Root length, leaf area, and biomass of crested wheatgrass and cheatgrass seedlings

TONY SVEJCAR

Abstract

Cheatgrass (*Bromus tectorum* L.) dominates large tracts of rangeland in the western United States. Previous research has demonstrated the competitive nature of this species; however, the mechanisms contributing to its dominance have not been well elucidated. It is often suggested that cheatgrass outcompetes perennial seedlings because it germinates and grows at lower soil temperatures. However, even in studies where temperatures are not limiting, cheatgrass outcompetes perennial seedlings. Therefore, I conducted a study to compare accumulation of root length, leaf area, and biomass of cheatgrass and crested wheatgrass (*Agropyron desertorum* (Fisch. ex Link) Schult. cv. Nordan) seedlings under non-limiting conditions. Seedlings were grown in pots in the greenhouse for 60 days post-sowing. There were 4 seedlings per pot, and sampling was conducted weekly at 24–60 days after sowing. Maximum and minimum temperatures were 28° C and 4° C, respectively, and plants were watered twice a week. Cheatgrass had greater root length density and leaf area than crested wheatgrass, especially during the later samplings. For the last 2 samplings, cheatgrass averaged about 12% more root mass and 56% more shoot mass, yet had more than twice the root length and leaf area of crested wheatgrass. Cheatgrass was more efficient (per unit of biomass) in producing leaf area and root length, which helps explain its ability to quickly become established and exploit soil nutrient and moisture reserves.

Key Words: *Agropyron desertorum, Bromus tectorum,* competition, root length density, root: shoot ratio

Cheatgrass (*Bromus tectorum* L.) is a dominant or co-dominant species in much of the Intermountain area of the western United States. In fact, there are situations where rangeland previously classified as sagebrush/bunchgrass is now virtually cheatgrass annual grassland (Young et al. 1987). Many mechanisms may account for the success of cheatgrass. Young et al. (1969) showed that cheatgrass has a flexible reproductive strategy, which allows it to take advantage of the highly variable climate typical of the Intermountain area. Cheatgrass also consistently outcompetes seedlings of perennial species (Evans 1961, Hull 1963, Harris 1967). Among the factors that might account for the competitive ability of cheatgrass relative to perennial seedlings are (1) more rapid germination and growth rate (Hull 1963, Harris 1967); (2) maintenance of root growth at low soil temperatures (Harris 1967); and (3) a root system that is structurally more efficient at exploiting soil moisture (Evans 1961, Harris 1967). Based on morphological and anatomical attributes, Harris (1977) estimated that cheatgrass may produce 3 to 4 times more root length per unit of root mass than bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith). However, I am not aware of any studies that actually quantify the efficiency of the cheatgrass growth habit relative to that of a perennial grass seedling. The objective of this study was to compare growth patterns of cheatgrass and crested wheatgrass (*Agropyron desertorum* (Fisch. ex Link) Schult. cv. Nordan) seedlings in terms of leaf area, root length, and biomass accumulations.

Author is range scientist, USDA, Agricultural Research Service, 920 Valley Road, Reno, Nevada 89512.
The author acknowledges Jim Trent for assistance during all phases of the research. James Young, Marshall Haferkamp, and an anonymous reviewer all made helpful suggestions on an earlier version of the manuscript.
Manuscript accepted 9 November 1989.

Materials and Methods

Seeds of cheatgrass and crested wheatgrass were planted in 10 by 10 by 10 cm pots in the greenhouse. The pots were filled with native soil (sandy loam, mesic Durixerollic Haplargids). Seeds were sown on 11 April 1988 and after germination, plants were thinned to 4 per pot. Pots were arranged in a randomized complete block design with 6 blocks and 5 pots of each species per block. Ambient temperatures were maintained at about 28° C during the day and 4° C at night. Pots were watered regularly to keep soil moisture near field capacity. Sampling was conducted 24 (4 May), 30 (10 May), 37 (17 May), 44 (24 May), and 60 (10 June) days after sowing.

