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COLD TOLERANCE OF SWITCHGRASS AND BIG BLUESTEM SEEDLINGS

by

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TITLE

COLD TOLERANCE OF SWITCHGRASS AND

BIG BLUESTEM SEEDLINGS

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COLD TOLERANCE OF SWITCHGRASS AND BIG BLUESTEM SEEDLINGS

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University of Nebraska, 1984

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The seeding of big bluestem (*Andropogon gerardii* Vitman) and switchgrass (*Panicum virgatum* L.) in pasture and range has been limited by slow seedling growth in the spring. Improved germination and growth at low temperatures would increase the likelihood of success for early spring plantings. The objectives of this study were to determine if the photosynthetic rates of big bluestem and switchgrass seedlings are reduced by cold (4.5 C) night treatments, to investigate the effects of divergent selection for high and low seedling fresh weight in a cold-night growth chamber regime, and to examine alternative selection techniques which might be used to improve seedling cold tolerance.

Switchgrass carbon exchange rate (CER) was reduced approximately 20% by one night at 4.5 C in a growth chamber. Big bluestem CER was not affected by the same treatment. This cold-night treatment did not affect the rate of oxygen evolution of switchgrass leaf pieces.

Southern switchgrass cultivars tended to have higher average leaf elongation rates (ALER) in both warm- and cold-night chambers. Progeny from high (HS) and low (LS) fresh weight switchgrass selections had significantly higher ALERs than 'Pathfinder' (PA) in the cold-night chamber. There were no significant differences in ALER

among PA, LS, and HS in the warm-night chamber. At low temperatures, LS and HS tended to germinate more rapidly than PA. For both big bluestem and switchgrass, the progeny of high fresh weight selections had higher seedling fresh weights than the progeny of low fresh weight selections in the cold-night chamber. The same was true for big bluestem, but not switchgrass, in the warm-night chamber. No significant seedling fresh weight differences were observed in the field. No significant differences in CER were found among LS, HS, and PA. For big bluestem, progeny from high fresh weight selections (HB) had a higher respiration rate at 10 C than progeny from low fresh weight selections (LB) and 'Pawnee' (PW). Selection based on seedling fresh weight in a cold-night growth chamber regime appears to be an effective and practical technique for improving seedling cold tolerance and increasing seedling vigor.

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INTRODUCTION

The production of meat, milk and wool is dependent to a large extent on forages which provide approximately 70% of the nutrients fed to ruminants (36). Perennial grass pastures are a potential source of grazed forage from early spring to late fall. Cool-season grasses are most productive in the spring and fall when temperatures are low while warm-season grasses are most productive during the hot summer months (18). The exclusive use of cool-season pastures in a grazing system often results in a marked lack of available forage during the summer (29,43,83). Grazing systems which incorporated both warm and cool-season pastures had higher production per hectare, gains per day and carrying capacity when compared to systems without warm-season grasses (17,52).

Big bluestem (Andropogon gerardii Vitman) and switchgrass (Panicum virgatum L.) are highly productive native perennial warm-season grasses with a number of desirable characteristics. Grazing and haying studies have shown that they can increase animal production when used in conjunction with other forages and are persistent when properly managed (17,43,51,52,83). Available cultivars have acceptable atrazine tolerance and are better weed competitors than other desirable native perennial warm-season grasses (59). Substantial genetic variability for dry matter digestibility has been found in

switchgrass and big bluestem indicating that phenotypic selection can improve the forage quality of these grasses (82,102).

The use of native perennial warm-season grasses has been limited by slow and uncertain stand establishment (59,69,75). These grasses are characterized by slow seedling growth in the spring which invites weed competition and extends the period that the pasture must be protected from grazing and haying. Newly established pastures often must be protected for 2 to 4 years in order to insure successful establishment (82,105). These grasses would be easier to establish if seedling vigor were improved (117).

Two likely components of poor seedling vigor in big bluestem and switchgrass are slow germination and a reduction in the rate of growth as a result of low temperatures in the spring. The germination and growth of big bluestem and switchgrass were severely slowed at temperatures of 20 C and lower (37). Improved germination and growth at low temperatures would increase the likelihood of success for early spring plantings.

Planting earlier in the spring would increase total seasonal growth. Since the longest day of the year occurs on 21 June, an increase in early spring growth would result in more exposed leaf area during the period of greatest radiation receipts. Earlier planting might also improve moisture availability during the seedling stage.

