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# HARVEST FREQUENCY AND CULTIVAR EFFECTS ON YIELD, QUALITY, AND REGROWTH RATE AMONG NEW ALFALFA CULTIVARS

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ABSTRACT OF THESIS

HARVEST FREQUENCY AND CULTIVAR EFFECTS ON YIELD, QUALITY, AND REGROWTH RATE AMONG NEW ALFALFA CULTIVARS

Alfalfa (*Medicago sativa* L.) is the most important forage crop in the United States and consistently produces high yields and quality, but harvest frequency is the most significant factor for maximizing forage yield and quality. The objective of this research was to determine forage yield, quality, and regrowth rate among new alfalfa cultivars under four different harvest frequencies. Some of these cultivars have been marketed as having rapid rates of regrowth after cutting to maximize the number of harvests per year. Five cultivars were placed under four harvest frequencies of 25, 30, 35, and 40 days in a split-plot design. There was a significant yield and regrowth rate effect across cultivars and harvest frequencies, but little forage quality effect during the two years of this research. These results confirm previous findings that a 35-d harvest frequency is optimal for forage yield, quality, and stand persistence.

KEYWORDS: Alfalfa, Forage Yield, Forage Quality, Regrowth Rate, Harvest Frequency

__________________Thomas Adam Probst_____

__________________April 17, 2008 ___________

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THESIS

Thomas Adam Probst

The Graduate School

University of Kentucky

2008

# HARVEST FREQUENCY AND CULTIVAR EFFECTS ON YIELD, QUALITY, AND REGROWTH RATE AMONG NEW ALFALFA CULTIVARS

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THESIS

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A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agriculture
at the University of Kentucky

By

Thomas Adam Probst

Lexington, Kentucky

Director: Dr. Ray Smith, Associate Professor

Lexington, Kentucky

2008

I would like to dedicate this work to my loving wife, Tracy, and son, Carson. Without their love and support, I would not have accomplished the achievements that I have today. They are the greatest gifts that God has blessed me with throughout my life.

I would also like to dedicate this work to the memory of my late grandfathers, Leonard B. Probst and Ronald P. Haley. It is through their love and passion for agriculture that I obtained a desire to learn and know more about their life's work.

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# Chapter I

## Introduction

Alfalfa (*Medicago sativa* L.) is commonly known as the "Queen of Forages" due to its ability to consistently produce high forage yields and forage quality. With the exception of the Gulf States, alfalfa is widely grown as a forage crop in every state in the continental USA (USDA, 2007). This forage legume is also known as an effective source of biological nitrogen fixation, an energy-efficient crop to grow, and an important source of protein yield. These qualities make it an excellent choice of feed for livestock producers (Barnes et al., 1988).

The development of hay quality standards (e.g. Relative Feed Value, RFV, and Relative Forage Quality, RFQ) has provided alfalfa producers with an efficient method of comparing and marketing their crop to livestock producers. During the 1990's, new technologies and genetic lines allowed alfalfa breeders to develop and release higher quality and higher yielding alfalfa cultivars.

The stage of maturity at harvest, or harvest frequency, has been shown to be the main factor affecting alfalfa quality (Collins and Fritz, 2003). Earlier maturity harvests are higher in quality, but repeated harvests at an immature stage will reduce stand longevity, vigor, and yield (Sheaffer et al., 1988; Smith et al., 1986). Within the last 10 years, new alfalfa cultivars have been developed that will supposedly tolerate a more aggressive harvest frequency. The objective of this study is to determine the effect of harvest frequency on alfalfa cultivar yield, quality, and regrowth rate using five improved alfalfa cultivars.

# Chapter II

## Literature Review

### Alfalfa

#### Description

Alfalfa is an erect-growing perennial that has many leafy stems that arise from the crown at the soil surface. The plant grows to be approximately 61 to 91 centimeters tall. The leaves are trifoliate with long narrow leaflets serrated at the tips. It also has a deep taproot that provides excellent drought-tolerance. The flower color of most cultivars recommended for the south-eastern USA is mostly some shade of purple (Ball et al., 2002).

#### History

Alfalfa occupies an important place in the history of world crop production. It is recognized as the "oldest plant grown solely for forage" (Michaud et al., 1988). It originated in central Asia and the region that overlaps modern-day Iran. However, the evolution of cultivated alfalfa, *Medicago sativa* ssp. *sativa* L., has been greatly influenced by its winter-hardy progenitor, *Medicago sativa* ssp. *falcata* L.

Alfalfa was introduced to the USA by the colonists as early as 1736, but these early plantings on the East Coast were not successful (Barnes et al., 1988). However, by the mid-1850's, alfalfa was being successfully grown under the ideal climatic and soil conditions of the western U.S. During the next fifty to seventy-five years natural selection and the introduction of new germplasm allowed alfalfa production to move towards the East Coast once again. The introduction of soil amendments, such as lime, in the mid-twentieth century, allowed alfalfa to be successfully grown on the low pH soils of the eastern United States (Lacefield et al., 1987).

As alfalfa hectarage increased, new pest problems became apparent with the crop. By the early 1960's alfalfa production was widespread in the eastern U.S., but the introduction and spread of the alfalfa weevil (*Hypera postica*) resulted in a significant reduction in hectarage (Lacefield et al., 1987). The successful release of new control tactics (e.g. insecticides, predatory wasps) has provided effective control against the alfalfa weevil in many regions.

**Adaptation**

The optimum growing temperature for alfalfa is between 20 to 30°C, however, it sustains growth at temperatures well above and below this optimal range (Fick et al., 1988). Alfalfa requires deep, well-drained soils for optimum growth with a pH between 6.5 to 6.8 (Lacefield et al., 1987). This pH range is optimal for essential nutrient availability (e.g. potassium and phosphorous), reduced toxicity (e.g. aluminum), and efficient biological nitrogen fixation.

One of the most important characteristics of alfalfa is its symbiotic relationship with *Rhizobium meliloti*. This bacteria stimulates the formation of nodules on alfalfa roots where the bacteria converts atmospheric $N_2$ into forms available for plant uptake or for release into the immediate soil environment. According to Lanyon et al. (1988), “Nitrogen concentration and removal [in alfalfa] equal or exceed that of any other nutrient, including K.” Therefore, this relationship is extremely important in maintaining plant health and vigor.

**Growth and Development**

According to Fick et al. (1988), in Alfalfa and Alfalfa Improvement, alfalfa seeds are quite small averaging 500 seeds per gram. Each seed is surrounded by a hard seed coat and contains two cotyledons, a radicle, a hypocotyl, and an epicotyl. The alfalfa seed germinates when it has absorbed 125% of its weight in water.

The germination process initiates with the radicle emerging through the seed coat near the point of the hilum. The radicle tip then grows deeper into the soil, and the hypocotyl elongates and pulls the cotyledons and epicotyl above the soil surface in a process referred to as epigeal germination. Once the cotyledons emerge they may turn green, but initially have limited photosynthetic activity. The first unifoliate leaf is produced from the epicotyl during elongation of the meristematic region of the epicotyl. This region of the epicotyl then produces the alternate trifoliate or multifoliate leaves. While stems, leaves, and flowers are being developed by the epicotyl, a secondary stem is formed in the bud of the unifoliate leaf. Secondary stems are also produced at other axillary buds located on the cotyledonary nodes.

The radicle continues to penetrate the soil while the hypocotyl and upper radicle begin contractile growth. Contractile growth pulls the cotyledonary and unifoliate nodes below the soil surface to develop the crown. The radicle develops into the primary tap root followed by the formation of smaller secondary roots. *Rhizobia meliloti* will then infect the root hairs about four weeks after germination.

After the initial harvest, alfalfa regrowth occurs much faster than seedling growth. During the vegetative stage, energy for growth comes from carbohydrates and other nutrients that have been stored in the roots and crown. Spring growth is principally from the crown buds and later regrowth also comes from axillary buds. Auxin is produced in the apical meristem and production decreases as the stem matures. When the plant is harvested, the apical meristem is removed and auxin concentration is low, which triggers growth from the crown bud (Fick et al., 1988).

The availability of root total available carbohydrates (TAC) under various harvest frequencies has been closely studied. Feltner and Massengale (1965) and Chatterton et al. (1977), all found forage yield to be closely related to carbohydrate levels in the roots and crown. John Reynolds (1971) found alfalfa that was harvested too frequently suffered significant stand loss after only two years. He also found TAC levels decreased after defoliation and then increased towards maturity after photosynthesis provided adequate amounts of carbohydrates. This complete cycle took about 42 days in Tennessee. Others have also cited decreased carbohydrate levels and greater stand losses in alfalfa harvested too frequently (Robison and Massengale, 1968). However, other research has shown grazing-type alfalfa cultivars to have higher levels of TAC than hay-type cultivars and may rely less upon them for growth (Smith et al., 1989, 1992; Smith and Bouton, 1993).

With the formation and development of flowers, a major physiological transition occurs. Before flowering, alfalfa's nutrient uptake has been to promote vegetative growth. After flowering, nutrient absorption and photosynthates are diverted into seed production. With alfalfa's indeterminate growth pattern, vegetative growth will still occur, but slower than before flowering. This allows for the forage yield to keep increasing, but forage quality decreases rapidly past this stage of development.

With shorter daylengths during the fall, the biochemical processes in the alfalfa plant begin to change. Some of the starch that can be found in the crown and root is converted into sugars that help keep the crown and crown buds from freezing. These crown buds can withstand temperatures as low as −15°C (5°F), and are also the source of the first spring growth (Fick et al., 1988).

The development of the visual alfalfa growth model by Av Singh (2000) has allowed for an increased understanding of alfalfa development. Measurements of individual plants, such as crown size, plant height, internode length, number of stems, etc., can be used in the computer modeling program L-Studio© to validate this model under various environmental conditions. Harvest frequency, cutting height, and cultivar effects are some conditions that can affect growth and development. Resulting plant models could be useful for classroom instruction and extension programming.

**Management**

Proper management of alfalfa is essential for a productive stand. Soil nutrient and pH levels should be properly maintained so that the plant has adequate nutrient availability and limited capability for luxury consumption. Alfalfa can remove as much as 314 kg $ha^{-1}$ of nitrogen and 336 kg $ha^{-1}$ of $K_2O$ during one growing season when harvested for hay based on a 11,200 kg $ha^{-1}$ annual yield (Ball et al., 2002).

