BUD GROWTH AND DORMANCY IN *ANDROPOGON GERARDI*, *PANICUM VIRGATUM* AND *ERAGROSTIS CURVULA*

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CHAPTER I

INTRODUCTION

Grasslands are composed of a mixture of plants. The diversity that is found makes it necessary to study each species as well as the community when looking for methods of improvement. The dominant grasses in a grassland deserve special attention since their growth patterns and nutrient requirements must be well understood for wise management decisions which preserve the range. Many researchers found that throughout the growing season there are periods of active growth and periods of reduced growth. Forage production is cyclic.

Environmental conditions and how plants respond to them may radically affect management. Laude (1953) demonstrated that the response to environmental conditions varies with grasses. The availability of adequate soil water delayed the onset of dormancy in some grasses. Others were found to be much more sensitive to daylength and temperature.

Rest, quiescence and apical dominance periodically limit forage production of big bluestem (Andropogon gerardi Vitman), switchgrass (Panicum virgatum L.) and weeping lovegrass [Eragrostis curvula (Shrad.) Nees]. Understanding factors that affect cessation of growth is necessary for

continued forage production.

One objective in this investigation was to evaluate cyclic growth of three important grasses: big bluestem, switchgrass and weeping lovegrass. Another objective was to utilize *in vitro* techniques in the laboratory in an attempt to distinguish between dormancy and apical dominance in these grasses.

CHAPTER II

LITERATURE REVIEW

Tall grass prairies evolved under the influence of: 1) climate, 2) topography, 3) soil, 4) biota, 5) fire, and 6) time. Two of the dominant grasses of the tall grass prairie are big bluestem (Andropogon gerardi Vitman) and switchgrass (Panicum virgatum L.). It has long been recognized that the forage of the prairie is productive, and will afford efficient and rapid gains on livestock. Man has utilized, and has often abused, these tall grass prairies. Abuses take time to repair. The management of the dominant climax species is the key to retaining the productivity and value of grasslands.

Weeping lovegrass [Eragrostis curvula (Schrad.) Nees], was introduced into the United States in the 1930's from South Africa where it was a success on disturbed lands such as strip mine areas (Crider, 1945). Weeping lovegrass quickly became successful in Oklahoma and Texas for erosion control in revegetating abandoned farmland. However, farmers and ranchers quickly became disenchanted with this species because livestock performance on these pastures was poor. Three decades after the introduction of weeping lovegrass, the species became very successful for livestock production

because management technology had developed. The importance of removal of the previous year's dead growth, fertilization, and rotation grazing were understood and practiced by ranchers.

The grasslands are composed of many different plants within the family Gramineae. Diversity is present within grass species as well. Each species must be studied to eventually have a greater understanding of the grasslands.

The general areas of concern in this investigation are: dormancy, grass shoot developmental morphology, characteristics of weeping lovegrass, and tissue culture protocol.

Dormancy

Growth Cycles

Bidwell (1974) recognized dormancy as a state of suspended growth and metabolism. This definition does not differentiate between dormancy due to environmental conditions or quiescence, and dormancy due to unfavorable internal conditions or rest, as defined by Samish (1954). Many researchers have quantified the conditions that induce dormancy, and studied conditions that terminate the dormant period. Bidwell (1974) stated that dormancy can be imposed from within the tissue, and controlled by mechanisms in the tissue. Vegis (1964, p. 209) noted that "...control of dormancy is of complex character, involving controlled growth promotion as well as controlled growth inhibition".

Dormancy is an adaptation mechanism. Plants are induced to dormancy as a procedure to survive hot dry summers, the cold, or desiccation in winter (Vegis, 1964).

Apical dominance is a general term used to denote the correlative influence of the apex on the growth and orientation of lateral organs such as buds, leafy shoots, stolons, branches and leaves (Woolley, 1972). Johnson and Buchholtz (1962) and Heidemann and Van Riper (1967) investigated the seasonal variation in the growth and inhibition patterns of plants. Both dormancy and apical dominance occasionally limited growth. These effects are often confounded and difficult to separate.

Johnson and Buchholtz (1961,1962) investigated the activity of quackgrass (Agropyron repens L.) Beauv. rhizomes in vitro. Quackgrass, a weedy grass species, is capable of producing three to six tons of rhizomes per acre. The mass of roots was not all viable, and the amount that was not viable fluctuated within the year. The rhizomes often displayed a high degree of bud activity in vitro in the laboratory while in the field the rhizome buds were almost completely inhibited. This was attributed to apical dominance. During the time from April 13 to about June 1 in Wisconsin the activity of the buds on the rhizome of quackgrass would remain dormant even when released from apical dominance. They concluded that there are two types of dormancy mechanisms at work in quackgrass rhizome: 1) an apical dominance when inactive good buds were subject to

apical inhibition of their growth; and, 2) a late spring dormancy that was coincident with the rapid growth stages of the aerial portion of the plant.

Heidemann and Van Riper (1967) used a procedure modified by Johnson and Buchholtz (1961) to investigate the activity of the meristematic areas of switchgrass at Lincoln, Nebraska. Cycles of activity and inactivity within the plant were noted. Apical dominance in switchgrass was apparent. The rhizome bud activity was high in the spring and the fall, declined in May and June, and increased again from July through September. Crown bud activity of switchgrass was greater than 90% *in vitro* in March, while stem bud activity was less than 30%. In May, crown bud activity was low and 66% of the stem buds were active. In summary, the cyclic nature of bud activity in switchgrass appeared to move upward (late April and early May) from the rhizome and basal crown areas into the stem until floral initiation in late June, then from the stem back down into the basal crown area, and finally into the rhizome late in the growing season. These investigators proposed that with a better understanding of the activity of the growth of the above ground buds and their management, longer periods of usable forage could be provided.

Shoop and McIlvain (1970) observed that weeping lovegrass growth cycles were not as well defined. Growth would generally start in March. This growth was a continuation of the new growth initiated the previous fall. This was in

agreement with Leigh (1961b) who noticed that growth occurred first on the northeast side of the bunchgrass clump in South Africa, the protected environment. Shoop and McIlvain (1970) and Shoop (1977), reported that the lovegrass plant would produce a rapid vegetative growth in the six to nine weeks from the first of April to the middle of June. In the middle of May weeping lovegrass flowered. Subsequent top growth then occurred with optimum environmental conditions.

McMurphy et al. (1975) investigated the native grasses big bluestem, switchgrass, and indiangrass, [Sorghastrum nutans (L.) Nash], and the introduced grass, weeping lovegrass. The native species produced one flush of growth during May and June with only limited regrowth occurring after July 1. Subsequent N applications usually did not cause appreciable regrowth in big bluestem or indiangrass, but did in switchgrass and weeping lovegrass. Thus, fertilizer applications to those grasses should be timed to give primary consideration to the spring flush of top growth. Weeping lovegrass produced more regrowth than the natives in years when there was below average precipitation in the July and August period. However, in one year with above average precipitation in the July-August period, some natives outperformed weeping lovegrass. In addition, switchgrass produced more regrowth at high N and P levels than during any other year. These events suggest that a dormant response to the hot dry summers evolved with the natives as noticed by Laude (1953).

Britton et al. (1978) observed a difference in seasonal biomass production between 1973 and 1974 in an experiment quantifying the biomass production of an Andropogon-Paspalum grassland in Texas. They concluded that higher 1973 production was due to higher available soil moisture from the April to mid-June period. The changes in green biomass weight followed the same trend during both growing seasons. Green biomass increased during spring, to a maximum in the summer, followed by a decline during the fall. This was a slightly different response than that noticed by McMurphy et al. (1975).

Evans and Ely (1935) worked with several cool season pasture and weedy grass species in northern Ohio. New rhizomes were developing in the greatest numbers in June, July, August and early September. This was in agreement with the observations of Johnson and Buchholtz (1962). Evans and Ely (1935) observed that the above ground shoots developed in relatively small numbers during the mid-summer months. The growth patterns of the shoots and the below ground plant parts were different. Although the seasons for the greatest numerical development of rhizomes and above ground shoots overlapped to some extent, they did not coincide. Rhizomes produced in the summer of the previous growing season were terminated as shoots during the current growing season. Weaver (1963) investigated the propensity of the sod forming characters of some native grasses in southeast Nebraska and southwest Iowa. The total length of rhizomes in a square

foot of topsoil was greater than 22 m. for big bluestem and 16 m. for switchgrass.

Lytle and Hall (1980) investigated the carbohydrate variations of two ecophenes, (a tall and a short type), of smooth cordgrass (Spartina alterniflora Loisel.) dealing with the physiology of plant parts associated with dormancy. Carbohydrates were mobilized from the rhizomes in March and April for use in early season growth. In June shoots became large enough to produce and store current carbohydrates. A higher percentage of viable rhizomes was observed in the short type plant. The taller plants had a higher annual turnover rate of rhizomes. They assimilated and utilized more carbohydrates than the short types. Smooth cordgrass stored its carbohydrates as simple sugars to form an osmotically active environment for the salt water environment that was its niche. The storage of carbohydrates in the tall type commenced with the crown's release from apical dominance after initiation of flowering. Storage commenced in October in the short type.

Plant Hormone Actions

Harrison and Kaufman (1980) studied the correlative action of hormones on the release of lateral buds of oat (Avena sativa L.). Decapitation induced 80-90% tiller activation of the buds within four days after treatment. Emergence of the flag leaf and inflorescences were also associated with an equally rapid tiller activation. The

presence of the apical portion of the shoot inhibited tiller activation and growth, presumably by providing auxin to the stem and axillary buds below it. The results on apical dominance have been studied repeatedly following the concentration cycle of one plant hormone. Harrison and Kaufman (1980) and Tucker (1977) inferred that investigating one hormone would not reveal the complete mechanisms of apical dominance. Several plant hormones interact. Tucker concluded that lateral bud outgrowth in the tomato was controlled by a balance of apically produced auxin, cytokinins synthesized in the buds themselves, and abscisic acid from the mature leaves. Harrison and Kaufman (1980) found that the auxins and abscisic acids were centrally involved in dormancy. Gibberellic acid and cytokinin have a more interactive role in the inhibition or release of the lateral buds.

Grass Shoot Developmental Morphology

Booth (1964) explained that the most common form of a branch in the grasses is one which develops from a bud at the base of the parent shoot and becomes rooted in the soil, such as tillers or suckers. It is the presence of these basal branches that permit the bunch type grasses to develop the bunch habit. It is also these basal buds that are functional in the development of new shoots each spring in the perennial grasses. Hamilton (1948) working with four oat varieties observed that buds are found in the axils of the coleoptile

and first and second leaves above the coleoptile. The main tillers developed from buds in the axils of the first two foliage leaves.

Researchers have determined several environmental factors that determine the fate of the buds in the leaf axil. Hamilton (1948) observed that oat bud germination was earlier at 28 C rather than at 16 C. At higher temperatures, relatively few buds develop to produce tillers.

Williams (1975) concluded that physical constraint was important in determining the fate of a wheat (Triticum aestivum L.) tiller. If the growth potential of the developing bud was not greater than the constraint of its physical surroundings, the tiller would not escape. The structural changes of the apical dome often alleviated the problem. During elongation the apex changed from a rather flat dome to eventually be shaped as a cylinder terminating with a dome.

The number of leaves was variable in some grasses. Sharman (1945) observed that there would be some variation from year to year, but that during one season approximately 80% of the plants would have the same number of leaves and the other 20% would vary, usually by one leaf.

The development of the shoot apex or the apical growing point has been the subject of numerous investigations. The leaf primordia development is one criterion for a successful bud. The buds referred to in the literature are numbered from the basal portion of the plant. Often there are leaves that are not readily identified. Stubbendieck and Burzlaff

(1971) indicated that six leaves of blue grama [Bouteloua gracilis (Willd. ex H.B.K.) Lag. ex Griffiths.] were initiated in the fall. Five of these leaves eventually matured below the soil surface. These leaves were designated as the pro axis. Stubbendieck and Burzlaff (1971) determined that blue grama had an average of 15 internodes, the pro axis as described above, the next eight which elongated and made up the reproductive culm, and the last two which were at the top of the peduncle and between the nodes to which the rachises of the spikes were attached. The starting point of jointing was the elevation of the growing point. The process spread vertically by the axis of the plant. The internodes of both wheat and blue grama did not elongate until the leaf attached to the node immediately above had completed elongation, but the internodes of blue grama did start to elongate before the internode directly below had stopped growth. Sims et al. (1973) documented the developmental morphology of blue grama and sand bluestem (Andropogon hallii Hack.). They observed 6 to 9 (average 7) phytomers during the growing season. They never documented the proaxis as did Stubbendieck and Burzlaff (1971). However, by May 29, 73% of the bud elongation had occurred, and by July 28, 96% had occurred. The main point was that a tiller was not an annual structure. Perenniality came from overwintering shoot apices of culmless vegetative shoots, overwintering intercalary meristem of the immature leaves, and axillary buds of the crowns. The shoots of sand bluestem originated primarily

from axillary buds and apical meristem of short, terminal rhizomes which turned upward in late summer or fall to initiate a negative geotrophic growth. The uppermost four phytomers generally produced lateral inflorescences from axillary buds, but these lateral inflorescences developed later than the terminal inflorescences.

Implications to management appear that decapitation would remove a plant from apical dominance. Sims et al. (1973) and Sims et al. (1971) noticed that clipping increased the number of shoots of both switchgrass and sideoats grama [Bouteloua curtipendula (Michx.) Torr.]; however, sideoats grama produced more tillers under mowing than did switchgrass.

Characteristics of Weeping Lovegrass

Palatability is a desirable characteristic of productive forage plants. It is defined as a plant characteristic determined by relative animal preference among two or more forages. Palatability and performance trials have been used to evaluate weeping lovegrass and combinations of weeping lovegrass and other grasses in Oklahoma and South Africa, where weeping lovegrass originated (Voigt et al. 1970, Leigh 1961c, Dwyer et al. 1964).

Leigh (1961c) compared 20 varieties of weeping lovegrass with Chloris and Digitaria. He also compared palatability as influenced by fertilizer levels. The results of this investigation were that Chloris and Digitaria were more

palatable than the Eragrostis. There was a difference among the Eragrostis species in palatability, with E. curvula being the least palatable, particularly at low fertility levels.

