half by sowing treatment (broadcast or drilled) and rotationally grazed. Seedling density was measured two months after sowing and grass, white clover, red clover, and weed biomass were periodically estimated via visual assessment and clipped biomass samples that were sorted to functional group. Compared to drilled treatment, broadcast treatment had 93% more clover seedlings two months after sowing ($P = 0.1087$). No difference ($P > 0.10$) for clover biomass was observed between sowing treatments in any year and clover establishment was considered successful (over 25% of pasture composition) in both sowing treatments. In the drilled treatment, clover seedling density was negatively affected by the amount of grass biomass present during sowing ($P = 0.0196$). In the broadcast treatment, a quadratic relationship between clover seedling density and residual grass biomass at sowing was found ($P = 0.0516$). Clover seedling density determined the amount of clover biomass in August 2009 ($P = 0.0008$) and the 2010 growing season mean ($P = 0.0249$). For successful establishment of clovers into permanent pastures, these data imply that removing residual grass biomass before sowing is more important than seeding method.

INTRODUCTION

The benefits of establishing legumes into permanent pastures have been well established. In pastures, legumes can fix atmospheric nitrogen and then act as a source of nitrogen for forage grasses (Carter, 1964). Addition of forage legumes to grass monocultures can increase forage biomass yield and can create a more even distribution of forage biomass throughout the growing season (Johnson et al., 2007). Forage nutritive value and animal intake can be increased by the addition of forage legumes to grass monocultures (Wilman et al., 1996; Zemenchik et al., 2002). Increased nutritive value and animal intake can lead to better animal performance on grass-legume sward over grass monocultures (Dewhurst et al., 2009). Forage legumes also help dilute the detrimental effects of tall fescue toxicity (Hoveland et al., 1997).

Establishment of forage legumes into permanent pastures can be challenging. Factors such as equipment availability, time, field slope, soil type, and weed pressure influence the selection of an appropriate seeding method (Cosgrove and Collins, 2003). Legumes can be overseeded by surface sowing without disturbance (broadcast) or drilling of seed through undisturbed sod and residue (no-till drilling) (Pearson and Ison, 1997). When overseeding legumes into existing swards they can be live, chemically killed, or partly disturbed (Cook, 1980). The advantages of overseeding into permanent pasture is that more land per time unit can be sowed, it is relatively inexpensive, and it minimizes soil erosion.

Both no-till drilling and broadcasting have strengths and weaknesses. The advantage of no-till drilling is more control over seeding depth to ensure good seed to soil contact. The disadvantage of no-till drilling is use can be limited by steep topography. Broadcasting requires less machinery and is virtually unrestrained by topography. No-till drilling is considered superior to broadcast due to more control is given in ensuring a proper seeding depth(Taylor et al., 1972).

There have been several experiments comparing broadcasting with no-till drilling with varying results. Taylor et al. (1969) found that drilling clover seed was important for successful establishment of clover. They found that extreme moisture and temperature fluxes on surface of the soil caused low establishment of broadcasted seed. Coumo et al. (2005) found no difference between drilling and broadcasting in terms of establishment across several forage legumes. They found the main factor that determine legume establishment was the suppression of grass species. Byers and Templeton (1988) found drilling produced more alfalfa (*Medicago sativa* L.) biomass over broadcasting, however. They found that when sowing was done in early spring broadcast treatments had more alfalfa biomass then drilling. They concluded this was due to higher than average rainfall that occurred in the early spring. Mueller and Chamblee (1984) also found that broadcasting was more effective when sowing was done in late winter than in spring. In their experiment white clover (*Trifolium repens* L.) broadcasted in mid-February had higher establishment than when broadcasted in mid-March, however. When averaged between the two sowing dates white clover establishment was higher in the drilled treatments. For alfalfa sown in mid-February, Mueller and Chamblee (1984) found no difference between broadcasting and drilling. They did find drilling treatment had two to four times as much alfalfa biomass as broadcast treatment when sowing took place in mid-March. These studies suggest that broadcast legume forages have higher establishment when sown in late-winter/early-spring. Kankanen et al. (2001) found that broadcast clover seeds establish at a higher rate when measures are taken to ensure good seed to soil contact, such as the use of seed covering equipment..

Frost-seeding is a form of overseeding when seed is broadcasted mid-winter on top of snow and frozen ground. Once sown, the freezing and thawing of the ground incorporates the seed into the soil. This allows for better seed to soil contact and reduces the equipment required. This experiment compared frost-seeding to no-till drilling. For the rest of the paper the term broadcast will be used instead of frost-seeding. Replicated experiments comparing broadcast to no-till drilling are limited. Taylor et al. (1972) conducted an experiment to compare broadcast with no-till drilling and found that drilling treatments had more seedlings than broadcast in every month of establishment (February, March, and April). They cited the reason for poor establishment in broadcast treatment was the seed was exposed to extreme fluxes in temperature and precipitation that occur on the soil surface and drilled seed was protected from these fluctuations.

More information is needed about these overseeding methods to provide producers with information to help increase the success rate of legume establishment. To add to literature pertaining to how sowing method affects clover establishment, a pasture experiment was conducted from 2009 to 2011 near Blacksburg, VA. The primary objective of this study was to compare the effectiveness of broadcast (frost-seeding) to no-till drilling for oversowing white and red clover. A secondary objective was to identify potential environmental variables that may help explain the success or failure of seeding methods.

MATERIALS AND METHODS

Study Site

A pasture experiment was conducted at Virginia Tech Kentland Farm near Blacksburg in Montgomery County, VA (37°11' N latitude and 80°35' W longitude) during the 2009, 2010, and 2011 growing seasons. The soils were mainly Unison and Braddock soils with a slope from 7 to 25% and a Guernsey silt loam with a slope of 2 to 7%. Climate data were collected from the Kentland Farm weather station. Historical climate data (averaging period of 1971 through 2000) were obtained from the National Oceanic and Atmospheric Administration's National Climatic Data Center (NCDC) using the weather station Pulaski 2 E, located at approximately 37°3' N latitude and 80°47' W longitude (NOAA Climatological Data Annual Summary 2009).

Experimental Design

The experiment was set up as a randomized complete block design with four replications. Four 1.1 ha permanent cool-season grass pastures (blocks) were split in half with each randomly assigned a sowing treatment (broadcast or no-till drill). Ten years prior, the pastures were sown to endophyte-infected tall fescue (*Festuca arundinacea* Schreb.) and then used in conjunction with various research experiments. No clover was sown to the pastures during this time. The species composition of the pastures at the beginning of this study was dominated by tall fescue and bluegrass (*Poa pratensis* L.), with a smaller proportion of orchardgrass (*Dactylis glomerata* L.). Clover made up less than one percent of the pastures composition. Pastures were fertilized with 58 kg ha^{-1} of P_2O_5 and 50 kg ha^{-1} of K_2O in March 2009 based on soil test results. Pasture were mob grazed for 3-4 days in the winter of 2009 using 57 cows to reduce grass biomass.

Pastures were overseeded the first week of February of 2009. Seeding rate for both treatments was 3.6 kg ha^{-1} of red clover (Liberty) (*Trifolium repens* L.), 1.8 kg ha^{-1} ladino white clover, and 1.8 kg ha^{-1} white clover (Kopu II).

Grazing Management

Pastures were split into six equal sized paddocks using single-strand electric poly-wire and back-fenced so animals were only allowed access to one paddock at a time. Bred beef cows (avg. wt = 640 kg) were used for the grazing trial, and three cows were assigned to each 1.1 ha pasture. Grazing lasted from April 21 to October 28 in 2009 and April 20 to October 4 in 2010. During the first three rotations (42 days) in 2009 pastures were stocked with six cows (11 au/ha), instead of three cows (2.5 au/ha), to help suppress grass competition and allow clovers to establish. Starting in April, cows were moved between paddocks every 2 days, with the residency period progressively lengthened to 5 days per paddock by fall. Animals were removed from pastures twice each season (10 to 15 days in June and 20 to 30 days in July/August) to graze warm-season perennial grass pastures that were part of a different study. Water and trace minerals were offered free-choice at all times. Bloat blocks (sweetlix, PM AG Products) were provided to the animals during the first three rotations in 2009 after which bloat preventives were not provided. During this experiment no animal grazing pastures suffered from bloat.

Measurements

Herbage Mass and Seedling Density

In January 2009 residual grass biomass present after mob grazing was estimated by clipping ten 0.25 m^{-2} quadrats to a 2.5 cm stubble height in each pasture. Biomass was then dried using a force air oven at 60^0C for at least 48 hours and weighed. Clover seedling density was measured in April 2009, using ten randomly placed 0.125 m^2 quadrats per treatment plot. The number of seedlings in each quadrat were counted and recorded. Species composition and aboveground biomass was measured nine times on: June 18, August 12, and October 10, in 2009; April 16, June 14, August 17, and October 16, 2010; and April 27 and June 15, 2011. Visual species composition was taken in ten randomly placed 0.25 m^2 quadrats per plot. Plant species present and ground cover percentage of the quadrat that species represented were recorded. Quadrats were then clipped to a 7.5 cm stubble and hand sorted to grasses, weeds, white clover, and red clover. The samples were then dried using a forced air oven at 60^o C for at least 48 hours and weighed.

Nutritive Value Analysis

Samples for forage nutritive values were collected every four weeks during the grazing season. Samples were collected for one paddock immediately before cows were allowed to graze on that respective date. Two randomly placed 0.25 m^{-2} quadrats per treatment were clipped to 7.5 cm stubble and then dried using a forced air oven at 60^oC for at least 48 hours. After the samples were dried, they were ground with a Wiley sample mill (Thomas Scientific, Swedesboro, NJ) to pass through a 1 mm screen. The samples were then analyzed to determine dry matter content, ash content, neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP) (Goering and Van Soest 1970, PerkinElmer 1999, AOAC 2000). Each sample was run twice and the results were averaged. Dry matter content was determined by placing 0.5 g of each sample in a porcelain container and then put in a drier for six hours. The samples were placed in a desiccator for 20 minutes and then weighed. The samples were then used to determine ash by placing the porcelain container in a muffle furnace. Samples were heated to 500^{o}C and ashed for two hours. The samples were then placed in a desiccator for 45 minutes and weighed. ADF and NDF were measured using Ankom 200 fiber analyzer. Approximately 0.5 g of sample were placed in filter bags and sealed. NDF was determined by placing the bagged samples into the Ankom fiber analyzer along with two L Neutral Detergent Solution, 20 g sodium sulfite, and four ml heat-stable alpha-amylase, heated to 100°C, agitated for 75 minutes, and washed three times with two L hot dH2O for five minutes each time. Four ml of alpha-amalyase were added to each of the first two washes. Samples were soaked in acetone for five minutes, dried and then weighed. After the samples were weighed for NDF, they were placed into the Ankom fiber analyzer with two L of Acid Detergent Solution, heated to 100°C agitated for 60 minutes, then rinsed three times with two L hot dH2O for five minutes each time. Samples were then soaked in acetone for five minutes, dried and weighed. Crude protein was determined using a combustion procedure. A 40 to 60 mg ground sample was weighed into a tin combustion boat. The boat was then shaped into a small ball. Samples were loaded into a nitrogen analyzer (Perkin Elmer 2410 Series II) and analyzed along with controls (40 to 60 mg EDTA as an analytical standard) and blanks.

Clover Populations and White Clover Morphology

A destructive sod harvest was taken in late October in 2009 and 2010 in order to measure the number of white clover and red clover plants in respective treatments. In addition to population counts, white clover stolon length, number of stolons per white clover plant, and average weight per stolon was also recorded. Sods within ten randomly placed 0.125 m^2 quadrats per plot were cut using a garden spade. The samples were then washed and red and white clover plants were separated from the sod. The number of red and white clover plants were counted and recorded. The number of stolons per white clover plant was counted and recorded as well as the length of the stolons. Stolons were removed from white clover plants and dried using a forced air oven at 60^{o}C for at least 48 hours and weighed.

Data Analysis

Herbage mass and visual assessment for respective species groups, seedling density, clover population, white clover morphology, and nutritive values indices-were analyzed using ANOVA. Analysis consisted of a treatment factor of overseeding method (broadcast or drill) blocked by pasture (b = 4 blocks) and with no replication of treatments within a block. Data was analyzed for each measurement date and in each year.

SAS statistical software (SAS, SAS Institute, Inc. 2008) was used to perform analyses. Regression analysis was performed on raw data using Sigma Plot 11.0 (Systat, Point Richmond, CA). A P-value of 0.10 was used to decide statistical differences between treatments.

RESULTS

Weather

The historic average temperature between February and October is 13.9 with 75.5 cm of rainfall (Table 3.1). Between February and October of 2009, 76.5 cm of rainfall occurred, 8.8 cm higher than the historic average. May, June and July had higher than or near the historical average rainfall. May had the highest amount of rainfall at 18.9 cm (historic May average is 10 cm). Below average rainfall was noted for February and

April. The average temperature for 2009 was 0.1^0C lower than the historic average. Between February and October of 2010 54.2 cm of rainfall occurred. April and June received as little as a third of the historic monthly averages. Above historic average rainfall occurred in August through October. Average temperature in 2010 was 1.7^0C above the historic average. In 2011 44.5 cm of rainfall fell between February and June. Above average rainfall occurred between March and May. Rainfall was low in February and June as both months had less than 30% of the historic averages. Monthly average temperatures in 2011 did not differ more than 2^oC from the monthly historic average.

Clover Seedling Density

Clover seedling data taken in April 2009 is provided in Figure 3.1. Red and white clover seedlings could not be accurately separated by species so they were counted together. The data indicates that broadcast treatments had a higher seedling density than drilled treatments ($P = 0.1087$).