Harvest management is another important management strategy that is essential for a productive stand. It can be broken down into three main objectives: yield, quality, and regrowth. A balance of these objectives is the main goal of harvest management. High yield, quality, and rapid regrowth are the optimum variables that should be achieved in forage production.

**Yield**

Cultivar selection and harvest frequency on forage yield, quality, and persistence has been widely studied. Studies during the 1920's and 1930's have shown significant yield reductions when alfalfa was harvested too frequently during the growing season. Nevertheless, by the early 1960's Kust and Smith (1961) claimed that 'Vernal' alfalfa could be harvested three times per year without compromising yield, quality, and persistence. Hoveland in Georgia (1996) and Sheaffer in Minnesota (2000) concluded that the optimal harvest interval for alfalfa is between 30 to 35 days. However, this harvest interval is also based upon a compromise between yield, quality, regrowth, and persistence. Maximum forage yield on alfalfa is achieved at reproductive maturity when the nutritive value of the forage is at a minimum (Collins and Fritz, 2003).

**Quality**

According to Collins (2003), digestibility and forage quality are both at a maximum during the vegetative stage and continually decrease as stems and flowers develop. Maturity at harvest is considered to be the most important factor affecting forage quality. With the development of near-infrared reflectance spectroscopy (NIRS), forage quality can now be quickly and inexpensively measured. Many high-quality cultivars have been released with the development of this new technology (Hall et al., 2000).

Near-infrared reflectance spectroscopy predicts forage quality components (i.e. acid detergent fiber {ADF}, neutral detergent fiber {NDF}, protein {CP}) through detection of rotational and vibrational amplitudes associated with hydrogen bonding (C-H, O-H, and N-H). These bonds absorb a specific band of near-infrared radiation between 800 and 2,500 nanometers. Materials high in proteins will absorb more radiation in the N-H region, while materials high in moisture will absorb more in the O-H region. The NIR spectrum for a sample will be a combination of the reflectance from all three regions.

This method of analysis is dependent upon the chemical analysis of these forage quality components. The NIRS machine requires calibration by analyzing an *n* amount of samples through wet chemistry in order to provide a reference point. This system then compares the spectrum of the current sample to that of the referenced samples to determine the forage nutritive components. Any samples whose spectrum does not fall within a certain range are classified as outliers and should be analyzed through chemical analysis. This is a very reliable and efficient method at predicting forage quality components for a large amount of samples (Halgerson et al., 2004). Many studies have found the prediction of CP, ADF, NDF, and in vitro digestible dry matter (IVDDM) by NIRS to be very accurate (Shenk et al., 1981; Marten et al., 1983), although it cannot directly predict inorganic components such as minerals (Clark et al., 1987). Shenk et al. (1981) reported $R^2$ values for CP to be as high as 0.99 between the predicted NIRS value and the known value.

**Regrowth**

Alfalfa's ability to re-grow after harvesting allows for multiple harvests per year. However, regrowth is influenced by many factors including temperature, availability of root carbohydrates, and moisture. When alfalfa plants were grown at a common stage (e.g. late vegetative) and exposed to a lower temperature, they developed more slowly and required at least ten more days to accumulate yield than plants exposed to warmer temperatures (Fick et al., 1988). Yet, when minimum night-time temperatures are in excess of 20°C, alfalfa growth may be slowed (Robison and Massengale, 1968).

Regrowth occurs from crown and axillary buds. Growth from these points has shown to be dependent upon the amount of non-structural carbohydrate (NSC) reserves in the root system. When plants are stressed with low levels of NSC reserves, the number and size of crown buds is decreased (Silkett et al., 1937; Sheaffer et al., 1988). If alfalfa plants are cut with high levels of NSC reserves, then buds are more numerous and developed (Bibbey, 1960; Singh et al., 1974; Sheaffer et al., 1988). Plants that are cut with high NSC reserves should have more rapid regrowth than those that are cut with low NSC reserves.

# Chapter III

## Objectives

The primary objective of this research was to determine forage yield, quality, and regrowth rate among recently developed alfalfa cultivars under different harvest frequencies. Cultivars included ‘HybriForce 400’ (hybrid), ‘Attention’ (lodging resistant), ‘WL357HQ’ (high quality), ‘Spredor 4’ (fall dormant), and ‘Pioneer 54V54’ (high yielding control). This study should provide information on how producers can obtain an equitable yield and forage quality with fewer energy inputs.

# Chapter IV

## Materials and Methods

### Treatments

Two locations were established on 11 April 2006. The first location was at the University of Kentucky Agricultural Experiment Station at Spindletop Farm on a Maury silt loam (fine, mixed, semiactive, mesic Typic Paleudalfs). The second site was located on Probst Farms in Scott County, Kentucky on a Lowell silt loam (fine, mixed, active, mesic Typic Hapludalfs). Each location had five replications with four harvest frequencies (25, 30, 35, and 40 days) as main plots and five alfalfa cultivars as subplots. All plots were arranged in a randomized split-plot design.

The cultivars included were:

'Attention' – Cal/West Seeds

This cultivar has high resistance to bacterial wilt and spotted alfalfa aphid. It has resistance to Phytopthora root rot, Fusarium wilt, Verticillium wilt, Anthracnose Race 1, pea aphid, stem nematode, Aphanomyces Race 1, and northern root rot nematode. Its intended region of use is the North Central and East Central region with a fall dormancy of 5 (National Alfalfa Alliance, 2007). This cultivar contains StandFast Technology™ which is marketed to maximize the total yield and quality for the season. Reduced lodging and more rapid regrowth after cutting are the primary ways that this is achieved (Alfalfa Technology, 2003).

‘HybriForce 400’ – Dairyland Seeds

This cultivar has high resistance to bacterial wilt, Fusarium wilt, Phytophthora root rot, spotted alfalfa aphid, and northern root knot nematode. It has resistance to Verticillium wilt, Anthracnose Race 1, pea aphid, and stem nematode. It also has moderate resistance to Aphanomyces Race 1 and blue alfalfa aphid. Its intended region of use is the North Central and East Central region with a fall dormancy of 4 (National Alfalfa Alliance, 2007). This cultivar is marketed as having an 8-15% yield advantage due to heterosis as well has having faster regrowth with more vigorous plants.

‘WL 357HQ’ – WL Alfalfas

This cultivar has been tested in Wisconsin, Michigan, and Kentucky and is adapted to the North Central and East Central regions with a fall dormancy of 5. This cultivar has high resistance to Race 1 anthracnose, bacterial wilt, Fusarium wilt, Verticillium wilt, Phytophthora root rot, pea aphid, and Aphanomyces root rot [Race 1] (North American Alfalfa Improvement Conference, 2003). WL357HQ is promoted as having the ability to retain high-forage quality for an extended period of time to facilitate greater harvest flexibility. It is also marketed as having superior standability and very fast recovery after cutting.

‘Spredor 4’ – NK Brand Alfalfa [Syngenta]

The selection criteria used in the development of this cultivar includes creeping rooted growth habit, grazing tolerance, forage yield, persistence, and resistance to the following pests: bacterial wilt, Verticillium wilt, anthracnose, and Phytophthora root rot. It has been tested in Wisconsin and Minnesota and its intended region of use is the North Central region with a fall dormancy of 2. It contains the highest percentage of

*Medicago sativa* ssp. *falcata* L. germplasm in this study with flower color of 55% purple, 35% variegated, 5% yellow, 3% cream, and 2% white. This cultivar has high resistance to Race 1 anthracnose, bacterial wilt, Fusarium wilt, Verticillium wilt, and Phytophthora root rot. It has resistance to pea aphid and Race 1 Aphanomyces root rot (North American Alfalfa Improvement Conference, 2003). Slower regrowth and indeterminate flowering prolonging vegetative growth generally occurs with cultivars with strong *Medicago sativa* ssp. *falcata* L. parentage.

'54V54' – Pioneer Hi-Bred International

This cultivar has high resistance to bacterial wilt, Verticillium wilt, Fusarium wilt, Anthracnose Race 1, and Phytophthora root rot. It has moderate resistance to Aphanomyces Race 1, low resistance to stem nematode, and resistance to spotted alfalfa aphid. Its intended region of use is the North Central and East Central region with a fall dormancy of 4 (National Alfalfa Alliance, 2007). It has been among the top yielding cultivars in University of Kentucky variety trials (Olson and Smith, 2006).

The individual subplots measured 1.5 m x 6.1 m. The main plot was 7.6 m wide and 6.1 m long. Each main plot had two border strips of 1.5 meters to reduce the edge effect between harvest treatments. The first and last 0.76 m of the subplots was harvested and discarded to reduce the edge effect. Each experimental location was established with conventional tillage methods, and all cultivars were planted with a Sukup seed drill (Sukup Manufacturing Co., Sheffield, IA) equipped with a Hege cone seeder (Wintersteiger AG, Kollmering, Germany) at 22 kg $ha^{-1}$ on 11 April 2006. However, the plots located at the Spindletop Farm were severely damaged by a suspected insect infestation and were replanted

28 days later on 9 May 2006. Measurements taken included: dry matter (DM) yield, forage quality analysis, regrowth rate, maturity at harvest, and lodging.

Insects and weeds were controlled according to University of Kentucky guidelines and recommendations. Broadleaf weeds were controlled with an application of imazethapyr ((±)[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid) at a rate of 71 g $ha^{-1}$ a.i. on the Probst Farms location in 2006 and at 191 g $ha^{-1}$ a.i. at Spindletop. This product has been shown to have an influence on growth patterns of alfalfa and may cause shortened plant height and internode lengths (Zollinger and Meyer, 1996). These effects have also been shown to influence forage quality as well (Hoy et al., 2002)

Other weeds, predominantly yellow nutsedge (*Cyperus esculentus*) and crabgrass (*Digitaria* spp.) were controlled with applications of bentazon (3-(1-methylethyl)-1H-2,1,3-benzothiodiazin-4(3H)-one 2,2-dioxide) at 1121 g $ha^{-1}$ a.i, sethoxydim (2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one) at 420 g $ha^{-1}$ a.i, pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) at 462 g $ha^{-1}$ a.i, paraquat dichloride (1,1-dimethyl-4,4-bipryidinium dichloride) at 140 g $ha^{-1}$ a.i, and a dormant treatment of hexazinone (3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione) at 631 g $ha^{-1}$ a.i.

