THE EFFECTIVENESS OF PARAQUAT HERBICIDE FOR THE RENOVATION OF HIGH ENDOPHYTE TALL FESCUE PASTURE

By

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CHAPTER I

INTRODUCTION

Tall fescue (Festuca arudinacea Schreb.) is an important cool season, perennial forage species occupying over 35 million acres in the continental United States (Hemken et al., 1984). An estimated 80% of the fescue pastures in the Southeast and Midwest are infected with the fungal endophyte, Acremonium coenophialum (Daniels et al., 1985). Animal maladies similar to those produced by ergot (Claviceps spp.) have plagued this forage species for years. In 1976 the discovery of the tall fescue endophyte, provided an explanation for these maladies (Stuedemann and Hoveland, 1988). The interaction between the fungus and the fescue plant is known to produce toxic alkaloid compounds, which are directly related to fescue toxicosis problems present in livestock grazing the infected pastures.

One solution to the problem is to provide noninfected forage by establishing endophyte-free tall fescue stands. However when using endophyte-free seed Bacon and Siegel (1988) warned that caution should be observed when using these, since endophyte-free fescue has proven to be highly susceptible to overgrazing, insect attacks, and environmental fluctuations. In most grassland communities change will occur in the direction of the more competitive plants. Thus it appears that within a mixed stand of endophyte-free and endophyte infected plants the change would be in the direction of the more hardy infected plants and over time these plants would dominate the community.

Over 30 years ago the partial destruction of sod with chemicals, followed by establishment of new forages was suggested. It has been an accepted practice applied to endophyte infected tall fescue pasture. Fribourg (1978) and Fribourg et al. (1978) recommended the renovation of infected tall fescue pastures with fall and late winter paraquat applications followed by interseeding with legumes. He suggested that legume seeding should be done in late February or early March for good stand establishment, using a mixture of red clover (Trifolium pratense, L.) and ladino clover (Trifolium repens, L.) for the best long-term improvement of tall fescue pastures. Fribourg et al. (1988) suggested that pastures having greater than 30% infection are good candidates for reestablishment, while those with 30% or less endophyte infection could be improved through the incorporation of legumes. Paraquat [(1, 1-dimethyl-4, 4-bipyridinium)] is the most highly recommended herbicide for renovation of high endophyte tall fescue pastures.

The initial objective of this research was to determine if endophyte infection levels would change in a mixed stand of endophyte-free and endophyte infected tall fescue plants over time. Due to the results of the first year study, the development of a new objective was necessary. This objective was to investigate perennial tiller regrowth and seedling plant emergence in an infected tall fescue stand following paraquat treatments.

CHAPTER II

LITERATURE REVIEW

History

Tall fescue, (*Festuca arundinacea* Schreb.) originated in northern Europe and entered the United States as a contaminant in other grass seed stock (Bacon et al., 1986). Tall fescue was growing as early as 1887 on the W. M. Suiter farm in Menifee County, Kentucky; however, it wasn't until 1931 that it caught the attention of agriculture research scientists (Fergus, 1972). In 1942 this grass was released for public use as, 'Kentucky 31' tall fescue. This cultivar offered many advantages to the livestock industry. It provided long grazing seasons, extreme winter hardiness, insect resistance, and could be used for turf and erosion control purposes (Siegel et al., 1985).

Fescue Toxicosis

By the early 1950's millions of acres had been planted with the Kentucky 31 cultivar. It was at this time that disturbing reports of poor animal performance and visible maladies associated with the grass began to surface (Pratt and Davis, 1954; Stuedemann and Hoveland, 1988). In 1973 a fungal physiologist, C. W. Bacon, and a medicinal organic chemist, J. K. Porter, hypothesized that a fungus living inside the plant might be involved with the toxic effects on livestock (Stuedemann and Hoveland, 1988). A fungal endophyte (endo = inside, phyto = plant), Acremonium coenophialum, was identified in 1976 (Morgan-Jones and Gams, 1982). This elusive pathogen became the prime suspect as the causal agent for tall fescue toxicities.

Fescue toxicosis is a general term applied to all toxic conditions such as summer slump, fescue foot, and bovine fat necrosis. These conditions are only associated with livestock grazing endophyte infected tall fescue pastures. Removal of the animal from the infected fescue diet to a different diet will stop the progression of these maladies.