Species Composition Herbage mass

Table 3.2 provides the herbage mass data from species composition measurements taken during the 2009, 2010, and 2011 growing seasons. In 2009 no difference between the drilled and broadcast treatment were found for grass, white clover, red clover, and weed herbage mass for either the entire growing season or any measurement date. In 2009, 84%, 8%, 6%, 2%, of the herbage mass was grass, white clover, red clover, and weed, respectively. Between June and August clover and grass herbage mass increased 400% and 150% respectively. White and red clover herbage mass decreased from August to October by 50% and 63%, respectively.

In 2010, no difference between the drill and broadcast treatments was found for white clover, red clover, and weed herbage mass. Grass herbage mass in April was significantly higher for drill treatment than broadcast ($P = 0.0212$). No difference was found for grass herbage mass in June, August, or October measurement dates. In April of 2010 clover was 33% (24% white clover and 9% red clover) of the total herbage mass, but declined to 9% (6% white clover and 3% red clover) of total herbage mass in October. The proportion of grass increased during the 2010 growing season. In April grass made up 63% total herbage mass and increased to 80% in October. Total herbage mass declined from 240 g m^{-2} in June to around 80 g m^{-2} October. Weeds made up 10% or less of herbage mass throughout the 2010 growing season. The June sampling date in 2010 had three times more clover herbage mass of June 2009 and twice the total herbage mass. August 2009 total herbage mass was 3.5 times higher than August of 2010 and clover herbage mass was six times higher in August 2009. Overall, in 2010 clover made up 24% of the total herbage mass, compared to 13% in 2009. The 2010 average clover herbage mass was higher (40 g m^{-2}) compared to 2009 (28.5 g m^{-2}). The proportion of red clover did not differ between 2009 and 2010. In both years red clover was approximately 13% of the total herbage mass. White clovers proportion of total herbage mass increased from 16% in 2009 to 24% in 2010. The season average herbage mass in 2009 was higher (209.9 g m^{-2}) than 2010 (161.6 g m^{-2}).

In 2011, no difference between broadcast and drill treatment was found for grass, white clover, and weed herbage mass in April or June. In April, no difference was found between the broadcast and drill treatments for red clover, but red clover herbage mass was higher in broadcast treatments in June ($P = 0.0856$). In April, clover made up 16%

(13% white clover and 3% red clover) of the total herbage mass and declined to 8% in June (7.5% white clover and 0.5% red clover). In June, a higher total herbage mass (108.6 g m^{-2}) was noted compared to April (90.1 g m^{-2}) due to increased grass growth. Clover herbage mass was higher in April (14.7 g m^{-2}) compared to June (9.3 g m^{-2}). The 2011 April and June total herbage mass average (99.32 g m^{-2}) was lower than the 2010 April and June total herbage mass average (244.7 g m^{-2}). Clover made up practically identical proportions of total herbage mass in 2011 and 2009 (12% and 13 %, respectively). Red clover declined to 2% of total herbage mass in 2011 from 8% in 2010 (April and June 2010 dates). White clover was 10% of the total herbage mass in 2011 which was higher than 2010 (7.5%) but lower than 2011 (14%).

Visual Species Composition

Table 3.3 provides the visual data from the species composition measurements taken during the 2009 and 2010 growing season. No difference was found between drilled and broadcast treatments for grass, white clover, red clover, or weed during the 2009 growing season. Visual assessment of white and red clover in 2009 was 25 and 13%, respectively. The percentage of white clover increased from 24% in June to 27% in October. Percentage of red clover grew from 11% in June to 14% in October. The percentage of grass decreased from 65% in June to 41% in October. Weed composition decreased from 7% in June to 3% in October. Overall, the amount of clover increased throughout the 2009 growing season, while the amount of weed and grass decreased.

In 2010, no difference was found between drilled and broadcast treatment for grass, white clover, red clover, and weed for the 2010 growing season. Red clover had a significantly higher percentage for broadcast treatments in August of 2010 (P=0.0113).

No difference was found for red clover composition in any other measurement date. White clover, grass, and weed percentage did not differ between treatments in any measurement date in 2010. Clover composition decreased from 52% (28% white clover and 24% red clover) in April to 24% in October (18% white clover 6% red clover). Grass composition increased from 47% in April to 68% in October. Grass and clover composition was at its lowest in August 2009 (43% and 19%, respectively)though, weed was at its highest (9%). Dead material and bare ground made up 29% of visual composition in 2010. The 2010 growing season species composition was practically identical to 2009, however, throughout the 2010 growing season the amount of clover declined and there was an increase in the percentage of grass and weed. June of 2010 had the highest percentage clovers for any measurement date in 2010 and, in 2009 June had the lowest amount of clovers. In 2009 grass and clover had equal proportion at 41 % each, and in 2010 grass was 64% and clover 23% of total composition. Visual assessments were not done in 2011.

Nutritive Value Analysis

Results from forage nutritive value analysis during the 2009 growing season is provided in Table 3.4. NDF and ADF were higher in broadcast compared to drill treatments in October of 2009 ($P = 0.0347$ and $P = 0.0668$ respectively). No difference in any other month or for the 2009 growing season was found for NDF or ADF. No difference in any month or for the 2009 growing season was found between broadcast and drill treatment for CP. The 2010 nutritive values are not included in this chapter. Since the amount of clovers did not differ between treatments the nutritive value data would likely be the same in both treatments. Mourino et al. (2003) found that nutritive value of grass-legume mixes was affected by amount of legumes present.

Clover Population and White Clover Morphology

Table 3.5 provides the data obtained from the destructive sod harvest taken in October of 2009 and 2010. No difference between broadcast and drilled treatments were found for red clover plants m^{-2}, white clover plants m^{-2}, number of stolons per white clover plant, or white clover stolon weight. Average stolon length was higher in drill treatment compared to broadcast treatments in 2009 ($P = 0.0919$).

In 2010, no difference between broadcast and drilled were found for red clover plants m^{-2}, white clover plants m^{-2}, number of stolons per white clover plant, average stolon length or stolon weight. In 2010 the number of red and white clover plants decreased. White clover plant population decreased by about 30%. White clover stolon length was also lower in 2010, from an average 3.9 cm in 2009, to an average 2.5 cm in 2010. Surprisingly, white clover stolon weight in 2010 increased from 0.29 g in 2009 to 1.95 g in 2010.

Effect of Grass Herbage mass at Sowing on Clover Establishment

Figure 3.2 shows the relationship between grass biomass at time of overseeding and seedling density. Grass herbage mass remaining after mob grazing was variable across the four pastures. Seedling density in the drill treatments was negatively related to the amount of grass biomass present at time sowing ($P = 0.0196$). A quadratic relationship was found for broadcast treatment ($P = 0.0196$). Clover seedling density was highest at a grass biomass of 175 g m^{-2}.

Seedling Density and its Relationship to Subsequent Clover Herbage Mass

Relationship between clover seedling density in April 2009 and clover herbage mass in August of 2009 is shown in Figure 3.3. Clover herbage mass data was obtained from species composition harvest taken in August of 2009 and the seedling density data was obtained from seedling density measurements taken in April 2009. Clover seedling density data was not species specific, therefore clover herbage mass was taken by summing white clover and red clover herbage mass together. The data show that there was a positive relationship between clover herbage mass in August of 2009 and seedling density in April of 2009 ($P = 0.0008$).

Figure 3.4 also shows a positive relationship between seedling density in April 2009 and clover herbage mass throughout the 2010 growing season ($P = 0.0249$). Clover herbage mass data was obtained from summing red and white clover biomass measurements taken in April, June, August, and October of 2010. The data showed a positive relationship between clover herbage mass in 2010 and seedling density in April of 2009 but, it was not as strong as in 2009.

Clover Herbage Mass vs. Visual Assessments

Data from species composition measurements taken in 2009 and 2010 were used to evaluate the relationship between percent cover estimations and herbage mass measurements for clover (Figure 3.5). A positive relationship was found ($P < 0.0001$). A 25% clover amount or greater in pasture is usually recommended to supply grasses with enough nitrogen to avoid the need for fertilizer application. In this study, 25% clover biomass by weight translated into a visual assessment of about 50% clover ground cover and 25% clover by visual assessment was approximately 10% clover by weight.

DISCUSSION

A pasture experiment was conducted from 2009 to 2011 to compare broadcast to no-till drilling for establishing clovers into permanent pasture. The hypothesis was that no-till drilling would allow for better clover establishment and produce more clover biomass than broadcast seeding. Although variable, more seedlings emerged in the broadcast treatments than drill treatments in April 2009. No difference was found between the two treatments for clover biomass in 2009, 2010, or 2011. The data suggests that grass biomass at sowing can play an important role in determining clover seedling density, especially for no-till drill planting. The results also point to the importance of having a high initial clover seedling density as it may help determine subsequent clover biomass in the year of sowing and into the next growing season.

Clover Seedling Density

The data indicate that broadcast treatment had a larger number of clover seedlings than drilled treatment. Taylor et al. (1969) conducted an experiment in which red clover seeds were broadcast or drilled in March, July, and September. They found that in every date drill treatments had more seedlings emerge per 100 seed than broadcast treatments. Their results coincides with a later study, Taylor et al. (1972), that found in February, March, or April, no-till drilled red clover seeds had more seedlings emerge per 100 seeds than broadcasted seeds. They cite that drilling provided protection from both moisture and temperature fluxes on the soil surface. They conclude that broadcast seeding could be used to establish clovers provided that normal seeding rates (11.2 kg ha^{-1}) are doubled (22.4 kg ha^{-1}). This study suggests that even during a relatively dry spring broadcasted clover seeds had a higher emergence rate than when drilled.

In early spring 2009 after clover seeds were sown, the conditions were dry compared to the historic average. February received 5.0 cm less than the historic average while April received 1.0 cm less than the historic average. Taylor et al. (1972) received more rain in February, April, and March. They also found a higher number of clover seedlings per 100 seeds sown in drilled treatments compared with broadcast. This study received less rain and found a higher clover seedling density for broadcast treatments. This finding suggests that the amount of early season rainfall may not be the main reason for difference in clover seedling density between broadcast and drill treatments.

Taylor et al. (1972) used red clover while this study used a mixture of white and red clover. We had difficulty in distinguishing between white and red clover seedlings and both species were counted together during seedling density measurements. White clover may have accounted for a larger number of the clover seedlings than red clover in broadcast treatments. The seeding rate was 7.2 kg ha^{-1}, with red and white clover being sown at a rate of 3.6 kg ha^{-1} each. White clover consisted of 1.8 kg ha^{-1} of ladino white clover and 1.8 kg ha^{-1} of kopu II white clover. Thousand seed weight for red clover, ladino, and kopu II is 1.8g, 1.5 g, and 0.65 g, respectively. Given the differences in seed weight there was roughly 30% more white clover seeds sown than red clover seeds. This study used approximately double the recommended seeding rate (1.12 to 3.36 kg ha^{-1}) for pasture renovation using white clover (Teutsch et al., 2009). Due to the relatively high number of white clover seeds planted, white clover seedlings may have made up a large percent of seedlings counted. This is supported by 2009 red and white clover population data that indicate the number of white clover plants was almost double the number of red clover plants when averaged between treatments.

The large number of white clover seedlings may have accounted for the difference between this study's result and those of Taylor et al. (1969, 1972). White and red clover may also have different emergence response to the same sowing method. Watkins and Vickery (1965) found that alfalfa and subterranean clover had more seedlings five weeks after sowing when drilled compared to broadcast, however. White clover seedling emergence was higher when broadcasted suggesting that response to sowing method may differ among legume species. Red clover seedlings are also more susceptible to below freezing temperatures than white clover seedlings (Meyer, 2001). Temperatures in February, March, and April of 2009 during this study were warmer than in Taylor et al. (1972). Since broadcast red clover seedlings were exposed to colder temperatures in Taylor et al. (1972), less red clover seedlings may have survived in broadcast treatments and drilled red clover seedlings would have had some protection from cold temperatures. A study by Casler et al. (1999) suggested that red clover may not be suitable for broadcast seeding in the early spring. Cold temperatures in early spring may also have a negative effect on white clover emergence in drilled treatments. Charles et al. (1991) studied the effect of temperature (3, 6, 9, 12, and 24^0C) and seeding depth (0, 1.5, 3.0, and 4.5 cm) on white clover emergence. They found that white clover was able to emerge over 80% in broadcast treatments at all temperatures. When white clover was drilled to 1.5 cm at 12^oC, 81% of the white clover seeds drilled emerged, however, only 42% of white clover seeds drilled to 1.5 cm where able to emerge when the temperature was 3^oC. Their study shows that at low temperatures white clover seedling emergence is higher for broadcast treatments than drilled. Charles et al. (1991) also found when white clover was sown 3.0 and 4.5 cm depth, regardless of temperature, white clover emergence was less than 20%.

Several other studies have found that drilling red and white clover to deep will decrease emergence. Peri et al. (2000) conducted a study on sowing depth and white clover. They found that from 1.5 cm to 2.5 cm planting depth white clover emergence decreased from 71 to 25%. They did not find a decrease in emergence from 0.5 cm to 1.5 cm. Campbell (1985a) conducted a study in which red clover was drilled with a winged coulter at 0.0, 1.3, 2.6, and 3.9 cm. He found that red clover emergence was the highest (90-95%) at 1.3 cm of depth and lowest at 0.0 and 3.9 cm (69% and 52%, respectively). An advantage was found for sowing at 1.3 cm due to the drill creating a moisture retaining burrow. At the deeper treatments there was no added protection and clover seedling emergence was hindered by a longer emergence time that caused clover seedlings to become more susceptible to moisture and pest stresses. Murphy and Arny (1939) conducted a study looking at emergence in different soil types at different depths. They also found that white and red clover emergence declined when sown at 2.5 cm from 0.6 cm.