Alfalfa weevil (*Hypera postica*) was controlled using permethrin (3-phenoxyphenyl)methyl (±) cis-trans 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate) at 224 g $ha^{-1}$ a.i, and potato leafhopper (*Empoasca fabae*) was also controlled with this product. Irrigation was supplied if there were 14 or more days without significant rainfall to also ensure a uniform growth pattern.

All plots were harvested with a Carter flail-type harvester (Carter Mfg. Co. Inc., Brookston, IN) at a 0.91 m width and a stubble height of 5.1 cm. The sample was collected in a cloth bag and weighed by hand. The first harvest at Probst Farms was taken on 6 July 2006, and the first harvest at Spindletop Research Station was taken on 17 July 2006. However, the first harvest at Probst Farms was discarded due to heavy weed pressure. Subsequent harvests were taken at their respective intervals until 15 October 2006.

### Forage Quality

Forage nutritive analysis included crude protein (CP), acid-detergent fiber (ADF), and neutral-detergent fiber (NDF). These were used to calculate total digestible nutrients (TDN) and relative feed value (RFV). Sub-samples of approximately 300 g fresh weight were obtained from each plot to calculate dry matter and for quality analysis.

The sub-samples were collected and secured in an individual paper sack, then dried in a forced-air oven at approximately 77 °C for 48 hours. They were then ground through a 2 mm screen in a Thomas Wiley mill (Thomas Scientific, Swedesboro, NJ), and then reground through a 1 mm screen in a FOSS Cyclotec 1093 Sample Mill (FOSS Inc., Hillerød, Denmark). Each sample was analyzed using NIRS with a FOSS 6500 autosampler (FOSS Inc., Hillerød, Denmark) and ISIscan software (Infrasoft International LLC., State College, PA).

Samples analyzed through NIRS were measured based upon the prediction equation provided by Foss. Shenk et al. (1985) found that calibration equations developed on one monochromator can successfully be transferred to another instrument with standard errors of difference (SED) less than the SED between laboratories for chemical analysis. The H-statistics of each sample were evaluated to determine an acceptable measurement by using the standard linear model notation of $E[Y] = XB$; the least squares fit values are $\hat{Y} = X(X'X)^{-1} X'Y = HY$. Samples that are not similar at the wavelengths used in the model calibration will have high values on the diagonal of the H matrix (Shenk et al., 1981).

The procedure of Shenk et al. (1981) was used, but modified so that spectra of samples with global H values greater than 3.0 were analyzed through chemical analysis. The global H value is a measure of how similar a sample's spectra is to the calibration samples and identifies spectral outliers. The neighborhood H value is a measure of how close a sample's spectra is to its nearest neighbor which aids in identifying redundant samples. Low global and neighborhood H values correspond to low sample error (Infrasoft International LLC., 2002). The fiber analysis was performed with an Ankom F200 Fiber Analyzer (Macedon, NY) using the ADF and NDF extraction methods outlined by Ankom Technology (Ankom, 2007). These same samples were also evaluated for nitrogen concentration using a LECO FP-528 nitrogen analyzer (St. Joseph, MI) with the procedure described by the LECO Corporation (Leco Corporation, 2003). The nitrogen concentrations were then multiplied by 6.25 to determine the crude protein percentage. These values were then used to further calibrate the data set. Relative feed value was calculated for all samples using the equation:

$$RFV = \{(120 / NDF) \times [88.90 - (0.779 \times ADF)]\} / 1.29$$

Where (120 / NDF) is the dry matter intake (DMI), and [88.90 – (0.779 x ADF)] is the digestible dry matter (DDM) (Undersander et al., 1993)).

The equation used to calculate total digestible nutrients was:

$$TDN = 4.898 + \{89.796 \times [1.044 - (0.0119 \times ADF)]\}$$

[1.044 – (0.0119 x ADF)] is the net energy of lactation ($NE_L$) (Undersander et al., 1993).

### Regrowth Rate

Regrowth rate was determined, in centimeters, by a weekly measurement of plant height in individual plots. The plant was measured from the soil surface to the height of the tallest stem when held upright. Five measurements per plot were averaged to determine a mean plant height for that week. The difference between that height and the previous measurement was divided by the number of days since the prior measurement to determine the rate of growth per day. This method of measurement did not take into consideration any growth from axillary buds or available biomass. Due to the range in environmental conditions between years, cultivars, and locations; growth rates were not measured before the first harvest.

### Maturity

A maturity rating was taken at each harvest date for each plot using a rating system (Table 4.1) developed by Kalu and Fick (1983). Maturity ratings were used to determine the effect of regrowth rate, harvest frequency, and cultivar on maturity. Jung et al. (1996), noted that many quality and cultivar differences can be related to many environmental factors. Ten percent bloom at which many alfalfa producers typically harvest has an approximate maturity rating between 4.5-5.0.

**Table 4.1. Definition of morphological stages of development for individual alfalfa stems.†**

| Stage # | Stage Name | Definition |
|---|---|---|
| 0 | Early Vegetative | Stem length <15cm; no buds, flowers, or seed pods |
| 1 | Mid-Vegetative | Stem length 16-30 cm; no buds, flowers, or seed pods |
| 2 | Late Vegetative | Stem length >31cm; no buds, flowers, or seed pods |
| 3 | Early Bud | 1-2 nodes with buds; no flowers or seed pods |
| 4 | Late Bud | >3 nodes with buds; no flowers or seed pods |
| 5 | Early Flower | One node with one open flower; no seed pods |
| 6 | Late Flower | >2 nodes with open flowers; no seed pods |
| 7 | Early Seed Pod | 1-3 nodes with green seed pods |
| 8 | Late Seed Pod | >4 nodes with green seed pods |
| 9 | Ripe Seed Pod | Nodes with mostly brown, mature seed pods |
| † - Adopted from Kalu and Fick, Crop Sci: 23:1167-1172 (1983). | | |

**Lodging**

Visual lodging scores were recorded for each plot at harvest (Table 4.2). Mature, lodged alfalfa stands may support inoculum for fungal and bacterial disease (Sheaffer et al., 1997), as well as impose harvest difficulties. The inclusion of Attention with StandFast™ technology required a valid measure of standability. Cal-West Seeds promotes StandFast™ technology to increase the standability of the crop through mid-bloom and reduce field and harvest losses (Alfalfa Technology, 2003). By having a lodging index (Table 4.2), this technology and any benefits associated with it were evaluated.

**Table 4.2. Definition of lodging index for alfalfa sward.**

| Stage # | Stage Name | Definition |
|---|---|---|
| 0 | Erect | No lodged plants. |
| 1 | Individual Lodging | Individual plants lodged; < 20% of sward. |
| 2 | Slight Lodging | Some lodged plants; 20-40% of sward. |
| 3 | Moderate Lodging | Many lodged plants; 40-60% of sward. |
| 4 | Severe Lodging | Many lodged plants; 60-80% of sward. |
| 5 | Extreme Lodging | All lodged plants; 80-100% of sward. |

**Stand Density**

Stand density was determined by counting the number of plants per foot of row in three random locations within each plot. Stand density was measured on 2 May 2006 and 9 June 2006; after emergence but before the first harvest, and on 11 December 2006. In the second year of production, stand density was measured on 22 April 2007, and 8 May 2007; after the plants broke dormancy, but before the first harvest. Densities at the Spindletop location were measured again on 7 November 2007. A visual score of percent stand was also measured on each date.

In 2007, abnormally warm temperatures in March (Table 5.1) encouraged most alfalfa to break dormancy, but these conditions were followed by below freezing temperatures 5 to 10 April 2007, which damaged or destroyed many alfalfa plants. The Probst Farms location suffered extreme stand loss and was discarded in 2007 with 76% of the plots having a 50%, or greater, stand loss. Sixty-seven percent of the plots had stand losses greater than 75%, and 7% of the plots had no plants. On 2 May 2006, the average plant population for Probst Farms was 207 plants $m^{-1}$, which thinned to an average 30 plants $m^{-1}$ on 8 May 2007. The Spindletop location had 205 plants $m^{-1}$ on 9 June 2006, and 62 plants $m^{-1}$ in 7 November 2007, which was still adequate for satisfactory yields (Jackobs and Miller, 1973; Mays and Evans, 1973; Tesar and Yeager, 1985, Ball et al., 2002).

**Statistical Analysis**

Since this study had two locations for the 2006 growing season, and one location for the 2007 growing season, all data was analyzed using the PROC MIXED procedure of SAS. Main and simple effects and any interactions were considered significant at $P < 0.05$. When the effect or interaction was significant, means were separated by LSMEANS ($\alpha = 0.05$).

The complexity of analysis of this study with different locations across years, forbid the analysis from being analyzed as a whole with PROC GLM.  High error and false differences would occur with this analysis, therefore the analysis was evaluated across locations within 2006, across years within Spindletop, and within 2006 within Probst Farms.  True differences and lower error occurred when this analysis was performed in this manner.

# Chapter V

## Results and Discussion

An abnormally dry growing season during the 2007 growing season (Table 5.1) required the use of irrigation in order to prevent plants from entering a drought induced dormancy (Metochis and Orphanos, 1981). The plots were irrigated through an overhead sprinkler system at a rate of 1.27 cm $hour^{-1}$. The plots at Spindletop received 6.35 cm on 8 August 2006, 3.81 cm on 29 May 2007 and 31 May 2007, and 1.91 cm on 5 September 2007 and 13 September 2007. Probst Farms received no irrigation.