Summer slump is the most common of these conditions and is characterized by rough hair coat, rapid respiration, excessive salivation, frequent urination, and an overall poor animal performance (Bush et al., 1979; Crawford et al., 1989). Goetsh et al. (1987) suggested poor animal performance in part is attributed to a reduced dry matter intake of the infected grass by the animal. Cattle will suffer a reduced average daily gain of about 0.1 lb/day for every 10% increase in endophyte level during the spring-summer grazing periods, but this relationship does not exist during fall grazing (Stuedemann et al., 1985; Crawford et al., 1989). Most of the problems during the spring grazing season are associated with higher ambient temperatures. Cattle grazing infected tall fescue when environmental temperatures were over 80F had difficulty controlling body temperature resulting in a 1 to 2F increase in body temperature (McMurphy et al., 1990). Higher body temperatures add to heat stress and care should be exercised when working with such cattle.

Fescue foot has more dramatic visible symptoms that occur during the lower ambient temperatures of late winter (Bush et al., 1979). Livestock grazing highly infected tall fescue pasture during the cooler months, will show a reduced blood circulation to the outer extremities of the body. As a result, a gangrenous response takes place causing the ear tips, tail and in severe cases, the feet to fall off.

The incidence of bovine fat necrosis is considerably less than summer slump or fescue foot. Fat necrosis is the accumulation of hard fat masses in the adipose tissue surrounding the intestines, causing digestive upset and calving problems (Bush et al., 1979).

At least three major classes of alkaloids have been isolated from infected tall fescue, 1) diazaphenanthrene with perloline as the dominant alkaloid, 2) pyrrolizidine group with N-formyl and N-acetly loline (FALA) as the major alkaloids, and 3) the ergot alkaloids with chanoclavine I and ergovaline as the dominant alkaloids (Yates, 1983). Buckner et al. (1973) found that perloline content was under genetic control of the plant. FALA is only found in fescue-endophyte systems, but it is not known if the compound is produced by the fungus or by the plant in response to the fungal infection (Bush et al., 1983; Jones et al., 1983).

Presently, seven ergot alkaloids have been identified with ergovaline, the predominant ergopeptide type alkaloid, and chanoclavine I, the predominant clavine ergot type (Bush and Burrus, 1988). The ergot alkaloids are apparently produced by the endophyte, which are found in both endophyte cultures and infected tall fescue plants. It is known that the endophyte is involved in the production of the toxin(s) per se, either by stimulating the grass plant to produce the toxin, or by synergistically producing the toxin with tall fescue. The conclusion that seems universal from all research on elucidation of the toxins from tall fescue is that it is unknown precisely which compounds cause fescue toxicosis.

Annual losses from fescue toxicosis have been estimated to range in the hundreds of millions of dollars in the United States alone (Siegel et al., 1985). These losses can be reduced by incorporating specific management practices into the livestock operations. The objective of these practices is to decrease the level of endophyte ingested by the grazing animal, thereby diluting the amount toxin entering the animals system. Suggested methods are, to overseed infected pastures with legumes, feed non-fescue hay, provide other forage species for grazing livestock, and keep seedhead production to a minimum. The seed is were concentrated amounts of the fungus are located.

Waller et al. (1988) describes a practical forage system (December to July) for fall-calving cows and their calves. The combination of fescue plus clover plus nitrogen and fescue plus legumes pastures would provide stockpiled forage harvestable by cattle in the winter and take advantage of legume nitrogen for grass growth in the spring. A pasture forage system suggested by McMurphy et al. (1990) using steers also describes a high endophyte plus clover mixture to help overcome the detrimental effects of the fungus. He futher indicated that cattle will differ in their ability to tolerate the toxic effects of the endophyte based on breed.

Endophyte-Infected vs. Endophyte-Free

The relationship between the fungus and grass plant is termed, 'symbiotic mutualism' (Siegel et al., 1985; Latch and Christensen, 1985). Mutualism as defined by Barbour et al. (1987) is an obligate interaction between two kinds of organisms whereupon the absence of the interaction depresses both partners.

The production and sale of endophyte-free seed became possible in 1980 after a stock of infected tall fescue seed left in storage was discovered to have undergone a reduction in endophyte infection level to nearly zero (Pedersen and Sleper, 1988). Later research demonstrated that long-term storage alone was an unreliable technique, because the degree of endophyte reduction was dependent upon environmental temperature, humidity and length of storage period. Long-term storage used in combination with short-term heat treatments and seed-applied fungicides produce a more consistent result.

