The grass seedling: When is it established?

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Abstract

Adventitious roots of sufficient length and diameter must develop to assure that the photosynthetic surfaces receive sufficient water and nutrients before grass seedlings can be considered established. We evaluated development of crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult.] and blue grama [*Bouteloua gracilis* (H.B.K.) Lag.] seedlings in the field to decide when they were established. Blue grama and crested wheatgrass seedlings, under the environmental conditions of this study, were considered established 21 days after emergence. At this time, crested wheatgrass seedlings had 4 leaves, 2 adventitious roots penetrating to a depth of at least 80 mm into the soil, and 1 tiller per plant. Blue grama seedlings had about 6 leaves, 2 adventitious roots penetrating to a depth of at least 100 mm into the soil, and 2 tillers per plant. Most seedlings that reached this stage by the end of the first growing season overwintered and survived the following growing season and provided adequate stands for both species.

Key Words: blue grama, *(Bouteloua gracilis)*, crested wheatgrass, *(Agropyron desertorum)*, establishment, seedling development

It is often difficult to decide when establishment occurs following grass seeding. Seedling development occurs in 3 general stages including (1) heterotrophic stage, (2) transition stage, and (3) autotrophic stage (Whalley et al. 1966). It follows that a grass seedling should be completely autotrophic (not reliant on seed reserves) before being considered established.

Hyder et al. (1971) and Hyder (1974) compared morphologies of blue grama [*Bouteloua gracilis* (H.B.K.) Lag.] (type A "panicoid") and crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult.] (type B "festucoid") seedlings. Seedling morphology of the 2 grass species was vastly different. When both species were planted at 18 mm, crested wheatgrass initiated adventitious roots at the depth of planting and blue grama initiated roots at only 2 mm below the soil surface. Thus, adventitious roots of blue grama are exposed to the harsh environment associated with the soil surface, and chances or root survival are poor.

Successful establishment of grass seedlings requires formation of adventitious roots (Hyder et al. 1971). This requirement relates to the water conducting capacity of seminal compared to adventitious roots. Xylem cross-sectional area of the subcoleoptile internode (through which water from the seminal roots must flow) is generally not adequate to supply sufficient water to developing seedlings (Hyder et al. 1971, Wilson et al. 1976, Wilson and Briske 1978, Cornish 1982). For blue grama, the amount of seedling leaf area that the seminal root system could support reached a maximum 68 days after emergence. At this time, blue grama seedlings were vulnerable to atmospheric drought (Wilson and Briske 1978). The total cross-sectional area of xylem in a large adventitious root of blue grama was about 5 times greater than that of the subcoleoptile internode (Wilson et al. 1976). These authors also found that water uptake was 1 to 2 ml per day for blue grama seedlings with only a seminal root and 5 to 10 ml per day for seedlings with 1 large adventitious root (Wilson et al. 1976). Cornish (1982) also observed that the effective xylem radius of seminal roots restricts water uptake and seedling growth for ryegrass (*Lolium perenne* L.) and phalaris (*Phalaris aquatica* L.). In further work, Cornish et al. (1984) found that delayed development of adventitious roots reduced transpiration of grass seedlings within 15 days of emergence and reduced leaf area and tiller development within 3 to 5 weeks. Most seedlings survived less than 4 months without adventitious roots, even when subsoil moisture was available to the seminal roots. Adventitious roots were able to support seedlings without seminal roots from about 20 days after sowing. Our objective was to evaluate the development of crested wheatgrass and blue grama seedlings in the field to decide when they could be considered established and document the above- and belowground development of the grass seedlings at that time.

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Manuscript 6 May 1991.

Study Area and Methods

This study was conducted at the Northern Great Plains Research Laboratory, Mandan, N.Dak., and is part of the study reported by Ries and Hofmann (1987). Soils of the study area are a Parshall fine sandy loam (coarse-loamy, mixed *Pachic Haploborolls).* This soil holds 19% soil water by weight at -0.03 MPa (field capacity) and 7% soil water by weight at -1.5 MPa (permanent wilting point). Plots were established on a tilled seedbed in a randomized, complete-block design with 2 replications. Crested wheatgrass and blue grama were seeded at 11 kg/ha of pure live seed on 21 June 1982. Crested wheatgrass was seeded with a drill with depth bands and packer wheels in 15-cm rows at an average 15-mm seeding depth. Blue grama was seeded by hand because its fluffiness did not allow it to flow evenly through the drill. It was seeded in 15-cm rows, raked to cover the seed, and rolled with a packer, at an average seeding depth of 10–12 mm.