Seeding depth may have played a role for differences between this study and Taylor et al. (1969, 1972). Taylor et al. (1969, 1972) conducted their study using a small plot experiment in which plots were 2.5 m long and 0.2 m wide. This study used 1.1 ha pastures that were split in half by treatment. Taylor et al. (1969, 1972) could have had more control in ensuring consistent seeding depth of 0.6 cm due to small size of plots. In this study ensuring a consistent drilling depth for clover was harder due to size of plots and variation of topography within plots. In this study the drill may have gone too deep in some areas causing a lower seedling emergence for drilled red and white clover seeds.

Mueller and Chamblee (1984) study differs with Taylor et al. (1972) and this study. They conducted an experiment looking at broadcast and drilling ladino clover in mid-February and in mid-March. They found no difference in clover seedling density in three of four years between broadcast and drilling for mid-February sowing date. The results from this study agree with Watkins and Vickery (1965). They found more white clover plants 5 weeks after planting for broadcast treatments than in drill treatments. A study by Charles et al. (1991) also agrees with this study. They found that 90% of white clover seed emerged at 3^{0}C (2.1^{o}C was the monthly average for February 2009) when broadcasted, though only 43% of white clover seeds emerged when drilled to 1.5 cm. They conclude that broadcasting white clover may be the most appropriate seeing method.

Clover Biomass

Although the data shows a higher clover seedling density for broadcast treatment, no difference was found between broadcast and drill treatments for grass, white clover, red clover, and weed presence and herbage mass in 2009, 2010, or 2011. Finding differences in clover seedling densities between seeding treatments and then not finding a difference in clover biomass in later measurements has been reported by other studies. Mueller and Chamblee (1984) found more ladino clover seedlings in drilled plots than in broadcast, though at the end of the establishment year ladino clover herbage mass was equal in both treatments. Byers and Templeton (1988) found that broadcasting produced more alfalfa herbage mass the year of establishment, though no difference was found between the drill and broadcast for alfalfa biomass the year after establishment. This result may be explained by Dear et al. (2007). They found that as alfalfa seedling density increased the rate of population decline also increased. In this study clover population numbers in the broadcast treatments may have declined faster than in the drilled treatments, resulting in similar clover population numbers between the two treatments.

Overall, both treatments showed successful clover establishment in 2009 and 2010 (over 25% composition) though clover biomass declined in 2011. The data is in agreement with Cuomo et al. (2001). They studied the effect of sod suppression with glyphosate, planting method, and legume species on establishment of legumes into permanent pastures. They found no difference between broadcast and drilled red clover, alfalfa, kura clover *(Trifolium ambiguum* Bieb) and birdsfoot trefoil (*Lotus corniculatus* L.) into grass pastures in the year of establishment or the next year. They cited grass suppression, regard less of sowing method, as the main factor effecting legume establishment. Without suppressing grass drilling and broadcast had low (<3% by composition) legume composition regardless of sowing method.

The data indicates that among the three years the amount of clovers peaked in the second year and declined in the third. Red clover went from 5% of the total herbage mass in 2009 to 3% in 2010 and then 2% in 2011. Lomas et al, (2004) also found that when red clover was drilled into tall fescue pastures it started at 5% of pasture composition and at the end of year three was at 2% of composition. Finding significant white clover in 2011 three years after planting was surprising. White clover stands commonly last two years and disappear in the third (Hoveland et al., 1991; Olsen et al., 1981). Hoveland et al. (1991) and Olsen et al. (1981) both found white clover contributed to total pasture yields for two years after establishment, but white clover was not present in the third year. This study found white clover biomass was approximately 15% of the total herbage mass in the third year. Difference between this study and Hoveland et al. (1991) and Olsen et al. (1981) may be due to higher seeding rates and the use of kopu II white clover. Both Hoveland et al. (1991) and Olsen et al. (1981) used ladino white clover at a seeding rate of 3.36 kg ha^{-1} and 2.24 kg ha^{-1}, respectively. The white clover seeding rate in this study was higher (3.6 kg ha^{-1}). During this study it was difficult to tell the difference between kopu II and ladino white clover, therefore both varieties were counted together as white clover. The use of kopu II may account for the presence of white clover after three years that was not seen in Hoveland et al. (1991) and Olsen et al. (1981). An unpublished study by Albrecht and Woodfield (1998) found that kopu II white clover had higher herbage mass after three years then ladino white clover varieties. Weather may have played a role in differences between the results of this study and Olsen et al. (1981) and Hoveland et al. (1991). During the summer of 2010 weather was dry. Pastures were grazed hard which opened up sward canopies and created bare ground. White clover is known for its ability to colonize open spaces in the sward (Frame 2005). Above historic rainfall occurred in the fall of 2010 and the extra moisture may have allowed white clover to colonize open areas. Sanderson et al. (2003) found that white clover stolon density decreased by 50% due to summer drought, though stolon density increased in September when rainfall occurred. High white clover stolon density may lead to higher persistence (Black et al., 2009). Another factor in this study that lead to long persistence of white clover is controlling grass competition by rotational grazing. Yu and Hou (2005) found that frequent cuttings (once a month) of ryegrass-white clover swards decrease the competition between ryegrass and white clover. Oates et al. (2011) found that rotational grazed pastures had higher white clover biomass than pastures used for hay. Rotational grazing in this study may have lowered grass competition to the point that it was never able to eliminate white clover from the sward and allowed white clover time to recover from defoliation.

Clover Populations and White Clover Morphology

No difference between broadcasting and drilling for white and red clover populations was found in either 2009 or 2010. The data could not be supported or refuted by existing literature. Most studies that have looked at the difference between broadcasting and drilling in overseeding clovers have measured total clover herbage mass, not individual plants later in the year of establishment or the second year. This study's result of finding a higher seedling population and then no difference between clover population is in agreement by Mueller and Chamblee (1984). They found a difference in seedling density for ladino clover between broadcast and drill, though found no difference in three of four years for ladino clover yield later in the growing season. White clover had a higher number of plants in both treatments compared to red clover. This could be due to the fact that more white clover seeds were sown then red clover. As noted above, there was roughly 30% more white clover seeds than red clover seeds.

White clover stolon length in 2009 was longer for drilled treatments compared to broadcast. A possible explanation is that white clover plant density may have been lower in the drill treatments leading to longer stolons. Marshall and James (1988) found that white clover planted at low densities (9 and 25 white clover plants m^{-2}) had longer stolons than white clover plants planted in high densities (50 and 100 white clover plants

m^{-2}). Not seeing a difference in stolon length in 2010 could have been due to dry conditions. Karsten and Fick (1999) found that dry condition in New York State caused a decrease in stolon size. Dry weather was also found to reduce stolon size in southeast Pennsylvania (Sanderson et al, 2003). It is possible that due to the dry weather in 2010 the drilled white clover stolons could not and rainfall that occurred in September may have caused stolons to start to accumulate reserves that where depleted during the summer. Sanderson et al. (2003) found that during a dry summer white clover stolon length decreased by 50%, however. They found that stolons weight increased from September to November, with no increase in stolon length, with increased rainfall.

Nutritive Value

No difference in 2009 was seen in any month between the drilled and broadcast for ADF, NDF, or CP. Mourino et al. (2003) found the amount of clover in a grass-clover mix is the variable that will raise or lower the nutritive value of a pasture. They found that kura clover-grass pastures had lower ADF and NDF, and a higher CP, than red clover-grass pastures, due to more kura clover present in the pasture. Zemenchik et al. (2002) also found that the proportion of legumes in grass mixtures were positively correlated to CP concentrations and negatively correlated to NDF concentrations. This study found no difference between the treatments for ADF, NDF and CP concentrations between treatments likely due to the fact that the proportion of clovers did not differ.

The ADF, NDF and CP concentrations in this study averaged 28.8, 57.5 and 17.0 $100g^{-1}$, respectively. Results of this study are comparable to results from other studies in Virginia. Allen et al. (2000) conducted an experiment at the Southwest Virginia Agricultural Research and Extension Center, in Glade Spring, VA, and found CP and

NDF concentrations of grazed fescue-red clover mixtures at 18 and 55.5g $100g^{-1}$ respectively. A study by Mundy et al. (1993) conducted at Kentland Farm near Blacksburg, VA found ADF, NDF and CP concentrations of grazed alfalfa-fescue mixture of 34.3, 52.2, and 16.7g $100g^{-1}$, respectively. In the same study, a pure tall-fescue sward fertilized with nitrogen had an ADF, NDF, and CP concentration of 31.7, 62.7, and 13.3g $100g^{-1}$ respectively. This study had a better nutritive value tall fescue fertilized with nitrogen (lower ADF and NDF, and a higher CP) likely due to the presence of clovers. Overall, both treatments had CP concentrations that are acceptable for beef stocker production (NRC 2000).

Grass Residue Height and Clover Seedling Density

Finding a negative relationship between grass biomass at sowing and seedling density for no-till drilling clover is supported by Springer (1997). He found a linear decrease in white clover ground cover with an increase in bermudagrass height at sowing. He found a 10% decrease in white clover for every 5 cm increase in bermudagrass height. He cited that higher bermudagrass canopy height caused a poor seed to soil contact and created a suitable habitat for the survival of insects that eat clover seedlings. Guretzky et al. (2004) found that clover had better emergence at lower sward heights compared to higher sward heights for no-till drilled clover. This study found a quadratic relationship between broadcast clover seedling density and grass biomass at the time of sowing. Watkins and Vickery (1965) found for broadcast subterranean clover (*Trifolium subterraneum* L.) the number of seedlings increased in plots that had a protective layer of grass biomass, however. Grass sward in ungrazed plots in their study was not dense enough to limit light penetration. Any advantage grass biomass would offer to broadcast clover seedlings would be void if grass biomass was too dense to allow light penetration. The data suggest that the relationship between broadcast clover seedling density and grass biomass at sowing may be quadratic.

The data showed that clover biomass was positively associated with a high seedling density two months after sowing. This result agrees with Dear et al. (2007). They found that a higher number of alfalfa seedlings at time of establishment lead to a higher population of alfalfa plants at the end of the growing season. Campbell and Kunelius (1984) studied seeding rates and initial grazing management on the establishment of red clover. They found that higher seeding rates, when averaged over grazing treatments, had higher red clover biomass accumulation. Gibson and Cope (1985) state that it is important to have a high initial seedling density of white clover, as it will produce more biomass in the 2nd and 3rd year than stands that had a low initial seedling density. Campbell (1985b) conducted a study looking at depth effects on summer red clover seedling survival. He found that lower seedling densities caused by seeding depths deeper than 1.3 cm or on the surface was translated into lower future red clover biomass.

CONCLUSION

Overall, the data does not support the hypothesis that no-till drilling would lead to better establishment of clovers into permanent pastures. Broadcast seeding produced a higher clover seedling density than drill treatments two months after sowing. No difference was found between the broadcast and drill treatments for clover biomass when measured visually or by weight. Both seeding treatments lead to successful clover establishment the year of establishment and the year after. Forage in both seeding methods also had similar ADF and NDF concentrations. Both seeding treatments forage had crude protein concentrations exceeded those required for use in the beef cattle industry due to high clover biomass. The data shows that removing grass biomass prior to sowing is important for creating a high number of clover seedlings, especially for no-till drilling. This is significant because the number of clover seedlings two months after planting was positively related to clover biomass at the end of the establishment year and the following year.

The data has several implications for producers. The first being broadcasting can be as effective as drilling for establishing clover into permanent pastures. The data also shows the importance of creating a favorable environment for clover seedlings to germinate and establish. In this experiment this was done by planting in a timely manner (early February), removing grass biomass prior to planting via mob grazing with cattle, and applying lime, phosphorous, and potassium to recommended levels. It is also very important to control grass competition, especially in early spring, when grass growth is the greatest and overseeded clover seedlings most susceptible to being shaded. Grass competition was controlled by an intense rotational grazing regime in the first year of this study. Of course, weather also played a crucial role for clover establishment. Higher than average rainfall in late spring probably helped clover seedling establish and grown into pasture canopy.

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TABLES

Table 3.1 Historic and monthly average temperature and total precipitation for February through October 2009, 2010, and 2011 in Kentland Farm region.

Month	Historic Average		2009		2010		2011	
	Temp (^{o}C)	Precip (cm)	Temp (^{o}C)	Precip (cm)	Temp (^{o}C)	Precip (cm)	Temp (^{o}C)	Precip (cm)
February	1.3	7.1	2.1	2.8	-1.6	5.5	-0.8	1.2
March	5.7	8.5	6.2	8.6	6.5	6.5	6.3	11.7
April	10.6	7.8	11.5	6.8	12.8	3.4	13.1	12.8
May	15.6	10.2	16.4	18.9	17.6	6.3	16.5	16.1
June	19.7	10	20.9	9.2	22.6	3.7	21.5	2.7
July	22.0	9.4	20.2	9.4	23.6	6.1	---	---
August	21.2	7.2	21.4	7.4	22.9	8.8	---	---
September	17.6	7.9	17.4	6.9	18.5	8.3	---	---
October	11.5	7.4	11.3	6.5	12.4	5.6	---	---
Average Temp (^{o}C)	13.9	---	14.2	---	15.0	---	11.32*	---
Total Precip (cm)	---	75.5	---	76.5	---	54.2	---	44.5*

*Average (^{o}C) and total precip (cm) are from February to July.