It is important to note that at the present time there are no commercially certified lots of tall fescue seed which are completely fungus free. Most seed lots contain some level of endophyte infection. The standard for the certification of endophyte-free tall fescue seed is that the level of infection must be 5% or less (Bacon and Siegel, 1988).

Pure stands of endophyte-free tall fescue have been established and proven to be both effective and economical. Grazing studies conducted on 15-year old endophyte-free fescue pastures were compared to the economics of cattle grazing infected tall fescue pastures in Alabama (Nance, 1987). Steers gained an average of 426 lb/acre on endophyte-free pastures while steers on infected pastures gained 301 lb/acre, an improvement of 125 lb/ acre for steers on the endophyte-free fescue. This in turn produced substantially higher dollar returns per acre. Similar studies performed by Boling (1985) from the University of Kentucky and Hoveland et al. (1983) from Auburn University had comparable results.

The removal of the fungus from the tall fescue grass produces undesirable changes in the plants, such as reducing the rate of seedling establishment, number of seed set (Clay, 1987), and rate of seedling growth (Pedersen and Burrus, 1989). Recent studies by Arachevaleta et al. (1989) demonstrated differences between endophyte-free and endophyte infected plants in leaf morphology, herbage production, and regrowth during moderate amounts of drought stress. They found leaf blades of the infected plants to be thicker, narrower, and more erect than the noninfected plants and these characteristics were not altered appreciably by flooding, nitrogen rate, or drought stress. The infected tall fescue plants were found to produce greater herbage and a more rapid regrowth over the noninfected plants. Bush et al. (1986) determined that endophyte-free plants under greenhouse conditions had fewer tillers, lower weight per pot, and lower water use efficiency than the infected tall fescue plants.

Another plant characteristic that is adversely affected when the endophyte fungus is removed is the ability to withstand defoliation by insects. The abundance of three leafhoppers, Draculacephala antica, Agallia constricta, and Endria inimica and the corn flea beetle, Chaetocnema pulicaria, was evaluated on both infected and noninfected tall fescue plants (Kirfman et al., 1986). As the level of endophyte infection increased, the number of leafhoppers decreased, indicating possible host plant resistance attributed to the endophyte. Johnson et al. (1985) observed the response of aphid feeding by Rhopalosiphum padi and

Schizaphis graminum on infected and noninfected tall fescue plants. They determined that both species of aphid were unable to survive when confined to infected plants. The endophyte-free tall fescue leaf sheaths were preferred for aphid feeding by greater than a 4-to-1 margin over the infected leaf sheaths. West et al. (1987) studied two types of root feeding soil-borne nematodes in tall fescue. Endophyte-free plants had substantially higher numbers of both the internal nematode (Pratylenchus scribneri) and the external nematodes (Quinisulcius acutus and Tylenchlorhynchus ewingi) than the endophyte infected plants. Thus, endophyte-free tall fescue plants are highly susceptible to nematodes and herbivory insects (Barker et al., 1983; Clay et al., 1985; Ahmad et al., 1986; Funk et al., 1985).

A few plant factors that do not seem to be affected by the presence of the endophyte fungus are the forage quality factors nutrient detergent fiber, acid detergent fiber, and crude protein content of the forage (Bush and Burrus, 1988; Arachevaleta et al., 1989). The amount of forage production from established fescue stands is not affected by this fungus (Pedersen et al., 1982; Burrus et al., 1987; Carlson and Umbaugh, 1988).

Bush and Burrus (1988) stressed that increased tolerance associated with the presence of the endophyte in tall fescue may be required for continued plant persistence in forage and turf production. With the greater hardiness of the infected plant, it seems logical that in a mixed stand of endophyte infected and endophyte-free tall fescue plants, that the infected plants would have a greater competitive advantage over the noninfected plants. Thus, over a period of time in a mixed stand the infected plants may eventually dominate the stand. Read and Camp (1986) demonstrated this competitive advantage conferred by the endophyte during the summer of 1984, when they reported stand loss in 2 out of 3 replications in low endophyte fescue pastures.

