CHAPTER II

LITERATURE REVIEW

TALL FESCUE

Description

Tall fescue is a cool season perennial grass that is generally considered a bunchgrass, but can form dense sods through a weakly rhizomatous growth habit. Leaf blades are dark green, 4 to 6 mm wide with prominent veination and rough edges (Ball et al., 2002). The surfaces of the leaf blades and sheaths are smooth (Terrell, 1979). Membranous ligules are present on tall fescue that can be up to 2 mm long, but auricles are either not present or very short. The panicle is erect, mostly compressed, and 10 to 50 cm long, but can also be broad and loosely branched (Terrell, 1979). Spikelets of tall fescue are elliptical in shape and can be 10 to 18 mm long with 3 to 10 florets each. Plants can possess awns up to 4 mm long or awns may be absent. The caryopses are oblong and enclosed tightly in the lemma and palea (Terrell, 1979). Tall fescue can grow 0.6 to 1.2 m tall (Ball et al., 2002).

Tall fescue (*Festuca arundinacea* Schreb.) is part of the genus Festuca, which has 80 species throughout the world with 20 species in the USA. The tribe of tall fescue is Festuceae, part of the subfamily Festucoideae (Terrell, 1979). Tall fescue and meadow fescue (*Festuca pratensis* Huds.) were initially recognized by the same name, *Festuca* *elatior*, but tall fescue was formally given the name *Festuca arundinacea* in 1771 (Terrell, 1979).

History

Tall fescue originated in Europe and was later introduced into North and South America, but the exact time of introduction is unknown (Buckner et al., 1979). It became prominent in the United States with the release of 'Kentucky 31' and the subsequent decline in the use of meadow fescue. Studies found that tall fescue was taller and more drought and cold tolerant than meadow fescue, which further encouraged tall fescue plantings (Buckner et al., 1979).

Kentucky 31 originated following a visit by Dr. E.N. Fergus from the University of Kentucky to the V.M. Suiter farm in Menifee County, Kentucky in 1931. Here he found an interesting tall fescue ecotype, collected seed, and tested it at several sites throughout Kentucky. Kentucky 31 was formally released as a cultivar in 1943 and has become the most popular tall fescue used in the United States (Ball et al., 1987). It is widely planted due to its persistence, productivity, length of growing season, adaptability and erosion control (Buckner et al., 1979).

Another popular tall fescue was 'Alta'. It took several years to develop a cultivar from the original ecotype collected in 1918. The criteria for the selection of Alta included winterhardiness, persistence, and drought tolerance. Alta was finally named and registered in 1940 (Buckner et al., 1979), but it has not been commonly used in recent years.

Adaptation

Tall fescue is used in many areas throughout the United States due to its broad adaptation over a range of environmental and climatic extremes. The major areas of use are the transition zone between the northern Great Lake states and southern Gulf Coast states. Tall fescue, like most temperate grasses, has its maximum growth at temperatures between 20 to 25°C (Cooper and Tainton, 1968)(cited by Burns and Chamblee, 1979). It can grow on very acidic to alkaline soils, with a pH range of 4.7 to 9.5 (Cowan, 1962). The majority of tall fescue is grown on soils with a pH of 5.3 to 5.5 and low organic matter (Burns and Chamblee, 1979). Its extensive root system allows it to survive and grow on droughty soils, but it is also able to tolerate poorly drained soils, waterlogging and periodic flooding. Tall fescue prefers soils with adequate moisture that have a heavy to medium texture and high organic matter (Buckner and Cowan, 1973). It is only able to withstand relatively short periods of drought and requires at least 45 cm of annual rainfall in low lying areas and at least 90 cm of rain on upland sites (Buckner et al., 1979). The adaptability of tall fescue to a wide range of climatic and soil conditions allow it to be grown on over one million acres in Virginia and 35 million acres across the United States (Ball et al., 2003).

Growth and Development

Tall fescue has the most growth in the spring when temperatures are cooler and it expresses periods of midsummer dormancy in most regions. In the autumn, growth resumes and can last into early winter in the southern range of adaptation. Tall fescue needs a well prepared, clean, firm seedbed (Cowan, 1956), but no-till seedings can be successful when competition is reduced. Seeding depth should not exceed 1.5 cm, except on sandy soils where seedlings will emerge from a 2.5 cm depth. Late summer/early autumn and late winter/early spring are acceptable times to seed tall fescue depending on soil moisture and winter temperatures, but autumn seeding is generally preferred. Danielson and Toole (1976) found that tall fescue seed had maximum germination at temperatures between 12 and 18°C. In western Virginia the growth of tall fescue begins in April with seedheads appearing in late May (Wolf et al., 1979). Wolf et al. (1979) reported that about 45% of tall fescue annual dry matter production occurs in the first six weeks of spring. Flowering and stem elongation occur only in the spring, so all subsequent regrowth is vegetative. The number of reproductive tillers present in the spring is determined by the population of tillers the preceding autumn (Wolf et al., 1979). Yeh et al. (1976) discovered that buds are present on the tall fescue plant during the summer, but most tillering does not occur until autumn in the southern Corn Belt. Late summer and autumn growth of tall fescue is good with higher dry matter production than most other grass species. Most tall fescue stands will remain green throughout the winter in the southeastern USA (Wolf et al., 1979).

Tall fescue also provides stockpiled forage for late autumn and winter grazing due to its excellent autumn growth and ability to maintain quality and palatability following frost (Ball et al., 2002). Stockpiling extends the grazing season and helps reduce winter feeding costs for many producers. Ocumpaugh and Matches (1977) showed that in Missouri frequent defoliation in the spring and summer reduced the dry matter yield, but had little effect on autumn growth. They determined that the environmental conditions during the autumn had the greatest effect on yield during the autumn-winter period. The amount of rainfall before a killing frost had the largest effect on autumn growth. After a killing frost, dry matter, crude protein content, digestibility, and K content all steadily decrease (Ocumpaugh and Matches, 1977). Even though the growth of tall fescue declines after a killing frost, stockpiled tall fescue can still be utilized by cattle through the winter in most regions. In fact, tall fescue maintains dry matter and quality better than most cool season grasses when stockpiled for winter feeding (Ball et al., 2002).

Management

Proper management is probably the most important factor for maintaining a good stand of tall fescue, including time of defoliation, defoliation frequency, cutting or grazing height, and N fertilization (Matches, 1979). Hart et al. (1971) reported that in Maryland cutting tall fescue to a shorter stubble height (5 cm vs. 10 or 20 cm) produced higher total forage yields. They also found that tall fescue was more productive when cut to 5 cm every month instead of every week. This research indicated that tall fescue was more productive under less frequent defoliation. Although Cowan (1962) gave a recommended grazing height of 5 to 10 cm, Virginia researchers showed tall fescue should not be grazed close during the hot, dry summer period because slow regrowth provides an opportunity for weeds to invade the stand (Wolf et al., 1979).

Nitrogen is an essential building block for protein in all plant species. The average content of N in vegetative tall fescue is 3.4 to 3.8% (21.25 to 23.75% crude protein) and N content greater than 4.0% is considered high (Martin and Matocha, 1973). Nitrogen fertilization will increase forage yield and crude protein up to a certain maximum for all non-legume forage species. Over fertilization of forages allows non-protein nitrogen to accumulate in the form of nitrate, especially during drought

(Wilkinson and Mays, 1979). Nitrate can become toxic to animals that consume the forage. Therefore, it is important that N fertilization be managed very closely.