Table 3.2 Species herbage mass for 2009, 2010, and 2011.

g m^{-2}	Year	April		P-value	June		P-value	Aug.		P-value	Oct.		P-value	Average		P-value
		BST	Drill		BST	Drill		BST	Drill		BST	Drill		BST	Drill	
Grass	2009	---	---	---	101.2	96.5	0.8949	251.7	242.2	0.8793	163.5	204.9	0.6005	171.3	182.8	0.7726
WC		---	---	---	14.5	7.3	0.2166	26	22.4	0.6729	13.4	12.9	0.9456	17.7	14.4	0.4421
RC		---	---	---	4.6	3	0.284	27.1	21.3	0.527	10.7	7.7	0.5189	14.2	10.7	0.4669
Weed		---	---	---	2.5	3.3	0.6374	7.6	8.6	0.8852	2.3	1.9	0.7963	4.1	4.6	0.8497
Grass	2010	129.8	179.92	0.0212	171.14	178.4	0.7968	78.2	58.2	0.3904	73.8	48.8	0.1715	112.7	116.3	0.8679
WC		63.2	43.9	0.1593	38	42	0.734	4	7	0.589	3.3	6.1	0.3599	27.1	24.7	0.7859
RC		29.8	24.9	0.6283	27	23.4	0.6093	2.3	2	0.3788	3.2	1.7	0.2812	15.5	12.8	0.6161
Weed		2.3	20.3	0.2346	2.1	2.7	0.5136	7	4.8	0.5818	11.5	5.3	0.3236	5.7	8.3	0.5215
Grass	2011	67.9	72	0.666	89.1	103.4	0.3465	---	---	---	---	---	---	78.5	87.7	0.3965
WC		12.4	10.3	0.7435	6.3	10.8	0.4452	---	---	---	---	---	---	9.4	10.5	0.7869
RC		3.1	3.6	0.7836	0.9	0.5	0.0856	---	---	---	---	---	---	2	2.1	0.9543
Weed		4.6	6.2	0.5095	2.7	3.4	0.4443	---	---	---	---	---	---	3.7	4.8	0.3917

Abbreviations: WC white clover, RC red clover, BST broadcast, Drill no-till drill.

Table 3.3 Species visual assessment 2009 and 2010.

%	Year	April		P-value	June		P-value	August		P-value	October		P-value	Average		P-value
		BST	Drill		BST	Drill		BST	Drill		BST	Drill		B.D.	Drill	
Grass	2009	---	---	---	60.9	70.7	0.2352	57.2	64.3	0.4532	40	42.7	0.7692	52.7	59.2	0.3117
WC		---	---	---	29.2	19.8	0.3191	27.8	20.4	0.2621	27.1	26.3	0.9093	28.1	22.2	0.1476
RC		---	---	---	11.2	10.5	0.8335	16.1	14.7	0.7262	15.2	13.8	0.6335	14.1	13	0.5515
Weed		---	---	---	7.9	6.1	0.5353	8.3	6.9	0.591	3	3.1	0.9619	6.7	5.3	0.4087
Grass	2010	46.6	58.9	0.3004	56.8	53.1	0.6327	41.2	46	0.1769	67.1	61	0.3431	52.9	53.3	0.932
WC		29.3	26.5	0.6288	20.6	25.1	0.5136	11.9	15.4	0.5019	14.4	21.7	0.3547	19.1	22.2	0.3686
RC		28.5	21.2	0.1692	24.2	20.4	0.4829	5.1	6.4	0.5848	5.3	6	0.7535	15.8	13.5	0.5498
Weed		4.2	7.3	0.1884	3	4.4	0.3919	12.6	6.1	0.0113	6.6	6.2	0.8466	6.7	6	0.5651

Abbreviations: WC white clover, RC red clover, BST broadcast, Drill no-till drill.

Table 3.4 Nutritive analyses for 2009 growing season.

Crude Protein g 100g^{-1}			
Month	BST	Drill	P-value
April	21.2	22.0	0.9330
May	21.3	22.9	0.7239
June	15.4	16/6	0.3766
July	15.7	15.5	0.8729
August	15.4	17.6	0.3025
September	14.7	13.3	0.3686
October	13.8	14.3	0.7743
Average	16.7	17.2	0.6740
Neutral Detergent Fiber g 100g^{-1}			
Month	B.D.	Drill	P-value
April	49.9	45.5	0.3008
May	57.9	56.4	0.5376
June	57.4	55.7	0.4151
July	57.8	54.6	0.6259
August	56.8	54.0	0.7227
September	53.4	56.7	0.4014
October	80.0	67.3	0.0347
Average	59.1	55.9	0.1945
Acid Detergent Fiber g 100g^{-1}			
Month	B.D.	Drill	P-value
April	22.4	21.1	0.4036
May	28.1	27.5	0.7584
June	20.2	28.0	0.4138
July	29.4	28.6	0.6340
August	31.2	30.0	0.4859
September	29.2	30.0	0.6497
October	36.1	33.8	0.0668
Average	29.2	28.4	0.4466

Abbreviation: BST broadcast, Drill no-till drilling.

Table 3.5 Destructive sod harvest for October 2009 and October 2010.

	2009			2010		
	Broadcast	Drill	P-value	Broadcast	Drill	P-value
# RC Plants (m^{-2})	40.6	30.4	0.4165	17.5	13.7	0.6101
# WC Plants (m^{-2})	79.2	54.0	0.3358	43.53	38.9	0.7978
Stolon # Per WC Plant	1.2	1.6	0.1241	1.5	2.8	0.2439
Ave. Stolon Length (cm)	3.0	4.7	0.0919	1.9	3.1	0.3213
Stolon Weight (g)	1.5	2.1	0.2967	1.6	2.3	0.6011

FIGURES

Figure 3.1 Seedling density in April 2009. ($P = 0.1087$)

Figure 3.2 Clover seedling density and its relationship to standing grass herbage mass at time of over seeding. (Linear relationship; $y = 116.25 + -0.25x$, $r^2 = 0.96$, $P = 0.0196$ Quadratic relationship; $y = -135.73 + 3.61x + -0.01x^2$, $r^2 = 0.99$, $P = 0.0516$)

Figure 3.3 Seedling density in April 2009 relationship with clover herbage mass in August 2009. ($y = -7.2 + 0.50x$, $r^2 = 0.8424$, $P = 0.0008$)

Figure 3.4 Seedling density in April 2009 relationship with clover herbage mass for the 2010 growing season. ($y = 80.9668 + 0.85x$, $r^2 = 0.5279$, $P = 0.0249$)

Figure 3.5 Clover biomass vs. clover visual assessment. Line connects 25% composition by weight with 49% composition by visual assessment. ($y = -4.74 + 0.61x$, $r^2 = 0.5680$, $P<0.0001$)

Figure 3.1

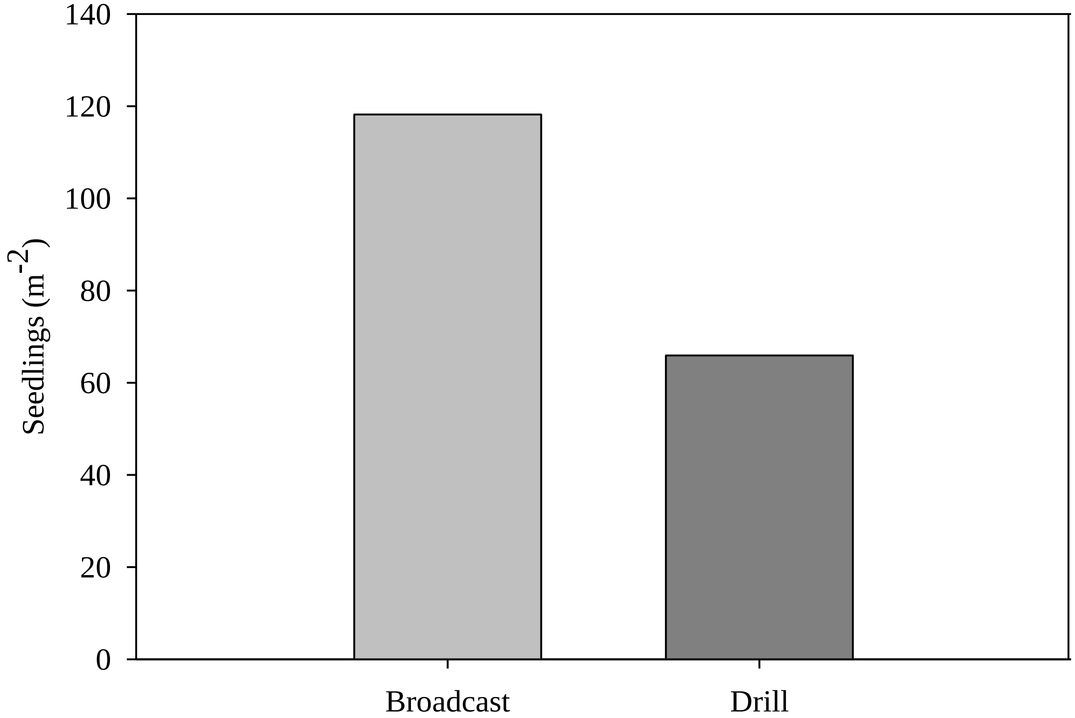
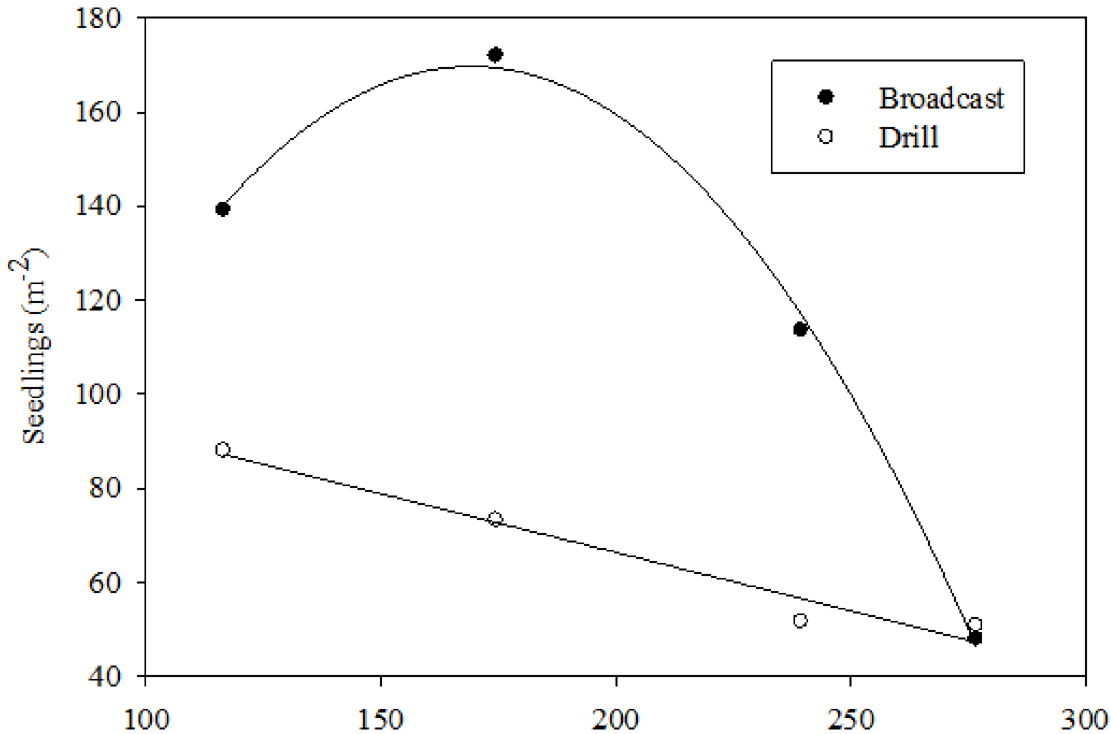


Figure 3.2



180
160
140
120
100
80
60
40
Seedlings (m-2)
100
150
200
250
300
Broadcast
Drill

Figure 3.3.