Sampling involved manually washing soil from roots and then separating roots from shoots. Roots from each pot were then analyzed for length using a root length scanner (Comair Corp., Melbourne, Australia)[1], dried at 65° C for 48 hr and weighed. Leaf lamina were separated from other shoot material, scanned for area (LI-3000 with conveyer belt, LI-COR, Inc., Lincoln, Nebraska), dried at 65° C for 48 h, and weighed. Remaining shoot material was also dried at 65° C for 48 h and weighed, and added to leaf lamina weight to give total shoot weight. Data were analyzed using the analysis of variance procedures found in the Statistical Analysis System (SAS). A Hartley's test for homogeneity of variance (Neter and Wasserman 1974) was conducted on root/shoot ratio data. With no transformation the results could be interpreted at $P \leq 0.01$, and with a square root transformation, results could be interpreted at $P \leq 0.05$.

Results and Discussion

Cheatgrass accumulated root length at a much faster rate than did crested wheatgrass (Fig. 1A), and with one exception (day 30), cheatgrass had produced more root length per unit root mass (Fig. 1B). These results are in agreement with the observation of Evans (1961) and Hull (1963). Although these authors were not able to measure root length, they both concluded that cheatgrass had finer roots than crested wheatgrass. By 2 months post-planting, cheatgrass produced twice as much root length as did crested wheatgrass (Fig. 1A). Based on examination of root diameter and structure, Harris (1967) estimated that cheatgrass could produce 3–4 times as much length per unit weight as bluebunch wheatgrass. Roots of crested wheatgrass have about 50% more length per unit weight than those of bluebunch wheatgrass (Caldwell and Richards 1986), so Harris' estimate was probably very close to correct.

Cheatgrass also had more leaf area than did crested wheatgrass (Fig. 2A). As with root length density, cheatgrass accumulated leaf area at a much faster rate than did crested wheatgrass, which resulted in a significant species by sampling date interaction. There was a decline in leaf area of cheatgrass between the fourth and fifth

[1]Mention of a tradename does not indicate endorsement by USDA.

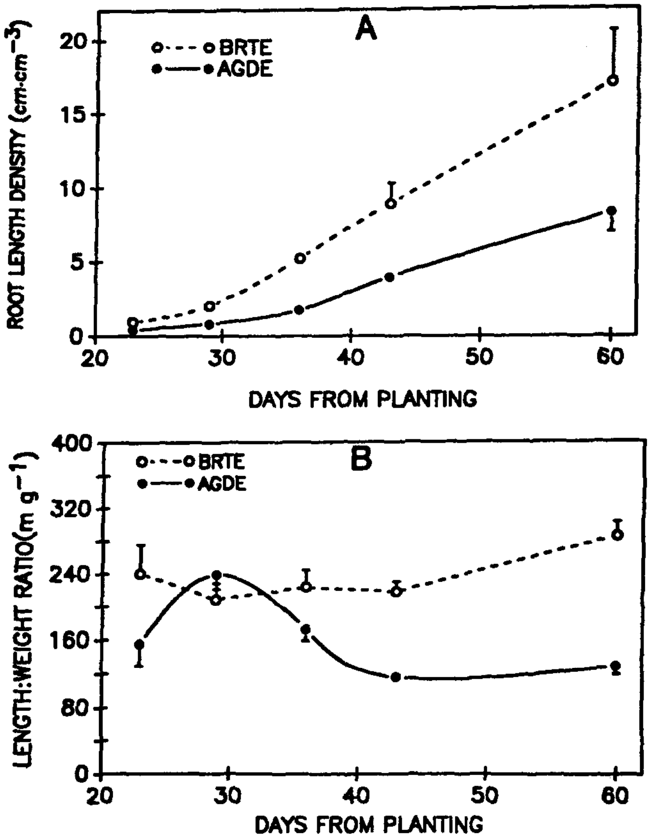

Fig. 1. **Root length density (A) and root length-to-weight ratio (B) of *Bromus tectorum* (BRTE) and *Agropyron desertorum* (AGDE) seedlings. Bars represent 1 standard error of the mean. Probability values for days from planting, species, and the interaction of the 2 factors were <0.0001, <0.0001, and 0.02, respectively, for root length density, and 0.07, <0.0001, and 0.0004, respectively, for length-to-weight ratio.**

sampling dates; presumably the decline was a result of senescence of lower leaves as the long days of June induced a shift from the vegetative to reproductive growth habit. Leaf area of cheatgrass declined even though shoot weight increased from the fourth to fifth sampling (Fig. 3). Cheatgrass generally produced more leaf