**Table 5.1. Mean temperature and rainfall‡ amounts for Spindletop Research Station in Lexington, KY.**

| | 2006 | | | | 2007 | | | |
|---|---|---|---|---|---|---|---|---|
| | Temperature | | Rainfall | | Temperature | | Rainfall | |
| | °C | DEV† | cm | DEV | °C | DEV | cm | DEV |
| JAN | 5.6 | 6.2 | 12.12 | 4.85 | 2.8 | 3.4 | 7.44 | 0.18 |
| FEB | 2.2 | 0.6 | 5.41 | -2.74 | -2.8 | -4.5 | 4.65 | -3.51 |
| MAR | 6.7 | 0.0 | 7.75 | -3.43 | 11.2 | 4.5 | 5.00 | -6.17 |
| APR | 15.1 | 2.2 | 8.94 | -0.91 | 11.8 | -1.1 | 9.83 | -0.03 |
| MAY | 16.8 | -1.1 | 7.59 | -3.76 | 20.2 | 2.2 | 3.68 | -7.67 |
| JUN | 21.3 | -1.1 | 4.62 | -4.67 | 23.5 | 1.1 | 4.50 | -4.80 |
| JUL | 24.6 | 0.0 | 13.03 | 0.33 | 23.5 | -1.1 | 17.53 | 4.83 |
| AUG | 24.6 | 0.6 | 8.20 | -1.78 | 26.9 | 2.8 | 6.50 | -3.48 |
| SEP | 17.9 | -2.2 | 23.55 | 15.42 | 22.4 | 2.2 | 2.92 | -5.21 |
| OCT | 12.3 | -1.7 | 12.40 | 5.87 | 17.4 | 3.4 | 13.41 | 6.88 |
| NOV | 8.4 | 1.1 | 4.52 | -4.09 | 7.8 | 0.6 | 7.26 | -1.35 |
| DEC | 5.6 | 3.4 | 6.22 | -3.89 | | | | |

†DEV is deviation from the long-term mean.
‡ - Irrigation amounts not reflected in rainfall accumulation.

**Yield**

There was a year X harvest frequency and year X cultivar interaction at the Spindletop location, as well as a location X harvest frequency interaction for 2006. Interactions did not exist between cultivar and harvest frequency, or for the three-way interaction of cultivar X harvest frequency X year. Therefore, yield data is presented by year, cultivar, location, and harvest frequency.

**Cultivar Response**

There was no cultivar effect during the establishment year of 2006, but there was in 2007 at the Spindletop location. The cultivars Spredor 4 and WL357HQ out-yielded the other cultivars by 13% in 2007 and 9% across both years (Table 5.2). There was no cultivar effect in 2006 for the Probst Farms location.

**Table 5.2. Mean alfalfa cultivar annual dry matter yield at Spindletop Research Station.**

| Cultivar | 2006 | 2007 |
|---|---|---|
| | --------MT $ha^{-1}$-------- | |
| WL357HQ | 4.17a† | 8.49a |
| HybriForce 400 | 4.23a | 7.49b |
| Attention | 4.22a | 7.31b |
| Pioneer 54V54 | 4.19a | 7.30b |
| Spredor 4 | 4.33a | 8.54a |

† - Values within a column followed by the same letter are not different at P>0.05.

The difference in annual yield could be attributed to winter injury; however, results indicated no difference in winter injury between Spredor 4, WL357HQ, and Pioneer 54V54, and no differences were observed between WL357HQ, Pioneer 54V54, and HybriForce 400 (Table 5.3). Therefore, the results do not support a general relationship between winter injury and yield, but, Attention did show higher winter injury than all other cultivars, with the exception of HybriForce 400, and this was the most probable reason for its lower yields.

**Table 5.3. 2007 winter injury on alfalfa cultivars at Spindletop Research Station and Probst Farms.**

| Cultivar | Winter Injury† |
|---|---|
| Spredor 4 | 2.6c‡ |
| WL357HQ | 2.9bc |
| HybriForce 400 | 3.0ab |
| Attention | 3.5a |
| Pioneer 54V54 | 2.9bc |

† - Rating based on 0-5 scale: 0~no winter injury; 5~extreme injury/death.
‡ - Values within a column followed by the same letter are not different at

Responses to harvest frequency were similar among cultivars. Spredor 4 and WL357HQ yielded 0.14 MT $ha^{-1}$ and 0.15 MT $ha^{-1}$ (respectively) more than HybriForce 400. Spredor 4 also produced higher yields than Attention and Pioneer 54V54 by 0.16 MT $ha^{-1}$, and WL357HQ yields were higher by 0.17 MT $ha^{-1}$(Table 5.4).

Spredor 4 and WL357HQ have demonstrated versatility in their harvest management. Although there were no differences among cultivars within a harvest frequency, a significant cultivar difference occurred across harvest frequencies. These two cultivars may have a greater ability to adapt to changes in harvest frequency than HybriForce 400, Attention, and Pioneer 54V54.

The only differences in stand density were found between cultivars at Spindletop in 2007, and between 2006 and 2007. This did not have a direct relationship with winter injury and forage yield, however, Attention did suffer significant stand loss compared to Spredor 4 and HybriForce 400 (data not shown) in spring 2007. No other differences in stand density were found.

**Table 5.4. Mean alfalfa cultivar yield per harvest at Spindletop Research Station for 2006 and 2007.**

| Cultivar | Mean Yield |
|---|---|
| | ----MT $ha^{-1}$---- |
| Spredor 4 | 1.69a† |
| WL357HQ | 1.70a |
| HybriForce 400 | 1.55b |
| Attention | 1.53b |
| Pioneer 54V54 | 1.53b |

† - Values within a column followed by the same letter are not different at P>0.05.

### Management Response

In 2006, there was a location X harvest frequency interaction. The 35-d and 40-d harvest frequencies at the Spindletop location averaged 1.44 MT $ha^{-1}$ more than the 25-d and 30-d frequencies at the same location. The 25-d and 35-d harvest frequencies at the Probst Farms location produced lower yields in 2006 at 2.85 MT $ha^{-1}$ than the 30-d and 40-d harvest frequencies. The higher yields produced at the 30-d harvest frequency at Probst Farms were likely influenced by the number of harvests per year, allowing this harvest frequency to be harvested once more than the 35-d frequency (Table 5.5).

**Table 5.5. Mean alfalfa cultivar annual dry matter yield and number of harvests for 2006.**

| | -----------MT $ha^{-1}$----------- | | -----Number of Harvests----- | |
|---|---|---|---|---|
| **Frequency** | **Spindletop** | **Probst Farms‡** | **Spindletop** | **Probst Farms‡** |
| 25 Day | 3.66b† | 2.85b | 4 | 3 |
| 30 Day | 3.66b | 3.64a | 3 | 3 |
| 35 Day | 4.74a | 2.85b | 3 | 2 |
| 40 Day | 4.86a | 3.49a | 3 | 2 |

†- Values within a column followed by the same letter are not different at P>0.05.
‡ - Initial harvest was discarded due to heavy weed pressure.

Forage yields over 2006 and 2007 were affected by a year X harvest frequency interaction between the 30, 35, and 40-d harvest frequencies for 2007. One noteworthy difference was the yield difference between the 25-d and 30-d harvest frequency for 2007. Both frequencies were harvested 5 times, however, the 30-d frequency yielded 2.43 MT $ha^{-1}$ more than the 25-d frequency (Table 5.6).

There was no yield benefit for harvesting 4 times versus 3 times at the Spindletop location in 2006. Both the 25-d and 30-d harvest frequencies provided the 3.66 MT $ha^{-1}$ with the 25-d frequency harvested 4 times, and the 30-d frequency 3 times (Table 5.6).

**Table 5.6. Mean alfalfa cultivar annual dry matter yield and number of harvests at Spindletop Research Station for 2006.**

| | ------MT $ha^{-1}$------ | | ---Number of Harvests--- | |
|---|---|---|---|---|
| **Frequency** | **2006** | **2007** | **2006** | **2007** |
| 25 Day | 3.66b† | 6.10b | 4 | 5 |
| 30 Day | 3.66b | 8.53a | 3 | 5 |
| 35 Day | 4.74a | 8.02a | 3 | 4 |
| 40 Day | 4.86a | 8.73a | 3 | 4 |

†- Values within a column followed by the same letter are not different at P>0.05.

**Forage Quality**

**Cultivar Response**

The only difference in forage nutritive value between the five cultivars for 2006 and 2007 were ADF levels. Spredor 4 had an average 0.77% less ADF than the other cultivars. No differences were found between cultivars for NDF, CP, RFV, and TDN.

The breeding lines used to develop Spredor 4 include *Medicago sativa* ssp. *falcata* L. germplasm. This winter hardy type of alfalfa is associated with increased fall dormancy, slower spring greenup, lower yields, and slower regrowth than cultivars with predominantly

*Medicago sativa* ssp. *sativa* L. parentage. Therefore, Spredor 4 should have produced lower yields and slower regrowth than the other cultivars. The surprising performance of this cultivar in this region creates a need for more research on the effects of multiple harvests on this type of cultivar in Kentucky. Other work has shown that pure *Medicago sativa* ssp. *falcata* L. provides sufficient quality even under a two-cut system in Michigan (Dietz and Leep, 2008).

### Management Response

Neutral detergent fiber and RFV were both affected by year X harvest frequency interactions in 2006 and 2007. However, within each year differences did not exist between harvest frequencies for these quality parameters (Table 5.7). These results were in contrast to previous studies that reported a decrease in ADF and NDF values with increasing harvest frequency (Brink and Marten, 1989; Sheaffer and Marten, 1990; Moyer et al., 1999; Sheaffer et al., 2000; Kallenbach et al., 2002), and an increase in crude protein (Jung et al., 1996).

This relationship with forage quality may be influenced by the effect of low water availability on the leaf:stem weight ratio (LSWR). Alfalfa subjected to drought has a higher LSWR, thereby resulting in higher overall forage quality (Vough and Marten, 1971; Carter and Sheaffer, 1983; Halim et al., 1989; Peterson et al., 1992). The association of water availability and LSWR was the most probable explanation for higher quality values in 2007, but lower LSWR in 2006 could have been attributed to slow growth during establishment.

**Table 5.7. Neutral detergent fiber and relative feed value across harvest frequencies for Spindletop Research Station in 2006 and 2007.**

| Frequency | NDF | | RFV | |
|---|---|---|---|---|
| | 2006 | 2007 | 2006 | 2007 |
| | ---------------% | --------------- | | |
| 25 Day | 39.8a† | 40.5a | 158.6a | 163.1a |
| 30 Day | 40.3a | 36.9a | 156.7a | 173.6a |
| 35 Day | 40.5a | 38.2a | 155.3a | 168.3a |
| 40 Day | 38.3a | 36.7a | 165.6a | 172.6a |

†- Values within a column followed by the same letter are not different at P>0.05.