Tall Fescue Endophyte

Most tall fescue plants are infected with the endophytic fungus *Neotyphodium coenophialum*. When tall fescue fields were tested in the USA, it was found that over 90% were endophyte-infected (Ball et al., 1987). The endophyte grows intercellularly in tall fescue tissue, but does not affect visible growth or morphological appearance (Ball et al., 2003). Although fungal hyphae grow in the leaves, stems and seedheads of tall fescue, the endophyte has no reproductive stage and can only spread through infected seed. Kentucky 31 was highly endophyte-infected, which led to its widespread use and adaptation. The endophytic fungus produces ergot alkaloids that are toxic to livestock (Ball et al., 2002). A broad range of other alkaloids are also produced by the endophyte, but ergopeptine alkaloids are most closely associated with animal toxicity (Hill et al., 1991).

The three main animal disorders caused by endophyte-infected tall fescue are fescue toxicosis, fescue foot, and fat necrosis (Ball et al., 2002). Fescue toxicosis is characterized by many symptoms in animals including decreased weight gains, decreased conception rates, heat intolerance, rough hair coat, and increased body temperature. Fescue foot is characterized by elevated respiration, leg tenderness, and gangrene that can lead to the loss of hooves, ears, and tails. Fat necrosis occurs when hard masses of fat form in the abdominal cavity. Endophyte-infected tall fescue has the potential to cause severe animal disorders. Interseeding legumes into endophyte-infected tall fescue can alleviate some of the negative effects of the endophyte by diluting the toxic effects of the alkaloids and increasing animal production (Hoveland, 2003). Petritz et al. (1980) documented that cow weight gain, calf weight gain, and cow conception rate were higher on pastures of endophyte-infected tall fescue with ladino or red clover compared to pure endophyte-infected tall fescue pastures in Indiana. Gross et al. (1966) obtained higher average daily gains from ladino clover with endophyte-infected tall fescue pastures than endophyte-infected tall fescue grazed in sequence with bermudagrass in a North Carolina study.

Although the endophyte can be harmful to the animal, it is actually helpful to the tall fescue plant. Endophyte-infected tall fescue produces alkaloids that are not only toxic to livestock, but result in reduced insect feeding and damage as compared to endophyte-free tall fescue (Malinowski and Belesky, 2000). Infected tall fescue also has resistance to nematodes, tolerates drought conditions, and shows more rapid recovery from drought than most cool season grasses. The endophyte creates adaptations in the tall fescue such as deeper, more extensive root systems and more rapid stomatal closure during periods of drought (Malinowski and Belesky, 2000).

Since alkaloids are produced by the endophytic fungus itself, endophyte-free tall fescue does not contain the toxic alkaloids that are produced in endophyte-infected fescue, and therefore does not negatively affect animals consuming it. Hoveland et al. (1983) reported that in an Alabama study cattle grazing a Kentucky 31 stand relatively free of endophyte infection had higher average daily gains and total beef production per hectare than cattle grazing heavily infected Kentucky 31. Although endophyte-free tall fescue offers advantages in animal production, plant performance is sacrificed. Hill et al. (1991) documented that endophyte-infected tall fescue plants were larger and more competitive than endophyte-free plants when the two were planted together in a Georgia study. Hill et al. (1998) showed in a later Georgia study that endophyte-infected tall fescue had higher dry matter yields than endophyte-free tall fescue in pure stands and mixed stands containing the two fescue types. Endophyte-infected tall fescue also crowded the endophyte-free plants when the two were mixed. They concluded that the location of the tall fescue stand had an effect on the competitive ability of endophyte-free tall fescue and the encroachment by endophyte-infected tall fescue.

Researchers have selected more stress tolerant endophyte-free (E-) tall fescue cultivars. Ghorbani et al. (1991) evaluated the effects of the three endophyte-free tall fescue cultivars ‘Johnstone’, ‘Kenhy’, and ‘Kentucky-31 E-’ on the performance of lactating dairy cows in a Kentucky study. They found that the crude protein contents of Johnstone, Kenhy, and Kentucky-31 E- were 14.1, 13.3, and 12.8%. Their data also indicated that there were no differences between daily forage intake, milk production, milk fat percentage, respiration rate, rectal temperature, or serum prolactin concentration among the three cultivars (Ghorbani et al., 1991). Hoveland et al. (1997) researched another endophyte-free tall fescue cultivar called ‘Jesup’ in Georgia. Their research showed that steers grazing Jesup E- tall fescue had higher average daily gains than steers grazing an endophyte-infected (E+) version of Jesup alone, in mixture with alfalfa, and pure alfalfa. Conditions during their study indicated that Jesup E- tall fescue can survive after a severe drought.

Researchers in New Zealand have discovered endophytes that are not toxic to animals because the most harmful alkaloids, ergot alkaloids, are not produced. These endophytes are commonly referred to as non-toxic or “novel”. Bouton et al. (2002)

reinfected Jesup E- tall fescue with a non-toxic endophyte strain named AR542 in a study conducted in Georgia. Their data indicated that Jesup (AR542) had higher yield and better stand survival than the Jesup E-, but yield and stand survival were equal to Jesup E+. Lambs that were used in the study gained 124 g/d on Jesup (AR542), equal to gains on Jesup E- and 57% greater than Jesup E+. Jesup (AR542) did not depress serum prolactic levels or elevate the body temperature of the lambs during the study (Bouton et al., 2002). Jesup E+ originated from an old stand of tall fescue in south Georgia and likely contains the same endophyte as Kentucky 31 E+, also called wild type endophyte.

Parish et al. (2003) tested cattle performance, toxicosis, and grazing behavior on 'Georgia-5' tall fescue infected with the non-toxic endophyte AR542, Jesup AR542-infected tall fescue, Jesup infected with another non-toxic endophyte AR502, Jesup E- tall fescue, and Jesup E+ tall fescue in an extensive study in Georgia. Cattle grazing E+ tall fescue had decreased serum prolactin concentrations as compared to those grazing AR542, AR502, and E-. The cattle on AR542, AR502, and E- tall fescue had lower rectal temperatures, higher average daily gain, and higher gain per hectare than cattle on E+ tall fescue. Parish et al. (2003) concluded that cattle on non-toxic endophyte-infected tall fescue perform similarly to cattle grazing E- tall fescue and avoid the negative effects of fescue toxicosis. The AR542 endophyte has been patented under the commercial name MaxQ. Two tall fescue cultivars, Jesup MaxQ and GA-5 MaxQ are now available from Pennington Seed, Inc. (Parish et al., 2003). Further research is being done to test MaxQ in a range of tall fescue cultivars.

ALFALFA

Description

Alfalfa (Medicago sativa L.) is often recognized as one of the most important forages in the United States and is widely known as the "Queen of the Forages". It received this recognition because of its high yield potential, high levels of protein, high quality, and broad adaptation (Lacefield et al., 1987). Alfalfa is a cool season perennial legume with trifoliate leaves and stems that originate from a single large crown at the soil surface (Ball et al., 2002). Leaves are commonly trifoliate because there are three leaflets that grow together on the petioles with the upper one-third of each leaflet edge serrated, but some alfalfa cultivars now have multifoliate leaves. Individual leaflets usually have an oblong or obovate shape with mid- and lateral veins (Teuber and Brick, 1988). Flower color is most commonly a shade of purple, but green, yellow, cream, white, and variegated are not uncommon. Alfalfa seeds are kidney-shaped and vary in color from yellow or olive green to brown. Mature seeds have a length of 1 to 2 mm, width of 1 to 2 mm, and thickness of 1 mm with a hilum in the center (Teuber and Brick, 1988). The alfalfa plant can grow 61 to 91 cm tall (Ball et al., 2002) and possesses a prominent taproot with recorded depths of 9 m and greater (Kiesselbach et al., 1929).