Dwyer et al. (1964), using relatively pure stands, compared the grazing preference of 18 species of native and introduced forage plants. Johnsongrass [Sorghum halepense (L.) Pers.] was the most highly preferred species. Other plants that were readily chosen were big and little bluestem [Schizachyrium scoparium (Michx.) Nash], sand lovegrass [Eragrostis trichodes (Nutt.) Wood], alfalfa (Medicago sativa L.), switchgrass, and King Ranch bluestem [Bothriochloa ischaemum var. songarica (Rupr. ex Fisch. & Mey.) Celar. & Harlan]. As the season progressed weeping lovegrass and sericea lespedeza [Lespedeza cuneata (Dumont) G. Don] apparently were avoided by livestock corresponding to the decrease in forage digestibility which is usually seen under these conditions.

The leaf anatomy of weeping lovegrass was studied by Leigh (1961a). He compared grasses of the five groups he proposed within the curvula species. He associated leaf size with the number of vascular bundles, and number of cells making up each vascular bundle. He found five morphologically distinct and anatomically distinct types. The use of Eragrostis curvula anatomical features as a method of separating these types was not practical he concluded.

Translocation of labeled assimilates in the weeping lovegrass plant were reported by Leigh (1961b) and Barnabas

and Steinke (1980), but their methods were different. Leigh compared young growth with the growth of a two year old plant and determined that the young plant assimilated more of the labeled CO_2. However, in the two year old plant labeled assimilates were found in leaves that were not exposed directly to the labeled CO_2. He concluded that some translocation occurred via the "stolons" to adjacent tissues. Barnabas and Steinke (1980) exposed a single leaf to labeled CO_2 and observed a bidirectional movement of the label in the leaf. The gas appeared to move in the lysigenous cavities of the vascular bundles, but at the same time, some of the label was incorporated into sucrose and transported in the phloem. The report of movement to adjacent tillers as reported by Leigh was not mentioned. However, the procedure of Barnabas and Steinke was 50 minutes exposure, and that of Leigh was 30 hours with a light and dark cycle.

There is a void in the center of a clump of an old weeping lovegrass plant. This is characteristic of some perennial bunch grasses. Shoop (1977) observed that the high position at which buds developed and grew into tillers on the parent plant appeared partially responsible for weeping lovegrass tillers not rooting in the center of crowns. Other researchers have noticed that weeping lovegrass would eventually grow itself out of the ground.

Leigh (1960) and Hilliard (1975) studied the effects of temperature and day length on the growth and physiology of weeping lovegrass. Leigh determined that of several factors

studied: 1) temperature was the most important affecting winter dormancy and spring growth; 2) soil moisture was of secondary importance; and, 3) photoperiod did not influence winter dormancy or spring growth. Hilliard (1975) noticed that growth was limited with 10 C nights. The cessation of growth was coincident with the accumulation of starch granules in the chloroplasts. At 18 C the accumultion of starch was not observed in any of the 5 varieties tested. Thus, the plant amyolytic activity was an indication of potential growth in that plants with high amylolytic activity at lower temperatures retained less starch and continued to grow.

Voigt and Bashaw (1972) reported that weeping lovegrass seed was derived by two routes: 1) the normal sexual reproductive processes, and 2) by apomixis. A portion of plants in a population were phenotypically identical to parent plants, but some had characteristics of both parents. This complicated the breeding program and made extensive progeny testing essential. The sexual plants lacked all the genes for the expression of apomixis. This meant that sexually propagated plants would ultimately lose the capacity to reproduce by apomixis and would only be capable of sexual reproduction.

Tissue Culture Protocols

Reductionists believe that a system is best studied by separating it into its component parts. This philosophy has been adopted by plant physiologists, biochemists, and molecu-

lar biologists. Tissue culture techniques enable the investigator to examine tissue, which with some modification and separations would be composed of mitotically synchronized protoplasts (Thorpe, 1981).

The utilization of tissue culture techniques has resulted in some useful discoveries. Gengenbach et al. (1977) discovered that after five cycles of subculturing, all corn (Zea mays L.) plants were resistant to the southern corn leaf blight (Helminthosporium maydis race T) toxin and 52 of 65 were fully male sterile. These plants, regenerated from the protoplasts, were tolerant to the toxin produced in plants by southern corn leaf blight, and would be of value to plant breeders. Chen et al., (1981) noted that the explant of big bluestem provided material for cloning field established individual plants that embryos could not.

Conger (1981) edited an extensive review and documentation of the procedures for tissue culture in most crop plants. In this review, Conger cited the work of others who have distinguished between totipotency, which is an inherent characteristic of most plant cells to regenerate to plants, and the competence of cell types to respond to a given set of conditions used to induce organogenesis. Competence has been a particular problem of Gramineae. Conger (1981) observed that workers spent considerable effort culturing leaf tissue of wheat, maize, and sorghum, but a callus regardless of age of the leaf and composition of the nutrient medium, was never obtained. Apparently, either the leaf cells of cereals lack

totipotency, or the proper conditions have not been developed.

Johnson and Buchholtz (1961) described an *in vitro* method of evaluating the activity of quackgrass rhizomes. Many combinations of placement of explants, and surface sterilization procedures were evaluated. Bud activity was reduced with sodium hypochlorite treatments when concentration and number of treatment times was increased to control fungi. The vertical positioning of the rhizomes gave more reliable results than the horizontal placement. The standard Whites medium in a 0.8% agar suspension was used in their initial studies, but this medium was reduced to agar omitting the nutrient medium because the nutrient medium presented an excellent environment for the growth of fungi. Bud growth was almost completely inhibited by severe contaminating growth of soil micro-organisms.

Koch and Wilson (1977) investigated the effects of phenolic compounds in the allelopathic action of one plant on another. Gentisic acid at a concentration of 230 umol in the medium with isolated mitochondria inhibited respiration by 90% within one minute. Growth inhibition by phenolic acids was less severe in beans (*Phaseolus aureus* Roxb.) exposed to light than in beans exposed to darkness.

Whittaker and Feeny (1971) reported that most soils contained significant amounts of potentially toxic materials from higher plants, notably phenolic acids. The bacteria and fungi of the soil were strongly concentrated towards the

surface of roots. They postulated that chemical gradients might determine which soil organisms could adapt to a specific environment.

CHAPTER III

GROWTH CYCLE STUDY

Introduction

The cyclic nature of plant growth has been reported for many types of grasses (Evans and Ely, 1935). Cyclic growth in rhizomes of quackgrass was an important factor in recommending herbicide application times (Johnson and Buchholtz, 1962). Heidemann and Van Riper (1967), in their dormancy study with switchgrass, found that late season grazing may keep the grass vegetative longer, thus extending the grazing season. Increased summer rainfall allowed more fall regrowth of switchgrass than years when below average rainfall occured (McMurphy et al., 1975).

This study was initiated to identify the growth and dormancy cycles of big bluestem, switchgrass and weeping lovegrass.

Materials and Methods

Field Procedure

Plant materials of three grass species, big bluestem (Andropogon gerardi Vitman), switchgrass (Panicum virgatum L.), and weeping lovegrass [Eragrostis curvula (Shrad.) Nees]

were removed from an established stand on a Teller loam soil (Udic Argiustoll) at the Agronomy Research Station near Perkins, Oklahoma. A previous study (McMurphy et al.,1975) on these grasses evaluated the effect of N and P fertilizer for five years, then the entire area received 90 Kg of N ha^{-1} annually thereafter. The grasses for this investigation were excavated from the check plots which had received no N or P fertilizer in the first five years of the previous studies. Excess soil was removed physically from the 0.3 m^2 blocks of sod. The plants were kept moist in polyethylene bags for transportation to the Plant Physiology Laboratory. The grasses were dug in the morning on the date of culture, and laboratory procedures began as soon as possible after removal from the field.

Laboratory Procedures

In the laboratory the plants were placed in a tray and washed with cold tap water. The roots, tops and foreign plant material were removed. Plants were separated into healthy crowns, rhizome shoots (r-shoots), and rhizome sections. The crowns were centers of older growth of both rhizomes and multiple shoots as seen in Fig. 1. Crowns selected for incubation bore evidence of active or recent topgrowth. The r-shoots were younger single shoots from a rhizome that in time would develop into the crowns with multiple shoots. These r-shoots bore evidence of current or last season's growth. During the growing season topgrowth

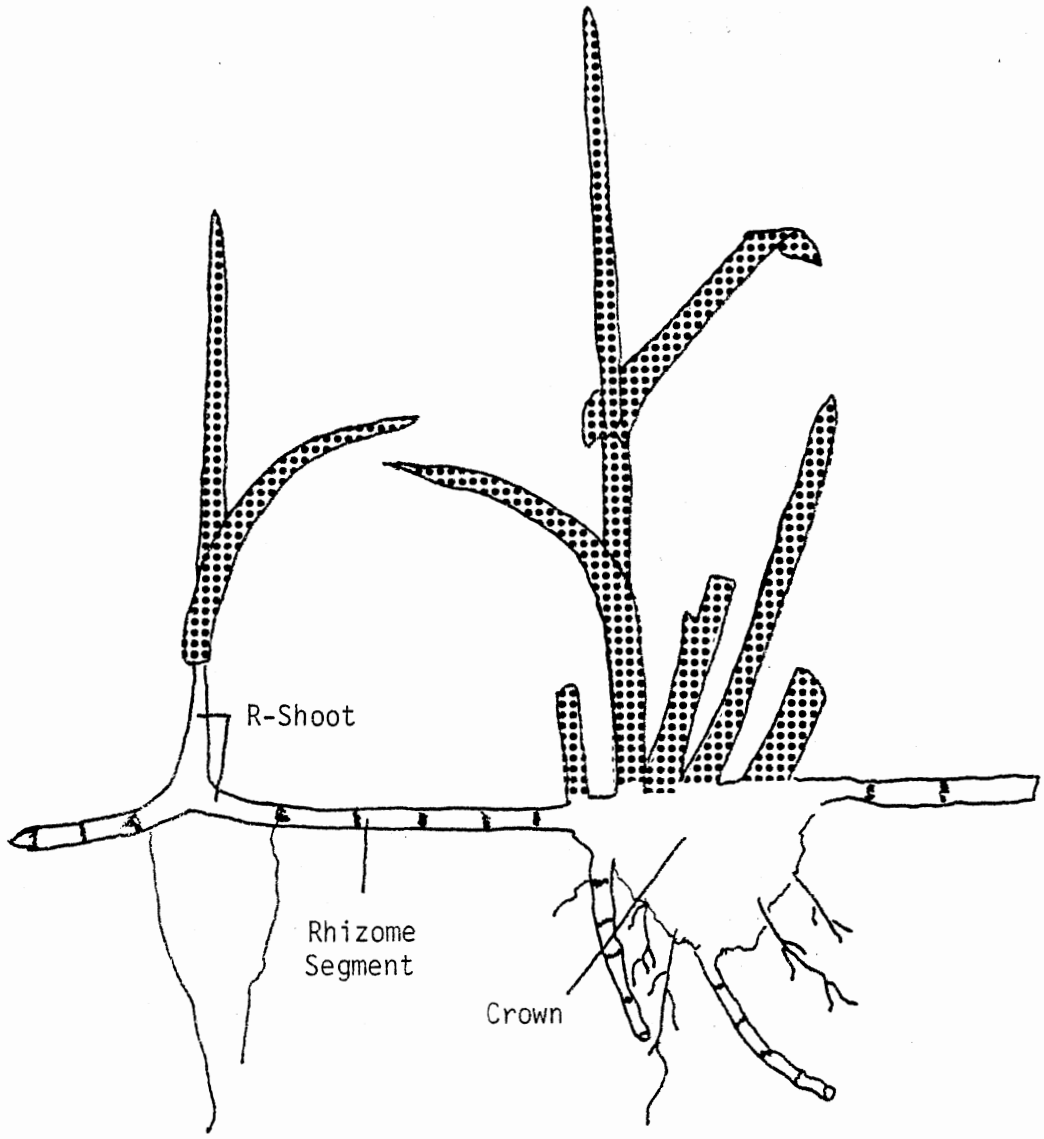

Fig. 1. A native grass plant and terms used in this study.

was obvious. The rhizome sections were apparent in switchgrass and big bluestem (Fig. 1). Weeping lovegrass has a bunchgrass growth habit and plants were separated into individual crowns for incubation. Plant parts were washed with distilled water, placed on moist filter paper in a petri dish, and covered to prevent contamination and desiccation.

An 0.8% agar suspension was used to support the plant parts, 50 ml of the agar suspension was alloted to 125 ml erlenmeyer flasks. Cotton plugs were used on the flasks to permit gas exchange. The flasks were then steam sterilized at 120 C and 1.3 kg cm^{-2} for 25 minutes.

Transfers were made under sterile conditions. The culture dates for the experiment are listed in Table 1. Sibling plant parts were selected for incubation. Twenty four flasks were prepared, six flasks for each of the four replications. Pairs of crowns of big bluestem, switchgrass, and weeping lovegrass were separated and cultured into different flasks so that for each replication there were two flasks of crown buds. The crown bud flasks contained one crown of each species studied. Pairs of r-shoots and rhizome segments of big bluestem and switchgrass were separated similarly and incubated. Thus, within each replication two flasks each contained crowns of all three grass species, two flasks contained r-shoots from big bluestem and switchgrass, and two flasks contained rhizome segments of big bluestem and switchgrass. There were eight observations of each bud type for grasses i.e., a pair of plant parts for the four replica-

Table 1. Incubation dates of the plant parts.

No.	Julian	Calendar	No.	Julian	Calendar
1	120	30 Apr 81	11	275	2 Oct 81
2	134	14 May 81	12	292	19 Oct 81
3	152	1 Jun 81	13	308	4 Nov 81
4	169	18 Jun 81	14	324	20 Nov 81
5	182	1 Jul 81	15	364	30 Dec 81
6	196	15 Jul 81	16	415	19 Feb 82
7	213	1 Aug 81	17	454	30 Mar 82
8	226	14 Aug 81	18	471	16 Apr 82
9	245	2 Sep 81	19	493	8 May 82
10	261	18 Sep 81	20	524	8 Jun 82

tions. The six flasks containing each replication were placed in a cardboard box after transfer. The box was closed to exclude light and the four boxes were incubated in the constant temperature room at 28 C.