Researchers at Auburn University have conclusively determined the endophyte fungus is transmitted only by seed (Ball, 1984). Pasture surveys by Siegel et al. (1984) and Belesky et al. (1987) indicated that endophyte infection levels may not change over long periods of time. However, Ball, (1988) recently disclosed that low level endophyte pastures will increase in infection at a rate of 1-2 % annually. Therefore, endophyte infected tall fescue stands must be complete destroyed, leaving no viable seed or perennial plants from the existing stand, before replanting the area. The final decision for reestablishment of pastures with endophyte-free fescue should be planned and consequences thoroughly understood. Both a high level of livestock and grass management must be practiced and incorporated into the agricultural operation when considering either type of tall fescue forage.

Herbicide Controls

Renovation as stated by Fribourg and Safley (1962), refers to the improvement of pasture without a complete destruction of the existing stand, in an attempt to establish or reestablish high yielding, palatable, and well adapted legumes and/or grasses into the sod.

The recommended herbicide labeled for pasture land use by the Environmental Protection Agency is, Paraquat (1,1'-dimethyl-4,4'-bypyridinium dichloride) marketed as Gramoxone Super (Fribourg et al., 1988). Early studies by Jeffery et al. (1978) compared the effects of various spring applications of dalapon, glyphosate, paraquat and disking for partial destruction and sod suppression of tall fescue. He found paraquat broadcast at a rate of 0.5 lb/acre combined with disking operations controlled 95 % of the tall fescue sod in some cases. Earlier studies conducted by Fribourg (1978) had reported similar results. The amount of permanent tall fescue sod suppression is dependent on the type of herbicide used, the date of application(s), and the location (Fribourg, (1978); Jeffery et al., (1978). Recent studies by Fribourg (1988) on infected tall fescue revealed paraquat applied in the fall at a rate of 0.25 lb/acre and followed 10-21 days later with 0.125 lb/acre paraquat produced 100% control on fescue. Stritzke and Woods (1987) observed that paraquat applied in early fall at 0.5 lb/acre followed by 0.25 lb/acre in late fall produced 87% tall fescue sod suppression, but a late fall plus an early spring treatment applied at those same rates produced 99% control of the infected sod. Studies by Koch et al. (1987) and Creech (1985) also report results on the effectiveness of paraquat when used for renovation purposes on tall fescue.

Chemical growth retardants offer possibilities for infected tall fescue. These agents prevent or hinder the advancement or accomplishment of plant growth. Dernoeden (1986) used three applications of diclofop {(+)-2-[4-(2,4-dichlorophenoxy)phenoxy] propanoic acid} at rates of 2, 3 and 4 lb/acre applied to infected tall fescue in Kentucky bluegrass (Poa pratensis, L.) turf. Tall fescue populations were reduced as much as 98%, complete control of tall fescue was not achieved. Fenoxaprop [(+)-ethyl 2-{4-[(6-chloro-2-benzoxazolyl) oxylphenoxy propanoate] applied at various rates did not successfully suppress tall fescue seedlings, but may serve as a preemergence herbicide for establishment of tall fescue in the spring and summer (Dernoeden, 1987). McCarty et al. (1985) applied selected growth retardants to infected Kentucky 31 tall fescue turf. Treatments were, 1) melfluidide, (N-[2,4-dimethyl-5-[[(trifluoromethyl) sulfonyl]amino] phenyl]acetamide) at 0.125 lb/acre; 2) MH (maleic hydrayide), (1,2-dihydro-3,6-pyridazinedione) at 4 lb/acre; and 3) melfluidide plus flurprimidol, (-(1-methylethyl)-[4-(trifluoromethoxy) phenyl]-5-pyrimidine methanol) at 0.27 plus 0.718 lb/acre. The melfluidide plus flurprimidol and the MH treatments reduced cumulative tall fescue turf height an estimated 40% and caused a 95% suppression of seedheads for six to eight weeks. The 0.125 lb/acre melfluidide treatment alone did not provide acceptable levels of tall fescue control. The removal of tall fescue from Kentucky bluegrass turf with chlorsulfuron, {2-chloro-N-[(4-methoxy-6-methyl-1,3,5 triazin-2-yl) aminocarbonyl]-benzenesulfonamide} after single and split herbicide applications was investigated by Larocque and Christians (1985); Maloy and Christians (1986). They found Kentucky bluegrass had a high tolerance to chlorosulfuron while tall fescue had a low tolerance. Control occurred at the single rate of 0.125 lb/acre and the split rate of 0.125 plus 0.125 lb/acre. Severe growth inhibition and discoloration with limited recovery of tall fescue was found at levels as low as 0.06 lb/acre.