Alfalfa (*Medicago sativa* L.) makes up part of the Medicago genus. The Medicago genus is made up of more than 60 species, both perennials and annuals. Scientists use legume and seed characteristics, chromosome number, pollen grains, and pubescence to differentiate between the Medicago species (Quiros and Bauchan, 1988). There are eight subspecies that make up the Medicago sativa complex (Quiros and Bauchan, 1988). In Europe, South Africa, Australia, and New Zealand alfalfa is referred to as lucerne. There are several common names given to alfalfa around the world including median herb, Burgundy clover, purple medic, and Chilean clover (Michaud et al., 1988).

History

Alfalfa first originated in Iran and central Asia and is commonly cited as the first cultivated forage species with written accounts dating back 3300 years (Michaud et al., 1988). Alfalfa was brought to the USA by colonists as early as 1736, but early cultivation efforts were not successful (Michaud et al., 1988). Alfalfa was first successfully grown in the western USA in the mid-1850s because it was well adapted to the western climate and soils and subsequently alfalfa cultivation spread eastward. Winter-hardy types of alfalfa were brought from Europe and Russia, which also allowed alfalfa to be grown in the northern states (Michaud et al., 1988). Alfalfa is now the most widely planted forage hay crop within the USA with 24 million acres in hay production and over 300 cultivars currently marketed (Natl. Agric. Stat. Serv., 2001).

Medicago falcata L., a yellow-flowered sub-species, was an important part of the development of cultivated alfalfa. *M. falcata* is cold-tolerant and well adapted to many northern areas. This sub-species has been widely used by alfalfa breeders to add drought resistance, winterhardiness, grazing tolerance, and creeping roots to modern alfalfa cultivars (Michaud et al., 1988).

Adaptation

Alfalfa is widely used in the USA and around the world due to its tolerance to a range of growing conditions. The optimum growing air and soil temperatures for alfalfa are 27°C and 12°C, respectively, but it is tolerant of air temperatures above and below

27°C (McKenzie et al., 1988). In fact, alfalfa can tolerate air temperature extremes from -27°C in Alaska to 54°C in California (Hanson et al., 1962). Cultivar choice is important when alfalfa is cultivated at either temperature extreme. During active growth alfalfa cannot tolerate temperatures below –2 to -5°C without significant frost injury. There are biochemical, biophysical, and morphological changes that occur in the alfalfa plant in the autumn that allow it to acclimate to lower temperatures, and allow the alfalfa roots and crown to tolerate air temperatures below -20°C (McKenzie et al., 1988). Alfalfa plant growth declines in temperate regions over 35°C, but non-dormant cultivars adapted to the southwestern USA are productive at temperatures of 40°C and higher (McKenzie et al., 1988).

Alfalfa benefits the soil by improving soil fertility and structure, and reducing erosion (Lacefield et al., 1987). The optimum soil pH range for alfalfa is 6.5 to 7.5. Low pH can cause N fixation to be reduced (Lacefield et al., 1987) and increases Al toxicity. Alfalfa grows best on well-drained, deep soils, but it thrives on sandy soils with adequate moisture and fertility (Barnhart, 1997). Alfalfa does not grow well in soils where root growth is limited such as shallow hardpans, high water tables, bedrock, or acidic subsoils (Lacefield et al., 1987). Poorly drained or waterlogged soils are strongly discouraged for alfalfa because root and crown diseases reduce stand longevity under these conditions. When the soil is saturated, livestock grazing and equipment will damage the crowns and roots and cause soil compaction (Gerrish, 1997).

Alfalfa has the ability to grow in a range of regions with different amounts of soil moisture. Heichel (1983) reported that it takes about 5.6 to 7.3 cm of water to produce 1 Mg ha^{-1} of alfalfa dry matter. It has been shown that the maximum daily water use by alfalfa is 5 to 11 mm. Seasonal water use is about 400 mm in the northeastern states and 1890 mm in the southwestern states, and depends on growing season length and temperature (Sheaffer et al., 1988). Water use by alfalfa is highest during daylight hours during warmer months when there is a larger canopy and increased evapotranspiration (Sheaffer et al., 1988). Water use efficiency for alfalfa is greatest during the spring season due to more optimum temperatures and lower evapotranspiration (Daigger et al., 1970). Alfalfa grows best in certain climatic and soil conditions, but its tolerance to a range of conditions makes it the most widely grown forage crop in the USA.

Growth and Development

Alfalfa seeds are relatively small (2 mg) and the small size of the seed makes it more difficult for the seedling to emerge and survive. Alfalfa is seeded either in the spring or late summer/early autumn (Barnhart, 1997). A cultipacker-seeder, drill, or broadcast seeder can be used to seed alfalfa depending on the seedbed. The seed should be planted about one-fourth of an inch deep in heavy soils and one-half of an inch deep in light soils (Lacefield et al., 1987). When the seed germinates the hypocotyl elongates causing the hypocotyledonary hook to move upward and push through the soil. Sunlight stimulates the hypocotlyedonary hook to straighten and this turns the cotyledons upward (Fick et al., 1988).

Once alfalfa is established, new growth and regrowth comes from primordia cells on the crown surface. These primordia form new crown buds, which eventually form new stems for the plant. Hormones keep the crown buds dormant until they are needed for new stems. When alfalfa is cut or grazed, the growing point where the hormones originate is removed and crown buds are released from dormancy. Alfalfa is able to have repeated regrowth cycles throughout the season because new crown buds are released (Dougherty and Absher, 1987). Partial defoliation is not recommended for the alfalfa plant because axillary buds on stems begin to elongate, suppress regrowth from crown buds, and the resulting weak branches cause reduced yield. Therefore, alfalfa should be grazed as low as possible without damaging the crown (Dougherty and Absher, 1987). Alfalfa is able to overwinter because sucrose is moved from the stems to the crown and upper taproot where it is converted to starch to keep the crown and taproot healthy throughout the winter. This starch will then be reconverted to sucrose for the new growth in the spring until carbohydrates can be made from photosynthesis (Dougherty and Absher, 1987).

The highest yields of alfalfa occur in the spring in most regions. Yield then decreases as days get longer and temperatures increase during the summer. The higher temperatures cause the plants to mature faster, leading to decreased yield (Dougherty and Absher, 1987). Without irrigation, available moisture usually declines during the summer months contributing to the lower yield.

Management

Alfalfa is a high quality and high yielding forage, but requires good management to reach its full potential. It does have flexibility as pasture forage due to its physiology and excellent regrowth. Several factors must be taken into consideration when determining the proper management of alfalfa, including grazing guidelines, nutrient requirements, and bloat potential.