Observations were made after approximately two weeks. Activity was recorded for all buds showing elongation of shoots greater than 5 mm. The number of active buds at each culture date was analyzed as a percent of the eight similar buds cultured. This is referred to as the percent active crowns, r-shoots, or rhizome segments. The percent active was analyzed by the analysis of variance to compare culture dates. The percent active in eight observations was analyzed by the Statistical Analysis System (SAS). The T-test was used to test the hypothesis that the mean percent active was equal to zero. Those means significantly greater than zero were considered active or active plant parts (Analysis of variance Tables are in the Appendix). The mean and standard error were used to compare adjacent culture dates.

Crown Results and Discussion

Activity

The data presented in Fig. 2 and Table 2 express the variation in percent active crown buds in the three grass species among different dates of culture. The percent active was the fraction of active crowns in eight observations. The standard error of the mean is presented.

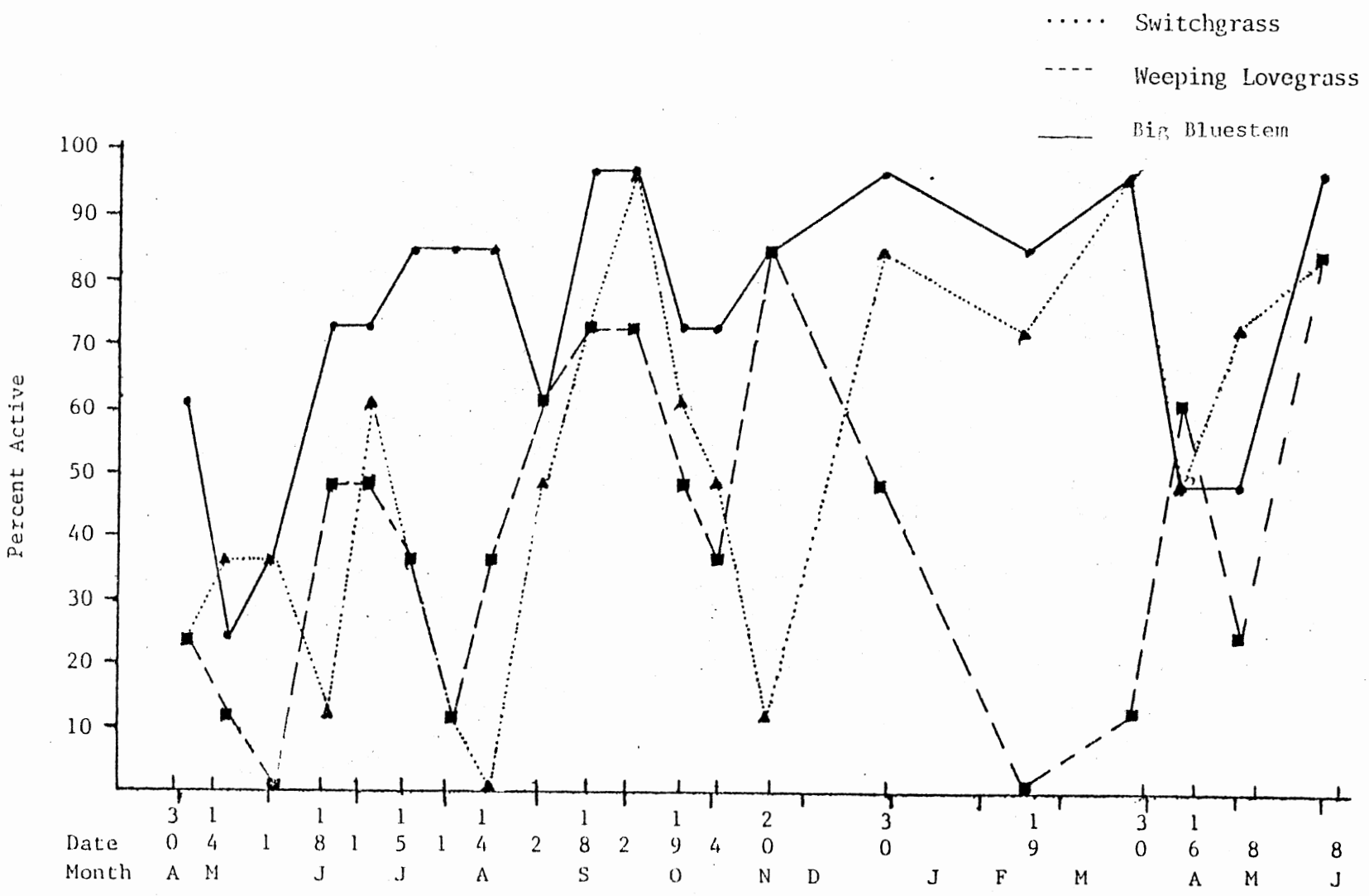

Fig. 2. The mean percent active crowns of big bluestem, switchgrass and weeping lovegrass at different culture dates in 1981 and 1982.

Table 2. Means and standard error of the percent active crowns in the three grasses at different culture dates in 1981 and 1982.

Culture Dates	Big Bluestem		Switch Grass		Weeping Lovegrass	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
30 Apr 81	62.5*	18.3	25.0	16.4	25.0	16.4
14 May 81	25.0	16.4	37.5	18.3	12.5	12.5
1 Jun 81	37.5	18.3	37.5	18.3	0.0	0.0
18 Jun 81	75.0*	16.4	12.5	12.5	50.0*	18.9
1 Jul 81	75.0*	16.4	62.5*	18.3	50.0*	18.9
15 Jul 81	87.5*	12.5	37.5	18.3	37.5	18.3
1 Aug 81	87.5*	12.5	12.5	12.5	12.5	12.5
14 Aug 81	87.5*	12.5	0.0	0.0	37.5	18.3
2 Sep 81	62.5*	18.3	50.0*	18.9	62.5*	18.3
18 Sep 81	100.0*	0.0	75.0*	16.4	75.0*	16.4
2 Oct 81	100.0*	0.0	100.0*	0.0	75.0*	16.4
19 Oct 81	75.0*	16.4	62.5*	18.3	50.0*	18.9
4 Nov 81	75.0*	16.4	50.0*	18.9	37.5	18.3
20 Nov 81	87.5*	12.5	12.5	12.5	87.5*	12.5
30 Dec 81	100.0*	0.0	87.5*	12.5	50.0*	18.9
19 Feb 82	87.5*	12.5	75.0*	16.4	0.0	0.0
30 Mar 82	100.0*	0.0	100.0*	0.0	12.5	12.5
16 Apr 82	50.0*	18.9	50.0*	18.9	62.5*	18.3
8 May 82	50.0*	18.9	75.0*	16.4	25.0	16.4
8 Jun 82	100.0*	0.0	87.5*	12.5	87.5*	12.5
Means	76.5		52.5		42.5	

* Denotes means that are significantly greater than zero P=0.05.

In Table 2 the probability that the mean percent active that was observed was significantly greater than zero is denoted for the grasses at each culture date. Big bluestem crown buds were considered active from the 18 June culture throughout the experiment (Table 2). The percent active crowns changed significantly between adjacent culture dates three times. There was a significant increase in percent active crowns between 1 and 18 June. There was a significant decline in percent active crowns after 30 March, followed by an increase in activity by 8 June.

Switchgrass crown buds were inactive early in the 1981 season. However, switchgrass crowns were considered active at the 1 July culture date (Fig. 2 and Table 2). After the 2 September culture date the crowns were active, except for a decline in percent active at the 20 November culture date. The percent active increased significantly at the 1 July, 2 September, 2 October, 30 December and 30 March culture dates. The percent active crowns decreased significantly at 15 July, 19 October, 20 November and 16 April culture dates.

The cyclic nature of growth in weeping lovegrass was similar to switchgrass (Fig. 2) except in the winter. Weeping lovegrass crowns were active from June through early July, from 2 September through 19 October, from 20 November through 30 December, and at 16 April and 8 June. The percent active crowns of weeping lovegrass increased significantly between adjacent culture dates at 18 June, 20 November, 16 April and 8 June. There was a significant decline in

activity at 30 December, 19 February and 8 May culture dates.

The three grasses were simultaneously active only at 1 July, 2 September through 19 October, 16 April and 8 June. The three grasses exhibited coincidentally low percent active crowns from the start of the experiment through 1 June. The percent active crowns appeared to simultaneously decline in October to early November also. Percent active crowns in weeping lovegrass and switchgrass exhibited a temporary decline in percent active crowns followed by similar increases in the period from 1 July to 2 September. However, big bluestem remained active at that time. At 30 December the percent active of big bluestem and switchgrass was high and remained there until the 30 March culture date, while weeping lovegrass percent active decreased at that time.

Shoot Growth

Variation in mean shoot growth, and number of active shoots from which the mean was composed is listed in Table 3 for the different culture dates. Mean shoot growth and number of active crowns was influenced by the environment within the plant, such as carbohydrate reserves, and recent field environment. The crowns were removed from the field and incubated in the dark in a favorable environment to evaluate the effect of the environment on plant growth.

Table 3. Number of active shoots and mean shoot growth from crowns of each grass species at each culture date in 1981 and 1982.

Date	Big Bluestem		Switch Grass		Weeping Lovegrass	
	Number	Length	Number	Length	Number	Length
		-mm-		-mm-		-mm-
30 Apr 81	5	28.2	2	53.1	2	90.0
14 May 81	2	71.0	3	36.0	1	12.0
1 Jun 81	3	19.0	3	28.6	0	0.0
18 Jun 81	6	33.0	1	20.0	4	30.8
1 Jul 81#	6	49.5	5	67.2	4	66.8
15 Jul 81	7	22.7	3	35.3	3	7.3
1 Aug 81	7	37.3	1	60.0	1	5.0
14 Aug 81	7	35.9	0	0.0	3	15.0
2 Sep 81#	5	55.3	4	57.8	5	62.2
18 Sep 81#	8	53.3	6	87.5	6	87.3
2 Oct 81#	8	70.1	8	102.6	6	87.1
19 Oct 81#	6	52.2	5	70.4	4	160.8
4 Nov 81	6	43.3	4	22.5	3	91.2
20 Nov 81	7	63.2	1	17.5	7	103.0
30 Dec 81#	8	63.4	7	62.6	4	172.4
19 Feb 82	7	58.3	6	72.9	0	0.0
30 Mar 82	8	52.0	8	73.3	1	200.0
16 Apr 82#	4	48.5	4	70.2	5	36.0
8 May 82	4	58.8	6	57.2	2	30.0
8 Jun 82#	8	44.8	7	49.1	7	45.0
Means		48.0		52.2		65.1

# Denotes dates of simultaneous activity of all three species.

At five of the eight culture dates at which all of the grasses were simultaneously active (Table 2) greater shoot growth than the mean was produced, except weeping lovegrass at the 2 September 1981 and 16 April 1982 culture dates (Table 3). The dates at which all grasses were considered active and shoot growth greater than their means were 1 July, 18 September through 19 October, and 30 December. Shoot growth was less than the mean in all grasses 8 June 1982, even though all crowns were considered active. From 14 May to 14 August most of the mean shoot lengths were less than the means in each grass.

The cyclic nature of crowns of big bluestem, switchgrass and weeping lovegrass were reported for a growing season. In 1981 there was a period of low activity in the crowns from the start of the experiment to 18 June in all grasses. Heidemann and Van Riper (1967) also observed a depression in switchgrass crown bud activity when the plant was vegetative through anthesis (shortly after mid-June). The anthesis dates of the grasses were mid to late June for switchgrass, the month of May for weeping lovegrass, and after 1 July for big bluestem. Percent active crowns declined after the 2 October culture in all grasses. The first 1981 frost occurred 23 October. There was a similar October decline observed by Heidemann and Van Riper (1967) in switchgrass though they didn't report frost dates. Percent active crowns declined between the 30 March and 16 April, 1981 cultures (Fig 2.), similar to that observed by Heidemann and Van Riper

(1967) at the onset of topgrowth.

A period of high activity was 1 July. This period would occur at the post anthesis stage for switchgrass and weeping lovegrass. Bidwell (1974) and Tucker (1977) have reported that lateral growth increases as the inhibition from the growing point is released. Big bluestem was active after the plant became autotropic in the spring indicating that apical dominance may function to a lesser extent in this species (Bidwell 1974). Crowns were active from early September to mid-October. Shoot growth was also greater than the mean then. The increase in activity observed in this investigation was common for all grasses. This period of growth before the October decline was not observed by Heidemann and Van Riper (1967) who reported a decrease in percent active at that time. The late summer and fall increase in top growth, given above average precipitation and high fertility levels observed by McMurphy et al. (1975), indicate that activity could have been high then too. However, they measured fall accumulation of topgrowth until after frost. Therefore the growth could have occurred as in this investigation, or earlier. Crown percent active may not reflect above ground events. The precipitation in July and August, 1981 was above the mean.

The native grasses were also active in winter after 20 November. There were five days below -1 C before the 20 November culture date. Crown activity in June, 1982 was different than June, 1981 and different than the observations

of Heidemann and Van Riper (1967). A decline in activity was reported in this study in June 1981 and in Heidemann and Van Riper's study in Nebraska. However, the lower temperatures (Appendix Tables 23 and 24) and May precipitation of over 360 mm (Appendix Table 22) delayed normal ontogenetic development in 1982.

R-Shoot Results and Discussion

Activity

The data presented in Fig. 3 and Table 4 express the variation in the percent active r-shoots in big bluestem and switchgrass among the different dates of culture. The percent active was the fraction of active crowns in eight observations. The r-shoots of the two grasses were inactive from the start of the experiment to 18 June culture (Table 4). R-shoots were active at the 1 July culture date, then activity declined from the mid-August to early September period. The r-shoots were active from 30 December to the 30 March culture.