In 2006, all quality parameters had a location X harvest frequency interaction, therefore the results were analyzed within a location. Some significant differences were found between locations, but were very erratic and did not follow the typical relationship between forage quality and harvest frequency. For example, there was were no differences in ADF between the 25, 30, and 40-d harvest frequencies at Spindletop and the 35-d and 40-d frequencies at Probst Farms (Table 5.8).

**Table 5.8. Forage quality analysis for Spindletop Research Station and Probst Farms in 2006.**

| | Spindletop† | | | | |
|---|---|---|---|---|---|
| | ----------%---------- | | | | |
| Frequency | ADF | NDF | CP | RFV | TDN |
| 25 Day | 27.9 | 39.8 | 19.5 | 158.6 | 68.8 |
| 30 Day | 27.5 | 40.3 | 18.1 | 156.7 | 70.4 |
| 35 Day | 28.5 | 40.5 | 19.5 | 155.3 | 68.2 |
| 40 Day | 27.5 | 38.3 | 19.2 | 165.6 | 69.3 |
| | **Probst Farms** | | | | |
| 25 Day | 25.5a‡ | 37.6a | 23.0a | 173.2a | 71.4a |
| 30 Day | 26.6b | 38.0a | 23.7a | 167.4a | 70.2b |
| 35 Day | 27.5bc | 38.0a | 21.5b | 165.8a | 69.2bc |
| 40 Day | 28.2c | 39.3a | 21.6b | 159.1a | 68.5c |

† - No significant difference at P<.05 level within each quality measurement.
‡- Values within a column followed by the same letter are not different at P>0.05.

When the 2006 results from Probst Farms were analyzed alone there was a more typical distribution of forage quality in relation to harvest frequency with the shorter harvest frequencies producing higher quality forage than the longer harvest frequencies. In Table 5.8, no differences were found in NDF and RFV levels, but there was a harvest frequency effect for ADF, CP, and TDN.

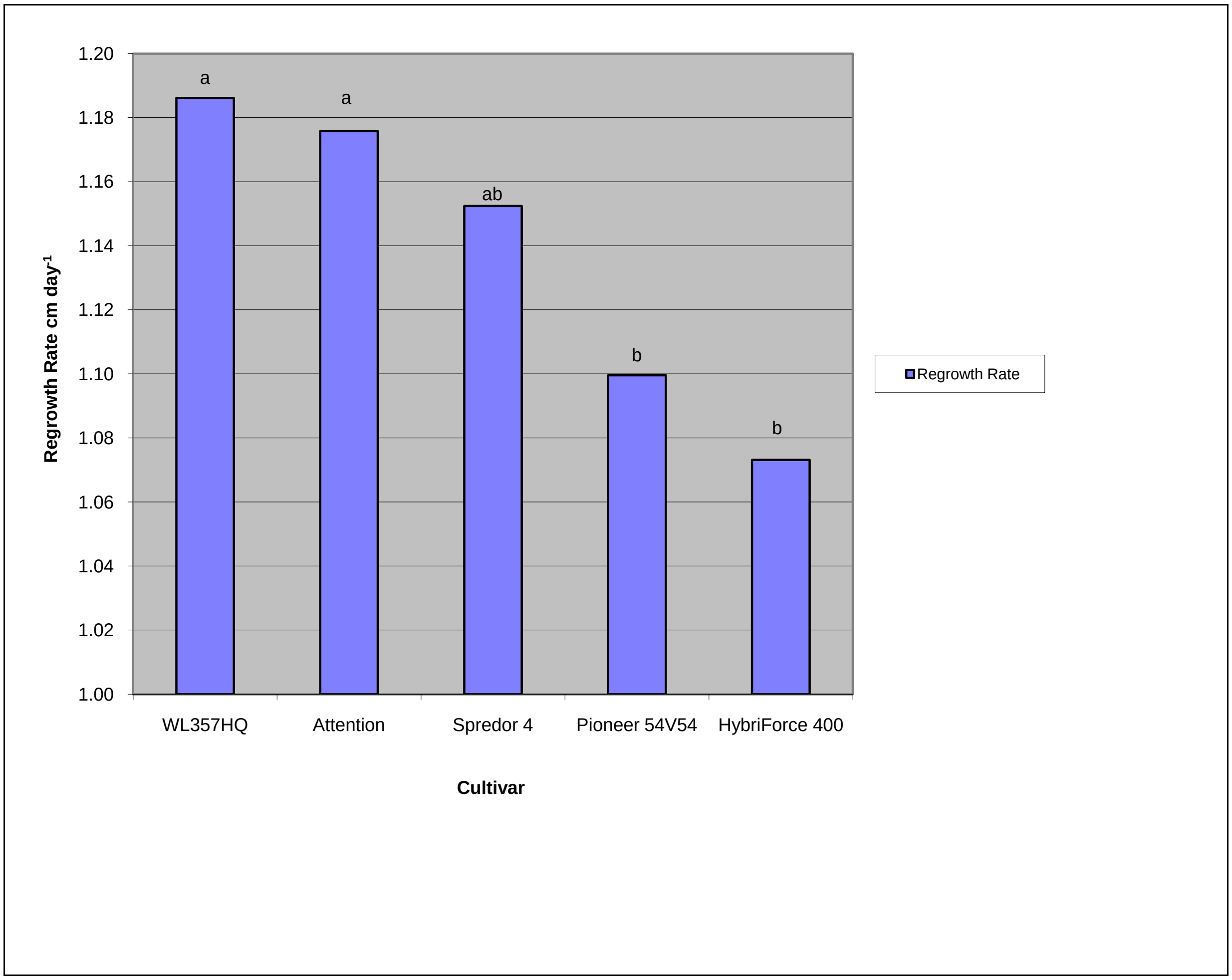
**Regrowth Rate**

Cultivar and harvest frequency effects on regrowth were significant across both locations for both years. Although there were no interactions on regrowth rate when analyzed across locations and years, there was a location X harvest frequency interaction in 2006.

### Cultivar Response

Two cultivars showed more rapid regrowth across harvest frequencies. WL357HQ grew 0.09 cm $day^{-1}$ more rapidly than Pioneer 54V54 and 0.12 cm $day^{-1}$ than HybriForce 400, while Attention grew 0.08 cm $day^{-1}$ more than 54V54 and 0.11 cm $day^{-1}$ more than HybriForce 400 (Figure 5.1). No statistical difference occurred between Spredor 4, Attention, and WL357HQ, or between Spredor 4, Pioneer 54V54, and HybriForce 400 at the $P < 0.05$ level. However, Spredor 4 grew more rapid than HybriForce 400 at the $P < 0.10$ level.

**Figure 5.1. Mean rates of relative regrowth (cm $day^{-1}$) among alfalfa cultivars at Spindletop Research Station for 2006 and 2007†.**

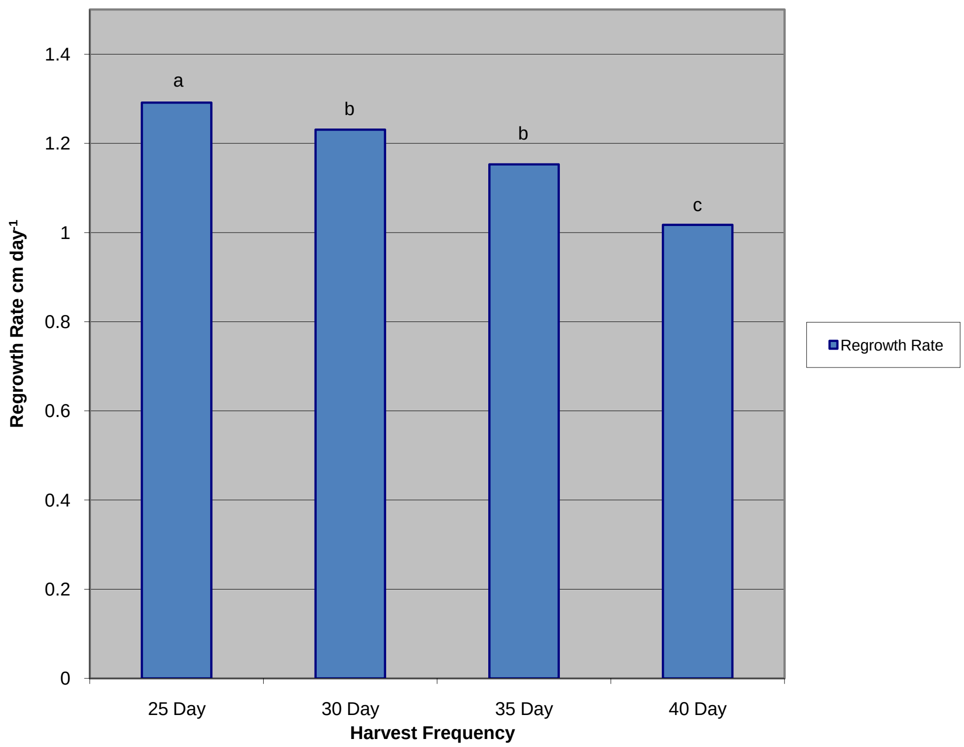



**† - Variables with the same letter are not significantly different at $P < 0.05$ level.**

## Management Response

As harvest frequency increased all cultivars exhibited a response to the more aggressive management. There were no interactions on regrowth rate; therefore, all values were averaged across cultivars. The 25-d harvest interval had the most rapid regrowth rate at 1.29 cm $day^{-1}$ as compared to the 40-d frequency at 1.02 cm $day^{-1}$ (Figure 5.2). This information may be important in determining timing intervals for other management practices between harvests (i.e. herbicide application). For example, cutting regimes that follow a 25-d schedule have a narrower application window than other harvest frequencies.