Other growth retardants known to reduce tall fescue growth are MBR 6033, (3-trifluoromethyl-sulfonamido-p-acetotoluidide); MON 820, (N-phosphonomethylimino-diacetic acid); MON 845, [N,N-Bis (phosphonomethyl)glycine] and Maintain CF125, (methyl-2-chloro-9-hydroxyfluorene-9-carboxylate, methyl-9-hydroxy-fluorene-9-carboxylate, methyl-2,7 dichloro-9-hydroxy florene-9-carboxylate) (Elkins and Suttner, 1974).

Fungicides have been evaluated in the control of the tall fescue endophyte fungus. A fungicide is an agent that destroys fungi or inhibits their growth. Williams et al. (1984) evaluated sterol inhibitor fungicides applied on infected tall fescue in field and greenhouse studies. In the greenhouse, the sterol inhibitor triadimenol and its analog triadimefon at a rate of 2.1 gallons active ingredient/lb were the most effective in reducing viable endophyte levels from 70% to 0%.

With the use of any chemical or physical treatment(s) for the control of the endophyte in tall fescue, there should be a grow-out test performed and a sufficient period of time allowed to elapse prior to determining whether the treatment was successful (Bacon and Siegel, 1988).

Over 90% of the tall fescue grown in the United States is endophyte infected (Siegel et al., 1985; Welty et al., 1986) as a direct result of the release in 1942 of the Kentucky 31 cultivar, determined to be 93% endophyte-infected. Analyses taken from 1983 to 1986 of 1,483 vegetative samples taken from pastures in 26 states by the Auburn Fescue Diagnostic Center indicated 94% of the samples contained the fungal endophyte and the average infection of the samples was 58% (Bacon and Siegel, 1988).

The relationship between Acremonium coenophialum and Festuca arundinaceae, has proven to be both perplexing and frustrating to agriculture scientists. The continued and combined efforts of university research in botany, chemistry, animal science, agronomy, plant pathology, and others is needed for a more complete understanding into the biological and biochemical significance of this grass-endosymbiont interaction.

CHAPTER III

MATERIALS AND METHODS

Two separate studies were conducted in the Cherokee Prairie Resource area of Northeastern Oklahoma on soils belonging to the Des Moinesian series and Allegheny group. The initial study began in October of 1985 through July of 1987. The second study that followed began in October 1987 and continued through April 1988. The herbicide paraquat (1, 1 -dimethyl-4, 4 -bipyridinium) was used to control endophyte infected tall fescue stand(s) for both studies. Following each paraquat application a temporary fence was placed around the entire experimental area(s) to eliminate livestock grazing and allow proper activation of the herbicide. Within approximately 10 days fences were removed.

Study 1. Endophyte-Infection Level

This study was located on the Frisbie Ranch, 4 miles west of Vinita, Oklahoma near the intersection of state highways 60 and 66. The experimental design was a randomized complete block in four replications with a factorial arrangement of three paraquat rates and three application dates, plus an untreated check. The plot size was 39 x 65 ft. The soil is a Dennis silt loam (fine, mixed, thermic Aquic Paleudolls, Mollisols) with slopes of one to three percent.

The three paraquat rates were 0.25, 0.50, and 1.00 lb/acre. The treatment dates were: 1) 24 October 1985, 2) 4 February 1986, and 3) 24 October 1985 plus 4 February 1986. All treatments were applied using a tractor-mounted boom sprayer. Environmental conditions on the first treatment date of 24 October 1985 were air temperature of 76F, southwest wind of 0-5 MPH, and adequate soil moisture. Environmental conditions on the second treatment date of 4 February 1986 were air temperature of 64F, southwest wind of 5-10 MPH, and adequate soil moisture.

The entire experimental area was seeded with Certified Missouri 96 tall fescue, 2% endophyte, on 24 February 1986 . A Marliss grass drill was calibrated to deliver a seeding rate of approximately 30 lb seed/acre, with a planting depth of 0.25 inch which placed the seed into moist soil. Percent herbicide control rating was determined from visual observations and recorded. A permanent four strand barbed wire fence was placed around the study area following seeding to prevent grazing until mid-May 1986. Seedling plant counts were made using a 6 x 36 inch quadrat and plant counts recorded on 2 May 1986.