Big bluestem r-shoots demonstrated significant activity changes between adjacent culture dates (Table 4). The percent active big bluestem r-shoots increased significantly at the following culture dates: 1 July, 18 September, 20 November, 1981, and 8 June, 1982. The percent active r-shoots declined significantly at 14 August and the 30 March

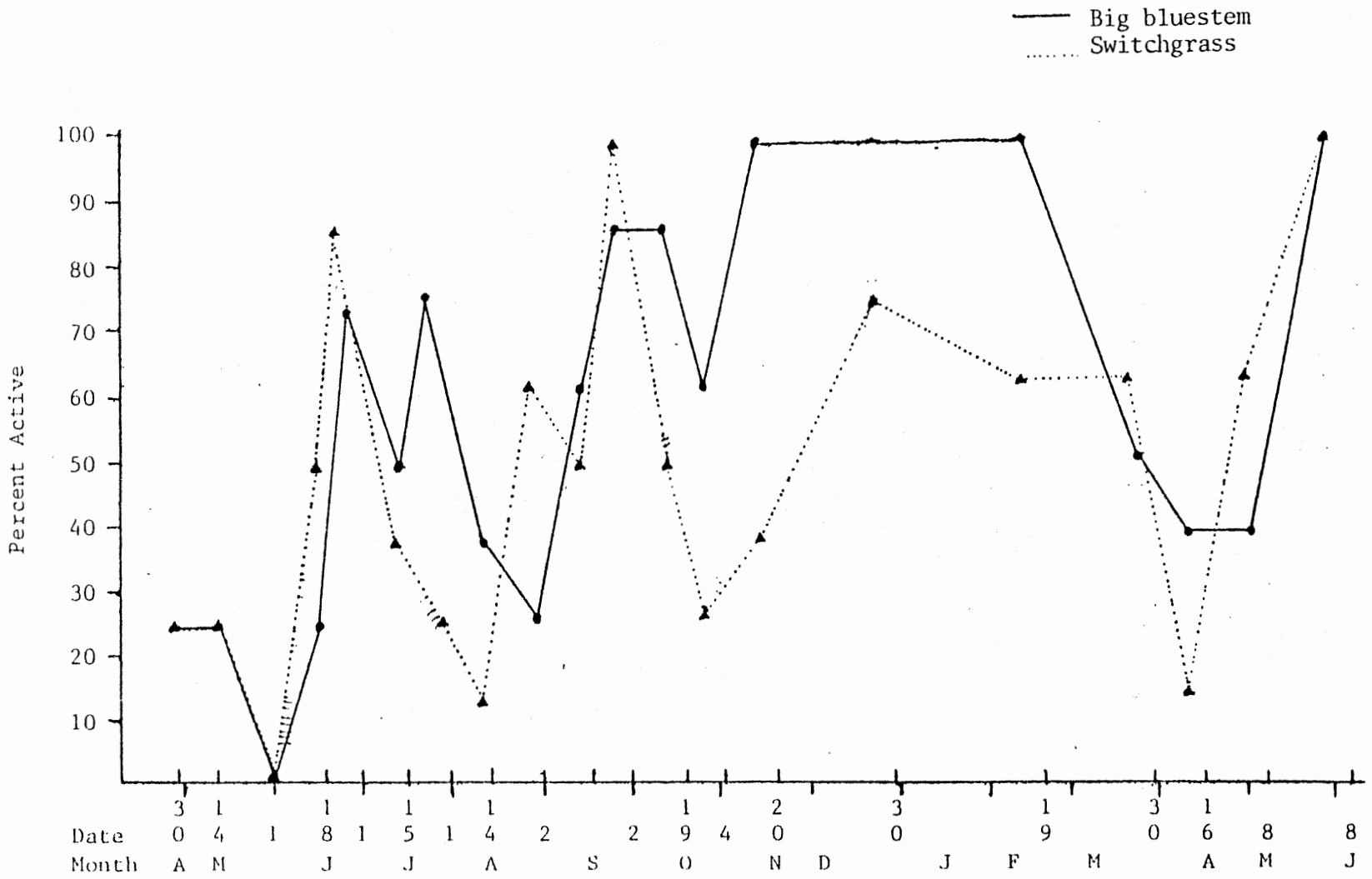

Fig. 3. The mean percent active big bluestem and switchgrass r-shoots at different culture dates in 1981 and 1982.

Table 4. Mean and standard error of the the percent active r-shoots in big bluestem and switchgrass at different culture dates in 1981 and 1982.

Date	Big Bluestem		Switchgrass	
	Mean	SE	Mean	SE
30 Apr 81	25.0	16.4	25.0	16.4
14 May 81	25.0	16.4	25.0	16.4
1 Jun 81	0.0	0.0	0.0	0.0
18 Jun 81	25.0	16.4	50.0*	18.9
1 Jul 81	75.0*	16.4	87.5*	12.5
15 Jul 81	50.0*	18.9	37.5	18.3
1 Aug 81	75.0*	16.4	25.0	16.4
14 Aug 81	37.5	18.3	12.5	12.5
2 Sep 81	25.0	16.4	62.5*	18.3
20 Sep 81	62.5*	18.3	50.0*	18.9
2 Oct 81	87.5*	12.5	100.0*	0.0
19 Oct 81	87.5*	12.5	50.0*	18.9
4 Nov 81	62.5*	18.3	25.0	16.4
20 Nov 81	100.0*	0.0	37.5	18.3
30 Dec 81	100.0*	0.0	75.0*	16.4
19 Feb 82	100.0*	0.0	62.5*	18.3
30 Mar 82	50.0*	18.9	62.5*	18.3
16 Apr 82	37.5	18.3	12.5	12.5
8 May 82	37.5	18.3	62.5*	18.3
8 Jun 82	100.0*	0.0	100.0*	0.0
Mean	58.1		48.1	

* Denotes means within columns that are not equal to zero P=0.05.

cantly between adjacent culture dates 1 June to 1 July, and at 2 September, 2 October, 30 December, 8 May and 8 June (Table 4). The percent active r-shoots declined significantly at the 1 June, 15 July, 19 October, and 30 March culture dates. Big bluestem and switchgrass were simultaneously active at the 1 July, 18 September through 19 October, 30 December through 30 March, and 8 June culture dates.

Shoot Growth

Growth of shoots of both big bluestem and switchgrass were usually above the mean of all culture dates in the fall and winter (Table 5). The r-shoots were active in both grasses and shoot growth was greater than the mean at 18 September, 2 October, and 30 December through 30 March. In the spring of both 1981 and 1982 the shoot growth was generally below the mean. At the 4 November culture date shoot growth was less than the mean.

The activity of crown buds and rhizomes in this paper directly compare with those of Heidemann and Van Riper (1967). However, their stem buds are not equivalent to r-shoots. The percent active r-shoots of big bluestem and switchgrass become quite active at the 1 July culture date. This time corresponds to the post anthesis release from the influence of the growing point as observed by Bidwell (1974) and Tucker (1977). After 1 July, a period of reduced activity was observed in r-shoot buds of both grasses. From

Table 5. Number of active shoots and mean shoot growth in big bluestem and switchgrass r-shoots in 1981 and 1982.

Date	Big Bluestem		Switchgrass	
	Number	Length	Number	Length
		-mm-		-mm-
30 Apr 81	2	17.0	2	11.5
14 May 81	2	57.5	2	25.0
1 Jun 81	0	0.0	0	0.0
18 Jun 81	2	19.5	4	41.0
1 Jul 81	6	41.5	7	37.8
15 Jul 81	4	23.5	3	24.0
1 Aug 81	6	30.8	2	13.5
14 Aug 81	3	22.7	1	18.0
2 Sep 81	2	47.3	5	50.5
18 Sep 81#	5	62.5	4	73.1
2 Oct 81#	7	83.7	8	118.6
19 Oct 81	7	37.0	4	44.8
4 Nov 81	5	36.0	2	12.5
20 Nov 81	8	66.8	3	60.7
30 Dec 81#	8	60.2	6	101.6
19 Feb 82#	8	53.3	5	57.3
30 Mar 82#	4	60.7	5	63.9
16 Apr 82	3	53.7	1	30.0
8 May 82	3	39.0	5	38.1
8 Jun 82	8	54.3	8	41.3
Mean		43.4		43.2

# Denotes culture dates when both grasses are active and growth is greater than the mean.

2 September to 19 October the carbohydrate reserves of the r-shoots are high. Lytle and Hall (1980) observed increase in stored carbohydrates in their investigation.

Percent active r-shoots decreased temporarily following the first frost on 23 October. At the 30 December to 30 March period grasses were active in response to the favorable environment in the laboratory. The shoot growth of both grasses was vigorous after 2 September and during the winter, except for the 4 November culture date. Inhibition was apparent at the 19 October and 4 November culture dates as the mean length of shoot growth declined.

Rhizome Segment Results and Discussion

Activity

The cyclic nature of activity as measured by percent active rhizome segments for big bluestem and switchgrass are presented in Fig. 4 and Table 6. The bluestem rhizome segments were active at the following culture dates in 1981 and 1982: from 1 August through 2 September, 2 October, 20 November, and 19 February. Big bluestem rhizome segments were never over fifty percent active. Analysis of variance indicated no differences in percent active big bluestem rhizome segments among culture dates (Table 6). There were significant increases in percent active rhizome segments comparing adjacent culture dates at 1 August and 2 October culture dates. There were significant declines in percent

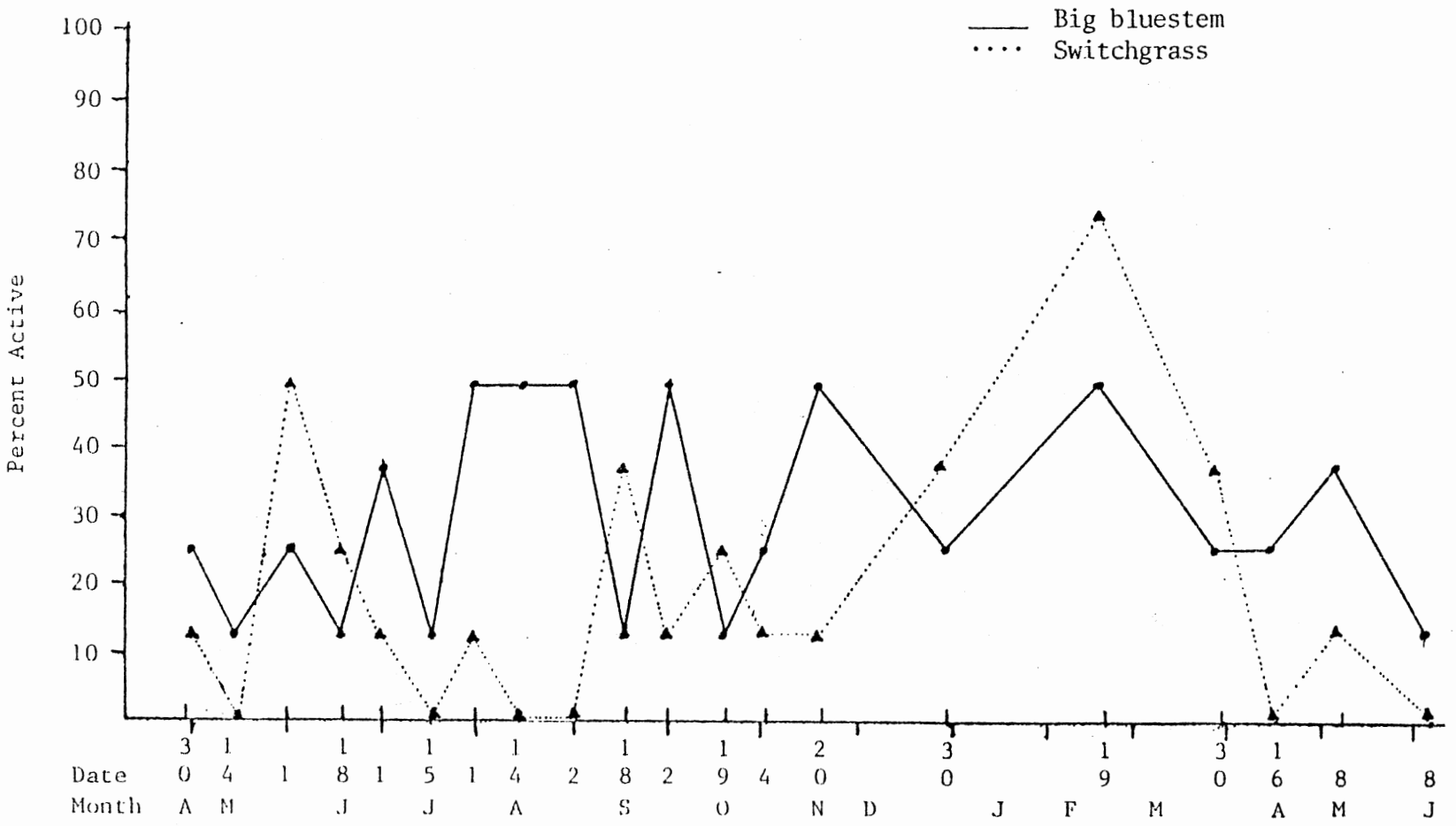

Fig. 4. The mean percent active big bluestem and switchgrass rhizome segments at different culture dates in 1981 and 1982.

Table 6. Mean and standard error of the percent active rhizome segments in big bluestem and switchgrass at different culture dates in 1981 and 1982.

Date	Big Bluestem		Switchgrass	
	Mean	SE	Mean	SE
30 Apr 81	25.0	16.4	12.5	12.5
14 May 81	12.5	12.5	0.0	0.0
1 Jun 81	25.0	16.4	50.0*	18.9
18 Jun 81	12.5	12.5	25.0	16.4
1 Jul 81	37.5	18.3	12.5	12.5
15 Jul 81	12.5	12.5	0.0	0.0
1 Aug 81	50.0*	18.9	12.5	12.5
19 Aug 81	50.0*	18.9	0.0	0.0
2 Sep 81	50.0*	18.9	0.0	0.0
20 Sep 81	12.5	12.5	37.5	18.3
2 Oct 81	50.0*	18.9	12.5	12.5
19 Oct 81	12.5	12.5	25.0	16.4
4 Nov 81	25.0	16.4	12.5	12.5
20 Nov 81	50.0*	18.9	12.5	12.5
30 Dec 81	25.0	16.4	37.5	18.3
19 Feb 82	50.0*	18.9	75.0*	16.4
30 Mar 82	25.0	16.4	37.5	18.3
16 Apr 82	25.0	16.4	0.0	0.0
8 May 82	37.5	18.3	12.5	12.5
8 Jun 82	12.5	12.5	0.0	0.0
Means	30.0		18.8	

* Denotes means within columns that are not equal to zero, P=0.05.

active rhizome segments at the 20 September and 19 October culture dates. Switchgrass rhizome segments were active at two dates, 1 July and 19 February. The percent active was above fifty percent only at the 19 February culture. Activity was variable during the remainder of the experiment. The activity of switchgrass increased significantly between adjacent culture dates at 1 June, 20 September, and 19 February. The percent active rhizome segments declined significantly at 30 March and at 16 April, 1982. Both grasses had simultaneously active rhizomes at the 19 February culture date.