In other warm-season grasses, growth and photosynthetic

rates were reduced by cold-night + warm-day regimes (71,108), but no work has been reported concerning the effects of cold-nights on the subsequent photosynthesis of big bluestem and switchgrass seedlings. The purposes of this study were to determine if the photosynthetic rates of big bluestem and switchgrass seedlings are reduced by cold (circa 5 C) night treatments and to examine the effects of divergent selection for high and low seedling fresh weight in a cold-night growth chamber regime.

LITERATURE REVIEW

SEEDLING VIGOR IN GRAMINEAE

Wright (117) provided an excellent review and discussion of seedling vigor. He pointed out that seedling vigor is reflected as stand establishment and that the environmental influences which affect a plant's genotypic expression during germination and early stages of growth are primary considerations in the definition and assessment of seedling vigor. Thus, the definition of seedling vigor will vary depending on the growing conditions and intended use of the plant. Crop plant seedling vigor has been related to resistance to microorganisms (42). Whalley et al. (109) suggested that range plant seedling vigor be defined in terms of competitive ability in the seedling stage. Rather than define seedling vigor, most authors use a criterion for vigor, such as yield or speed of emergence, which relates to their particular field of interest (96).

The relationship between seed weight and the various criteria for seedling vigor has been extensively investigated. Positive correlations between seed size and seedling vigor have been reported in forage grasses (19,28,38,49,50,55,57,67,80,96, 118) and in grain crops (4,9,46,47,63). Lawrence (54)

reported no consistent relationship between seed weight and the depth from which *Agropyron intermedium* (Host.) Beauv. would emerge. In general, positive correlations between seed weight (or size) and seedling vigor have been found most often within seed lots or seed sources, less often among seed sources within a species and rarely among species (109,117). The effect of seed weight is generally confined to the early stages of growth (57).

Whalley et al. (109) divided grass seedling growth into three stages: 1. Heterotrophic stage: From seed imbibition to emergence and the commencement of photosynthesis. 2. Transition stage: Following commencement of photosynthesis, but before exhaustion of reserves. 3. Autotrophic stage: Following exhaustion of endosperm. McWilliam *et al*. (65) proposed that grass seed reserves were probably in excess of requirements under favorable conditions and might be of value under adverse conditions. Wright (118) and Hsu (37) reported that seed weights dropped most rapidly during the first week after planting and that the seeds had nearly stopped losing weight within three weeks after planting. In Wright's study (118), heavy and light seed genotypes had similar patterns and rate of use of the original seed reserves, but heavy seed genotypes grew more rapidly in the transitional and autotrophic stages. Seed from fast germinating genotypes of blue panicgrass (*Panicum antidotale* Retz.) were heavier and seed reserves were utilized more rapidly than those from slow germinating genotypes (119).

In Altai wild ryegrass (Elymus angustus Trin.), a fast germinating population established significantly better in a field test than a slow germinating population (56). Eragrostis superba Peyr. had a higher initial rate of seed reserve mobilization and utilization and had larger shoots at 3, 7 and 14 days than Panicum coloratum L. (98). Respiration rates of germinating seeds (48,115,116) and mitochondria of seedlings (9) have been positively correlated with seedling vigor.

Patterns of seedling development and seedling morphology have been related to seedling vigor. Through a series of papers from Colorado State Univ. (10,11,40,100,110,111,112), researchers have concluded that seedings of blue grama (Bouteloua gracilis (H.B.K.) Lag.) often fail as a result of an interaction between morphology and environment. Blue grama seedlings have a short coleoptile and a long subcoleoptile internode (mesocotyl) which places tissues from which permanent roots develop near the soil surface. Dry soil conditions (< -50 bars) and temperatures below 15 C prevent permanent root development which restricts seedlings to a single seminal root, limiting leaf area production and ultimately resulting in stand failure. Robacker et al.(77) noted that Elymus canadensis L. seedlings, which had four seminal roots, developed much more rapidly than big bluestem and switchgrass seedlings, each having one seminal root. Rhodes (76), working with Phalaris coerulescens Desf., Festuca

arundinacea Schreb., Dactylis glomerata L., Lolium rigidum Gaud., and Lolium perenne L. X Lolium multiflorum Lam., suggested that the rate and extent of permanent root production was closely associated with seedling competitive ability. Hsu (37) found a close relationship between the development of permanent root dry weight and the development of other tissues in seedlings of big bluestem, switchgrass, indiangrass (Sorghastrum nutans (L.) Nash.), caucasian bluestem (Bothriochloa caucasica (Trin.) C.E. Hubb.) and crabgrass (Digitaria sanguinalis (L.) Scop.).