Determination of endophyte infection levels in the renovated study area was delayed for one year to permit plant stand establishment and stabilization of the fescue community. During this time specific plot selections were made for the purpose of intensive tiller sampling. These plot selections were necessary because of the long and time consuming laboratory procedures involved in the identification of the fungal endophyte. These plots were to be continuously monitored over a period of years for changes in infection levels. The selections were based on the percent control achieved through paraquat use on 24 February 86 and seedling plant counts from 2 May 86. Treatments selected were, 1) 0.25 lb/acre on 24 October 1985, 2) 1.0 lb/acre on 24 October 1985 and 4 February 1986, and 3) the untreated check in all replications.

The level of endophyte infection was determined by randomly selecting 40 tiller samples from each plot on 19 May 1987. Twenty of those tiller samples were analyzed for the presence of the endophyte fungus. Laboratory techniques as described by Reddick, (1988) were used to identify the fungus. Techniques involved dissecting the tiller culms longitudinally, followed by removing thin layers of pith material from the lower area of the culm. The pith tissue was then mounted on a glass slide, and stained with a prepared analine blue stain. The staining process gave the fungus mycelium a deep blue color thereby enhancing its appearance. Three slides were prepared from each tiller sample. The prepared slides were examined for the fungus mycelium using a compound microscope set at 100X magnification. This microscope examination was continued until the presence of the fungus was identified, or until all three slides had been thoroughly inspected. If all three slides were found to contain no fungus the tiller was scored as noninfected, however, upon discovery of the fungus in any one of the three slides the search stopped and the tiller was scored as infected.

A second set of 40 tiller samples was taken from the selected plots on 13 July 1987. However, tiller samples were removed directly from the drill rows, in order to evaluate only seeded (not original or volunteer) plants for the presence of the endophyte. The presence of the fungus was determined by using the same laboratory procedures as described for the 19 May 1987 tiller analysis.

Study 2. Paraquat Effectiveness

At three locations in northeastern Oklahoma perennial tiller regrowth and seedling plant emergence was evaluated on high endophyte tall fescue pastures following paraquat treatments.

Prior to the initiation of these studies 20 tiller samples from each location were taken in order to determine beginning endophyte infection levels. All twenty samples from each location were analyzed. The laboratory procedures and method of analysis were the same as described in the above endophyte infection level study.

The first location was the Robson Ranch, approximately

5 miles southeast of Catoosa, Oklahoma. The soil is Dennis silt loam (fine, mixed, thermic; Aquic Paleudolls; Mollisols). The existing fescue stand measured 10-12 inches in height, and was 90 % endophyte-infected. The second location was the Willis Ranch at Lenapah, Oklahoma. The soil is Parsons silt loam (fine, mixed, thermic Mollic Albaqualfs, Alfisols). The existing stand measured 5-7 inches in height, intermixed with white clover, and the endophyte infection level was 80%. The third location was on the Ms. Frank Stritzke Ranch, approximately 3 miles southwest of South Coffeyville, Oklahoma. The soil is Okemah silt loam (fine, mixed, thermic Aquic Paleudolls, Mollisols). The existing fescue stand measured 3-6 inches in height and the endophyte infection level was 70%. Slopes for all locations ranged from one to three percent.

The experimental design for each location was a randomized complete block in four replications with two paraquat treatments and two application dates plus an untreated check. Treatments were 0.25 and 1.0 lb/acre paraquat rates, applied on 27 October 1987 and 4 December 1987. A bicycle plot sprayer with a 7.5 ft boom was used to administer all treatments. The plot size was 16.5 x 33ft. No seeding was performed at any location.

Environmental conditions on the first treatment date of 27 October 1987, were air temperature 67F, north wind 3-10 MPH, and adequate soil moisture. Environmental conditions on the second treatment date of 4 December 1987, were air temperature of 60F, no wind, and adequate soil moisture.

A percent herbicide control rating was determined from visual observations and recorded for each location on 25 February 1986. On 20 April 1988 the number of perennial tillers and seedling plants that occurred following paraquat treatments were determined by counting plants in ten 4-inch diameter sod plug samples per plot. These samples were removed from the plots to facilitate counting.