Shoot Growth

At the 2 October and 20 November culture dates big bluestem produced above the mean shoot growth and had one half of the segments active (Table 7). In late summer the shoot growth was reduced, however half of the rhizome segments were active 1 August through 2 September. Shoot growth (Table 7) was above the mean from 2 October through 30 December except for the 4 November culture date.

In switchgrass, at 1 June, 1981 and 19 February, 1982 when the rhizome segments were considered active, resultant shoot growth was greater than the mean (Table 7). Periods with greater than average shoot growth were from 18 September through 19 October, and from 30 December through 30 March. At 4 and 20 November culture dates few shoots were active and resultant growth was below the mean.

Table 7. Number of active shoots and mean shoot growth in big bluestem and switchgrass rhizome segments in 1981 and 1982.

Date	Big Bluestem		Switchgrass	
	Number	Length	Number	Length
		-mm-		-mm-
30 Apr 81	2	22.5	1	8.0
14 May 81	1	59.0	0	0.0
1 Jun 81	2	27.3	4	40.4
18 Jun 81	1	36.0	2	35.0
1 Jul 81	3	54.0	1	56.0
15 Jul 81	1	27.0	0	0.0
1 Aug 81	4	21.4	1	13.0
19 Aug 81	4	19.7	0	0.0
2 Sep 81	4	31.0	0	0.0
18 Sep 81	1	30.0	3	62.7
2 Oct 81	4	44.8	1	72.0
19 Oct 81	1	35.0	2	39.0
4 Nov 81	2	8.5	1	5.0
20 Nov 81	4	57.3	1	12.0
30 Dec 81	2	55.5	3	41.3
19 Feb 82#	4	20.5	6	69.2
30 Mar 82	2	21.3	3	60.0
16 Apr 82	2	57.5	0	0.0
8 May 82	3	31.3	1	60.0
8 Jun 82	1	32.0	0	0.0
Means		34.6		28.7

# Denotes culture dates when both grasses are active.

Rhizome segments of both species were active at 19 February in this study. Heidemann and Van Riper (1967) observed high rhizome activity in November and March though no observations were made over the winter. From 1 August to 2 September rhizome segments percent active was high in this investigation. Switchgrass and big bluestem rhizome sections had fewer culture dates when both were simultaneously active than the other plant parts cultured.

The length of shoot growth from rhizome segments of big bluestem and switchgrass was greater in the period 2 September, 1981 to 30 March, 1982 than at other times of the year. However, shoot growth and number of active rhizome segments was reduced at the 4 November date, and from 4 and 20 November in big bluestem and switchgrass respectively. The length of shoot growth in both species was above the mean during the period 18 June to 1 July, although the number of shoots appearing was below the mean (Table 7).

Summary

The activity of the crowns and r-shoots of the grasses was cyclic as activity increased and decreased significantly in reaction to the environment, but the rhizomes percent active in big bluestem was not different among dates. The mean percent active in crowns and r-shoots increased substantially at the post anthesis stage of development. Weeping lovegrass percent active crowns declined from 1 July to 1 August, and switchgrass crowns and r-shoots reacted

similarly. This activity decrease following the post anthesis release is perhaps the return of the plants to apical dominance. Big bluestem crowns remained active indicating a weak apical dominance response. Plant parts reacted sequentially to the improved environment in late summer. The percent active increased in early August, mid-August, and mid-September in crowns, r-shoots and rhizome segments, respectively. Activity decreased from mid-October to mid-November in all plant parts possibly in response to freezing temperatures. In the mid-October to mid-November period shoot growth of the plant parts was below the mean as well.

Activity of the native species was high in the winter for all plant parts. However, weeping lovegrass activity declined from November to February.

CHAPTER IV

BREAKING DORMANCY STUDY

Introduction

Breaking dormancy appeared to be different in our previous investigations with big bluestem (Andropogon gerardi Vitman), switchgrass (Panicum virgatum L.), and weeping lovegrass [Eragrostis curvula (Shrad.) Nees]. Some grasses terminated dormancy when supplemental moisture was added (Laude, 1953). Other grasses terminated dormancy when day-length and temperature conditions were correct, regardless of soil moisture conditions. Vegis (1964) noted, "...control of dormancy is of complex character, involving controlled growth promotion as well as controlled growth inhibition."

This study was designed to compare the reaction of the three grasses at the termination of the dormant period.

Materials and Methods

Field Procedure

Plant material of the three grass species, big bluestem, switchgrass and weeping lovegrass, were removed from an established stand on a Teller loam soil (Udic Argiustoll) at the Agronomy Research Station near Perkins, Oklahoma. A pre-

vious study (McMurphy et al., 1975) on these grasses evaluated the effect of N and P fertilizer for five years, then the entire area received 90 Kg of N ha^{-1} annually thereafter. The grasses for this investigation were excavated from the check plots which had received no N or P fertilizer in the first five years of the previous studies. Excess soil was physically removed from the 0.3 m^2 blocks of sod. Plants were kept moist in polyethylene bags for transportation to the laboratory.

Laboratory Procedures

The plants were washed and separated. Topgrowth and rhizomes were removed, and roots were pruned sparingly. Plant parts from the second field replication were selected and placed by species in moist sand in an enameled pan 25 x 50 cm, and covered with polyethylene film to avoid desiccation. The pan was placed in the constant temperature room at 28 C in constant light. The three incubation dates were 31 December, 1981, 19 January, 1982, and 30 March, 1982. Data from the 31 December and 19 January incubations were pooled and are reported as the winter incubation. The 30 March incubation was reported as the spring incubation. Shoot counts were made for eight days for each species in the winter incubation. After the incubation period the percent of shoots that emerged each day of the experiment were calculated. These data were analyzed by analysis of variance. Procedures for the spring incubation were similar to the

winter incubation. Identity of the grasses from the four replications from the field were retained through the study. The plants were incubated in plastic pots with a diameter of 16 cm, and a depth of 7 cm. The pots were placed on a Plant Physiology laboratory bench at 23 C with nine hours of light and fifteen hours of darkness.

Results and Discussion

Winter Incubation

The mean percent emerged for weeping lovegrass did not change significantly from the second day after incubation throughout the study (Table 8). The two native grasses were similar in rate of emergence. By the second day, 88.5 percent of weeping lovegrass shoots had emerged, but less than 5 percent of big bluestem and switchgrass shoots had emerged.

Spring Incubation

The mean percent emerged of the four replications are found on Table 9 for the spring incubation. The first observations were made 30 hours after incubation. The percent emerged weeping lovegrass at each observation date was not different (Table 9). After the first day many of the weeping lovegrass shoots had become active.

Big bluestem had a significantly higher mean percent emerged at day four, seven and twelve than at day one or two (Table 9). The mean percent emerged at days one and two were

Table 8. The cumulative mean percent emerged each day of the winter incubation.

Day	Weeping Lovegrass %	Switch-grass %	Big Bluestem %
0	0.0	0.0	0.0
1	69.5	0.0	0.0
2	88.5	4.3	3.5
3	90.5	14.5	3.5
4	98.5	58.5	27.5
5	98.5	78.5	43.5
6	98.5	87.5	82.0
7	100.0	100.0	100.0
LSD 0.05	15.0	14.8	20.2

Table 9. The cumulative mean percent emerged each day of the spring incubation.

Day	Weeping Lovegrass %	Switch-grass %	Big Bluestem %
1	93.3	0.0	0.0
2	96.3	7.5	10.8
4	100.0	48.4	51.3
7	100.0	90.8	80.8
12	100.0	100.0	100.0
LSD 0.05	NS	20.3	36.0

not different, and day seven and twelve were not different.

Switchgrass mean percent emerged was not significantly different comparing days one and two, or seven and twelve. Mean percent emerged at day four was significantly higher than earlier culture dates, but significantly less than later culture dates.

The percent shoots that emerged from crowns was cyclic in our previous investigation and in a study by Heidemann and Van Riper (1967). However, crowns were active in both studies during the period of this investigation.

The procedure as modified by Johnson and Buchholtz (1961) and utilized by Heidemann and Van Riper (1967) suggested incubation in the dark for 14 and 15 days respectively. In this investigation an 8 and 12 day incubation period was utilized in the light. Within grass species there was no difference in percent emerged after seven days in the spring incubation. Thus, the incubation period of the grasses may possibly be shortened.

Laude (1953) measured regrowth to differentiate the grass species that went dormant because of soil moisture deficit from those that became dormant in response to other environmental effects. The difference in weeping lovegrass and the natives in mean percent emerged suggested different mechanisms affected regrowth. Weeping lovegrass continued growth from previously initiated areas. However, the native species initiated a bud and later a new shoot emerged from a crown.

Summary

Weeping lovegrass mean percent emerged increased rapidly and was active after one day in the winter and spring incubation. The native species took two days after incubation to begin visible growth, then activity accelerated rapidly. At one week after incubation no subsequent differences were observed in mean percent emerged within the three grasses. Perhaps the incubation period could be shortened from the previously published two weeks to one week.

CHAPTER V

REGROWTH STUDY

Introduction

Dormancy is an adaptive mechanism that enables plants to survive periods of drought or cold (Vegis, 1964). Quackgrass rhizomes are occasionally active *in vitro* but inactive in the field (Johnson and Buchholtz, 1962). Grasses respond differently to rapid improvement in environmental conditions. Some grasses responded with continued growth, while others are dormant (Laude, 1953).

This study was designed to compare the response of big bluestem, switchgrass, and weeping lovegrass to improvement in environmental conditions.

Materials and Methods

Plant materials of three species, switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardi* Vitman), and weeping lovegrass [*Eragrostis curvula* (Shrad.) Nees] were removed from an established stand on a Teller loam soil (Udic Argiustoll) at the Agronomy Research Station near Perkins, Oklahoma. A previous study (McMurphy et al., 1975) on these grasses evaluated the effect of N and P fertilizer for five years, then the entire area received 90 kg of N ha^{-1} annually

thereafter. The grasses for this investigation were excavated from the check plots which received no N or P fertilizer in the first five years of the previous studies. Excess soil was removed physically from the 0.3 m^2 blocks of sod. The plants were kept moist in polyethylene bags for transportation to the laboratory.

This study was initiated October 13, 1981. The flats were filled with soil from a field adjacent to the plots, then sterilized. Big bluestem and switchgrass plants were taken from a 100 mm^2 area in each replication. Individual bunches of weeping lovegrass of equivalent size were selected for study. Excess soil was physically removed. The below ground plant parts were transplanted intact. Two replications of the three grasses were placed in separate wooden flats. The grass shoots were clipped to a uniform height of 60 mm. The flats were placed in a controlled environment chamber set to provide 14 hours of light, and 10 hours of dark. Day temperature was 24 C, night temperature was 18 C. The relative humidity was 65 to 80% during the day and 100% at night.

Individual shoots growth was harvested on three dates and measured for length (Table 10). The flats were then replaced in the environmental chamber for subsequent harvests. The shoot length and number of shoots were compared by analysis of variance.

Table 10. Mean shoot number and shoot length at each regrowth harvest on 7 November and 28 November, 1981 and 3 January, 1982.

Species	Number of shoots				Length of shoots			
	Nov. 7	Nov. 28	Jan. 3	Mean	Nov. 7	Nov. 28	Jan. 3	Mean
					---------mm---------			
Big Bluestem	1.0	0.5	1.0	0.8a*	51	45	60	52x
Switchgrass	2.0	3.5	7.3	4.3a	99	119	213	144x
Weeping Lovegrass	46.7	52.3	42.5	47.2b	295	228	238	254y
Mean	16.6a	18.8a	16.9a		148u	131u	170u	

* Mean followed by the same letter are not different (LSD with P=0.05).

Results and Discussion

Weeping lovegrass had significantly greater number of shoots, and greater mean shoot length than the native species (Table 10). Switchgrass and big bluestem were similar in number of shoots and length of shoot growth. In all three grasses the mean shoot number and length of shoots harvested at each harvest date were not different.

Laude (1953) had observed a difference in the reaction of plants to improved environmental conditions at the time they usually began dormancy in the spring. Some plants remained green and produced regrowth, others lost color and went dormant as scheduled. The objective of our investigation was to evaluate the response to improvement in conditions of these three grasses at the normal time of the onset of dormancy to determine if they respond similarly.

Sims et al., (1973) found blue grama regrowth proceeded rapidly after cutting when growing conditions were favorable. In this investigation the number of shoots harvested did not change at subsequent harvests. Apparently the growth chamber conditions were such that the three grasses continued growth. In our previous investigation the three species all showed a decrease in crown activity perhaps in response to freezing temperatures in late October and November.

Leaf length and number of leaves per plant are specific plant characters (Sims et al., 1973). The difference in growth habit in this study appeared to influence the number

of shoots emerged. Weeping lovegrass is a bunchgrass Leigh (1961b) and there were many plants per unit area in the observed bunch. The native species are rhizomotous. Weaver (1963) found that big bluestem shoots were more densely spaced than switchgrass. However, with the native species in this investigation, similar blocks of sod produced similar number of shoots, but less than weeping lovegrass. In this investigation the mean number of shoots did not change among harvests.

Summary

Weeping lovegrass produced significantly more shoots of greater length than the native species. Big bluestem and switchgrass were not significantly different in number of shoots produced or length of shoots among the three harvest dates.

CHAPTER VI

FUNGICIDE STUDY

Introduction

Tissue culture has been used to preserve and increase plants of special value, or biotypes with important characteristics such as the tolerance to phytotoxins in maize (*Zea mays* L.) (Gengenbach et al. 1977). Chen et al. (1977) grew viable plants from the callus of big bluestem (*Andropogon gerardi* Vitman), a grass that increases slowly vegetatively. Modifications of *in vitro* techniques have been used by Johnson and Buchholtz (1961) and by Heidemann and Van Riper (1967) to investigate the nature of bud activity in dormancy and physiological studies.

This *in vitro* study, investigating dormancy in crown buds of some Oklahoma grasses, was complicated by procaryotic fungal contaminants. Surface sterilization with ethanol or sodium hypochlorite solution has been recommended in some tissue culture procedures (Conger, 1981). However, Johnson and Buchholtz (1961) reported significant reductions in germination of quackgrass [*Agropyron repens* L. (Beauv.)] buds with several surface sterilization compounds and duration of the treatments. Sodium hypochlorite treatments reduced bud activity by 50 to 80 percent with the greatest reductions

associated with the higher concentrations and repeated applications. Fungal growth was reduced when Whites nutrient medium was omitted.