Crested wheatgrass and blue grama seedlings for this study were subject to only natural weather conditions. Precipitation, air temperature, and free water evaporation were measured with standard U.S. Weather Bureau instruments and techniques. Weather data were averaged and reported weekly throughout the study except precipitation, which was recorded daily. Soil temperature at the surface (n = 2) and at seeding depth (13 mm) (n = 4) was recorded with ice bath calibrated maximum/minimum thermometers and averaged weekly. Soil water was monitored weekly by neutron probe to a depth of 2 m in 305 mm intervals. Gravimetric soil water samples were taken weekly from the soil surface to a depth of 76 mm in two 13 mm and two 25 mm increments.

Upon emergence, the development of numbers of leaves (main stem), adventitious roots, and tillers per each establishing crested wheatgrass and blue grama seedling was determined. Five seedlings/plot were dug from the soil each Friday, washed from the soil, and measured. Measurements recorded included actual seeding depth in the soil, depth from the soil surface to the point of adventitious root initiation, and depth adventitious roots had penetrated into the soil. Food reserves remaining in the caryopses were observationally evaluated by dissection to estimate the time seedlings could be considered autotrophic.

Weather and soil water data were plotted at the mid-point of each week to provide an evaluation of these parameters throughout the study period. Plant development data were plotted at the weekly harvest date to show sequential plant growth. Differences in seedling development between weekly harvest dates for each species were determined by analysis of variance using a protected

Waller-Duncan test ($P \leq 0.05$) to separate significant mean differences.

Results and Discussion

Ries and Hoffman (1987) report 30 August 1982 densities of 26 and 606 plants/m² for crested wheatgrass and blue grama stands, respectively. The pattern and timing when water was received by the establishing stands appeared more important than amount of water received. The late seeding date (21 June 1982) and subsequent environmental conditions favored warm-season grass establishment.

Maximum soil surface temperatures were 20 ± 2° C warmer than maximum air temperatures. At the 13 mm soil depth, maximum soil temperature was about 10 ± 1° C lower than the soil surface temperature (Fig. 1). Minimum air and soil temperatures 13 mm in the soil were similar.

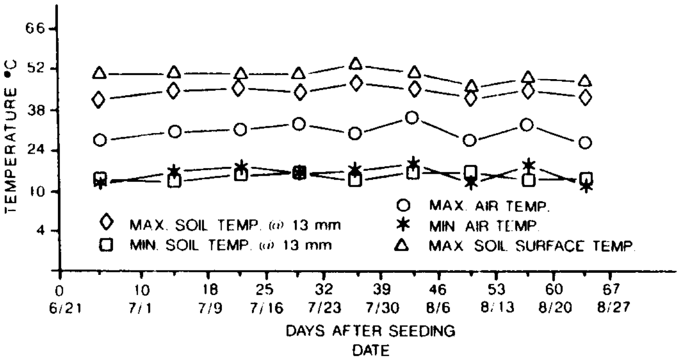

Fig. 1. Weekly average maximum and minimum air and soil temperatures during the summer of 1982 at Mandan, N.Dak.

The longest period without precipitation during the study was 9 days from 28 July through 5 August (Fig. 2). Precipitation received 8 July and 23 through 27 July was very effective because of low water demand as reflected in free water evaporation during these dates.

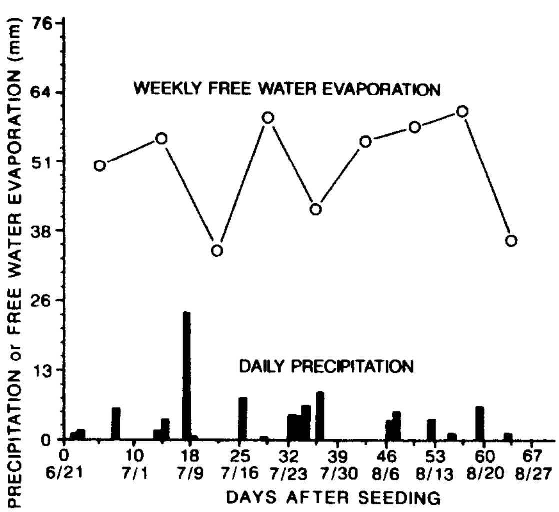

Fig. 2. Weekly average free water evaporation and daily precipitation during the summer of 1982 at Mandan, N.Dak.