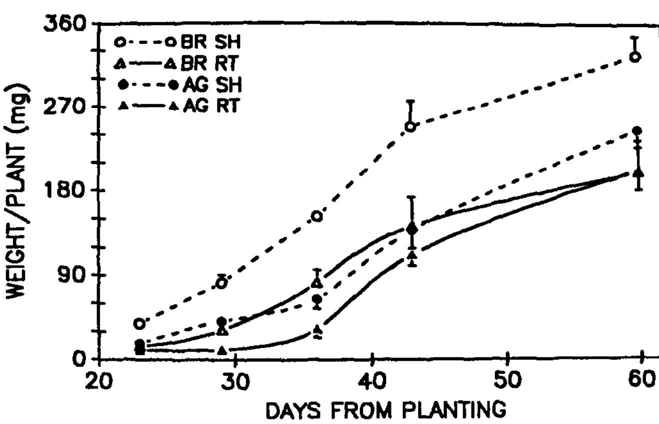

Fig. 3. Root (RT) and shoot (SH) weights for *Bromus tectorum* (BRTE) and *Agropyron desertorum* (AGDE) seedlings. Bars represent 1 standard error of the mean. Probability values for days from planting, species, and the interaction of the 2 factors were <0.0001, 0.045, and 0.48, respectively, for root weight, and <0.0001, <0.0001, and 0.02, respectively, for shoot weight.

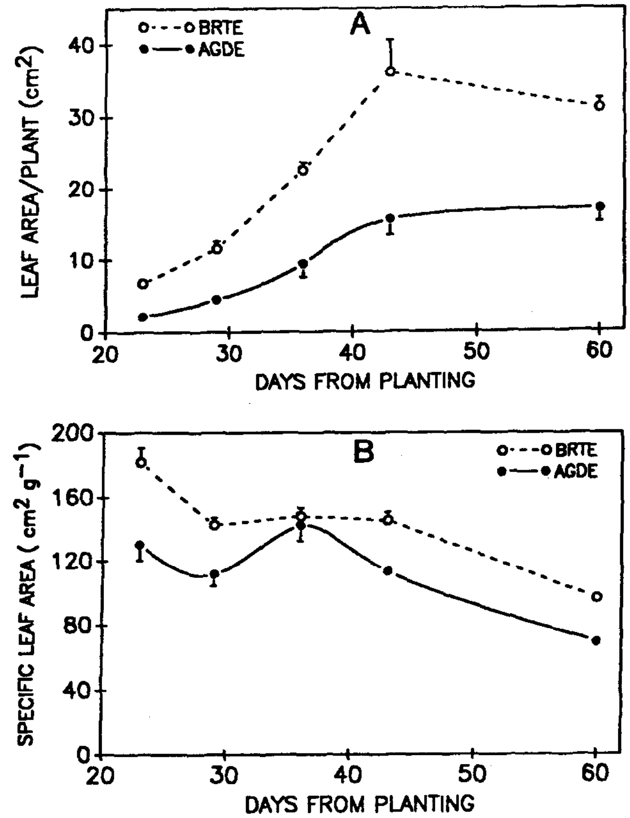

Fig. 2. Leaf area (A) and specific leaf area (B) of *Bromus tectorum* (BRTE) and *Agropyron desertorum* (AGDE) seedlings. Bars represent 1 standard error of the mean. Probability values for days from planting, species, and the interaction of the 2 factors were <0.0001, <0.0001, and 0.0005, respectively, for leaf area, and <0.0001, <0.0001, and 0.02 respectively, for specific leaf area.