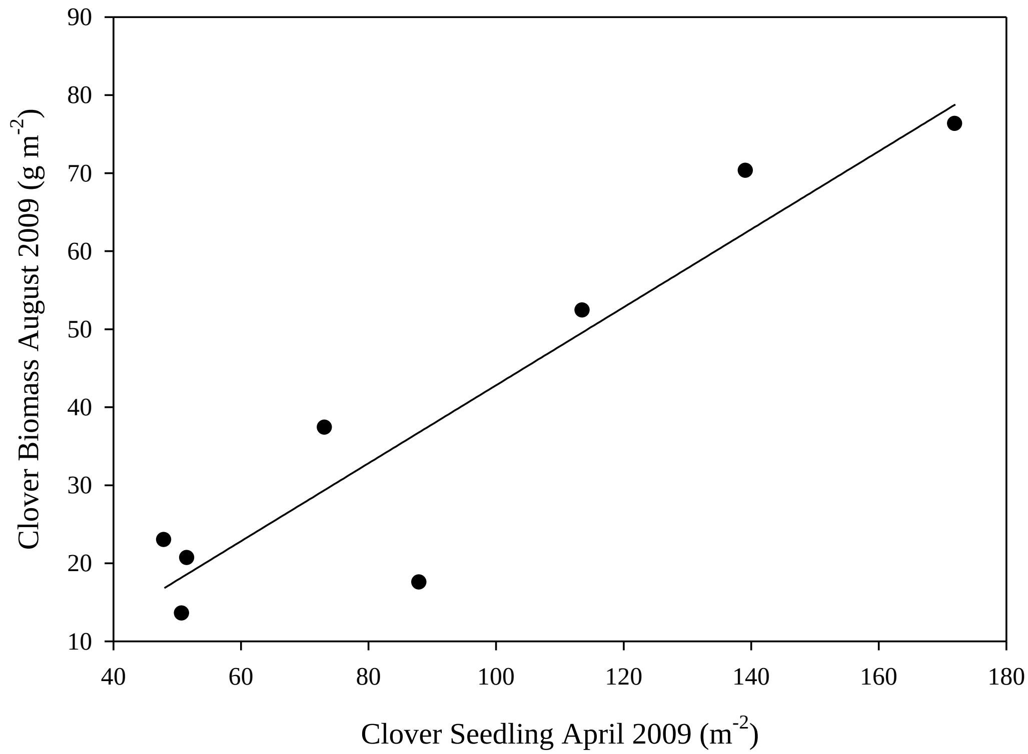
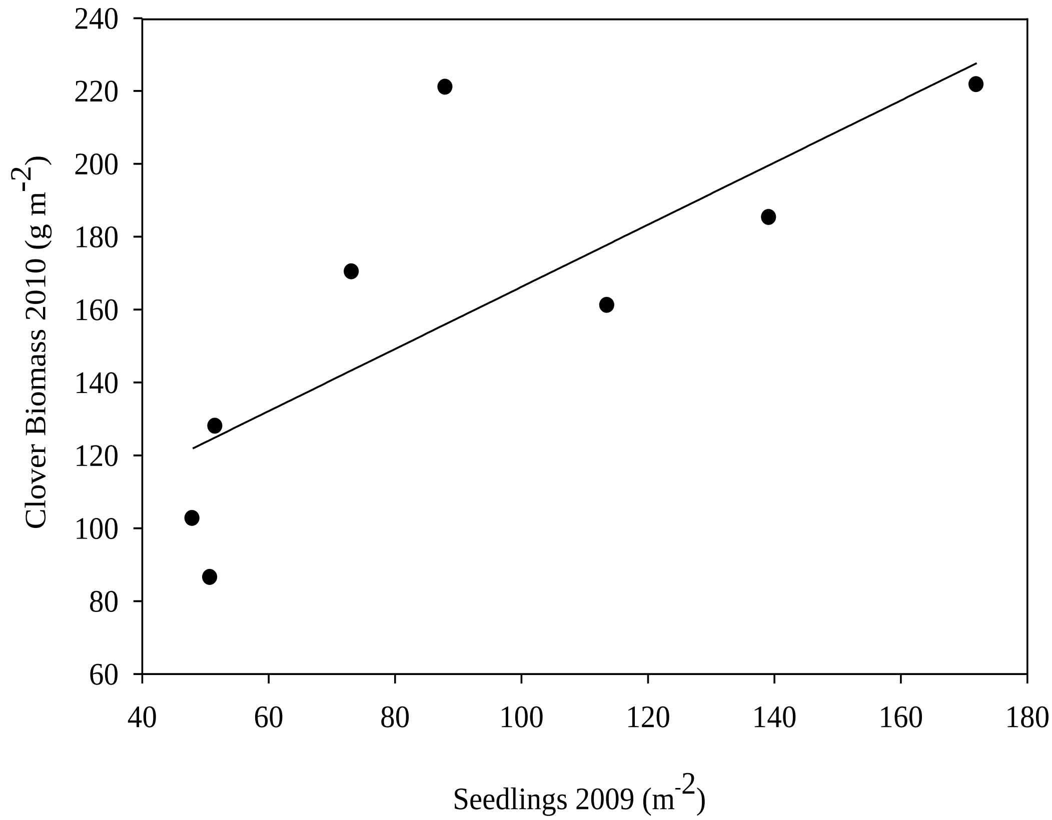
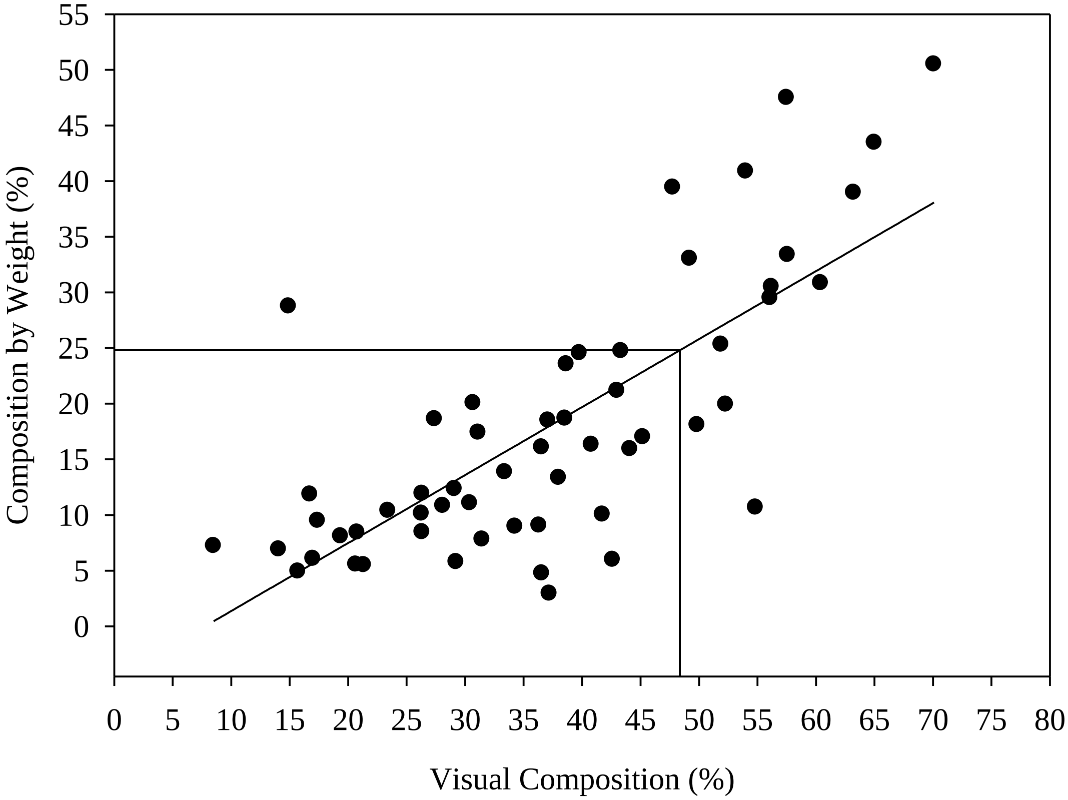

Clover Biomass August 2009 (g m-2)
Clover Seedling April 2009 (m-2)
10
20
30
40
50
60
70
80
90
40
60
80
100
120
140
160
180

Figure 3.4



240
220
200
180
160
140
120
100
80
60
Clover Biomass 2010 (g m-2)
40
60
80
100
120
140
160
180
Seedlings 2009 (m-2)

Figure 3.5



Composition by Weight (%)
55
50
45
40
35
30
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
Visual Composition (%)

CHAPTER 4

The Effect of Fertilization with P and K, Grass Biomass at Sowing, and Cutting Frequency on the Establishment of Clover into Permanent Sod.

ABSTRACT: Study of the variables that affect the establishment of clover into pastures will lead to better management decisions. A split-split plot small plot study was conducted to understand how the three variables of fertilization with P and K, grass biomass at sowing, and cutting frequency affected a mixture of frost-seeded red clover *(Trifolium pratense* L.) and white clover (*Trifolium repens* L.) establishment into permanent sod. Fertilization with P and K was assigned to whole plots that were split in half and assigned a high or low grass biomass at sowing treatment. The grass biomass subplots received treatments of either high or low cutting frequency. Prior to cutting, samples from each plot were sorted to grass, white clover, red clover, and weed. PAR (photosynthetically active radiation) readings were taken every two weeks for the entire experiment. Plots with a low grass biomass at sowing (232 seedlings m^{-2}) had a higher seedling density ($P < 0.0001$) compared with plots with a high grass biomass at sowing plots (111 seedlings m^{-2}). Greater biomass of white and red clover depended both on having a low grass biomass at sowing and a high frequency of defoliation ($P = 0.0026$ and $P < 0.0001$, respectively). Red clover yield was also determined by interactions between fertilization and a high frequency of defoliation ($P < 0.0001$), as well as between fertilization and low grass biomass at sowing ($P = 0.0026$). Dry conditions resulted in low clover yields (6% of total herbage mass) with red clover producing four times the herbage mass of white clover. Sowing into low residual grass biomass improves clover

establishment and reduction of grass competition through cutting and adding P and K fertilizer is needed for maximum clover yield.

INTRODUCTION

Various environmental factors can influence the establishment of clover in to permanent pastures. Two of the more important factors are grass competition and soil fertility. Grass competition can be suppressed by herbicides, light tillage, and defoliation. Defoliation is also desirable as it brings light into the bottom of the sward and stimulates legume growing points (Frame, 2005). Frequent defoliation has been found to increase the competitiveness of establishing white clover over associated grasses (Boatman and Haggar, 1985). Wen and Jiang (2005) found that cutting decreased the inhibitory effects that ryegrass and white clover have on each other. Clover establishment can be lowered if establishing clover plants are defoliated too young or if too much plant material is removed (Hayes and Williams, 1995). Elgersma and Schlepers (1997) found that clover response to cutting follows a quadratic curve, with medium levels being the best for DM production. The positive effect of cutting varies among legume species and cultivars (Hill and Hoveland, 1993; Swift et al., 1992).

Soil phosphorous (P) and potassium (K) concentrations can also affect clover establishment. Phosphorous is a key nutrient for clover seedlings (Frame, 1992). Phosphorous is found in proteins, nucleic acids, adenosine triphosphate, lipids, esters and enzymes. Phosphorus influences synthesis and degradation of starch and transport of nutrients throughout the plant. Deficiencies of P affects shoot and root growth, movement of nutrients within plant, and seed formation and viability (Barnes et al., 2003). Baker (1980) found that P was the most important factor that influenced emergence and yield of oversown clovers. He also found that the addition of P fertilizers resulted in a higher increase in clover yield when applied to limestone soils than sandstone soils and liming increased the effectiveness of P. Woodman et al. (1997) found that establishing legumes response to P fertilizer was influenced by placement of P. They found P was more effective when it was drilled with the seed than when P was placed below seed.

Potassium is required at high concentrations in plants. Potassium plays an important role in activating enzymes, opening and closing stomata, photosynthesis, transport of water and nutrients in the xylem, and for every major step in protein synthesis (Barnes et al., 2003). Deficiencies in K can reduce the translocation of nitrates, amino acids, starch, Ca, Mg, and phosphate. Potassium deficiencies also reduce plant tolerance to drought and insect stresses. Hunt and Wagner (1963) looked at the effects of potassium fertilization on seven different mixtures of grass and legumes. They found that swards fertilized with high levels of potassium (278.9 kg K ha^{-1}) had double the amount of legume biomass as swards fertilized with low levels of potassium (93.0 kg K ha^{-1}). Hunt and Wagner (1963) also found the ladino clover (*Trifolium pratense* L.) persisted longer when high levels of potassium fertilizer were applied. Collins and Land (1985) found that red clover herbage mass was higher in plots fertilized with potassium then unfertilized plots. They also found that nitrogen fixation of red clover was increased with K fertilization. Managing K levels in clover-grass swards is important when competition for K exists between grass and legumes. Grasses are able to absorb K 2 to 5 times faster than legumes (Dunlop et al. 1979).

In order to gain a better understanding how grass competition and soil fertility interact to affect clover establishment into permanent sods, a factorial experiment was conducted in 2010. The specific objective of this study was to evaluate how grass biomass at planting, defoliation frequency, and soil fertility affected the establishment of overseeded clover into permanent sods.

MATERIALS AND METHODS

Experimental Design

The experiment was conducted at Virginia Tech, Kentland Farm near Blacksburg in Montgomery County, VA (37°11' N latitude and 80°35' W longitude). Details on the study site were provided in Chapter Three. Experimental plots were established on permanent sod that consisted of primarily tall fescue (*Festuca arundinacea* Schreb.) with smaller amounts of orchardgrass (*Dactylis glomerata* L.) and bluegrass (*Poa pratensis* L.). The sods were largely unmanaged except for periodic mowing approximately twice each growing season. A broadleaf herbicide (2,4-D) was applied in the future study plot area in summer of 2009 and fall of 2009 in order to remove clovers present. The experiment consisted of a split-split plot arrangement of treatments in a randomized complete block design with eight replications. Sixteen 4 m^{-2} plots were established in December of 2009 and randomly assigned a whole plot factor of fertilization with P and K (+ or -). Soil test were taken in November 2009 and the results showed the P soil levels were at 6.7 kg ha^{-1} and K soil levels were at 53.8 kg ha^{-1}. Based on recommendations, whole plot treatments were fertilized with 56 kg P ha $^{-1}$ and 135 kg K ha $^{-1}$ in early March 2010. All plots were frost-seeded with a mixture of 3.6 kg ha^{-1} of red clover (Liberty) (*Trifolium repens* L.), 1.8 kg ha^{-1} ladino white clover (*Trifolium pretense* L.), and 1.8 kg ha^{-1} white clover (Kopu II) (*Trifolium pretense* L.) in early February 2010.

Whole plots then were split and randomly assigned treatments that represented either high or low grass biomass at sowing. Low grass biomass treatments were mowed in December of 2009 to 2.5 cm stubble and biomass was removed. High grass biomass were not cut at that time. In April 2010 the average sward height for low grass biomass at sowing was 13 cm and 27 cm for high grass biomass at sowing. The low grass biomass at sowing and high grass biomass at sowing were different from each other ($P < 0.0001$). Spilt plots were subdivided again and randomly assigned a high or low cutting frequency. High cutting frequency treatments were cut every three weeks starting on April 31, 2010 and ending on October 16, 2010 to mimic a rotational grazing regime. Low cutting frequency treatments were cut on May 21, September 3, and October 16 in 2010 to mimic a hay harvest. Plots were cut using a push mower and biomass was removed from plots.

Measurements

Clover seedling density was measured in April 2010. A 0.125 m^2 quadrant was placed in each plot and the number of seedlings were counted and recorded. Species composition and biomass were taken prior to plot harvest. One 0.125 m^2 quadrant was placed in each plot prior to harvest and cut clipped to 7.5 cm stubble. Samples were hand sorted to white clover, red clover, grass, and weeds. The samples were dried for 48 hours at 60^oC and then weighed. Yield for each plant component were calculated by summing all harvests. In addition to yield measurements, leaf area index (LAI) and photosynthetically active radiation (PAR) were measured using a PAR/LAI ceptometer (AccuPAR LP-80 PA, Decagon Device, Inc.). Ten light reading were taken simultaneously at ground level and above the sward canopy on every plot and then averaged. Readings were taken every two weeks starting on April 31, 2010 and ending on October 16, 2010.