Water from the rainfall event of 8 July increased the soil water at all levels in the soil (Fig. 3). The greatest increase in soil water occurred from the rainfall events during 23–27 July. The surface 13 mm of soil was drier than –1.5 MPa during 5 of the 9 sample periods.

Both species emerged during the same week, 25 days after seeding (Figs. 4 and 5). Emergence occurred after the 23 mm precipita-

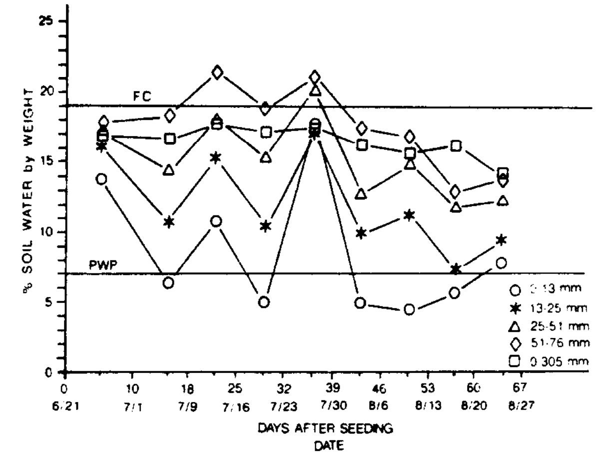

Fig. 3. Weekly average soil water during the summer of 1982 at Mandan, N.Dak. Soil is a Parshall fine sandy loam (coarse-loamy, mixed *Pachic Haploborolls*). (PWP = -1.5 MPa and FC = -.03 MPa).

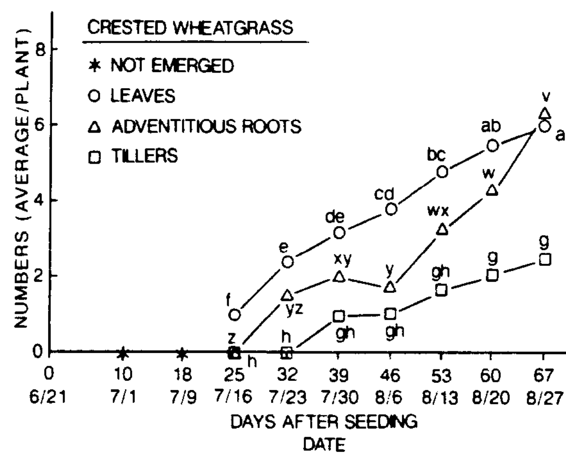

Fig. 4. Weekly number of leaves, adventitious roots, and tillers developed by crested wheatgrass seedlings during the summer of 1982. Points on the same line labeled with the same letter are not significantly different ($P \leq 0.05$).

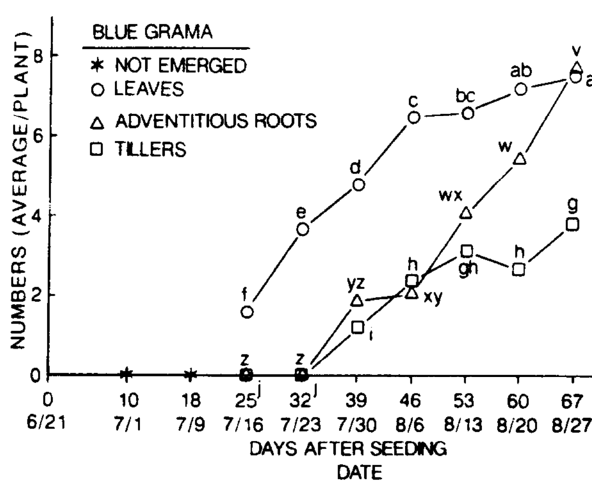

Fig. 5. Weekly number of leaves, adventitious roots, and tillers developed by blue grama seedlings during the summer of 1982. Points on the same line labeled with the same letter are not significantly different ($P \leq 0.05$).

tion event on 8 July (Fig. 2, Fig. 3). On 21 July, 17 and 39% of the pure live seed/m^2 had emerged for crested wheatgrass and blue grama, respectively. Leaf numbers for both species continually increased through the study.