Yasue and Kazuhiro (120) classified gramineous crops and grasses into three types: coleoptile elongation type, mesocotyl elongation type and intermediate type. With the exception of corn (Zea mays L.), Panicoideae and Eragrostoideae were of the mesocotyl elongation type. Of the Festucoideae, Triticeae were of the coleoptile elongation type while Oryzoideae, Festuceae and Aveneae were of the intermediate type. Mesocotyl length and seed weight were positively correlated within elongation type.

Emergence problems were associated with short coleoptile characteristics in wheat (Triticum aestivum L.) (1,25), but not in barley (Hordeum vulgare L.) (3). Coleoptile length was positively correlated with seed size, emergence and seedling height in intermediate wheatgrass (Agropyron intermedium (Host) Beauv.) (39).

Greater seedling leaf area and total top growth were related to the superior establishment of late-maturing switchgrass strains (75). Giant foxtail (Setaria faberi Herrm.), a vigorous warm-season annual grass, had a more rapid leaf elongation rate and developed dry weight more rapidly than big bluestem, switchgrass, indiangrass and caucasian bluestem. The root/shoot dry weight ratio of switchgrass was similar to giant foxtail, but big bluestem allocated more assimilates to the roots (69). Crabgrass seedlings had higher and faster dry matter accumulation than big bluestem, switchgrass, indiangrass and caucasian bluestem (37).

Clements and Latter (16) stated that above ground seedling weight is probably the best single criterion of seedling vigor. In Phalaris tuberosa Hack. heritabilities of 0.35, 0.12, 0.61 and 0.38 were obtained for seed weight, seedling weight, leaf size and rate of leaf appearance, respectively (16). Breeding programs based on selection for seedling weight have produced populations of Phalaris tuberosa (Hack.) Hitchc. with improved establishment from aerial seeding (20). Selection for seedling leafiness and vigor in sideoats grama (Bouteloua curtipendula (Michx.) Torr.) increased seedling height and survival (103). In corn, divergent selection based on juvenile stalk volume produced populations differing in seedling dry weight and leaf area (32).

LOW TEMPERATURE EFFECTS IN C4 GRAMINEAE

Teeri and Stowe (95) investigated correlations between climatic parameters and the relative proportion of North American grasses having the C4 photosynthetic pathway. Decreases in the proportion of C4 grasses were most strongly correlated with average minimum July temperatures. Few or no C4 species were found in locations with average minimum July temperatures below 8 C. In the Hawaiian Volcanoes National Park, Rundel (84) found that the percent grass cover accounted for by C4 species declined from 100% to less than 5% over a vertical rise of 600 m, corresponding to a 3 C decrease in mean temperature. On Mt. Kenya, no C4 grasses were found at altitudes where the average minimum temperature was below 8 C (97). In an excellent review, Long (58) concluded that C4 species decrease in abundance with decrease in temperature along latitudinal, altitudinal and temporal gradients.

Low temperatures reduce the percentage and rate of germination and emergence of C4 grasses. Emergence of C4 grasses was affected more by low temperatures than C3 grasses (2,8,87). Estimates of optimum C4 germination temperatures ranged from 20 C for big bluestem to 35 C for sand bluestem (*Andropogon hallii* Hack.) and 35/25 C day/night for kleingrass (8,23,26,37,90).

Interactions between the effects of moisture stress and temperature on germination have been observed (64,70,92). Similar temperature effects and interactions have been reported for emergence (31,44,70,).

Laboratory cold germination tests have not been found to be reliable predictors of field performance of corn and grain sorghum (Sorghum bicolor (Moench)) (12,60,61,66,88). Germination of some C4 species was better under alternating temperatures than at constant temperatures (35,90). When unchilled seed was studied, maximum germination percentages of big bluestem, switchgrass, caucasian bluestem and indiangrass were obtained between 12 and 20 C, reflecting the dormancy-breaking effect of a chilling treatment in these grasses (37).

The growth of C4 grasses is generally maximal in the range of 30-35 C and may be very slow or cease entirely around 10-15 C (18,66). In corn, the minimum temperature for autotrophic growth was higher than the minimum for germination and heterotrophic growth (7,34,66). Tillering, leaf appearance rate, leaf area development, root and top growth dry matter accumulation of crabgrass, big bluestem, caucasian bluestem, indiangrass and switchgrass seedlings were dramatically reduced at 20 C compared to 25 and 30 C. The leaf elongation rate was maximal at 25 C for big bluestem and caucasian bluestem and at 35 C for the other grasses (37). A linear reduction in the root growth of pangolagrass (Digitaria decumbens Stent.) was