Data Analysis

All data were analyzed as a split-split-plot design using PROC GLIMMIX of the SAS software (SAS SAS Institute, Inc. 2008). For each dependent variable, main effects of fertilization with P and K, grass biomass at planting, and cutting frequency were tested, along with all possible interactions. A P-value of less than 0.10 was considered significance when comparing treatment effects.

RESULTS

Weather

Table 4.1 shows the weather data for 2010. Compared to the historic average, the 2010 growing season was hotter and drier. August and September of 2010 were 5.2 and $7^{o}C$ higher than the historic averages for these months. From February to October 2010, 20.3 cm less precipitation fell compared to the historic average of the same time span. Less than the monthly historic average rainfall fell from February to July, April and June received about a third of the historic average monthly rainfall. August and September had above average rainfall.

Seedling Density

Clover seedling density measurements from April 2010 are shown in Figure 4.1. Differentiating between red clover and white clover could not be done accurately and both species were counted together. The data show that there was a significantly higher number of clover seedlings in plots with low grass biomass at sowing than plots with a high grass biomass at sowing ($P < 0.0001$).

Species Composition Herbage Mass

Herbage mass data for grass, white clover, red clover, and weed is provided in Table 4.2. There was no difference between any of the treatment or treatment combinations for weed herbage mass. For grass, herbage mass in treatments with a high grass biomass at sowing at 568.6 g m^{-2} compared to low grass biomass at sowing at 361.3 g m^{-2} ($P < 0.0001$). Maximum white clover biomass was determined by an interaction between high cutting frequency and low residual at sowing (Figure 4.2) ($P = 0.0026$). A significant cutting frequency x grass biomass at sowing interaction ($P < 0.0001$) was also found for red clover biomass (Figure 4.3). For both clovers, the greatest biomass was found in plots that had low grass biomass at sowing and then were clipped every three weeks. Maximum red clover biomass was also determined by an interaction between fertilization with P and K and cutting frequency (Figure 4.4), and P and K fertilization with grass biomass at sowing (Figure 4.5).

Light Measurements

Above canopy PAR (Photosynethic Active Radiation), below canopy PAR, and LAI (Leaf Area Index) were measured throughout the 2010 growing season. There was no difference between any of the treatments or treatment combination on above canopy PAR. Below canopy PAR were significantly higher ($P < 0.0001$) for treatments with high cutting frequency and low standing biomass at sowing (Figure 4.6). Leaf Area Index was significantly higher ($P < 0.0001$) for plots with both high standing biomass at sowing and a low cutting frequency (Figure 4.7).

DISCUSSION

A small plot experiment was conducted during the 2010 growing season in order to determine how fertilization with P and K, grass biomass at sowing, and cutting frequency interact to influence clover establishment into permanent sod. Having a low grass biomass at sowing had a positive effect on clover seedling density. Maximum white and red clover herbage mass was determined by an interaction between low grass biomass at sowing and a high cutting frequency. Red clover biomass also benefited from fertilization with P and K, but only when it was coupled with either low grass biomass at sowing or a high cutting frequency. Even though frequent defoliations improved light availability for clover, successful establishment depended more on having a high number of clover seedlings that emerged in the spring.

Seedling Density

The data indicate that treatments with low grass biomass at sowing had a higher clover seedling density than those with high grass biomass at sowing. Springer (1997) found that the number of overseeded white clover seedlings decreased as bermudagrass (*Cynodon dactylon* (L.) Pers.) residue height increased. Poor seed to soil contact was the reason for low white clover seedling establishment in tall bermudagrass (Springer, 1997). Guretzky et al. (2004) also had similar results to the current study. They conducted a study in which red clover was sown into three canopy heights; uncut, 5 cm, and 13cm. They found that red clover had the highest emergence at 5 cm and the lowest emergence in uncut. Watkins and Vickery (1965) results differ slightly from this study. They conducted a study looking at pre-graze treatment (ungrazed, light, and heavy) on the establishment of clovers. They found that ungrazed treatments had better establishment, due to protection given to clover seedlings from temperature fluxes, however. They found that grass canopy was not dense enough to limit light penetration to the bottom of the sward. In this experiment grass canopy in high grass biomass plots was dense and under canopy PAR was low. Clover seedlings likely did not benefit from having a protective grass cover because the grass canopy was too dense and did not allow light penetration.

Grass Biomass at Sowing and Cutting Frequency

Both white and red clover biomass were affected by an interaction between low grass biomass at sowing and a high cutting frequency. This was due to two reasons. First, low grass biomass at sowing probably allowed a higher number of clover seedlings to emerge from the soil. In turn, the data suggest that a higher number of seedlings is needed to produce high clover biomass later in the growing season. Dear et al. (2007) found a higher number of alfalfa seedling lead to a higher alfalfa population later in the growing season. Results from this study are similar to Springer (1997). He found as the height of the Bermuda grass sward decreased, the amount of white clover biomass found in plots increased. Campbell (1985) found that low red clover seedling densities caused by deep planting depths, lead to lower future red clover biomass. Suggesting that variables that cause low seedling density lead to low red clover biomass.

In order to allow clover seedlings to establish grass competition needs to be controlled (Coumo et al. 2004). Guretzky et al. (2004) conducted an experiment that studied how landscape position and grass competition affected red clover emergence and survival. They found red clover had the most herbage mass in treatments where grass competition was limited (backslopes, no nitrogen fertilization, and low cutting height).

They also found that red clover seedling emergence was highest when it was sown into 5 cm tall swards than 13 cm tall swards or uncut. They also found that high red clover herbage mass not only depended on successful red clover establishment, but also red clover survival. Byran (1985) found that overseeded red clover biomass was higher when grass competition was controlled using paraquat. The PAR data from this study further shows the importance of a high seedling density after sowing. As expected a high cutting frequency increased the PAR at the bottom of the canopy. The high cutting frequency did not increase clover biomass alone, however. High clover biomass was also dependent on their being a low grass biomass at sowing. It appears that the low grass biomass at sowing allowed for more clover seedlings to emerge. After emergence, the clover seedlings were able to take advantage of the high light conditions in the more frequently cut treatments and produced more biomass.

Controlling grass competition by cutting to achieve a higher clover biomass was found by Hill and Hoveland (1991). They conducted an experiment looking at grass competition, moisture stress, and cutting frequency (every three or six weeks) on the establishment of white clover grown with tall fescue. They found the competition from grass hindered white clover growth more so then moisture or cutting stress. They also found that white clover competitiveness was increased by cutting every three weeks. Furthermore, they found that cutting every three weeks without moisture increased white clover biomass more than swards that were cut every six weeks and had unrestricted moisture. The reason for higher clover biomass in frequent cutting treatments compared to infrequent cutting was due to the decrease in grass competition and the increase in competiveness of white clover. Yu and Hou (2005) found that high cutting frequencies (once a month) promoted a positive interaction between ryegrass and white clover and decreased the inhibitory effects of ryegrass and white clover on each other. When cutting decreased to four times a year or less, the relationship between ryegrass and clover went from mutual promotion to inhibition. Hoveland et al. (1999) found that tall fescue competition was controlled by grazing every three weeks and allowed red clover to become established.

Clover biomass was relatively low in the small plot experiment compared to the pasture experiment in chapter three. Clover made up 6% of the total herbage mass in the smallplot study in plots with low grass biomass at sowing and high cutting frequency. In the pasture experiment clover biomass made up 13% and 25% of the total herbage mass in 2009 and 2010 respectively. Low rainfall, during early spring 2010 through July, probably reduced clover herbage mass and limited clover establishment in the smallplot study. The high frequency cutting (every three weeks) may have had been too frequent for high clover growth. Clover biomass may have benefited from a period of rest from June to July, when temperatures were hot and moisture scarce. Gooding et al. (1996) found that white clover biomass benefitted from having a rest period from continuous stocked sheep during July to mid-August.

The low clover herbage mass in this experiment may suggest that defoliation regimes, especially in dry time periods, should not be based on time but rather clover morphology and growth. Belesky et al. (2002) conducted a study on the influence on defoliation on oversown kentucky bluegrass and white clover into bermudagrass stands. Their results agree with my data, in that they found more white clover biomass when cut every two weeks compared to every six weeks. They found the highest amount of clovers when plots where cut when they reached 20 cm. They also found that cutting had a more positive influence on white clover biomass when cut based on sward height then when cutting was based on time. William and Hayes (1995) found that white clover was positively influenced by cutting, as it decreased grass competition. They also found that if cutting was held off until white clover had three to four growing points the white clovers had higher persistence and production then if cutting had began when the white clover had one to two growing points. They further point out that even though clover seedling have considerable ability to recover from leaf removal, with continuous defoliation (every week), opportunities for recovery are clearly limited. Brink (1995) also found that frequent close cutting resulted in more white clover herbage mass, though when done in late summer and autumn, frequent close cutting reduced white clover survival.

Red clover biomass was three times larger than white clover biomass in low grass biomass and high cutting frequency plots. This result is in contrast to Kelly et al. (2005), who found at higher frequency of cutting, white clover had more herbage mass then under infrequent cutting while, while red clover had a higher herbage mass under infrequent cutting than in frequent cutting. John and Lazenby (1973) also found that white clover yielded more under infrequent cuttings than frequent cuttings. Several studies have shown that red clover growth is reduced as the frequency of cutting increases (Black et al., 2009; Kleen et al., 2011; Sheldrick et al., 1986). The current experiment showed the opposite as red clover was likely shaded out from grass competition in low frequency cutting treatments and produced more biomass under higher cutting frequency. In this study, under canopy PAR was significantly higher in low grass biomass treatment interaction with high cutting frequency treatment than in other treatments. Finding white clover yields lower than red clover in dry conditions is supported by Frankow-Lindberg et al. (2009). They conducted a study on different mixtures alsike, red, and white clovers and grass. They found in a dry environment red clover-grass mixtures had higher biomass than multi-clover-grass mixtures. In environments with adequate moisture white and red clover-grass mixtures produced the most herbage mass. In the current experiment the greater red clover compared with white clover was probably due to red clover having higher drought tolerance (Frame 2007).

Fertilization with P and K and Red Clover Biomass

Maximum red clover biomass was determined by an interaction with fertility and either a high cutting frequency or low grass biomass at sowing. Hunt and Wagner (1963a) studied the effect of fertilization with P and K on seven grass-legume mixtures. In mixtures, fertilization with P (72.8 kg ha^{-1}) and K (92.32 or 278.9 kg ha^{-1}) increased the percentage of red clover. They also found that plots receiving high levels of potassium had double the amount of red clover than plots fertilized with low levels of potassium. Ribera et al. (2010) found that in acid soils fertilization with P increased red clover herbage mass, even when lime was not applied. Hellsten et al. (2000) found that red clover fertilized with high levels of P had increased herbage mass, nodule dry matter, and nitrogen fixation. Fertilization with K is important in grass-clover swards when levels are low, due to the ability of grass to out compete clovers for potassium (Dunlop et al. 1979).

In this study a high cutting frequency was able to control grass competition, so that red clover biomass was able to grow, and the added P and K likely helped increase the biomass over plots that were not fertilized. Having very little grass biomass at sowing allowed red clover seedlings to emerge, grow and then take advantage of the fertilization. Fertilization addition in high grass biomass treatment did not increase red clover biomass, due to the low numbers of clover seedlings that emerged. The clover seedlings that did emerged were likely shaded out by grass biomass.

Unlike red clover, white clover biomass was not affected by an interaction between fertility and a low grass biomass at planting or a high cutting frequency. Williams et al. (1985) found that when white clover was oversown into grass swards using propyzadime to suppress grass growth, that more white clover was found in plots fertilized with potassium then unfertilized plots. Singh and Sale (1997) found that increasing the P supply to white clover growing on P deficient soil increased the cumulative dry matter of white clover plants throughout the experiment. They found that P allowed for more regrowth of white clover after cutting. In another experiment, Singh and Sale (1998), found that higher P was able to negate the effect of lack of moisture in dry soils under frequent cutting. Other studies have found a positive effect of fertilization with P and/or K on white clover biomass (Junquan et al. 2007, Hunt and Wagner 1963b, Hogh-Jensen 2003, Bailey and Laidlaw 1998,)

Fertilization with P and K not having an effect on white clover biomass, in the current study, may be due to the dry conditions of 2010. Davis (1991) conducted a study looking at the response of different temperate legumes to P fertilization. He found that in dry conditions white clover herbage mass did not increase when fertilized with P although, red clover did. He also found when moisture was not limiting, that red clover had a higher response than white clover to higher levels of P. Another possible reason why red clover showed a response to fertilization and white clover did not is that the fertilizer was broadcasted. Red clover may be better at utilizing broadcast fertilizer more than white clover. Watkins and Vickery (1965) concluded that the lack of proximity to fertilizer in broadcast treatments lead a loss of in white clover seedling vigor and a decline in subsequent yield. Soon (1997) found in the first year harvest, red clover herbage mass was higher when P was broadcast then when it was drilled. The third reason why red clover showed a response to fertilization with P and K but not white clover may be due to root length. Trolove et al. (1996) found that birdsfoot trefoil (*Lotus corniculatus* L.) was able to utilize P fertilizers better than white clover, not because of differences in plants efficiency with P, but due to longer roots in birdsfoot trefoil. These results suggest that it is not the difference between plants use efficiency of P but root length. Thus, red clover may have had a response to P due to longer root system. Caradus (1983) found that among genetically different white clover populations use of P fertilization was based on P uptake, which was higher in populations with longer roots.

CONCLUSION

The data indicates that future clover biomass not only relies on having a high clover seedling density after sowing, but also suppressing grass competition. Soil fertility allowed red clover to produce at a maximum given the environmental conditions, but only when combined with a low grass biomass at sowing or a high cutting frequency. High clover yields appear highly dependent on a high clover seedling density. In order to get a high clover seedling density it is important to remove grass biomass before sowing.