Grazing

It has long been suggested that alfalfa for grazing should be managed similarly to alfalfa for hay production (Dougherty and Absher, 1987), consequently alfalfa does best under rotational stocking (Allen, 1985). Alfalfa in rotationally stocked pastures can be of higher quality than when continuously stocked because the plants tend to regrow more uniformly (Popp et al., 2000). Popp et al. (2000) showed that animals consumed more nutrients in a day when rotationally stocked. Overgrazing, which can occur under continuous stocking, weakens crowns and roots, kills weaker plants, and limits stand life. An alfalfa stand is more susceptible to weed invasion after overgrazing (Dougherty and Absher, 1987). Livestock should start grazing grazing-intolerant alfalfa cultivars in the late bud to early bloom stage and cattle should be moved within 7 to 10 days (Lacefield et al., 1987). Ideally, alfalfa should not be grazed for short periods (1 or 2 days) except at high stocking densities because over time selective grazing will occur and undesirable weed species will increase (Dougherty and Absher, 1987). Alfalfa should be allowed to rest for about 28 to 35 days before it is grazed again (Gerrish, 1997). During this rest period, alfalfa is able to replenish carbohydrate reserves in the crown and produce new crown buds (Dougherty and Absher, 1987).

Nutrients

Alfalfa requires adequate amounts of the proper nutrients to reach optimum productivity. Large amounts of nutrients are removed when alfalfa is harvested or grazed. Nitrogen is one of the most important nutrients for alfalfa. Fortunately, alfalfa is able to supply its own N through N fixing rhizobium. The concentration of N in alfalfa and its subsequent removal are higher than any other nutrient (Lanyon and Griffith, 1988). Phosphorus is also an important nutrient for alfalfa, but is required in smaller amounts than N or K. Phosphorus is important because it makes up adenosine triphosphate (ATP), which is required in large amounts for N fixation and for root and aboveground growth (Lanyon and Griffith, 1988). Potassium is the most common limiting nutrient for alfalfa production. Inadequate K levels affect alfalfa in many ways since it is required for water regulation, disease resistance and winter survival. Nitrogen fixation can be reduced if there are inadequate levels of K (Lanyon and Griffith, 1988). Grewal and Williams (2002) also found that K increased nodulation, yield, and leaf to stem ratio, and decreased leaf drop and common leaf spot diseases in alfalfa. Alfalfa requires several other nutrients for maximum productivity including Ca, S, Mg, B, and Mo. It is essential that soil tests are taken in alfalfa fields and the proper amounts of nutrients are added to have a successful crop.

Some elements (e.g. Al) can have a negative effect on alfalfa when present at high levels. Baliger et al. (2001) discovered that Al in the soil was detrimental to the growth of alfalfa and other legumes and interfered with the uptake of important minerals by roots. In their studies, Baliger et al. (2001) observed decreased alfalfa shoot and root weights, and increased Fe and Cu concentrations with increasing amounts of Al. The Ca concentrations in alfalfa shoots were also reduced with increased Al (Baliger et. al., 2001). The solubility of toxic elements such as Al increases with decreasing pH, therefore liming in accordance with soil test recommendations will not only increase pH, but also reduce the availability of these undesirable elements (Lanyon and Griffith, 1988).

Bloat

The possibility of bloat in cattle is probably the largest concern when grazing alfalfa. Bloat occurs because alfalfa is rapidly digested in the rumen of cattle. This rapid digestion causes the viscosity of rumen fluid to increase and froth or stable foam builds up in the rumen. Gases that are normally released by belching are trapped in this foam and cannot escape (Popp et al., 2000). The trapped gas can eventually cause the animal to suffocate. Bloat can be prevented in several ways, such as adding grass to alfalfa stands, not turning hungry animals out onto lush alfalfa, giving the cattle anti-foaming agents, and providing salt-molasses blocks containing surfactants (Howarth, 1988; Ball et al., 2002). Bloat can be avoided even in pure alfalfa stands with careful management.

ALFALFA CULTIVARS

Introduction

Traditionally, most alfalfa in the USA has been grown in pure stands and harvested as hay or silage, but it started as a pasture crop before it was cultivated for stored feed (Caddel, 1997). Caddel (1997) explains that alfalfa and its progenitor species were grazed by many different animal species thousands of years ago. Although the majority of alfalfa cultivars on the market today were developed to be harvested as hay, the development of grazing tolerant cultivars has generated a renewed interest in grazing alfalfa (Smith et al., 2000). Grazing alfalfa has economic advantages because the labor and equipment costs of harvesting hay are eliminated (Caddel, 1997). Alfalfa can be grazed at times when making hay is difficult such as the late autumn and early winter when low temperatures and high relative humidity create unfavorable drying conditions. Grazing alfalfa also provides an alternative in the late summer when conditions are dry and hay yields are low (Caddel, 1997). There are several advantages to grazing alfalfa, but are only relevant when the proper management practices are used. A key component to grazing alfalfa is giving the alfalfa an adequate rest period (28 to 35 days) to insure recovery after grazing. A rest period is important for both grazing-tolerant and other alfalfa cultivars.

Grazing Tolerance

The development of grazing-tolerant alfalfa cultivars became important as the use of alfalfa for grazing increased. Hay-type cultivars provide high quality and yield, but are not able to withstand the pressures of frequent grazing (Smith and Bouton, 1993). Rotational stocking appears to be the best way to maintain alfalfa stands because this management system allows the alfalfa to have a rest period. Beef producers are frequently unable or unwilling to provide the management or costs required for rotational stocking, therefore continuous stocking is common (Smith et al., 2000). Alfalfa cultivars are needed that can persist and yield under any stocking system.

The traits that are important in alfalfa for grazing tolerance have been disputed. Most of the early grazing-tolerant alfalfa cultivars developed in North America were selected for creeping rootedness (Heinrichs, 1963). The creeping rooted trait proved to be unimportant in many regions of the USA due to winter dormancy, slow regrowth rate, and variable expression of the trait (Smith and Bouton, 1993). Traits associated with crowns, budding, leaf area, roots, and stored carbohydrates have been used to develop grazing-type cultivars. These grazing-type cultivars and hay-type cultivars were then evaluated under actual grazing stress to determine which traits were truly important for grazing tolerance. Brummer and Bouton (1991) believed that decumbency, thin stems, and low yield were related to grazing tolerance. They also recognized the importance of root total nonstructural carbohydrates and perhaps residual leaf area for grazing tolerant alfalfa (Brummer and Bouton, 1992).

Several studies using different methods have been conducted for selection of grazing-tolerant alfalfa cultivars. Brummer and Bouton (1991) clipped grazing-type and hay-type cultivars biweekly to evaluate plant traits such as decumbency and crown area and their relation to grazing tolerance. In a later study, Brummer and Bouton (1992) used frequent and infrequent clipping to determine which physiological traits of alfalfa were associated with grazing tolerance that could be used to select grazing-tolerant cultivars. Smith et al. (2000) reasoned that it is difficult to select alfalfa traits for grazing tolerance because there are so many traits to test for. They recognized that animals could be used instead of trait selection to develop cultivars that are grazing tolerant. Animals can apply the necessary pressures during grazing to isolate those alfalfa cultivars that can tolerate the intensive grazing (Smith et al., 2000). Smith et al. (1992) took this approach and increased grazing tolerance within existing alfalfa cultivars using continuous close grazing.

The continuous stocking evaluation method has also been used in evaluating existing alfalfa cultivars for grazing tolerance. Smith et al. (1989, 1992) employed continuous stocking to evaluate several alfalfa cultivars in pure and mixed stands for alfalfa persistence, regrowth, and productivity. Continuous stocking was successful in determining grazing-tolerance of alfalfa cultivars, therefore a standard test was developed with this methodology. The standard test sets the exact procedures that should be followed to evaluate alfalfa cultivar grazing tolerance under continuous stocking (Bouton and Smith, 1998). Bouton and Gates (2003) took this a step further and tested several alfalfa cultivars selected under continuous stocking against the parental cultivar germplasms under continuous stocking, rotational stocking, and hay harvesting. They showed that overall plant survival was better in the rotationally stocked and hay harvested plots as compared to the continuously stocked plots. They also concluded that the grazing-tolerant cultivars had greater survival than their parent cultivars and cultivars selected using continuous stocking perform as well or better under rotationally stocking or hay harvesting (Bouton and Gates, 2003).