Data were analyzed using analysis of variance, and the Least Significant Difference (P=0.05) was used to detect differences among treatment means.

CHAPTER IV

RESULTS AND DISCUSSION

Study 1: Endophyte Infection Level

Tall fescue control achieved by 25 February 1986 was dependent on the date and rate of paraquat (Table 1). The best control of high endophyte tall fescue was with the single 24 October 1985 application of 0.50 or 1.00 lb/acre paraquat and the split applications (24 October 1985 and 4 February 1986) at all rates of paraquat. These treatments produced 91-99% control of tall fescue. The single 0.25 lb/acre application on 24 October 1985 produced a 76% level of control of the high endophyte tall fescue. The single February application of any paraquat rate was ineffective with the best control achieved from the 1.0 lb/acre rate which produced only 11% control of the tall fescue.

The various paraquat treatments provided an adequate range of control in the high endophyte tall fescue plant community. Hopefully this would allow a range of endophyte infection levels to be established with the seeding of Missouri 96 low endophyte tall fescue. The best establishment of seedlings corresponded with the paraquat treatments that produced the highest level of control on the infected plant community. Seedling plant establishment ranged from 23 to 27 plants/ft^2 (Table 2). The 4 February 1986 treatments revealed a significant decrease in seedling plant establishment. This was presumably due to the intense competition from the previously existing high endophyte stand.

Random samples taken from the selected plots on 19 May 1987 revealed high levels of endophyte infection. Infection levels ranged from 55% for the control to a 68% found in the 0.25 lb/acre treatment (Table 3). No reduction in endophyte levels had been produced by the herbicide treatments and reseeding with endophyte-free fescue. The renovation techniques applied were not successful, therefore the high endophyte levels encountered in the treated plots were unforeseen. This raised questions about the infection level of the tall fescue seed that was planted. Samples of the Missouri 96 tall fescue seed were sent to Auburn University Fescue Toxicity Diagnostic Center in Auburn, Alabama for testing in early July 1987. Laboratory analysis performed on the second tiller sampling taken on 13 July 1987 from the drill rows revealed a significant reduction in endophyte levels between the untreated check and the treated plots (Table 3). The untreated check had 65% infection, while the 1.0 lb/acre treatment applied in October 1985 and February 1986 contained 5% endophyte infection. The drill rows in the untreated check plots were not as easily recognized thus, the sample taken was more representative of a random sampling. Results received from the Auburn laboratory confirmed the certified seed tag of 2% endophyte. The seed was low endophyte, and the biased plant samples from the drill rows were low endophyte.

The random sampling of 19 May 1987 indicated endophyte infection levels within the treated plots to be above 60%. This unacceptable infection level developed within 18 months of the use of paraquat and reseeding. The endophyte infected plant population apparently came from either seedling plants or surviving perennial plants of the original pasture population.

During the time this study was being conducted, several states east and southeast of Oklahoma were still promoting the use of paraquat and reseeding with endophyte-free fescue for renovation of high endophyte infected pastures (Jefferys et al., 1978; Creech, 1985; Fribourg et al., 1978; Hoveland et al., 1986). These data indicate that this system is not acceptable for northeastern Oklahoma.

Study 2: Paraquat Effectiveness

Visual observations on 25 February 1988 at all locations and all paraquat treated plots revealed over 97% control of the high endophyte tall fescue. The maturity of tall fescue and seed development occurs in June. With normal fall precipitation the conditions in tall fescue sod are ideal for seed germination. Rampton and Ching (1966) reported that fescue seed did not survive long, probably less than one growing season, on the soil surface, but buried seed retained viability slightly longer. It was not known if all of these seed would germinate during the fall and thus be susceptible to the paraquat applications. Seed germination was found to take place after the late winter herbicide applications on 4 December 1987 (Table 4). No significant differences in seedling number were attributed to paraquat treatments. Although the density of seedling plants appeared low, successful grass stand establishment has been defined as 1 plant/ft^2 in native grass seedings (Great Plains 6 Technical Committee, 1966).

The highest reduction in perennial tiller density occurred with 1.0 lb/acre paraquat rate at the Lenapah location with 92 tillers/ft^2 (Table 4). A significant location x paraquat rate interaction occurred; therefore, each location was analyzed separately. The 1.00 lb/acre paraquat application significantly reduced the number of perennial tillers from that of the untreated check at all locations, but substantial plant survival, over 92 tillers/ft^2, had developed.