This study was initiated: 1) to determine if a fungicide suspended in agar would provide fungal control; 2) to compare the effectiveness of two fungicides for controlling the fungal contaminants which occurred during tissue culture; and 3) to determine if the fungicides affected crown bud activity.

Materials and Methods

The two grasses used in this study were 'Kaw' big bluestem (Andropogon gerardi Vitman) and 'Caddo' switchgrass (Panicum virgatum L.). Intact plants were removed from a previously established plot on the Agronomy Research Station at Perkins, Oklahoma. A description of that work was published by McMurphy et al. (1975). Excess soil was removed from the basal shoot in the field, and the plant material was placed in plastic bags for transport to the laboratory. Plant crowns were washed with distilled water in the laboratory, then the roots, rhizomes and topgrowth were excised, leaving the basal culm with crown buds intact.

The two fungicides evaluated in this study were captan, cis-N-[(trichloromethyl)-thio]-4-cyclohexene-1,2-dicarboximide 50% wetable powder, and PCNB penta chloro-nitrobenzene) 75% wetable powder. Treatments tested were three concentrations of each fungicide plus a control with no fungicide. The captan treatments were 50, 100, and 200 mg 200 ml^{-1} of agar.

The PCNB treatments were 75, 150, and 300 mg 200 ml^{-1} of agar. The experimental design was a 2x3 factorial, plus a control, in a completely randomized design with four replications. The experiment was repeated three times with culture dates of 18 September, 4 October and 18 October, 1981.

Each growth medium was prepared by weighing and combining 1.6 g of agar and the appropriate amount of fungicide. Hot water was added to bring the final volume to 200 ml, and 50 ml of the solution were transferred to each of four 125 ml erlenmeyer flasks. The media was steam sterilized at 120 C at 1.3 kg cm^{-2} for 30 minutes. After the agar had solidified one crown bud from each of the two grass species was placed in each flask. Buds were then incubated in the dark at 30 C for 10 days. Buds were considered active when 5 mm of new growth was observed.

Fungal growth was evaluated using a visual rating scale from one to five with one being no fungal growth and five representing a complete fungal covering of the tissue. Fungal ratings were recorded for the 4 October and 18 October experiments only. Fungal rating data were analyzed using the Kruskal-Wallis one-way analysis of variance, a non parametric test, and by the one way analysis of variance. Orthogonal contrasts were used to compare fungal growth in the fungicide treatments to the fungal growth in the control.

Results and Discussion

Fungi growing in the tissue cultures were identified as *Trichoderma* spp. and *Fusarium* spp. Both species belong to the form-class Deuteromycetes (*Fungi Imperfecti*) and are common rhizosphere inhabitants which could be expected to occur in saprophytic association with underground plant parts such as crown buds. Although *Fusarium* can be parasitic on higher plants, it is unlikely that either fungus had any effect on the germination of the crown buds. Both fungi appeared to be growing only as surface contaminants.

The percent relative frequency of crown bud activity as influenced by species, dates, and fungicides treated was recorded. The fungicide treatment value is the mean relative frequency of 24 observations on 18 September and 18 October, and 12 observations on 4 October as the captan treatment failed to gel. Crown activity was not affected by fungicides compared to the control in either grass at any of the culture dates (Table 11). Ontogenetic phases reduced big bluestem bud germination at the 18 October culture. The decline of bud activity, as observed in big bluestem, was not observed in switchgrass and the buds were treated similarly.

Fungal ratings for each treatment are the mean of the fungal ratings of four replications (Fig. 5). Larger fungal rating values indicate greater fungal growth, while lower fungal ratings indicate fungal growth was reduced. PCNB treatments in both big bluestem and switchgrass significantly

Table 11. Percent relative frequency of crown bud germination comparing fungicide treatments to the control.

Culture Dates	Big Bluestem		Switchgrass	
	Fungicide Treatments*	Control	Fungicide Treatments*	Control
	%			
18 September, 1981	63	75	67	75
4 October, 1981#	83	100	58	50
18 October, 1981	8	0	63	100

* No significant difference between the treatment and the control was detected at P=0.05.

Captan treatments omitted, value represents PCNB data only.

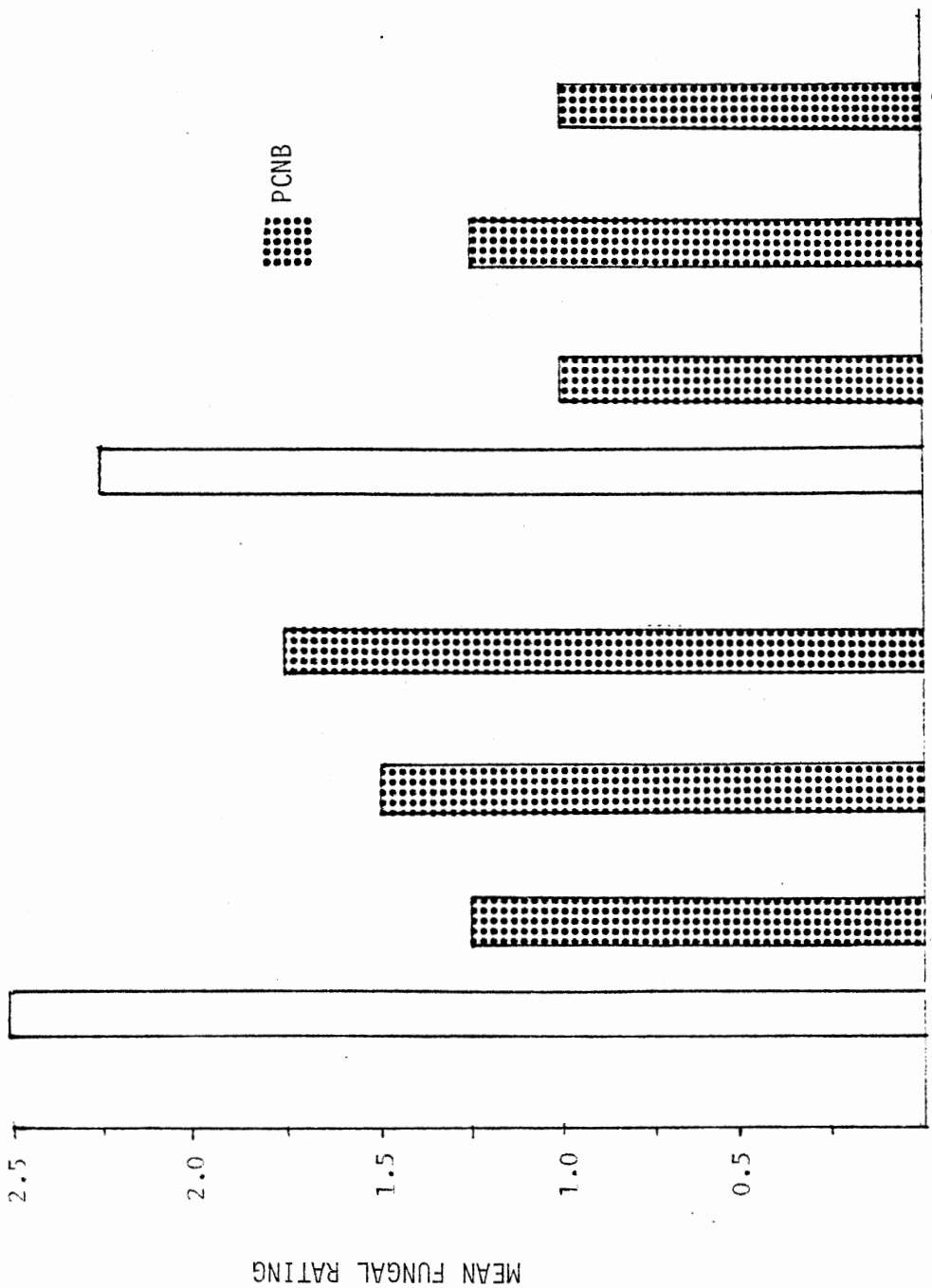

Fig. 5. Fungal growth reduction as mean fungal ratings by PCNB treatments and the control on big bluestem and switchgrass at the 4 October, 1981 culture.

reduced fungal growth compared to the control. Analysis of variance revealed that the fungicide levels did not significantly affect fungal growth in either grass at the 4 October culture (Fig. 5).

Fungicides in the medium significantly reduced fungal contaminants compared to the control in big bluestem at the 18 October culture (Fig 6). PCNB controlled fungal growth on big bluestem crowns significantly better than captan. Captan did not reduce big bluestem fungal growth ratings compared to the control by the nonparametric analysis.

Fungal growth on switchgrass crowns was not reduced at the 18 October culture (Fig. 6), however, the difference between fungicides approached significance (Observed Significance Level = 0.07).

Results of the 4 October culture indicated no reduction in crown bud activity due to fungicide treatment. Bud activity in September and October was variable between the species and dates. The time of year apparently influenced a portion of the crown buds. Heidemann and Van Riper (1967), and Johnson and Buchholtz (1962) noted inactivity of buds and attributed it to apical dominance, or dormancy depending on the time of year.

Fungal contaminants were present in tissue cultures of Johnson and Buchholtz (1961) and Heidemann and Van Riper (1967) and in this investigation. The fungal contaminants were observed to be nonparasitic on mature crowns in this investigation. However, surface sterilization methods to

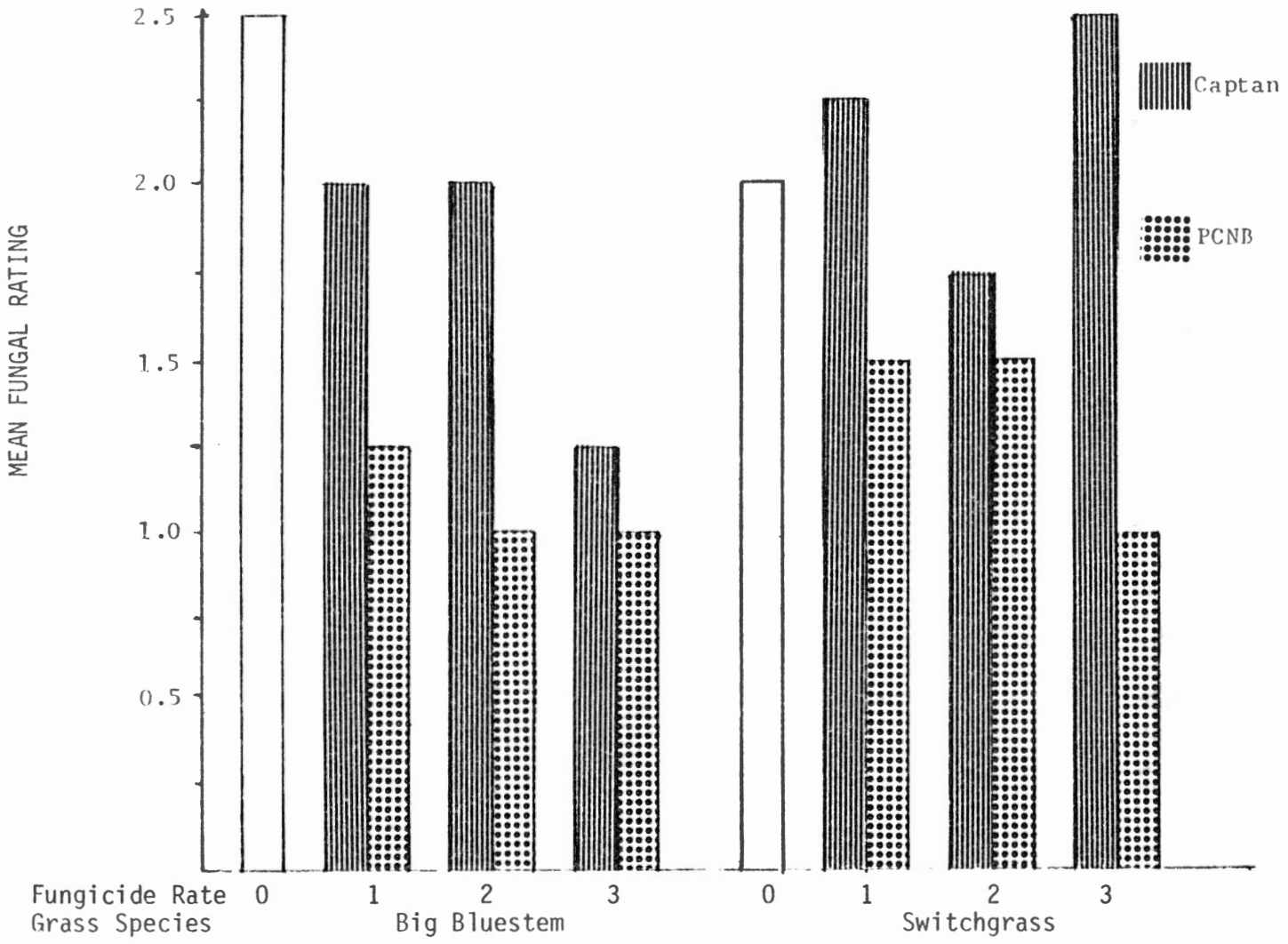

Fig. 6. Fungal growth reduction as mean fungal ratings by fungicide treatments and the control on big bluestem and switchgrass at the 18 October, 1981 culture.

control rhizosphere microorganisms associated with underground plant parts appear necessary to protect emerging shoots.

Summary

Fungicides in the agar medium did help retard the growth of fungi in bud tissue culture and had no effect on crown bud activity *in vitro*. PCNB provided better fungi control than captan.

Fungal control due to concentration of fungicide applied was not different at either culture date. The pooled PCNB treatments significantly reduced fungal growth compared to the control in both grasses at the 4 October culture and in big bluestem at the 18 October culture date. In switchgrass, at the 18 October culture PCNB reduced fungal contamination (Observed Significance Level=0.07) while captan did not. Captan was usually ineffective for fungi control in these tests.