Alfalfa cultivars also need to be adapted to the region where they are being grown to maintain grazing tolerance. Environmental conditions play a major role in determining which cultivars will be successful for grazing. Katepa-Mupondwa et al. (2002) reported that in western Canada it is necessary that alfalfa cultivars possess winter hardiness to be used for pasture. In the southern USA alfalfa cultivars have to tolerate high temperatures and sometimes dry conditions to survive. Disease resistance is also an important trait in alfalfa cultivars. Smith and Bouton (1993) concluded that cultivars with higher disease resistance did not show higher survival under grazing. Grazing tolerance was the most important trait for the alfalfa cultivars, and disease resistance was secondary (Smith and Bouton, 1993).

ALFALFA-GRASS MIXTURES

Introduction

Alfalfa is commonly grown in mixtures with perennial grasses. The best mixtures are those that contain a persistent alfalfa cultivar with a well adapted, productive grass. Although there are many advantages to alfalfa-grass mixtures, there are several limitations. By carefully managing the advantages and limitations of alfalfa-grass mixtures, a high yielding, high quality mixture can be available for pastures and hay fields.

Advantages

Alfalfa is frequently included in mixtures with grasses because of the many advantages of polycultures in comparison to monocultures. McCloud and Mott (1953) observed that alfalfa-grass mixtures were higher yielding than pure grass stands and Katepa-Mupondwa et al. (2002) reported a longer growing season when alfalfa was included in a grass pasture. McCloud and Mott (1953) reasoned that the higher yield of mixed stands could be attributed to the N fixing ability of alfalfa, while pure grass stands often have suboptimal levels of soil N.

McCloud and Mott (1953) reported that legumes, such as alfalfa, increase the protein and carotene of their companion grasses when planted in mixed stands due to the release of nitrogen into the soil. Forage intake by livestock is higher because legumes have an increased digestion rate as compared to grass, which increases rumen passage rate. Increased intake and high quality result in improved daily gain (Blaser et al., 1986). Alfalfa also appears to have an advantage over other legumes used in mixtures. Roberts and Olson (1942) observed that lespedeza and white clover were not as competitive with grasses. Alfalfa had the highest production and longest persistence of any of the legumes mixed with grass in a study conducted by Jackobs (1963). When alfalfa is included in a grass pasture, it has the potential to increase animal production as well as forage production (Popp et al., 1997).

Conversely, grasses provide improved soil cover that helps to reduce soil erosion and weed invasion. This higher ground cover is especially important on sloping topography (Popp et al., 1997). Another very important advantage to adding grass to alfalfa is its ability to reduce the potential for frothy bloat. Both alfalfa and grass can benefit when the two are grown together in a mixture.

Limitations

Although there are several advantages to growing alfalfa with grass, competitive interactions between the alfalfa and grass can create some limitations. There is little competition between the alfalfa and grass in the seeding year since both are immature and not highly competitive until the end of the first season (McCloud and Mott, 1953). Alfalfa seeds germinate and emerge more quickly than grass, but the alfalfa seedlings grow more slowly than the grass once emerged. As the plants mature grass competition at the crown level generally causes alfalfa shoot production to decrease, with a concurrent reduction in yield and decreased persistence of alfalfa (Nelson et al., 1986). Most grass species also begin growing earlier in the spring than alfalfa, and provide competition for alfalfa, especially when it is weakened from overwintering.

Many studies have been done to test the interaction of alfalfa with different grass species. McCloud and Mott (1953) conducted an experiment that mixed alfalfa with smooth bromegrass and found that the sod-forming bromegrass reduced the yield of the alfalfa in the mixture. They believed much of the competition came from bromegrass shading out the alfalfa due to its tall, leafy plant structure. Katepa-Mupondwa et al. (2002) also studied the interaction of meadow bromegrass with alfalfa and found similar results to McCloud and Mott (1953). The bunch-type meadow bromegrass reduced alfalfa persistence in the mixture compared to pure stands of alfalfa. In their study alfalfa plant persistence and basal cover were reduced under both continuous and rotational stocking. Mooso and Wedin (1990) used mixtures of alfalfa-reed canarygrass and alfalfa-orchardgrass to investigate yields of mixtures and found that alfalfa plant persistence decreased over time, and grass cover increased. There is a general trend in most alfalfa-grass mixtures that the alfalfa composition will decrease over time and the grass will increase, resulting in an overall decline in nutritive value. Management is the key to maintaining alfalfa in combination with grasses in pastures.

Management

A good balance of grass and alfalfa in a mixture is affected by choice of species and cultivar, seeding date, seeding density, fertility, and defoliation time and height (Chamblee and Collins, 1988). The alfalfa component of the mixture can be increased by the use of a grazing-tolerant cultivar and bunch-type grass species. Alfalfa plant numbers are usually reduced by high grass seeding rates. Conversely, alfalfa seeding rates decrease the seedling growth of grasses, therefore a balanced seeding density must be achieved (Chamblee and Collins, 1988). It is generally recommended that seeding density should slightly favor the less aggressive species, usually alfalfa. One option is to seed alfalfa and grass in alternating rows, but this requires seeder modifications and

Tewari and Schmid (1960) found that alfalfa yield and total forage yield were higher when the grass and alfalfa were seeded together in every row.

The selection of a grazing-tolerant alfalfa cultivar is important for successful alfalfa-grass mixtures. An alfalfa-grass mixture can be even more successful if the alfalfa cultivar selected has been tested in alfalfa-grass mixtures previously and shown to excel. Alfalfa cultivars vary in survival when mixed with grass due to differences in competitive abilities (Chamblee and Collins, 1988). Katepa-Mupondwa et al. (2002) and Smith et al. (1992) documented that the inclusion of a grass with all alfalfa cultivars reduced alfalfa persistence. Both groups of researchers reported that alfalfa cultivar persistence in pure stands under continuous stocking was associated with higher persistence in mixed stands. Katepa-Mupondwa et al. (2002) did indicate though that alfalfa cultivar persistence in mixed stands under rotational stocking differed from persistence in mixed stands under continuous stocking. This research suggests that the type of grazing management system (rotational vs. continuous stocking) may play an important role in evaluating alfalfa cultivars in mixtures.

Soil fertility and soil pH are also very important in establishing and maintaining a balanced alfalfa-grass mixture. Soil tests should be taken and recommended nutrients and lime applied as with any other crop. Nitrogen fertilization should be limited on alfalfa-grass mixtures because even low rates of N stimulate grass competition. Under low soil moisture conditions fibrous rooted grasses can have a competitive advantage unless alfalfa can reach subsoil moisture with its long taproot. Potassium fertilization is also important because most grasses show luxury consumption of K that can create a K deficiency for alfalfa (Blaser et al., 1986).

Defoliation timing and height have a strong effect on the botanical composition of alfalfa and grass in mixtures. Temperate or cool season grasses regrow earlier than alfalfa in the spring because they are physiologically active at lower soil temperatures. Therefore, they can have more growth than alfalfa in the spring. Early grazing of the mixture in the spring can benefit alfalfa by reducing grass shading (Blaser et al., 1986).