Frequency provides information about the uniformity of distribution of plants within a stand. Perennial tillers were reduced in frequency more at Lenapah in plots treated with the 0.25 lb/acre paraquat rate. However these plots still had a 48% frequency of perennial tillers present

(Table 5). Thus, the best treatment revealed a perennial tiller surviving in nearly half of the four-inch diameter samples. Seedling plant frequency of the treated plots ranged from a low of 30% at the South Coffeyville location to a high of 50% at the Catoosa location.

The normal phenology of tall fescue in spring would be development of new green shoots in early March. However, the sampling for perennial tiller regrowth and seedling plant emergence was delayed until 19 April 1988 because very little green growth had developed on the paraquat treated plots until that time. In contrast the untreated plots had green growth at a height of 8-10 inches.

Paraquat for the control of high endophyte tall fescue pasture was ineffective. Paraquat had produced an excellent suppression of the above-ground growth but only a delay in plant regrowth processes.

Table 1. Control (%) of high endophyte tall fescue on 25 February 1986, Vinita.

Paraquat rate (lb/acre)	Application Date		
	24 Oct 85	4 Feb 86	24 Oct 85 & 4 Feb 86
0.25	76	3	93
0.50	91	3	96
1.00	99	11	98

Source	ANOVA F-test
Date	**
Rate	**
Date x Rate	*

*, ** = 0.05 and 0.01 levels of probability, respectively.

Table 2. Missouri 96 tall fescue seedling density (plants/ft^2) on 2 May 1986, Vinita.

Paraquat rate (lb/acre)	Application Date		
	24 Oct 85	4 Feb 86	24 Oct 85 & 4 Feb 86
0.25	15	0.5	27
0.50	23	1	26
1.00	25	2	25

Source	ANOVA F-test
Date	**
Rate	NS
Date x Rate	NS

**, NS = 0.01 level of probability and non significance, respectively

Table 3. Endophyte infection level (%) in renovated tall fescue, Vinita.

Paraquat rate (lb/acre)	Sampling date	
	19 May 87	13 Jul 87
Check	55	65
0.25	68	18
1.00	66	5
LSD(0.05)	NS	12

Table 4. Density (plants/ft^2) of tall fescue perennial tillers and seedling plants on 19 April 1988.

Paraquat rate (lb/acre)	Location					
	Catoosa		Lenapah		S.Coffeyville	
	tillers	seedl.	tillers	seedl.	tillers	seedl.
0.00	264	15	321	23	368	5
0.25	242	25	94	50	296	7
1.00	171	40	92	24	125	6
LSD(0.05)	47	NS	102	NS	64	NS

Table 5. Frequency (%) of tall fescue perennial tillers and seedling plants in 4-inch diameter samples on 19 April 1988.

Paraquat rate (lb/acre)	Location					
	Catoosa		Lenapah		S.Coffeyville	
	tillers	seedl.	cillers	seedl.	tillers	seedl.
0.00	100	58	100	23	100	25
0.25	100	50	48	48	100	35
1.00	100	50	73	33	95	30
LSD (0.05)	NS	NS	NS	NS	NS	NS

CHAPTER V

SUMMARY

Renovation of high endophyte tall fescue pasture to develop endophyte-free tall fescue pasture will require eradication of the existing high endophyte plant community. Paraquat was evaluated using rates up to 1.0 lb/ac in single and split applications for control of the endophyte-infected tall fescue plants. The paraquat applications were made October through February. The least amount of perennial tiller regrowth occurred at the Lenapah location following fall and late winter applications of 1.0 lb/acre paraquat rate. Ninety-two tillers/ft^2 still survived with the best treatment. Seedling plant emergence was also exposed, thus establishing that not all seed can be destroyed by paraquat applications in late winter. The number of seedling plants ranged from a low of six to a high of 50/ft^2 in the treated areas. Paraquat provided an excellent above ground plant suppression but only delayed regrowth processes of the infected tall fescue plants.

The suppression produced by paraquat on infected tall fescue pasture could be beneficial for introducing legumes into the existing sod, but not for converting from high endophyte to endophyte-free tall fescue. Paraquat alone was not effective for the removal of high endophyte tall fescue in Oklahoma.

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