CHAPTER VII

PHYTOMER EMERGENCE IN WEEPING LOVEGRASS STUDY

Introduction

The phytomer is considered to be the basic unit of structure of the grass shoot. It is defined as an internode together with the sheath plus the leaf at its upper end and the bud at its lower end. Position on the parent plant may determine if a shoot of weeping lovegrass [Eragrostis curvula (Shrad.) Nees] will survive (Shoop, 1977). The void in the center of weeping lovegrass may prevent shoots from rooting on the inside, therefore, growth is concentric. Williams (1975) postulated that for a wheat (Triticum aestivum L.) tiller to become active, it must overcome the physical constraint of the phytomers that surround it.

This investigation was initiated to outline the sequence of phytomer emergence in weeping lovegrass, and to determine if bud growth was asymetric.

Materials and Methods

Weeping lovegrass plants were collected from an established stand on a Teller loam soil (Udic Argiustoll) at the Agronomy Research Station near Perkins, Oklahoma. A previous study (McMurphy et al., 1975) on this site evaluated

the effect of N and P fertilizer for five years, then the entire area received 90 kg of N ha^{-1} annually thereafter. The weeping lovegrass plants were excavated from the check plots which had received no N or P fertilizer in the first five years of the previous study. Excess soil was physically removed from the bunch grass plants. The plants were kept moist in polyethylene bags for transportation to the Plant Physiology Laboratory.

The plants were separated into individual crowns in the laboratory. They were placed on moist filter paper in a covered petri dish.

The culture medium was modified to 0.8% agar suspension in full strength Hoaglands solution. Then 50 ml of the medium was placed in 125 ml erlenmeyer flasks. They were steam sterilized at 120 C and 1.3 kg cm^{-2} for 20 minutes. When cool 6 Benzyl adenine was added to make a 3% suspension.

While the medium cooled, the crowns were dissected free of attached leaves and sheaths. The apex was removed on some of the crowns. These crowns were placed upright in the medium. Other crowns were divided vertically with meristematic tissue remaining perpendicular to the plane of the slice and placed on the agar sliced edge down. The crowns were placed in the constant temperature room at 28 C for 24 to 48 hours. Crowns at different stages of development were selected for observation. The two dates of incubation were February 23 and March 30, 1982.

The crowns were dehydrated by serial treatment for 30

minutes in ethanol baths at the Electron Microscopy Laboratory. The ethanol concentration progressed from 70% to absolute. The ethanol and other moisture was removed by freeze drying in liquid CO_2. The crowns were plated and mounted by standard procedures. The Joel 30 Scanning Electron Microscope was utilized for viewing and photography.

Results and Discussion

The potential of weeping lovegrass to produce many shoots through the growing season is shown at 60X in Fig. 7. This view is a lateral bud with two shoots beginning growth. Several shoots can emerge from active buds near the apex of weeping lovegrass crowns. The crowns not selected for microscopic examination were left to grow in the medium for several days. The apical shoots grew rapidly in that period of time, and the lower shoots retained color but ceased growing. Thus, new young dormant shoots remained at the base of the active apical shoot ready to commence the rapid regrowth if released from dominance. Perhaps one reason for the rapid regrowth characteristic of weeping lovegrass is that the regrowth is ready to start from a dormant shoot instead of initiating a bud. Dominant shoots grew regardless of the plane in which the crown was divided. The inclusive view of the crown (Fig. 8) indicates that new growth originates from buds near the apex. The base of the sheath of older top growth, surrounding newly emerged growth, can be

Fig. 7. Weeping lovegrass crown with two active shoots emerging from one bud.

Fig. 8. Weeping lovegrass crown showing growth of three shoots on the same crown.

seen. The character of new growth emerging from within the whorl of more mature growth is seen in Fig. 9.

Weeping lovegrass crown bud activity is different than cereals. Weeping lovegrass shoots originated from the apex, or the one or two top lateral buds of the crown. In oats Hamilton (1948) observed that tillers originated from lateral buds in the coleoptile and first leaves. Sims et al., (1973) observed bud activity and shoot growth in blue grama [Bouteloua gracilis (H.B.K.) Lag. ex Steud.] and sand bluestem (Andropogon hallii Hack.) originated similar to weeping lovegrass, that is activity originated near the apex of the crown.

Sims et al. (1973) observed that the number of shoots of both switchgrass (Panicum virgatum L.) and sideoats grama [Bouteloua curtipendula (Michx.) Torr.] increased with clipping. Perhaps clipping throughout the season would provide stimuli to bring about the same response in weeping lovegrass, but in our previous study there was no change in the number of shoots present after three repeated clipping treatments.

Leigh (1960) determined that temperature was the most important environmental factor effecting growth of weeping lovegrass. The grass was apparently dormant in the field when the samples were collected in February. However, within two days at 28 C shoot growth occurred rapidly.

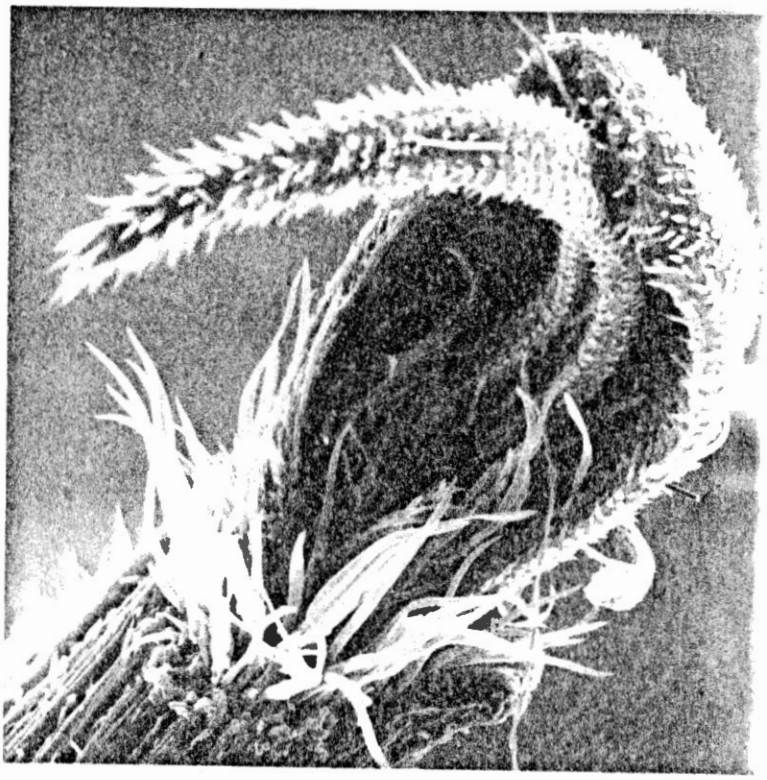

Fig. 9. Emergence of an apical shoot from within an existing sheath.

Summary

Weeping lovegrass has the ability to produce many new shoots if the proper stimuli is present. The orientation of the crowns with respect to the void at the center of a mature plant or the outside of the plant should be investigated. The initiation of new bud growth through the year should be investigated as well.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Growth Cycle Study

The activity of the crowns and r-shoots of the grasses was cyclic, as activity increased and decreased significantly in reaction to the environment, but the rhizome percent active in big bluestem was not different among dates. The mean percent active in crowns and r-shoots increased substantially at the post anthesis stage of development. After the post anthesis release, activity declined in mid-July to August in weeping lovegrass. Similar declines in percent active were observed in all switchgrass plant parts at that time. However, big bluestem crowns remained active indicating a weak apical dominance response. Plant parts reacted sequentially to the improved environment in late summer. The percent active increased in early August, mid-August, and mid-September in crowns, r-shoots and rhizome segments, respectively. Activity decreased from mid-October to mid-November in all plant parts possibly in response to freezing temperatures. In the mid-October to mid-November period shoot growth of the plant parts was below the mean as well.

Activity of the native species was high in the winter

for all plant parts. However, weeping lovegrass activity declined from November to February.

Breaking Dormancy Study

Weeping lovegrass mean percent emerged increased rapidly and was active after one day in the winter and spring incubation. The native species took two days after incubation to begin visible growth, then activity accelerated rapidly. At one week after incubation no subsequent differences were observed in mean percent emerged within the three grasses. Perhaps the incubation period could be shortened from the previously published two weeks to one week.

Regrowth Study

Weeping lovegrass produced significantly more shoots of greater length than the native species. Big bluestem and switchgrass were not significantly different in number of shoots produced or length of shoots among the three harvest dates.

Fungicide Study

Fungicides in the agar medium did help retard the growth of fungi in bud tissue culture and had no effect on crown bud activity *in vitro*. PCNB provided better fungi control than captan.

Fungal control due to concentration of fungicide applied was not different at either culture date. The pooled PCNB

treatments significantly reduced fungal growth compared to the control in both grasses at the 4 October culture and in big bluestem at the 18 October culture date. In switchgrass, at the 18 October culture PCNB reduced fungal contamination (Observed Significance Level=0.07) while captan did not. Captan was usually ineffective for fungi control in these tests.

Phytomer Emergence In Weeping Lovegrass

Weeping lovegrass has the ability to produce many new shoots if the proper stimuli is present. The orientation of the crowns with respect to the void at the center of a mature plant or the outside of the plant should be investigated. The initiation of new bud growth through the year should be investigated as well.

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APPENDIX

Table 12. Monthly precipitation and deviation from the long term mean at the Agronomy Research Station, Perkins, 1981 and 1982.

	1981		1982	
	PPT	Deviation	PPT	Deviation
	mm			
January	1.3	-37.6	62.2	23.4
February	25.9	-11.2	44.2	7.1
March	42.2	-13.7	34.8	-21.1
April	26.7	-53.6	59.9	-20.3
May	175.8	46.5	370.6	241.3
June	114.8	-1.5	134.1	17.8
July	124.2	36.6	94.2	6.6
August	128.5	47.5	8.4	-72.6
September	49.0	-47.8	22.4	-74.4
October	98.8	17.3	23.1	-58.4
November	102.6	54.4	76.2	27.9
December	4.8	-31.2	92.7	56.6
TOTALS	894.6	+5.7	1022.8	+133.9

Table 13. Minimum and maximum temperatures (C) at the Agronomy Research Station, Perkins, 1981.

Day of Month	Apr		May		June		July		Aug		Sept		Oct		Nov		Dec	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1		23	13	32	14	25	20	27	21	33	19	32	12	31	6	16	-2	7
2		28	10	27	16	29	22	33	22	29	16	23	7	23	5	6	1	11
3		29	17	29	18	28	23	33	26	31	17	27	8	24	6	9	-5	13
4		25	17	23	18	28	22	28	21	33	17	29	14	24	2	10	-3	9
5		19	18	26	18	28	20	29	23	32	17	31	21	31	3	11	-1	13
6		23	11	24	19	30	20	32	22	33	17	30	12	28	2	18	6	17
7		27	9	19	19	32	21	30	19	36	18	31	11	21	2	16	0	18
8		28	12	23	22	33	22	34	17	28	12	29	8	12	7	19	-3	14
9		29	12	23	23	37	22	35	17	29	12	26	8	16	1	10	1	14
10			6	18	24	37	22	37	19	32	13	28	14	15	-4	1	1	8
11		29	3	18	22	30			19	28	17	29	8	20	-1	13	2	4
12	21	33	11	22	21	33	23	35	18	22	17	33	11	15	2	18	1	3
13	9	32	15	25	23	32	22	37	19	22	16	29	15	19	3	17	-4	6
14	7	17	7	25	24	32	26	37	22	31	15	24	15	21	3	18	-2	8
15	8	17	9	22	23	32	24	38	22	33	16	29	12	28	6	18	-11	7
16			12	21	12	26	27	38	20	35	13	25	13	16	4	18	-14	-4
17			15	21	13	28	26	37	19	28	5	19	13	21	4	22	-13	-2
18	18	30	17	28	18	29	24	38	14	24	3	18	6	24	7	22	-9	1
19			8	25	22	33	27	36	14	24	8	27	1	13	4	23	-7	1
20	8	30	5	20	22	36	26	35	14	31	9	27	3	21	-7	5	-2	1
21	12	16	11	24	24	37	23	40	14	26	13	29	9	22	-6	8	1	4
22	13	20	16	27	23	36	22	38	16	27	15	32	4	18	-1	14	-8	1
23	7	25	14	28	22	33	24	38	16	29	17	34	-1	11	1	17	-8	6
24	8	26	16	32	22	35	24	39	18	29	17	30	-2	8	0	17	-5	4
25	15	31	17	27	21	37	22	39	18	33	21	29	3	14	4	23	-6	6
26	13	30	14	25	23	37	24	37	19	33	21	32	-1	4	-2	9	-4	6
27	17	32	16	28	22	36	23	36	17	31	16	31	-1	14	1	8	-2	12
28	17	31	19	31	20	32	18	35	15	27	16	28	7	21	4	11	-7	1
29	12	29	17	30	23	34	19	26	18	31	17	32	9	21	5	9	-9	6
30	17	32	17	24	19	35	18	24	19	32	17	32	12	22	2	12	-8	7
31			15	26			20	26	21	32			13	18			-3	8

Table 14. Minimum and maximum temperatures (C) at the Agronomy Research Station, Perkins, 1982.

Day of Month	Jan		Feb		Mar		Apr		May		June	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1	-8	6	-4	3	1	15	5	21	8	17	7	18
2	-3	7	-4	6	6	19	6	24	8	20	13	22
3	-4	16	-11	-2	3	19	1	28	14	22	13	16
4	-7	0	-15	-9	-4	6	8	19	9	26	12	18
5	-6	11	-16	-11	-4	4	4	23	17	27	12	26
6	-8	15	-19	-9	-9	1	-3	12	7	24	13	26
7	-13	-3	-12	0	-9	6	-3	8	3	13	14	27
8	-13	-4	-4	3	-2	8	2	9	9	21	19	30
9	-9	6	-12	1	-1	14	1	12	12	26	20	31
10	-20	-2	-16	-7	1	17	2	12	14	21	12	29
11	-21	-16	-12	1	3	23	3	17	13	27	16	26
12	-18	-6	-11	2	10	20	10	21	13	17	12	21
13	-13	-3	-12	-1	3	21	9	33	13	20	12	24
14	-15	-6	-3	7	5	17	11	28	11	23	14	26
15	-10	13	5	12	3	13	16	30	12	27	12	31
16	-18	13	-1	14	8	24	19	30	10	20	13	26
17	-17	-11	-1	4	7	24	3	28	12	22	13	26
18	-12	1	1	8	9	27	6	18	14	26	16	26
19	-7	9	-3	11	16	27	11	21	14	23	15	29
20	-6	13	0	19	5	26	5	21	13	27	13	26
21	-6	5	1	21	1	18	-1	14	13	19	16	28
22	-4	7	2	23	-2	11	-3	15	13	24	15	26
23	-12	15	7	26	-1	13	7	21	14	26	17	29
24	-9	1	-1	22	3	18	8	18	13	18	16	29
25	-3	9	-3	11	2	20	9	13	12	22	16	24
26	-6	8	-4	2	-6	10	9	21	13	23	17	27
27	-1	13	-4	3	0	12	8	21	14	26	17	29
28	-5	18	-2	11	2	4	3	21	16	22	16	27
29	-3	13			2	11	6	16	20	31	17	29
30	1	15			7	16	6	16	13	31	20	32
31	-7	1			5	21			13	31		

Table 15. Probabilities that the crowns mean percent active is not zero for the three grasses at all the culture dates in 1981 and 1982.