Several studies have shown that closer, more intensive defoliation favors alfalfa growth in alfalfa-grass mixtures. Rhykerd et al. (1967) showed that under intensive cutting management, smooth bromegrass and timothy declined in mixtures with alfalfa over time. Wolf et al. (1962), in a greenhouse study, observed that alfalfa composition (when mixed with smooth bromegrass, orchardgrass, and timothy) increased when the cutting height was decreased from 12.7 to 2.5 cm.

Research conducted by Popp et al. (1997) in western Canada combined alfalfa, meadow bromegrass, and Russian wild ryegrass. The meadow bromegrass declined in the mixture under heavily stocked continuous grazing and under rotational grazing. Interestingly, the amount of alfalfa in the mixture was greater in heavily stocked pastures as compared to lightly stocked pastures. Alfalfa made up more than 75% of the mixture in the continuously heavily stocked pastures. Popp et al. (1997) reasoned that continuous grazing at high intensity caused repeated defoliation of the grass, which weakened recovery of the grass, leaving alfalfa to dominate. Blaser et al. (1986) found similar results with alfalfa-orchardgrass mixtures. Close defoliation reduced the leaf growth of orchardgrass and helped the growth of alfalfa increase because there was less light competition from orchardgrass. The alfalfa-orchardgrass mixture was cut to 3.8 cm and 7.6 cm. The mixture cut to 3.8 cm contained more alfalfa than orchardgrass, while the

7.6 cm cutting height allowed orchardgrass to dominate (Blaser et al., 1986). Defoliation height is a key management tool to create uniform alfalfa-grass mixtures where alfalfa can compete with the grass and survive.

ALFALFA-TALL FESCUE MIXTURES

Introduction

Many legume-grass mixtures have been tested throughout the United States and around the world. Alfalfa grown with tall fescue would appear to be an ideal mixture for Virginia and the eastern United States. Alfalfa is a high quality, nutritious legume and tall fescue is a well adapted, persistent grass. Alfalfa-tall fescue mixtures exhibit many of the same advantages, problems, and management practices associated with legume-grass mixtures and alfalfa-grass mixtures, but there are unique considerations with this combination. Although research is limited on the establishment and management of alfalfa-tall fescue mixtures, there are several studies that show the productivity of this mixture.

Advantages

Alfalfa-tall fescue mixtures have the same advantages as other legume-grass mixtures such as reduced soil erosion, increased water conservation, greater weed control, and reduced stand thinning caused by legume plant mortality (Smith et al., 1992). The advantage of including tall fescue with alfalfa compared to other grasses, such as orchardgrass, is that tall fescue is longer lived and produces more dry matter in the autumn and early winter. Tall fescue also retains quality, biomass, and nonstructural carbohydrates longer under winter stockpiling than most grass species (Blaser et al., 1986). Hoveland et al. (1986) conducted a study comparing several grass-legume mixtures and observed that the legume mixtures with orchardgrass yielded less than those legume mixtures with tall fescue. Smith et al. (1973), in an experiment testing alfalfa-grass mixtures and their response to cutting, reported that reed canarygrass and tall fescue showed greater tolerance to frequent cutting than other grasses. Smith et al. (1973) concluded that the superior persistence of tall fescue was due to its continuous state of tiller production. Casler and Walgenbach (1990) compared the ground cover potential of different temperate grasses when mixed with alfalfa, and found that orchardgrass and tall fescue had the highest ground cover of all the grasses (76%). Smith et al. (1992) reported that tall fescue had good growth in late winter and spring, which increased yields of alfalfa-tall fescue mixtures. Comstock and Law (1948) reported in eastern Washington that alfalfa-tall fescue produced higher yields than pure alfalfa under three cutting treatments (hay stage cutting, frequent cutting, and rotational cutting).

There are several overall advantages of growing alfalfa with tall fescue. Alfalfa-tall fescue mixtures have been shown to have longer growing seasons and higher yields than alfalfa or tall fescue grown alone. Smith et al. (1992) reported that alfalfa showed greater regrowth in pure stands and mixtures after continuous stocking than tall fescue had alone. Hoveland et al. (1995) also reported that alfalfa composition during the summer was higher than tall fescue in alfalfa-tall fescue mixtures. The advantage of alfalfa regrowth in the warmer months and good growth of tall fescue in late autumn and spring provides a longer growing season than either species alone. Hoveland et al. (1986) reported that alfalfa-tall fescue mixtures produced higher yields than either tall fescue or orchardgrass fertilized with up to 269 kg N ha^{-1}. In a subsequent study, Hoveland et al.

(1995) showed that pure tall fescue fertilized with 168 kg N ha^{-1} only produced 76% of the yield obtained with alfalfa-tall fescue mixtures. Alfalfa has been shown to provide tall fescue with about 202-303 kg N ha^{-1} when the two are mixed (Chamblee and Collins, 1988).

Limitations

Although there are many advantages to growing alfalfa and tall fescue together, there are also limitations that occur with this mixture. Similar to many grass species, tall fescue competes and reduces the survival of alfalfa, reducing the nutritive value of the mixture (Smith et al., 1992). Most of the competition in the mixture occurs due to the seasonal growth pattern of tall fescue. In early spring and late autumn, tall fescue expresses vigorous tillering and crown expansion. The increased tiller numbers and crown size of the tall fescue shade the alfalfa plants, reducing photosynthesis and growth (Smith et al., 1992). Chamblee and Lovvorn (1953) reported in North Carolina that tall fescue suppressed alfalfa growth more than orchardgrass. The alfalfa plants were in closer contact with the tall fescue than the orchardgrass, resulting in the shading of crown buds, inhibiting bud elongation, and increasing alfalfa mortality. Jackobs (1952) also reported Alta tall fescue suppressed alfalfa to a greater extent than orchardgrass. Additionally, alfalfa-orchardgrass mixtures had a higher annual yield than alfalfa-Alta mixtures (Jackobs, 1952). As alfalfa plant numbers decline, tall fescue plants compensate and become a greater component of the mixture (Smith et al., 1992). Tall fescue reduced the persistence of four alfalfa cultivars tested in a study conducted by Smith et al. (1992) under continuous stocking, even the most persistence cultivars were reduced by the tall fescue.

The growth pattern of tall fescue is not the only characteristic that reduces alfalfa persistence in a mixture. Tall fescue also reduces growth and persistence of other species through its chemical properties. Mandava (1985) reported tall fescue extracts inhibited the germination and growth of pinto bean and mungbean; these extracts contained complex mixtures of secondary plant products including phenolic compounds. Chung and Miller (1995) tested the effects of nine forage grass extracts on the germination and seedling growth of alfalfa. The extracts from tall fescue leaves and roots reduced the germination and radicle length of alfalfa by 31%. The germination of alfalfa seeds was reduced the most by tall fescue and smooth bromegrass extracts. Chung and Miller (1995) included a residue test in their experiment where alfalfa was grown in soil containing leached and nonleached residues from the nine grasses. The nonleached residue of tall fescue greatly inhibited alfalfa plant height. The residue of tall fescue also reduced alfalfa stem and leaf weight (Chung and Miller, 1995).