**Figure 5.2. Mean rates of relative regrowth (cm $day^{-1}$) among alfalfa harvest frequencies at Spindletop Research Station for 2006 and 2007†.**




**† - Variables with the same letter are not significantly different at P < 0.05 level.**

There was a location X harvest frequency interaction on regrowth rate in 2006. Probst Farms showed a difference of 0.39 cm $day^{-1}$ between the 30-d and 40-d harvest frequencies, while Spindletop had only a 0.13 cm $day^{-1}$ difference (Table 5.9). The growth rate of the 40-d harvest frequency may have been influenced by the method of measuring. Plant heights were measured by the height of the tallest stem, but axillary stem growth was not measured. The 40-d harvest frequency may have had more axillary growth than the other harvest frequencies that was not measured. Many other factors may influence regrowth rate; however, it was uncertain why there was a greater response at Probst Farms.

**Table 5.9. Relative regrowth rates (cm day$^{-1}$) across alfalfa harvest frequencies at both Spindletop Research Staion and Probst Farms in 2006.**

| Frequency | Spindletop | Probst Farms |
|---|---|---|
| 25 Day | 0.94a† | 1.19a |
| 30 Day | 0.89ab | 1.22a |
| 35 Day | 0.85b | 0.91b |
| 40 Day | 0.76c | 0.83b |

† - Values within a column followed by the same letter are not different at P>0.05.

### Maturity

#### Cultivar Response

There were no differences in the maturity rating between cultivars for 2006 or 2007 at either location. This was surprising because Spredor 4 should have exhibited slower regrowth and a more gradual rate of maturation (Julier et al., 1995; Leep et al., 2001; Riday et al., 2002). However, this cultivar responded similarly to the other cultivars that had fall dormancy ratings of 4 or 5.

#### Management Response

The expected increase in relative maturity with decreasing harvest frequency did occur during 2007 at Spindletop. A year X harvest frequency interaction occurred at the Spindletop location, as well as a location X harvest frequency interaction for 2006, therefore data is presented by year and location.

During the 2006 growing season the 35-d harvest frequency showed a higher maturity rate than the 40-d frequency (Table 5.10). This could be attributed to the relationship between regrowth rate and relative maturity.

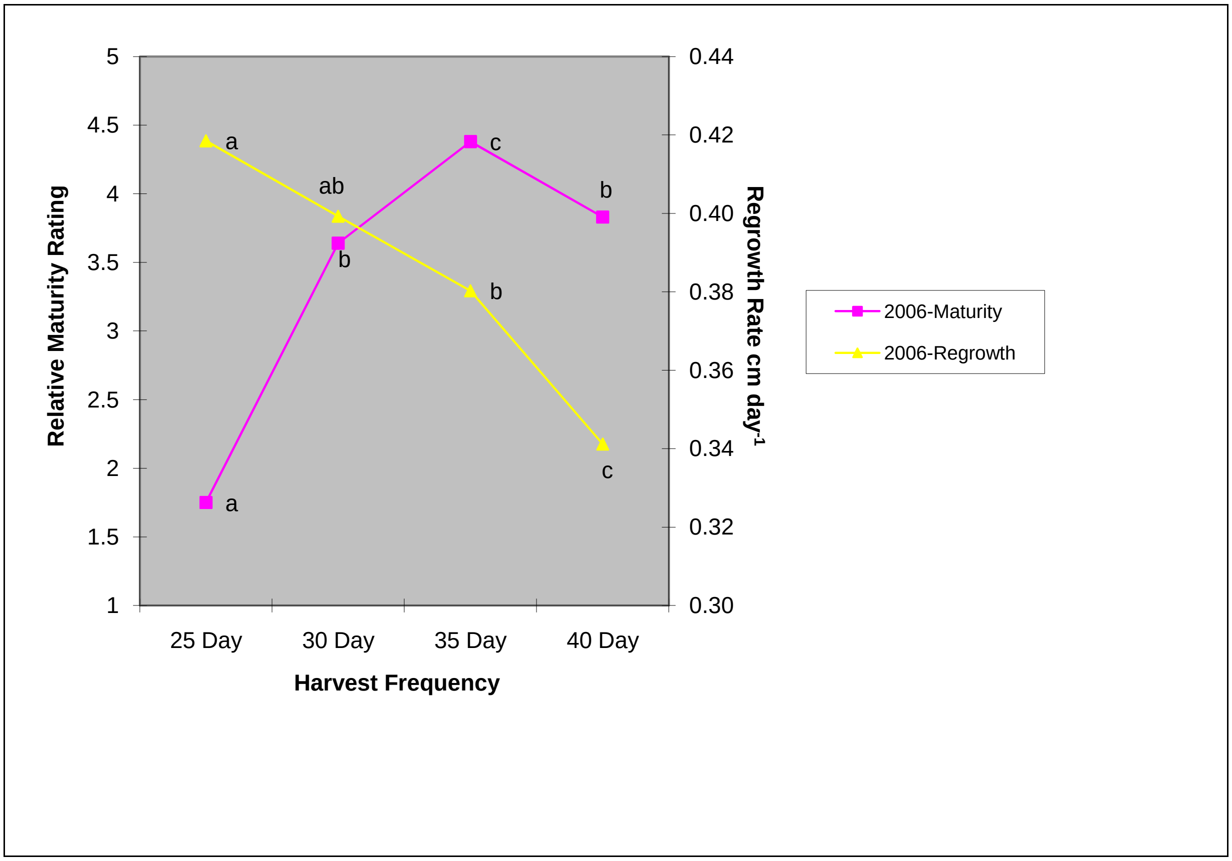
**Table 5.10. Relative maturity rating for alfalfa harvest frequencies at Spindletop Research Station in 2006 and 2007.**

| Frequency | 2006 | 2007 |
|---|---|---|
| 25 Day | 1.8a† | 3.1a |
| 30 Day | 3.6b | 4.2b |
| 35 Day | 4.4c | 4.9c |
| 40 Day | 3.8b | 5.2c |

† - Values within a column followed by the same letter are not different at P>0.05.

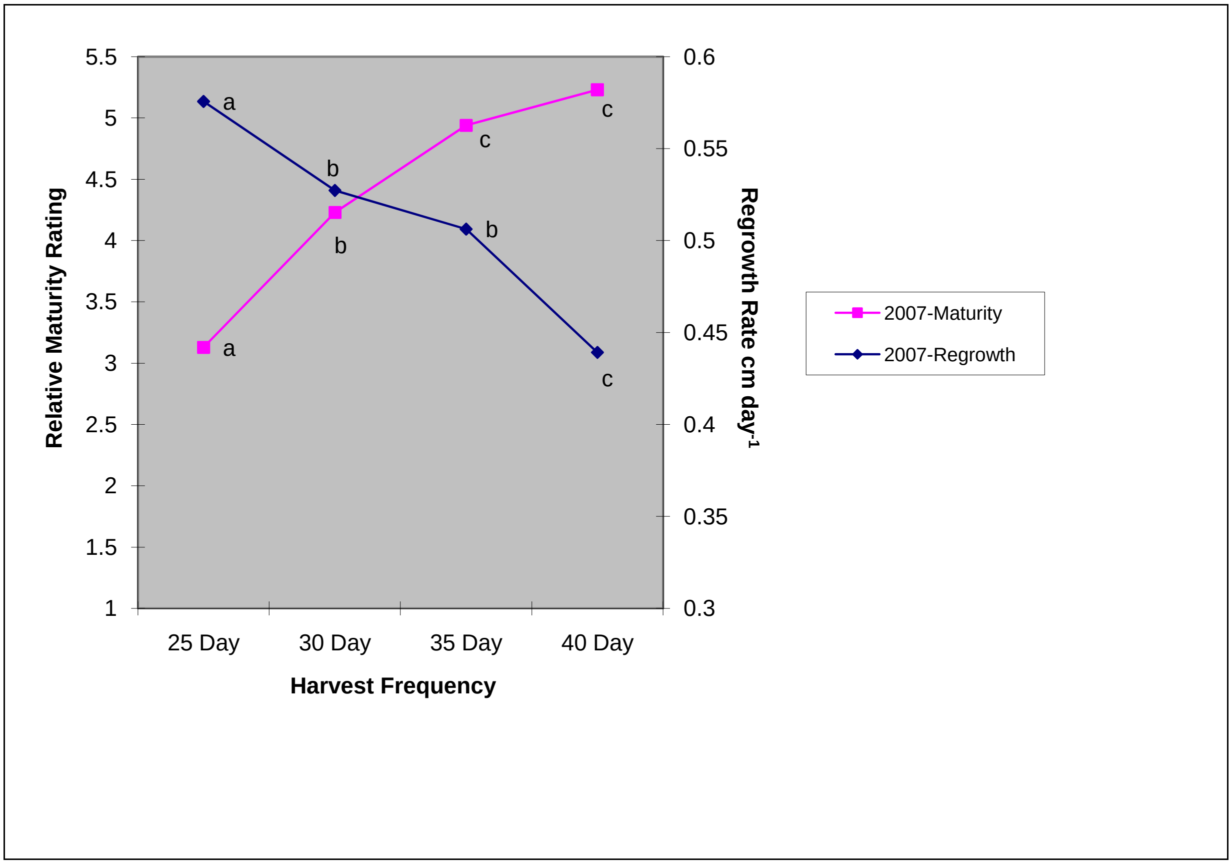
The more rapid regrowth rate at the 35-d harvest frequency provides the most plausible explanation as to why it was more mature than the 40-d frequency in 2006. In both 2006 and 2007, the 35-d harvest frequency was growing 0.04 and 0.07 cm $day^{-1}$ faster than the 40-d harvest frequency, respectively (Figures 5.3a, 5.3b). The slower growth rate that the 40-d harvest frequency exhibited could be a primary reason that it is not as mature as the 35-d frequency in 2006. This could be due to many physiological factors such as more axillary stem growth. More energy may have been used in developing these growing points, rather than growth of the primary stem.