Culture Dates	Big Bluestem	Switch Grass	Weeping Lovegrass
30 Apr 81	0.01	NS	NS
14 May 81	NS/1	NS	NS
1 Jun 81	NS	NS	*
18 Jun 81	*/2	NS	0.03
1 Jul 81	*	0.01	0.03
15 Jul 81	*	NS	NS
1 Aug 81	*	NS	NS
14 Aug 81	*	*	NS
2 Sep 81	0.01	0.03	0.01
18 Sep 81	*	*	*
2 Oct 81	*	*	*
19 Oct 81	*	0.01	0.03
4 Nov 81	*	0.03	NS
20 Nov 81	*	NS	*
30 Dec 81	*	*	0.03
19 Feb 82	*	*	*
30 Mar 82	*	*	NS
16 Apr 82	0.03	0.03	*
8 May 82	0.03	*	NS
8 Jun 82	*	*	*

/1 NS = Mean not significantly different than zero P=0.05.

/2 * The crowns are observed active therefore the probability that the mean is different than zero P<0.01.

Table 16. Analysis of variance for percent active big bluestem crowns at each culture date in 1981 and 1982.

Source	df	Sum squares	Mean square	F	P>F
Total	159	29.00			
Culture Date	19	7.48	0.39	2.67	0.0006
Replication	7	1.89	0.27	1.82	0.09
Error	133	19.63	0.15		

Table 17. Analysis of variance for percent active switchgrass crowns at each culture date in 1981 and 1982.

Source	df	Sum square	Mean square	F	P>F
Total	159	39.90			
Culture Date	19	14.15	0.74	4.02	0.0001
Replication	7	1.10	0.16	0.85	0.55
Error	133	24.65	0.19		

Table 18. Analysis of variance for percent active weeping lovegrass crowns at each culture date in 1981 and 1982.

Source	df	Sum Square	Mean Square	F	P>F
Total	159	39.10			
Culture Date	19	11.35	0.60	2.92	0.0002
Replication	7	0.50	0.07	0.35	0.93
Error	133	27.25	0.20		

Table 19. Probabilities that the r-shoot mean percent active is not zero for big bluestem and switchgrass at all culture dates in 1981 and 1982.

Culture Dates	Big Bluestem	Switch Grass
30 Apr 81	NS/1	NS
14 May 81	NS	NS
1 Jun 81	NS	NS?
18 Jun 81	NS	0.03
1 Jul 81	*/2	*
15 Jul 81	0.03	NS
1 Aug 81	*	NS
14 Aug 81	NS	NS
2 Sep 81	NS	0.01
18 Sep 81	0.01	0.03
2 Oct 81	*	*
19 Oct 81	*	0.03
4 Nov 81	0.01	NS
20 Nov 81	*	NS
30 Dec 81	*	*
19 Feb 82	*	0.01
30 Mar 82	0.03	0.01
16 Apr 82	NS	NS
8 May 82	NS	0.01
8 Jun 82	*	*

1/ NS= Mean not significantly different than zero P=0.05.

2/ * Crowns are observed active therefore the probability that the mean is different than zero P<0.01.

Table 20. Analysis of variance for percent active big bluestem r-shoots at each culture date in 1981 and 1982.

Source	df	Sum squares	Mean square	F	P>F
Total	159	38.94			
Culture Date	19	14.82	0.78	4.77	0.0001
Rep	7	2.39	0.34	2.09	0.05
Error	133	21.73	0.16		

Table 21. Analysis of variance for percent active switchgrass r-shoots at each culture date in 1981 and 1982.

Source	df	Sum square	Mean square	F	P>F
Total	159	39.94			
Culture Date	19	12.57	0.66	3.47	0.0001
Rep	7	1.99	0.28	1.49	0.17
Error	13	25.38	0.19		

Table 22. Probabilities that the rhizome segment mean percent active is not zero for big bluestem and switchgrass at all culture dates in 1981 and 1982.

Culture Dates	Big Bluestem	Switch Grass
30 Apr 81	NS/1	NS
14 May 81	NS	NS
1 Jun 81	NS	0.03
18 Jun 81	NS	NS
1 Jul 81	NS	NS
15 Jul 81	NS	NS
1 Aug 81	0.03	NS
14 Aug 81	0.03	NS
2 Sep 81	0.03	NS
18 Sep 81	NS	NS
2 Oct 81	0.03	NS
19 Oct 81	NS	NS
4 Nov 81	NS	NS
20 Nov 81	0.03	NS
30 Dec 81	NS	NS
19 Feb 82	0.03	*/2
30 Mar 82	NS	NS
16 Apr 82	NS	NS
8 May 82	NS	NS
8 Jun 82	NS	NS

1/ NS=Mean not significantly different than zero P=0.05.

2/ * Crowns are observed active therefore the probability that the mean is different than zero P<0.01.

Table 23. Analysis of variance for percent active big bluestem rhizome segments at each culture date in 1981 and 1982.

Source	df	Sum square	Mean square	F	P>F
Total	159	33.60			
Culture Date	19	3.60	0.19	0.89	0.59
Rep	7	1.60	0.23	1.07	0.39
Error	133	28.40	0.21		

Table 24. Analysis of variance for percent active switchgrass rhizome segments at each culture date in 1981 and 1982.

Source	df	Sum square	Mean square	F	P>F
Total	159	24.38			
Culture Date	19	6.13	0.32	2.53	0.001
Rep	7	1.28	0.18	1.43	0.20
Error	133	16.98	0.13		

Table 25. Analysis of variance for mean percent emerged at the winter incubation in big bluestem.

Source	df	Sum of squares	Mean Square	F-ratio
Total	15	22728.0		
Days	7	21894.0	3127.7	42.9
Replication	1	324.0	324.0	4.5
Error	7	510.0	72.9	

Table 26. Analysis of variance for mean percent emerged at the winter incubation in switchgrass.

Source	df	Sum of squares	Mean square	F-Ratio
Total	15	26017.2		
Days	7	25483.0	3640.4	93.0
Replication	1	260.0	260.0	6.6
Error	7	274.1	39.2	

Table 27. Analysis of variance for mean percent emerged at the winter incubation in weeping lovegrass.

Source	df	Sum of Squares	Mean square	F-Ratio
Total	15	16626.0		
Day	7	16235.0	2319.3	57.8
Replication	1	110.3	110.3	2.7
Error	7	280.8	40.1	

Table 28. Analysis of variance for mean percent emerged at the spring incubation in big bluestem.

Source	df	Sum of squares	Mean square	F-Ratio
Total	19	36088.9		
Days	4	27001.7	6750.4	12.4
Replication	3	2532.6	844.2	
Error	12	6554.7	546.2	

Table 29. Analysis of variance for mean percent emerged at the spring incubation in switchgrass.

Source	df	Sum of squares	Mean square	F-Ratio
Total	19	35539.6		
Days	4	32900.5	8225.1	47.2
Replication	3	548.6	182.9	
Error	12	2090.4	174.2	

Table 30. Analysis of variance for mean percent emerged at the spring incubation in weeping lovegrass.

Source	df	Sum of squares	Mean square	F-Ratio
Total	19	410.8		
Days	4	104.3	26.1	1.8
Replication	3	134.8	44.9	
Error	12	171.7	14.3	

Table 31. Analysis of variance for number of shoots at the three harvests in 1981 and 1982.

Source	df	Sum Square	Mean Square	F-Ratio	P>F
Total	35	35491.0			
Replication	3	3100.1	1033.4		
Harvest	2	32.7	16.3	0.1	NS/1
Species	2	16001.2	8000.6	36.8	**/2
Harvest X Species	4	217.7	54.4	0.3	NS
Error	24	5219.2	217.5		

1/ NS= The difference was not significant P=0.05.

2/ **= The difference was significant P>0.01.

Table 32. Analysis of variance for shoot length at the three harvests in 1981 and 1982.

Source	df	Sum Square	Mean Square	F-Ratio	P>F
Total	35	12474.8			
Replication	3	569.4	189.8		
Harvest	2	108.8	54.4	1.2	NS
Species	2	2403.0	1201.5	27.3	**
Harvest X Species	4	317.3	79.3	1.8	NS
Error	24	1057.1	44.0		

1/ NS= The difference is not significant P=0.05.

2/ **= The difference is significant P>0.01.

Table 33. Analysis of variance comparing activity of big bluestem crowns treated with fungicide with the control at the 18 September culture.

Source	df	Sum Squares	Mean Square	F	P>F
Total	27	6.43			
Treat	6	1.93	0.32	1.50	0.23
(Control X Fungicides)	1	0.05	0.05	0.25	0.62
Error	21	4.50	0.21		

Table 34. Analysis of variance comparing activity of switchgrass crowns treated with fungicide with the control at the 18 September culture.

Source	df	Sum Square	Mean Square	F	P>F
Total	27	6.11			
Treat	6	0.86	0.14	0.57	0.75
(Control X Fungicide)	1	0.02	0.02	0.10	0.76
Error	21	5.25	0.25		

Table 35. Analysis of variance comparing activity of big bluestem crowns treated with PCNB with the control at the 4 October culture.

Source	df	Sum Square	Mean Square	F	P>F
Total	15	1.75			
Treat	3	0.25	0.08	0.67	0.59
(Control X Fungicides)	1	0.08	0.08	0.67	0.59
Error	12	1.50	0.13		

Table 36. Analysis of variance comparing activity of switchgrass crowns treated with PCNB with the control at the 4 October culture.

Source	df	Sum Square	Mean Square	F	P>F
Total	15	3.94			
Treat	3	1.88	0.06	0.20	0.89
(Control X Fungicides)	1	0.02	0.02	0.07	0.80
Error	12	3.75	0.31		

Table 37. Analysis of variance comparing activity of big bluestem crowns treated withfungicide with the control at the 18 October culture.

Source	df	Sum Square	Mean Square	F	P>F
Total	27	1.86			
Treat	6	0.86	0.14	3.00	0.02
(Control X Fungicides)	1	0.02	0.02	0.50	0.49
(Fungicides)	1	0.17	0.17	3.50	0.07
Error	21	1.00	0.05		

Table 38. Analysis of variance comparing activity of switchgrass crowns treated with fungicides with the control at the 18 October culture.

Source	df	Sum Square	Mean Square	F	P>F
Total	27	6.11			
Treat	6	3.36	0.56	4.27	0.006
(Control X Fungicides	1	0.48	0.48	3.68	0.07
(Fungicides)	1	2.04	2.04	15.5	0.007
Error	21	2.75	0.14		

Table 39. Analysis of variance and the Kruskal-Wallis test on fungal growth ratings effected by PCNB on big bluestem at the 4 October culture.

Source	df	Sum Square	Mean Square	F	P>F
Total	15	10.93			
Treat	3	3.48	1.16	1.86	0.18
(Control X Fungicides)	1	3.00	3.00	4.76	0.04
Rate	2	0.50	0.25	NS	NS
Error	12	7.56	0.63		

- - - - - - - - - - - Nonparametric Test - - - - - - -

Among PCNB treatments	H=0.8	NS
Among PCNB treatments with control	H=4.8	NS

Table 40. Analysis of variance and the Kruskal-Wallis test on fungal growth ratings effected by PCNB on switchgrass at the 4 October culture.

Source	df	Sum Square	Mean Square	F	P>F
Total	15	11.75			
Treat	3	4.25	1.42	2.26	0.12
(Control X Fungicides)	1	4.08	4.08	6.53	0.03
Rate	2	0.17	0.08	NS	NS
Error	12	7.56	0.63		
- - - - - - - - - - - Nonparametric Test - - - - - - - - - - -					
Among PCNB treatments			H=2.13	NS	
Among PCNB treatments with control			H=4.6	NS	

Table 41. Analysis of variance and the Kruskal-Wallis test on fungal growth ratings effected by fungicides on big bluestem at the 18 October culture.

Source	df	Sum Square	Mean Square	F	P>F
Total	27	18.86			
Treat	6	8.39	1.39	2.79	0.04
Fungicides	1	2.67	2.67	5.33	0.03
Rates	2	1.08	0.58	NS	NS
F X R	2	0.58	0.29	NS	NS
(Control X Fungicides)	1	4.02	4.02	8.05	0.01
Error	21	10.50	0.50		

- - - - - - - - - Big Bluestem Nonparametric Test - - - - - - - - -

PCNB		
Among PCNB treatments	H= 1.9	NS
Among PCNB treatments with control	H=12.2	0.01>OSL
Captan		
Among captan treatments	H= 1.9	NS
Among captan treatments with control	H= 4.6	NS

Table 42. Analysis of variance and the Kruskal-Wallis test on fungal growth ratings effected by fungicides on switchgrass at the 18 October culture.

Source	df	Sum Square	Mean Square	F	P>F
Total	27	28.71			
Treat	6	6.21	1.04	0.96	NS
Fungicides	1	4.16	4.16	3.88	0.07
Rates	2	0.25	0.25	NS	NS
F X R	2	1.58	0.79	NS	NS
(Control X Fungicides)	1	0.21	0.21	NS	NS
Error	21	22.77	1.07		

- - - - - - - - - Switchgrass Nonparametric Test - - - - - -

PCNB		
Among PCNB treatments	H=2.0	NS
Among PCNB treatments with control	H=4.4	NS
Captan		
Among captan treatments	H=1.2	NS
Among captan treatments with control	H=0.8	NS

VITA

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Doctor of Philosophy

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