Management: Agronomic

Management is the most important way to reduce the problems associated with alfalfa-tall fescue mixtures. Many of the management practices that are successful with other alfalfa-grass mixtures can also be used to improve alfalfa-tall fescue mixtures. Tall fescue has unique features that make it different from other grasses, and therefore may require specific management practices

Seeding rate, seeding method, and fertilization are all important aspects of alfalfa-tall fescue establishment and maintenance, as shown with any alfalfa-grass mixture. Chamblee and Lovvorn (1953) tested the effects of different seeding rates and methods on alfalfa-tall fescue mixtures. Their research showed that alfalfa plant numbers and alfalfa yield were decreased by high tall fescue seeding rates. These high seeding rates also reduced the total yield of the alfalfa-tall fescue mixtures. Total yield of alfalfa-tall fescue was lower when the mixture was planted by alternate-row spacing as compared to mixed-in-the-row and broadcast seeding. The alternate-row method of seeding also decreased alfalfa growth and increased tall fescue growth. Chamblee and Lovvorn (1953) concluded that alfalfa had the most growth when the alfalfa-tall fescue mixtures were broadcast, but broadcast seedings cannot always obtain the same establishment achieved from drilled seeding. In addition, Chamblee and Lovvorn (1953) showed that tall fescue is highly competitive with alfalfa for K, shown by the signs of K deficiency on alfalfa the second spring after seeding and the higher K_2O content in tall fescue throughout most of the study. Jackobs (1952) reported from his research with alfalfa-Alta fescue mixtures that phosphate is another important fertilizer for alfalfa-tall fescue mixtures. His data showed that alfalfa-Alta fescue mixtures increased in yield by 673 kg ha^{-1} with the addition of phosphate fertilizer. Seeding and fertilizer are only two of the many practices that must be evaluated to find the optimum management for alfalfa-tall fescue mixtures.

Management: Grazing

Most of the management research on alfalfa-tall fescue mixtures has been done for hay production and not grazing, but cutting height and frequency studies may be applicable for grazing management. Comstock and Law (1948) examined the effects of clipping on the botanical composition and yield of alfalfa-grass mixtures. They reported that an alfalfa-Alta fescue mixture had higher yields when clipped at the hay stage as compared to frequent or rotational clipping, and the rotational clipping had higher yields than the frequently clipped plots. Frequent clipping also resulted in a higher percentage of fescue (43%) in comparison to rotational clipping (34%). The percentage of fescue under frequent clipping remained high throughout the three years of the study. These results from Comstock and Law (1948) indicate that frequent defoliation with short rest periods will result in an increased percentage of tall fescue, as compared to alfalfa.

Smith et al. (1973) tested the persistence of several temperate grasses, including tall fescue, grown with alfalfa and harvested two, three, and four times annually at 4 and 10 cm stubble heights. Tall fescue maintained a good stand at all three cutting frequencies at both stubble heights, except it was nearly eliminated when it was cut twice to 4 cm. This may indicate that closer grazing can reduce the tall fescue and its competition with alfalfa. Jackobs (1952) reported that alfalfa-tall fescue mixtures survived and remained productive under sheep grazing when grazing duration was three to seven days, repeated five times per season.

Smith et al. (1992) measured the persistence of four alfalfa cultivars in mixtures with tall fescue under continuous stocking in Georgia. They found that grazing-tolerant cultivars maintained a higher percentage of root total nonstructural carbohydrates than grazing intolerant cultivars. These results suggest that the first step for proper management of alfalfa-tall fescue mixtures is to choose a persistent, grazing-tolerant alfalfa cultivar. Smith et al. (1992) also used a hay harvest in March to reduce the competition from tall fescue spring regrowth. Further research should be conducted to determine if hay harvesting should be combined with grazing to manage alfalfa-tall fescue mixtures.

Allen et al. (1992a) implemented a large 7-year study at the Virginia Agricultural Experiment Station, Middleburg to examine forage systems for beef production from conception to slaughter. They included stockpiled alfalfa-tall fescue as part of the forage system for the stocker portion of the study. Kentucky-31 tall fescue and 'Arc' alfalfa were seeded in 1981 and 1982, with their research beginning in 1983. Tall fescue endophyte infection ranged from 0 to 55%. Stockpiling was done by taking the last hay harvest of alfalfa-tall fescue in early September and allowing the forage to accumulate until grazing began on October 31. Each pasture replicate was 0.8 ha in size with three stockers grazing the pasture. The stockers on the stockpiled alfalfa-tall fescue were allowed to graze the forage down to 2.5 cm, then they were moved to the drylot and fed alfalfa-tall fescue hay for the rest of the stocker period. Hay was fed an average of 9 and 27 days in December and January and continuously fed from February until April over the five years of the stocker study. They reported that the alfalfa percentage in the stockpiled alfalfa-tall fescue pastures remained constant and undesirable forage species were negligible under this management program over the five years of the study.

V.G. Allen (pers. comm., 2004), J.P. Fontenot, and many colleagues created an extensive interdisciplinary research and education farming system project at the Virginia Tech Kentland Farm, Blacksburg from 1989 until 2000 comparing a conventional crop/livestock system to a new sustainable system. Alfalfa-tall fescue mixtures were included in the pasture portion of the project. Kentucky-31 endophyte-free tall fescue and 'Cimmarron' alfalfa were established in late summer 1988 (Mundy, 1993). Each alfalfa-tall fescue pasture was 1.6 ha with four replications. The management of these pastures included a combination of stockpiling, hay harvesting, and grazing. The pastures were clipped in early September and allowed to accumulate forage until November. In November, six weanling steers began grazing the stockpiled alfalfa-tall fescue and hay feeding began in December on the pastures when forage available for grazing was not adequate to provide needed dry matter intake for steers. The steers were removed in February and returned to the pastures in the spring. Alfalfa-tall fescue pastures were continuously grazed for up to four weeks in the spring. After steers were moved to other parts of the project, regrowth of alfalfa-tall fescue was harvested for hay when alfalfa reached the one-tenth bloom stage. The steers returned to the alfalfa-tall fescue pastures in the summer, which had been divided into eight sections to allow for rotational stocking. Grazing in each section of the pasture averaged one week before cattle were moved to the next section. Any excess alfalfa-tall fescue forage was harvested for hay during the summer. The cattle were rotationally stocked until September, weather permitting, when stockpiling would start again for winter grazing. Mundy (1993) reported that in the fourth year of the stand (1993) the botanical composition of the alfalfa-tall fescue pastures was approximately 50% tall fescue and 50% alfalfa on a biomass basis. Alfalfa was able to survive and remain productive during the study under the prescribed management program (Allen, pers. comm., 2004).

Blaser et al. (1986) conducted research on the growth of alfalfa-orchardgrass mixtures. They observed that close defoliation reduced the leaf growth of orchardgrass leading to reduced light competition and increased alfalfa growth. When the alfalfa-orchardgrass mixture was cut to 3.8 cm, the alfalfa was able to remain competitive, but when the mixture was cut to 7.6 cm, the orchardgrass dominated. These same results could possibly be seen in alfalfa-tall fescue mixtures. A study was conducted by

Hoveland et al. (1995) to determine the effects of different management strategies on Alfagraze alfalfa-tall fescue mixtures. The alfalfa component of their mixtures was reduced when the mixtures were harvested at 3- and 4-week intervals, compared to a 6-week interval. These results suggest that a longer rest period or harvest interval would help alfalfa remain competitive with tall fescue in mixtures. More research on alfalfa-tall fescue management needs to be conducted to confirm these hypotheses and obtain new information on the mixture.