Adventitious roots were observed on 20% of the crested wheatgrass seedlings during the week of 23 July, 7 days after emergence, while blue grama seedlings had no adventitious roots (Figs. 4 and 5). Adventitious roots were observed on 90% of the crested wheatgrass seedlings and 100% of the blue grama seedlings during the week of 30 July, 14 days after emergence (Figs. 4 and 5). The difference in time of adventitious root formation appears related to the type A (blue grama) vs. type B (crested wheatgrass) growth form. Crested wheatgrass initiated adventitious roots near planting depth (15 mm), where soil water was above -1.5 MPa from 17–23 July (Fig. 3). However, adventitious roots of blue grama were initiated only 5 mm below the soil surface where soil water was below -1.5 MPa during 17–23 July (Fig. 3). Initiation of adventitious roots by blue grama followed the precipitation event during 23–27 July (Fig. 2) that increased soil water (Fig. 3) in the 0–13 mm soil depth to above -1.5 MPa. This is consistent with the results reported by Hyder et al. (1971).

During the week of 31 July through 6 August mean maximum air and soil temperatures exceeded 35° C. On 6 August, sampled seedlings of crested wheatgrass (Fig. 4) and blue grama (Fig. 5) had not increased in number of adventitious roots since 30 July. On 6 August, adventitious roots were measured at soil depths greater than 80 mm for crested wheatgrass and 100 mm for blue grama. These depths were well into the zone of available soil water below 25 mm. Adventitious root numbers continued to increase after 6 August to 27 August when measurements ceased. Tiller formation was first observed for crested wheatgrass and blue grama during the week of 30 July, 14 days after emergence, and showed continual increase throughout the rest of the study (Figs. 4 and 5).

Adventitious root numbers and number of leaves increased proportionately until mid-August following adventitious root initiation (Figs. 4 and 5). After mid-August, the number of adventitious roots continued to increase at the same rate, but leaf numbers increased at a much slower rate. This gave essentially the same ratio of adventitious roots/leaves for both crested wheatgrass and blue grama (Fig. 6). Similarly, Svejcar (1990) found that the ratio of root length/leaf area of crested wheatgrass seedlings remained fairly constant during the first month of growth then increased during the second month.

Crested wheatgrass and blue grama seedlings in this study were considered established on 6 August (46 days after seeding and 21 days after emergence). Crested wheatgrass and blue grama seedlings in our study were autotrophic by 6 August because all seed food reserves were exhausted. At this time, crested wheatgrass seedlings had about 4 leaves, 2 adventitious roots, and 1 tiller per plant and blue grama seedlings had 6 leaves, 2 adventitious roots, and 2 tillers per plant. Adventitious roots had formed and had sufficient penetration into the soil to supply the available water (Fig. 3) to the photsynthesizing seedlings. The continuing increase in tiller and adventitious root numbers by the seedlings from 6 August throughout the rest of the study also supports the conclusion that establishment had occurred by 6 August (Figs. 4 and 5). Plant development can be rapid when environmental conditions are favorable. This is shown by the rapid increase in plants with adventitious roots from 23 July to 30 July and by the steep slope of the graph line for number of adventitious roots developed from 6 August to 27 August (Figs. 4 and 5). Observations of these stands the next September showed that most plants present in September 1982 survived the 1982–83 winter and 1983 growing season.

We believe that data presented in this paper support the theories in the literature concerning when grass seedlings are established. Under the environmental conditions of this study, seedlings of both species were considered established 46 days after seeding or 21 days after emergence. These data represent grass seedling development in response to a particular set of environmental conditions. The time required for emergence and leaf, adventitious root, and tiller development can be expected to be different under other sets of environmental conditions. In the future, seeding trials should include some assessment of when adventitious roots become established. Such information in conjunction with weather data will help in building a data base to better assess environmental impacts on seeding success.

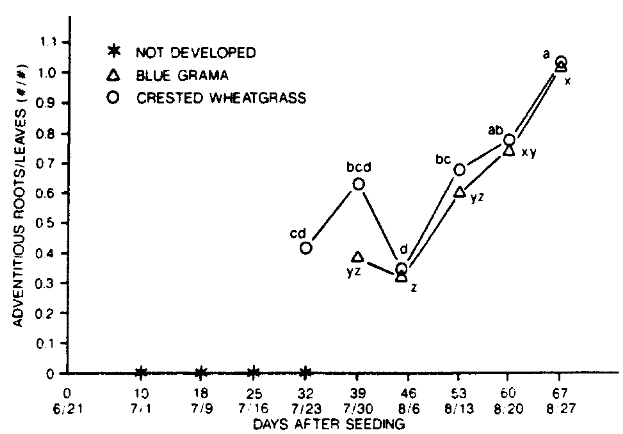

Fig. 6. Ratio of adventitious root number/leaf number for crested wheatgrass and blue grama seedlings during the summer of 1982. Points on same line labeled with the same letter are not significantly different ($P \leq 0.05$).

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