**Figure 5.3a. Relationship between relative maturity and relative regrowth rate of alfalfa harvest frequencies for Spindletop Research Station in 2006†.**




**† - Variables with the same letter are not significantly different at P < 0.05 level.**

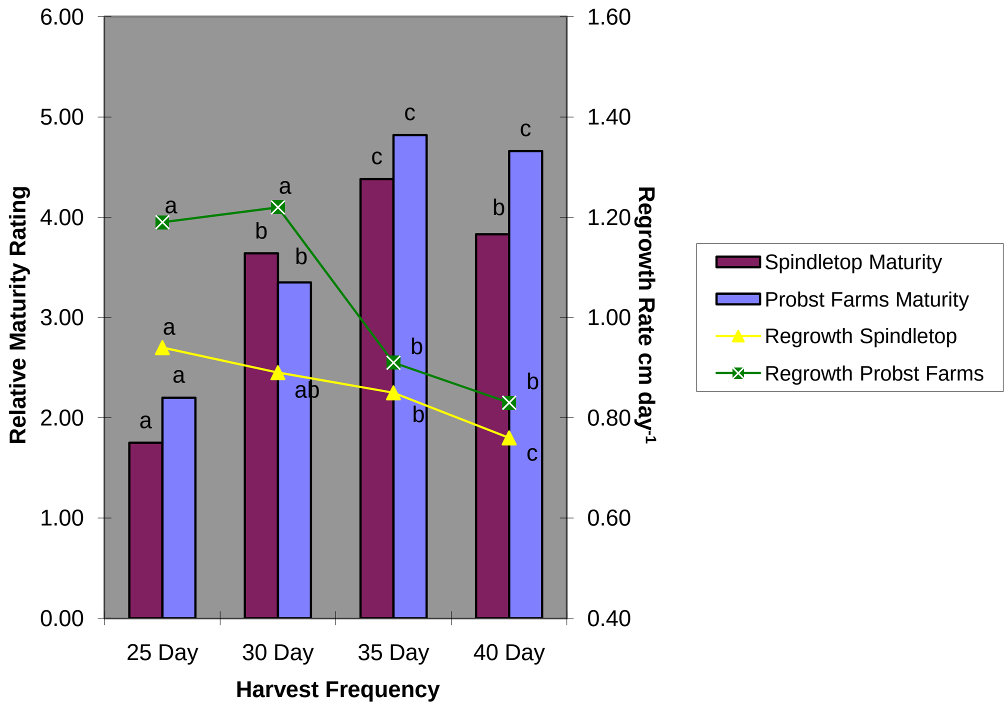
**Figure 5.3b. Relationship between relative maturity and relative regrowth rate of alfalfa harvest frequencies for Spindletop Research Station in 2007†.**




**† - Variables with the same letter are not significantly different at P < 0.05 level.**

In 2006, there was a location X harvest frequency interaction for maturity between the Spindletop and Probst Farms locations, therefore data is presented by location. A similar trend was found between the two locations, but at Probst Farms the 40-d harvest frequency did show a lower maturity rate than the 35-d frequency (Figure 5.4). However, differences were found between the 25, 30, and 35-d harvest frequencies for both locations in 2006. The more rapid regrowth rates reported from the 25-d harvest frequency did not allow the plants to mature more rapidly as was observed between the 35-d and 40-d frequencies.

**Figure 5.4. Relative regrowth rate and relative maturity rating for alfalfa harvest frequencies in 2006 at both locations†.**




**† - Variables with the same letter are not significantly different at P < 0.05 level.**

## Lodging

### Cultivar Response

A lodging resistant cultivar was included in this study because longer harvest frequencies often lead to harvest difficulties with severely lodged stands. There was no lodging effect among cultivars, however, there were year X harvest frequency and location X harvest frequency interactions, therefore data is presented by year and location.

### Management Response

At the Spindletop location in 2006, no differences occurred in lodging across harvest frequencies at the $P < 0.05$ level. The only difference in 2007 was a slightly higher incidence of lodging in the 40-d harvest frequency (Table 5.11).

**Table 5.11. Alfalfa lodging values at Spindletop Research Station in 2006 and 2007†.**

| Frequency | 2006 | 2007 |
|---|---|---|
| 25 Day | 0.04a‡ | 0.00a |
| 30 Day | 0.00a | 0.00a |
| 35 Day | 0.00a | 0.00a |
| 40 Day | 0.14a | 0.34b |

† - Rating based on 0-5 scale: 0~no lodging; 5~all plants lodged.
‡ - Values within a column followed by the same letter are not different at P>0.05.

In 2006, Probst Farms showed a similar lodging trend as the Spindletop location in 2007. No differences were found between the 25, 30, and 35-d harvest frequencies or between cultivars. Nonetheless, the 40-d frequency did have a higher incidence of lodged plants (Table 5.12).

**Table 5.12. Alfalfa lodging values in 2006 at Spindletop Research Station and Probst Farms†.**

| Frequency | Spindletop | Probst Farms |
|---|---|---|
| 25 Day | 0.04a | 0.00a |
| 30 Day | 0.00a | 0.00a |
| 35 Day | 0.00a | 0.08a |
| 40 Day | 0.14a | 0.72b |

† - Values within a column followed by the same letter are not different at P>0.05.

# Chapter VI

## Conclusions

The results of this research indicated that modern cultivars of alfalfa should be harvested every 35-d, even if marketed as having very rapid rates of regrowth. Based upon the data collected over the two years of this study, similar yields were found between the 30, 35, and 40-d harvest frequencies; even though the 35-d and 40-d harvest frequencies resulted in one less harvest per year than the 30-d frequency.

Forage nutritive values did not vary between harvest frequencies at the Spindletop location over both years, but some differences were found in ADF, CP, and TDN for Probst Farms in 2006. Therefore, harvesting at a more immature stage showed little influence in forage quality during these two years. In contrast to the large body of literature for alfalfa, these results suggest that harvest frequency does not influence forage quality, but more years and studies are needed to validate this. Drought conditions and slow growth during establishment may also have played a role in this trend.

Based upon the regrowth rates measured during this study, there was no difference in the 30-d and 35-d harvest frequencies, and the 40-d harvest frequency showed the slowest regrowth rate per day. In theory, rapid regrowth should be beneficial in quickly capturing more solar energy to conduct photosynthesis and compete with other plants in the sward; however, other stand management applications may be compromised. The intermediate rate of regrowth exhibited by the 35-d harvest frequency appeared to be optimum for the conditions during this study.

The lack of differences in forage quality over harvest frequencies at the Spindletop location, and the little differences at Probst Farms seems to indicate that maturity has little effect on forage quality of alfalfa. This trend implies that contemporary cultivars are not declining in forage quality as rapidly as previously thought. Digestibility was still decreasing, but at a slower rate during this time period of 25 through 40 days after harvest. The interaction between forage quality and yield has been widely studied and verified. As forage yield increases as plants mature, digestibility does decrease. The rate of this decrease has been shown to be influenced by many environmental and physiological factors. This rate of decline in forage quality may be decreased by adjusting these environmental and physiological factors.

Although the incidence of lodging was still very low, the 40-d harvest frequency was not optimum due to the elevated levels of lodging found in this management system. Lodging has been shown to provide difficulties in mechanical harvesting and an increase in disease pressure.

This study was designed to determine the validity of marketing claims for recently released cultivars with rapid rates of regrowth, and their effect on forage quality, yield, and stand persistence. The concept was with rising energy costs; producers may not be getting any additional agronomic benefit in harvesting these cultivars more frequently. Overall, the cultivars included here were much better suited to being harvested every 35-d, although WL357HQ and Spredor 4 have demonstrated the most flexibility in their management.

The strong agronomic performance of Spredor 4, even as a cultivar with a fall dormancy of 2, indicates an increased need to determine the long-term effects of producing cultivars of this dormancy rating in this climate. Increased stand persistence with maximum yields and forage quality may be an added benefit for these types of cultivars.

Data in this study is being applied through the visual alfalfa growth model originally developed by Av Singh (2000). The number of nodes, internode length, and stem diameter measurements were measured to validate the original measurements taken by Singh. Other parameters were also included in the model such as regrowth rate and stand density of the different harvest frequencies.  This application is currently being used for demonstration of these results through extension programming at the University of Kentucky (S.R. Smith, personal communication, 2008).

# Appendices

## Appendix A

**Table A.1. Node number, internode length, and stem diameter measurements taken for validation of visual alfalfa growth model developed by Av Singh.**

| | | 8/17/2006 | | | 9/15/2006 | | |
|---|---|---|---|---|---|---|---|
| Plot | Cultivar | Nodes† | IL‡ | SD§ | Nodes | IL | SD |
| **101** | Spredor 4 | 11.33 | 40.67 | 0.19 | 8.67 | 41.67 | 0.19 |
| **102** | 54V54 | 10.33 | 36.44 | 0.15 | 7.67 | 39.33 | 0.17 |
| **103** | Attention | 13.00 | 38.00 | 0.23 | 8.33 | 37.67 | 0.19 |
| **104** | WL357HQ | 13.00 | 34.44 | 0.19 | 8.00 | 49.33 | 0.20 |
| **105** | HybriForce 400 | 13.33 | 40.44 | 0.15 | 9.33 | 42.33 | 0.17 |
| **206** | 54V54 | 13.00 | 18.33 | 0.14 | 8.33 | 49.33 | 0.16 |
| **207** | HybriForce 400 | 12.00 | 23.00 | 0.16 | 8.33 | 38.00 | 0.15 |
| **208** | Spredor 4 | 12.00 | 22.44 | 0.15 | 8.00 | 29.33 | 0.20 |
| **209** | Attention | 13.33 | 24.56 | 0.19 | 7.33 | 51.67 | 0.20 |
| **210** | WL357HQ | 12.00 | 21.22 | 0.17 | 7.00 | 38.67 | 0.18 |
| **311** | 54V54 | 12.33 | 29.11 | 0.16 | 7.67 | 46.67 | 0.16 |
| **312** | Spredor 4 | 9.00 | 28.78 | 0.13 | 9.00 | 31.33 | 0.17 |
| **313** | Attention | 12.33 | 30.67 | 0.18 | 8.00 | 52.00 | 0.20 |
| **314** | HybriForce 400 | 11.67 | 27.89 | 0.15 | 8.00 | 37.33 | 0.17 |
| **315** | WL357HQ | 12.67 | 25.00 | 0.14 | 7.00 | 33.67 | 0.17 |
| **406** | Attention | 11.33 | 25.00 | 0.15 | 8.33 | 44.00 | 0.19 |
| **407** | 54V54 | 11.33 | 30.11 | 0.16 | 8.00 | 41.00 | 0.14 |
| **408** | WL357HQ | 11.67 | 31.22 | 0.18 | 8.33 | 38.67 | 0.19 |
| **409** | HybriForce 400 | 11.33 | 26.00 | 0.14 | 8.00 | 24.67 | 0.16 |
| **410** | Spredor 4 | 8.33 | 28.11 | 0.15 | 8.00 | 41.33 | 0.14 |
| **511** | HybriForce 400 | 8.67 | 27.56 | 0.13 | 7.00 | 38.33 | 0.11 |
| **512** | Attention | 10.33 | 26.78 | 0.17 | 9.00 | 39.67 | 0.18 |
| **513** | WL357HQ | 15.00 | 22.22 | 0.18 | 7.67 | 35.67 | 0.14 |
| **514** | Spredor 4 | 10.33 | 27.22 | 0.15 | 8.33 | 42.00 | 0.15 |
| **515** | 54V54 | 11.33 | 27.44 | 0.16 | 6.33 | 47.67 | 0.14 |

† - Mean number of nodes on primary alfalfa stem at harvest.