ADVANTAGES OF GRASS-LEGUME MIXTURES FOR BEEF PRODUCTION

Introduction

The major costs in beef production are feed costs. For a beef producer to improve profitability, the maintenance cost of beef cows must be reduced (Hoveland, 1986). The best way to reduce feed cost, and thus maintenance cost, is by using forages. Many farmers have realized that the cheapest way to produce beef is to emphasize using their cattle to harvest forage and minimize harvesting with machinery.

In the eastern USA, beef production is mainly cow-calf production on small farms, with the calves being sold at weaning to producers in the Midwest (Allen et al., 1992b). Producers in the eastern USA could potentially increase profitability by retaining ownership of their calves and setting up stocker and finishing systems. Historically, pastures and hay fields have primarily contained N-fertilized grasses (Hoveland, 1986). Research shows that grass-legume mixtures can provide advantages over grass alone in each of the three systems of beef production.

Cow-Calf Systems

A major key to cow-calf production is breeding and an appropriate breeding program should be implemented in all beef production systems. A controlled breeding season is important because it allows pasture production to be synchronized with critical times in cow-calf production. A controlled breeding season can allow for good quality forage to be available to the cow during lactation and to the nursing calf for growth (Hoveland, 1986). Major areas of concern in cow-calf production are cow health and body condition, conception rate, birth rate, birth weight, lactation, pre-weaning gain, and weaning weights. Grass-legume mixtures can have a positive influence on all of these areas.

Allen et al. (1992b) conducted a 7-year study at the Virginia Agricultural Experiment Station, Middleburg containing five spring calving seasons that showed the performance of Angus cows and their calves being fed grass-legume mixtures. These cows maintained about a 484 kg body weight throughout the study on these mixtures. They also showed excellent longevity throughout the study. They experienced an overall pregnancy rate of 94%, and 97% of the cows produced live calves while consuming the grass-legume mixtures. The majority of the calves were born naturally without assistance and had an average birth weight around 37 kg. The period between birth and weaning is also very important because it determines the weaning weight of the calf. They provided abundant and high quality forage during late gestation and early lactation by using stockpiled grass-legume pastures and grass-legume hay when needed. The adequate lactation by the cow and available creep feed of grass-legume pasture led to average weaning weights of 250 kg for the calves.

Burns et al. (1973) also conducted an experiment using Angus cows and calves to test their performance on pasture containing endophyte-infected tall fescue with ladino clover versus pasture containing just endophyte-infected tall fescue. They found that cows grazing pure tall fescue had lower gains (23.9 kg/cow) than those grazing tall fescue with ladino clover (50.5 kg/cow). They also experienced higher calf gains with cows and calves grazing ladino clover-tall fescue as compared to tall fescue alone, with ladino clover-tall fescue producing about 29 kg/calf more. Heavier weaning weights translate to greater returns when the calves are sold and better condition of the calves going into a stocker system.

Stocker Systems

There is an opportunity for profitability by stocking weaned calves on high quality forage, especially in the eastern USA where there is an abundant supply of weaned calves (Hoveland, 1986). A stocker system containing fall-weaned calves will require feeding through winter into early spring, which is usually done using stockpiled forage and hay. Forage yield, average daily gain, total gain, final weight, and forage quality factors are all important for stocker systems.

Allen et al. (1992a) included a stocker system study with their 7-year cow-calf study using the weaned calves. The weaned calves were fed from October until early April in different feeding groups. Three of the feeding groups were fed stockpiled forages of either red clover-tall fescue, alfalfa-tall fescue, or pure tall fescue. The other three feeding groups were barn-fed from October to April on either tall fescue hay, orchardgrass-alfalfa hay, or tall fescue silage. Tall fescue endophyte-infection ranged from 0 to 55%. The average daily gains (ADG) of calves grazing stockpiled alfalfa-tall fescue were 0.50 kg/d as compared to 0.34 kg/d for the N-fertilized stockpiled tall fescue. The feeding of alfalfa-orchardgrass hay also resulted in greater ADG of 0.50 kg/d as compared to fescue hay (0.18 kg/d) and fescue silage (0.07 kg/d). The greater ADG of stockpiled alfalfa-tall fescue and alfalfa-orchardgrass hay led to greater total gains and final weights for calves on these forages. The quality of the stockpiled alfalfa-tall fescue was also superior to that of the stockpiled pure tall fescue. The stockpiled alfalfa-tall fescue had an average crude protein content of 24% as compared to stockpiled tall fescue with 13% crude protein. The alfalfa-orchardgrass hay had 12.6% crude protein and 40% ADF, while the pure tall fescue hay had 9.5% crude protein and 42% ADF. This study showed that the gain and quality of these legume-grass mixtures for beef stockers is superior to that of grass alone.

Blaser et al. (1956) conducted a stocker system study where steers and heifers grazed ladino-endophyte-infected tall fescue mixtures, ladino-orchardgrass mixtures, N-fertilized endophyte-infected tall fescue, or N-fertilized orchardgrass. Their data reflect a greater daily gain (1.02 kg/steer) on the grass-ladino mixtures than the pure grass (0.89 kg/steer). The grasses fertilized with N also had lower quality than that of the grass-ladino mixtures.

Finishing Systems

The final stage in beef production is finishing cattle for slaughter. This can be done on high quality forage in the eastern USA. Research done by Allen et al. (1996) showed that forages fed during the stocker phase have an influence on the performance of finished cattle. Supplemental grain is usually fed when cattle are grazed during the finishing phase to shorten this period. The supplements alone and their interaction when mixed with different forages have an impact on the finished cattle. The major areas of concerns in the finishing system are average daily gain (ADG), total gain, final live weight, and carcass characteristics.

The study by Allen et al. (1996) included finishing systems, where the stocker heifers and steers were finished out on forages and supplements starting in April. One-half of the cattle that had grazed the stockpiled N-fertilized tall fescue were finished out on pure endophyte-infected tall fescue, while the other half was finished on grass-legume mixtures. The steers and heifers that had grazed stockpiled grass-legume mixtures or were barn-fed hay or silage, were finished out on grass-legume pasture.

Heifers and steers that had been wintered on stockpiled tall fescue and then went into the all-fescue finishing system with had lower gains, final live weights, and carcass weights than those heifers and steers that had been wintered on tall fescue and finished out on grass-legume pasture (Allen et al., 1996). Those steers that had grazed only fescue during the stocking and finishing phase and were fed corn silage until January had higher daily gains and total gains than those steers that were wintered on tall fescue, and then grazed grass-legume mixtures before going into the feedlot. But, the steers grazing grass-legume combinations before the feedlot had higher final live weights and carcass weights because the steers grazing all tall fescue did not have adequate compensatory gain to catch up during the feedlot period.

Heifers that were barn-fed alfalfa-orchardgrass hay during the winter had higher final live weights, quality grades, marbling, back fat thickness, ribeye area, and dressing percent at slaughter than those heifers fed tall fescue hay or silage (Allen et al., 1996). Also, steers that were given alfalfa-orchardgrass hay during the stocking phase had greater final live weights and carcass weights when slaughtered in October than those steers wintered on fescue hay or silage. The steers fed alfalfa-orchardgrass hay over winter, and given no corn grain supplement during grazing but were fed corn silage, had higher final live weights, carcass weights, and ribeye area than those steers fed fescue hay or silage during the winter. Stockpiled grass-legume mixtures, grass-legume hay, and grass-legume pastures can all provide large advantages over N-fertilized grass in cow-calf, stocker, and finishing systems, resulting in a more desirable finished product.

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