Frequent cutting, allowed PAR to penetrate to the bottom of the canopy to be used for clover growth. Adequate P and K concentrations are important to obtain maximum clover yields though higher rates may need to be applied in dry years or more precise placement of fertilizer in order for white clover to be able to take up fertilizer due to shallow root system. The benefit of sowing red clover and white clover together is that it reduces the risk of planting failure due to environmental fluxes. Due to deeper root length, red clover allowed for clover production in dry conditions, while white clover production was low. Defoliation regimes, especially in dry conditions, should be decreased and pastures allowed to rest for extended periods of time to allow for greater clover yield and persistence.

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TABLES

Table 4.1 Historic and 2010 monthly and year temperature and precipitation data from Kentland Farm region.

	Historic Average		2010	
	Temp (^oC)	Precip (cm)	Temp (^oC)	Precip (cm)
February	1.3	7.1	-1.6	5.5
March	5.7	8.5	6.5	6.5
April	10.6	7.8	12.8	3.4
May	15.6	10.2	17.6	6.3
June	19.7	10	22.6	3.7
July	22.0	9.4	23.6	6.1
August	21.2	7.2	22.9	8.8
September	17.6	7.9	18.5	8.3
October	11.5	7.4	12.4	5.6
Average Temp (^oC)	13.9	---	15.0	---
Total Precip (cm)	---	75.5	---	54.2

Table 4.2 Species composition herbage mass for 2010. NO, PK, Grass Bio, Cut Freq, WC, and RC represent not fertilized, fertilized with P and K, grass biomass at sowing, cutting frequency, white clover, and red clover respectively.

Fertility	Grass Bio	Cut Freq	Grass g m^{-2}	WC g m^{-2}	Weed g m^{-2}	RC g m^{-2}
No	High	High	554.6	0.1	0.0	0.0
No	High	Low	633.5	0.0	0.0	0.2
No	Low	High	370.6	4.4	0.7	14.5
No	Low	Low	337.4	1.00	0.3	1.1
PK	High	High	588.8	0.2	0.0	1.8
PK	High	Low	497.4	0.1	0.0	0.0
PK	Low	High	359.6	7.8	4.8	27.9
PK	Low	Low	377.6	0.8	0.0	2.5

FIGURES

Figure 4.1 Seedling density April 2010 (P < 0.0001).

Figure 4.2 White clover biomass relationship with the interaction between cutting frequency and biomass at sowing. Cut Frequency x Grass Biomass at Sowing (P = 0.0026).

Figure 4.3 Red clover biomass relationship with the interaction between cutting frequency and biomass at sowing. Cut Frequency x Grass Biomass at Sowing (P < 0.0001).

Figure 4.4 Red clover biomass relationship with the interaction between cutting frequency and fertilization with P and K. P and K x Cutting Frequency (P < 0.0001).

Figure 4.5 Red clover biomass relationship with the interaction between grass biomass at sowing and fertilization with P and K. P and K x Grass Biomass at Sowing (P = 0.0026).

Figure 4.6 Under canopy PAR relationship with the interaction between grass biomass at sowing and cutting frequency. Cut Frequency x Grass Biomass at Sowing (P < 0.0001).

Figure 4.7 LAI relationship with the interaction with grass biomass at sowing and cutting frequency. Cut Frequency x Grass Biomass at Sowing (P < 0.0001).

Figure 4.1

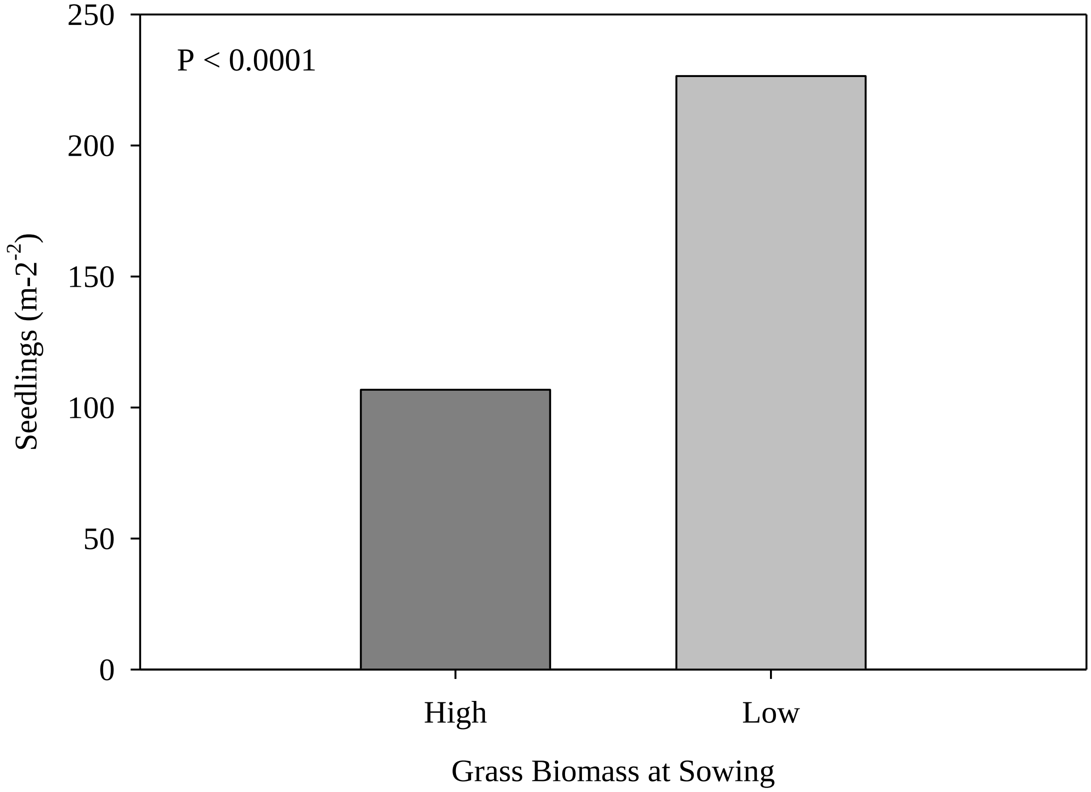
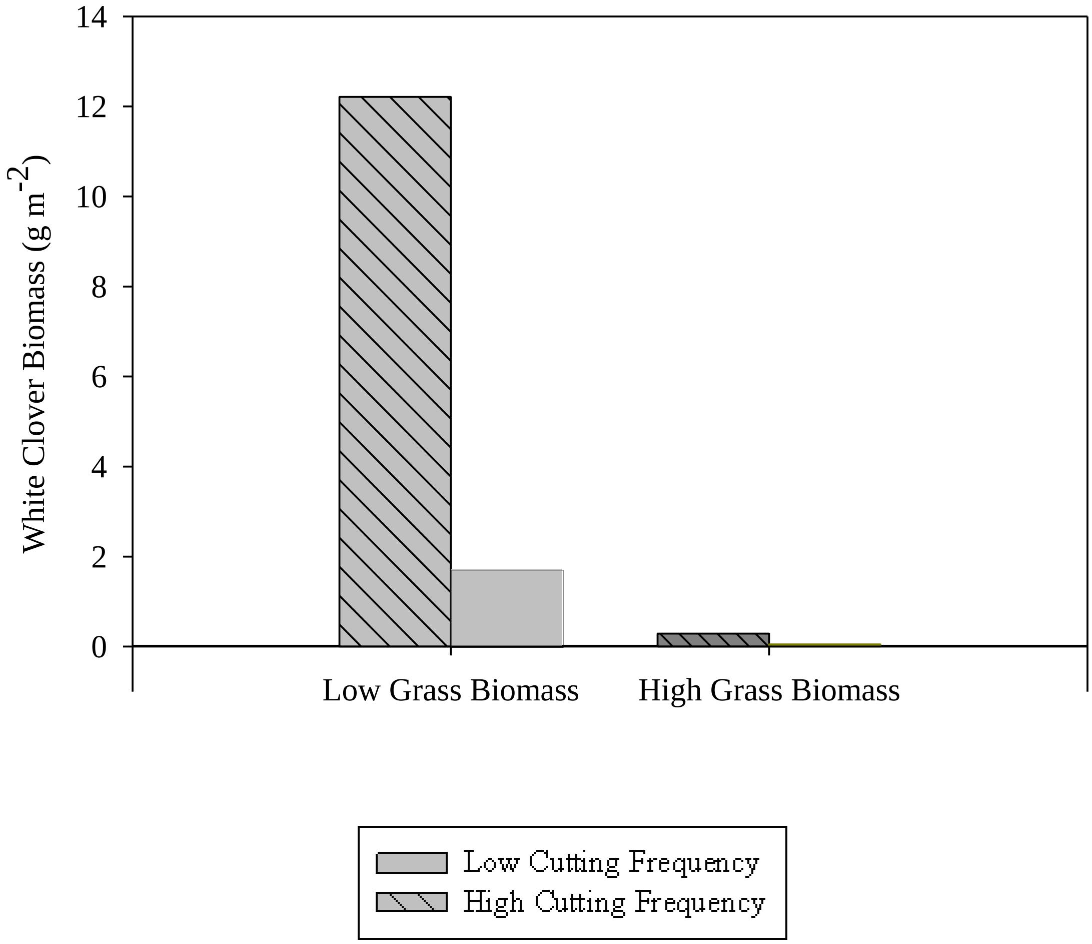
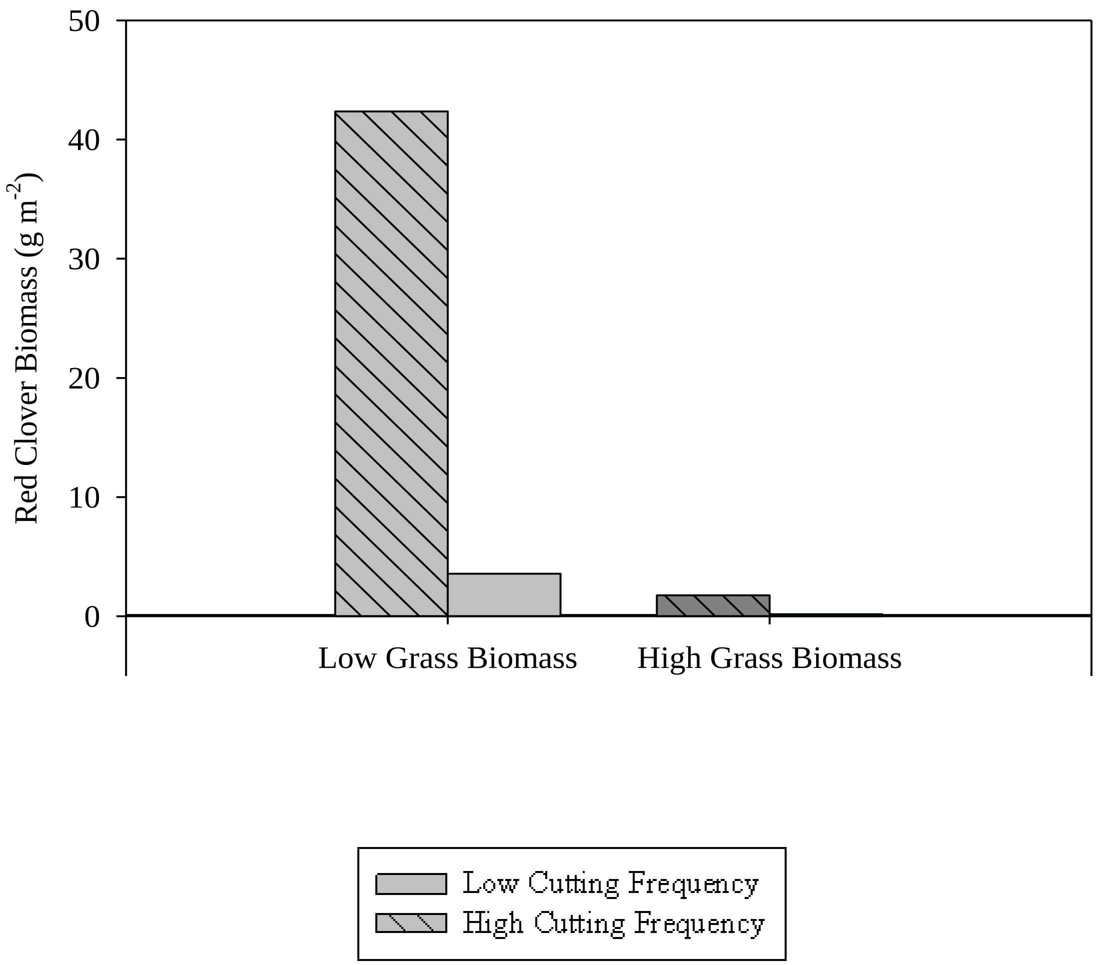

250
200
150
100
50
0
P < 0.0001
Seedlings (m-2-2)
High
Low
Grass Biomass at Sowing

Figure 4.2



14
12
10
8
6
4
2
0
White Clover Biomass (g m-2)
Low Grass Biomass
High Grass Biomass
Low Cutting Frequency
High Cutting Frequency

Figure 4.3



Red Clover Biomass (g m-2)
50
40
30
20
10
0
Low Grass Biomass
High Grass Biomass
Low Cutting Frequency
High Cutting Frequency