‡ - Mean internode length at fourth internode in mm.

**Table A.1. (continued)**

| | | 5/22/2007 | | | 6/21/2007 | | |
|---|---|---|---|---|---|---|---|
| Plot | Cultivar | Nodes | IL | SD | Nodes | IL | SD |
| **101** | Spredor 4 | 10.00 | 53.33 | 0.37 | 11.00 | 57.00 | 0.31 |
| **102** | 54V54 | 9.33 | 55.00 | 0.27 | 11.67 | 56.33 | 0.24 |
| **103** | Attention | 8.67 | 56.67 | 0.28 | 11.00 | 70.00 | 0.34 |
| **104** | WL357HQ | 9.33 | 55.00 | 0.25 | 11.00 | 65.33 | 0.32 |
| **105** | HybriForce 400 | 10.67 | 50.00 | 0.28 | 11.00 | 55.33 | 0.27 |
| **206** | 54V54 | 9.67 | 44.33 | 0.20 | 10.67 | 57.00 | 0.22 |
| **207** | HybriForce 400 | 10.33 | 47.00 | 0.28 | 10.67 | 48.00 | 0.22 |
| **208** | Spredor 4 | 9.33 | 50.00 | 0.25 | 10.67 | 53.00 | 0.26 |
| **209** | Attention | 10.33 | 48.33 | 0.36 | 11.33 | 60.33 | 0.30 |
| **210** | WL357HQ | 10.33 | 49.00 | 0.35 | 11.00 | 46.00 | 0.26 |
| **311** | 54V54 | 10.67 | 46.67 | 0.33 | 11.67 | 45.00 | 0.22 |
| **312** | Spredor 4 | 11.00 | 47.33 | 0.29 | 12.00 | 52.67 | 0.29 |
| **313** | Attention | 11.33 | 47.33 | 0.30 | 10.67 | 47.33 | 0.23 |
| **314** | HybriForce 400 | 10.33 | 42.33 | 0.23 | 10.67 | 46.67 | 0.24 |
| **315** | WL357HQ | 10.00 | 55.33 | 0.22 | 12.00 | 51.67 | 0.24 |
| **406** | Attention | 10.33 | 50.00 | 0.24 | 10.67 | 52.67 | 0.27 |
| **407** | 54V54 | 8.67 | 45.00 | 0.20 | 12.00 | 53.00 | 0.25 |
| **408** | WL357HQ | 10.33 | 41.67 | 0.28 | 9.67 | 59.33 | 0.24 |
| **409** | HybriForce 400 | 9.33 | 41.00 | 0.22 | 10.33 | 47.33 | 0.24 |
| **410** | Spredor 4 | 10.67 | 41.00 | 0.31 | 10.00 | 53.67 | 0.22 |
| **511** | HybriForce 400 | 11.00 | 46.67 | 0.25 | 10.00 | 49.00 | 0.24 |
| **512** | Attention | 9.00 | 46.67 | 0.28 | 9.67 | 51.33 | 0.29 |
| **513** | WL357HQ | 10.67 | 54.00 | 0.29 | 10.67 | 50.33 | 0.26 |
| **514** | Spredor 4 | 11.33 | 45.67 | 0.23 | 9.67 | 66.33 | 0.24 |
| **515** | 54V54 | 8.67 | 46.67 | 0.23 | 10.67 | 62.33 | 0.27 |

**Table A.1. (continued)**

| | | 7/20/2007 | | | 8/22/2007 | | |
|---|---|---|---|---|---|---|---|
| Plot | Cultivar | Nodes | IL | SD | Nodes | IL | SD |
| **101** | Spredor 4 | 12.33 | 63.67 | 0.28 | 11.33 | 73.00 | 0.29 |
| **102** | 54V54 | 11.00 | 65.33 | 0.26 | 10.67 | 70.67 | 0.25 |
| **103** | Attention | 10.00 | 53.33 | 0.31 | 11.33 | 60.00 | 0.26 |
| **104** | WL357HQ | 10.33 | 63.33 | 0.34 | 10.00 | 77.00 | 0.26 |
| **105** | HybriForce 400 | 11.33 | 49.67 | 0.26 | 11.33 | 49.00 | 0.20 |
| **206** | 54V54 | 11.00 | 46.67 | 0.24 | 12.33 | 49.33 | 0.25 |
| **207** | HybriForce 400 | 12.00 | 43.67 | 0.23 | 12.67 | 45.67 | 0.21 |
| **208** | Spredor 4 | 10.33 | 49.33 | 0.28 | 9.00 | 56.67 | 0.28 |
| **209** | Attention | 10.00 | 55.67 | 0.30 | 9.33 | 56.00 | 0.27 |
| **210** | WL357HQ | 11.00 | 45.67 | 0.24 | 9.33 | 60.00 | 0.25 |
| **311** | 54V54 | 11.67 | 47.67 | 0.25 | 10.67 | 54.33 | 0.25 |
| **312** | Spredor 4 | 9.00 | 57.33 | 0.28 | 8.33 | 60.00 | 0.20 |
| **313** | Attention | 11.00 | 46.67 | 0.27 | 10.67 | 41.00 | 0.26 |
| **314** | HybriForce 400 | 10.33 | 45.33 | 0.24 | 11.67 | 48.33 | 0.22 |
| **315** | WL357HQ | 10.67 | 49.67 | 0.26 | 9.33 | 58.00 | 0.23 |
| **406** | Attention | 11.67 | 53.33 | 0.33 | 9.00 | 54.33 | 0.27 |
| **407** | 54V54 | 11.67 | 50.00 | 0.24 | 10.33 | 47.67 | 0.24 |
| **408** | WL357HQ | 9.33 | 52.67 | 0.29 | 9.33 | 47.67 | 0.23 |
| **409** | HybriForce 400 | 11.00 | 45.00 | 0.23 | 9.33 | 53.33 | 0.21 |
| **410** | Spredor 4 | 10.00 | 55.67 | 0.25 | 9.33 | 62.67 | 0.23 |
| **511** | HybriForce 400 | 11.00 | 54.33 | 0.24 | 11.00 | 55.00 | 0.25 |
| **512** | Attention | 11.33 | 55.00 | 0.30 | 10.33 | 55.67 | 0.28 |
| **513** | WL357HQ | 12.00 | 46.00 | 0.26 | 11.33 | 43.33 | 0.22 |
| **514** | Spredor 4 | 10.33 | 53.67 | 0.23 | 9.67 | 59.00 | 0.23 |
| **515** | 54V54 | 11.00 | 52.67 | 0.21 | 10.00 | 56.67 | 0.22 |

**Table A.1. (continued)**

| | | | 9/21/2007 | |
|---|---|---|---|---|
| Plot | Cultivar | Nodes | IL | SD |
| **101** | Spredor 4 | 8.33 | 41.67 | 0.18 |
| **102** | 54V54 | 8.67 | 41.00 | 0.18 |
| **103** | Attention | 10.00 | 34.67 | 0.20 |
| **104** | WL357HQ | 9.67 | 37.33 | 0.16 |
| **105** | HybriForce 400 | 8.67 | 48.00 | 0.19 |
| **206** | 54V54 | 9.33 | 38.33 | 0.18 |
| **207** | HybriForce 400 | 7.67 | 39.00 | 0.16 |
| **208** | Spredor 4 | 9.00 | 51.33 | 0.21 |
| **209** | Attention | 8.33 | 41.00 | 0.19 |
| **210** | WL357HQ | 8.33 | 50.00 | 0.21 |
| **311** | 54V54 | 7.67 | 43.33 | 0.19 |
| **312** | Spredor 4 | 7.67 | 55.67 | 0.23 |
| **313** | Attention | 7.33 | 58.33 | 0.19 |
| **314** | HybriForce 400 | 7.00 | 53.33 | 0.20 |
| **315** | WL357HQ | 8.67 | 46.00 | 0.18 |
| **406** | Attention | 8.67 | 50.33 | 0.20 |
| **407** | 54V54 | 8.67 | 41.33 | 0.17 |
| **408** | WL357HQ | 8.67 | 26.67 | 0.16 |
| **409** | HybriForce 400 | 8.00 | 40.00 | 0.14 |
| **410** | Spredor 4 | 7.67 | 38.33 | 0.22 |
| **511** | HybriForce 400 | 8.33 | 35.67 | 0.19 |
| **512** | Attention | 7.00 | 32.33 | 0.18 |
| **513** | WL357HQ | 8.33 | 37.33 | 0.16 |
| **514** | Spredor 4 | 7.67 | 38.33 | 0.18 |
| **515** | 54V54 | 8.67 | 34.33 | 0.17 |

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VITA

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Adam went on to the University of Kentucky and majored in Plant and Soil Science with an emphasis in Crops and Livestock. Eager to learn about crop and animal relationships, his FFA hay project soon turned into a profession. While pursuing his undergraduate degree, Adam won the National FFA Forage Production Proficiency in 2002, and received the American FFA Degree in 2003. In 2005, he was also recognized by the American Society of Agronomy, Crop Science Society of America, and the Soil Science Society of America for his leadership and achievements in agronomy.

After receiving his Bachelor's of Science degree in 2005 from the University of Kentucky, Adam started working on his Master's of Science degree in Forage Utilization and Management, which should be awarded in May 2008. Upon completion, he plans to remain at the University of Kentucky working on the potential of switchgrass and other forages as sources of renewable energy in the state. He continues to maintain his passion for production agriculture by maintaining his hay business for future generations.