Figure 4.4

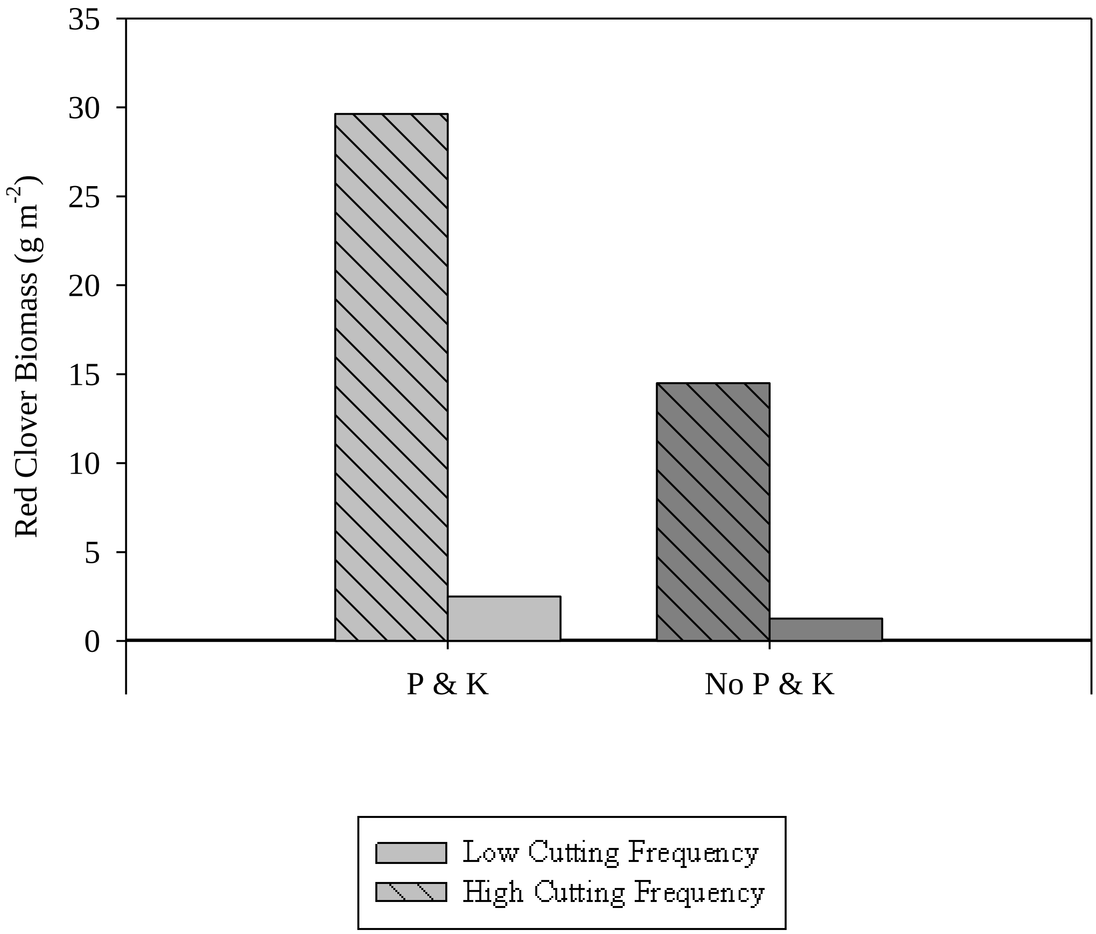

35
30
25
20
15
10
5
0
Red Clover Biomass (g m-2)
P & K
No P & K
Low Cutting Frequency
High Cutting Frequency

Figure 4.5

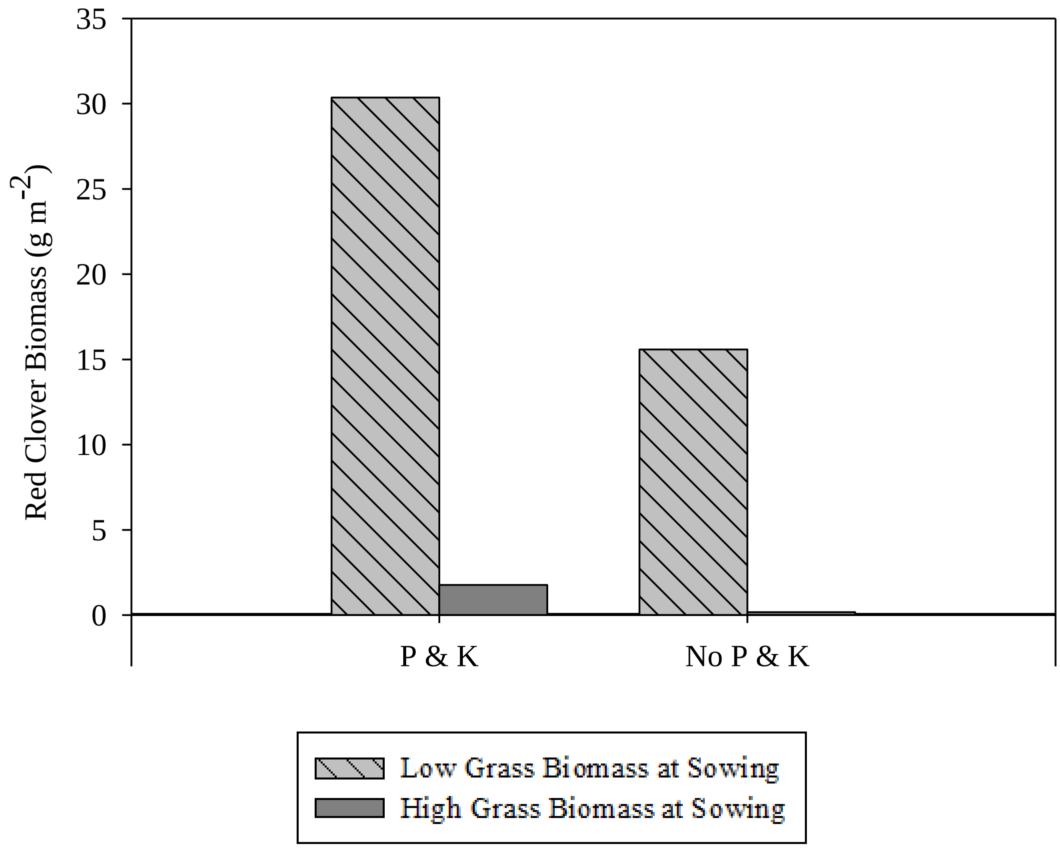
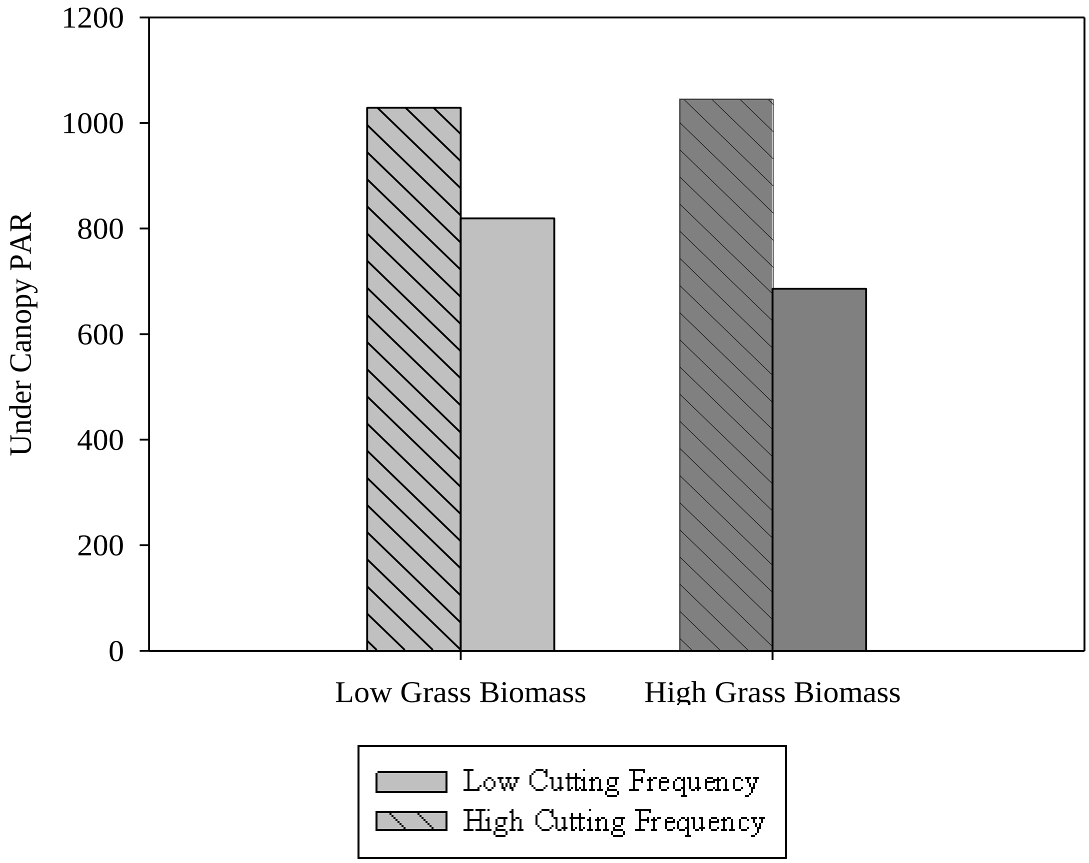
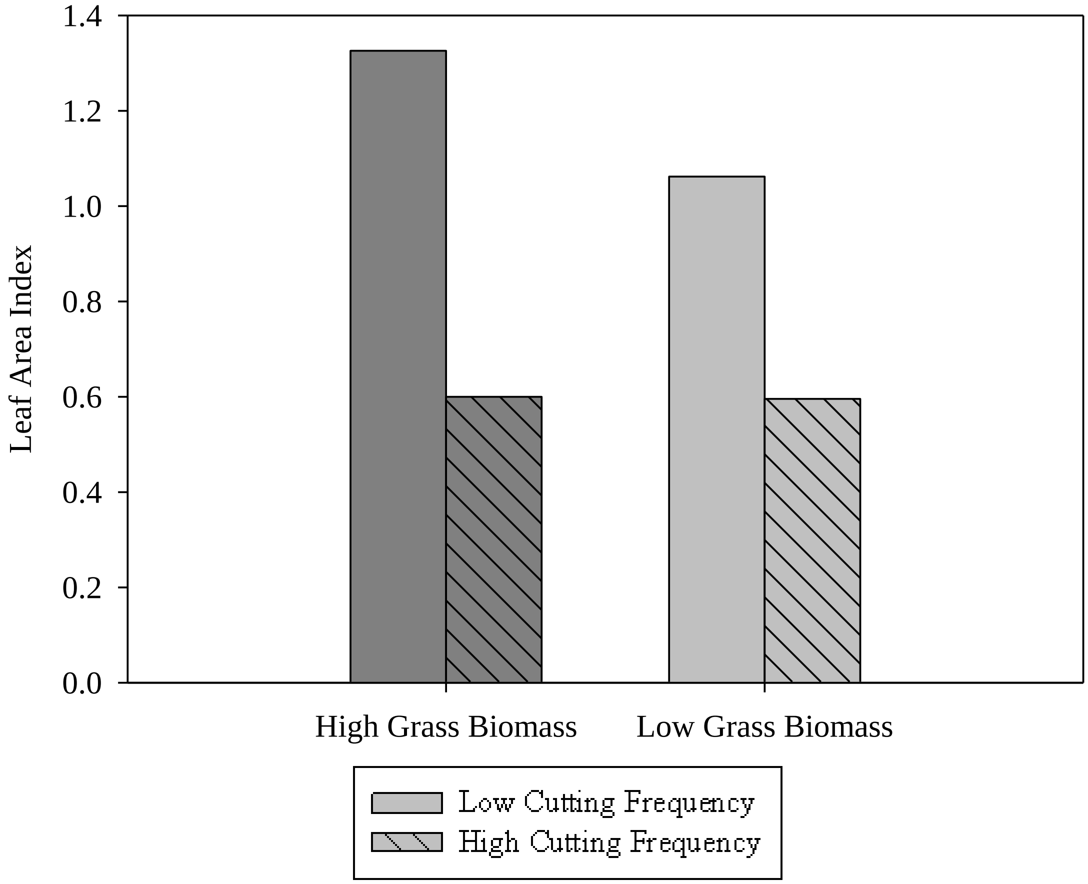

35
30
25
20
15
10
5
0
Red Clover Biomass (g m-2)
P & K
No P & K
Low Grass Biomass at Sowing
High Grass Biomass at Sowing

Figure 4.6



1200
1000
800
600
400
200
0
Under Canopy PAR
Low Grass Biomass
High Grass Biomass
Low Cutting Frequency
High Cutting Frequency

Figure 4.7


1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Leaf Area Index
High Grass Biomass
Low Grass Biomass
Low Cutting Frequency
High Cutting Frequency

CHAPTER FIVE

CONCLUSION

Increased biomass production, increased animal performance, and addition of nitrogen are a few of the benefit of establishing clovers into permanent pastures. Several factors effect clover establishment into permanent pasture and management decisions are important to ensure successful clover establishment. Two sowing methods commonly used are no-till drill and broadcast, though studies comparing the two methods are scarce. Two experiments were conducted near Blacksburg, Va. in order to better understand the effects of sowing method and sward management on clover establishment.

My hypothesis was that no-till drilling would lead to better clover establishment due to higher assurance of creating a favorable environment for clover seedlings. Data from a grazing experiment conducted from 2009 to 2011 found the hypothesis to be wrong. Both seeding methods lead to successful clover establishment. Further results from the experiment found that a high clover seedling density determine future clover yield and having a high grass biomass at sowing had a negative effect on seedling density. The results imply that producers should be more concerned with creating a favorable environment for clover seedling emergence than choosing a sowing method. Since both sowing methods were successful, producers should choose whichever method is works best for their operation. It is important for producers to remove grass biomass, by hay cut or mob grazing, to allow clovers to emerge and become established. Creating high seedling density is extremely important, as if seedling density was low, it will have negative consequences on future clover yield. Adequate soil P and K concentrations are important for red clover yield, though in dry weather levels might need to be increased in order to see a response in white clover. Sowing multiple clover species should be used when overseeding permanent pastures to avoid planting failures. Overall, creating an environment for high clover seedling emergence is extremely important. Reducing grass competition through rotational grazing or cutting will not help clovers establish unless a high number of seedlings emerge in early spring.