area per unit mass than did crested wheatgrass (Fig. 2B). Using shoot weight and shoot area from Buman et al. (1988), I calculated specific leaf areas of about 142 and 115 cm^2 g^{-1} for cheatgrass and crested wheatgrass, respectively. These values, which are for 6-week-old seedlings, are similar to the results obtained on the fourth sampling date in this study (Fig. 2B). It appears that cheatgrass is generally more efficient in producing both leaf area and root length. For example, on the last 2 sampling dates cheatgrass averaged about 12% more root mass and 56% more shoot mass than crested wheatgrass; however, cheatgrass had more than twice the root length and leaf area of crested wheatgrass.

Concepts relating to comparative root and shoot growth have changed over the past several decades. vanNoordwiyk and deWilligen (1987) indicate that thinking has progressed from a morphogenetic equilibrium (the more roots the better shoot growth) to a functional equilibrium which places emphasis on nutrient and water uptake of roots and not just the size of the root system. Emphasis is placed on the interdependence of the functional attributes of root and shoot systems. Generally, root/shoot relationships are best expressed in terms of root and shoot surface areas (Brouwer 1983, Kummerow 1980) or shoot area and root length (Körner and Renhardt 1987). In the present study, I found that root/shoot biomass ratios tended to have high variability and the species comparisons were inconsistent (Fig. 4A). When values were expressed as root length per leaf area, the variability was low during the first 4 sampling dates, and the 2 species exhibited nearly identical trends (Fig. 4b). There are few published reports of root length/leaf area ratios with which to compare my results. Svejcar and Christiansen (1987) measured root length/leaf area ratios of 60

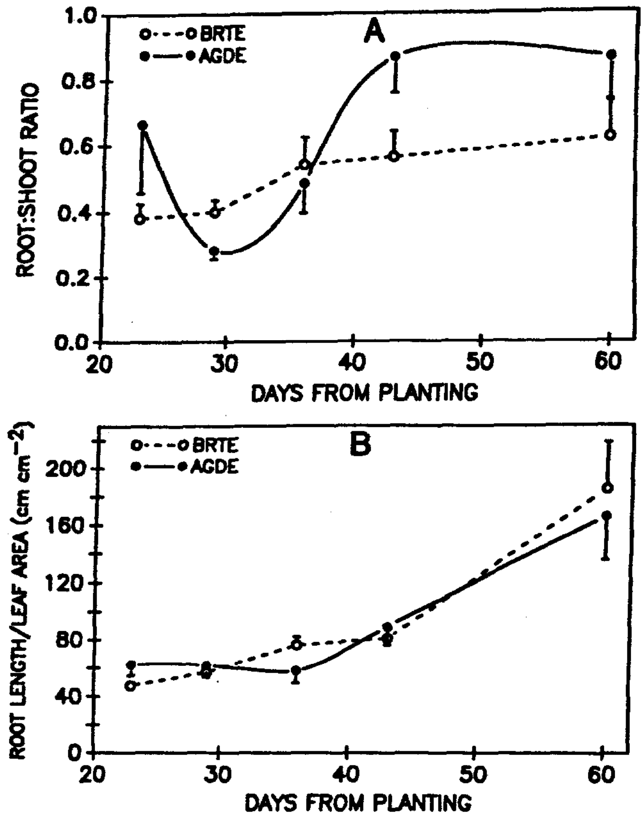

Fig. 4. Root-to-shoot ratio (A) and root length per leaf area (B) for *Bromus tectorum* and *Agropyron desertorum* seedlings. Bars represent 1 standard error of the mean. Probability values for days from planting, species, and the interaction of the 2 were 0.0004, 0.08, and 0.08, respectively, for root/shoot ratio (using a square root transformation) and $<$0.0001, 0.84, and 0.73, respectively, for root length per leaf area.

to 80 cm cm^{-2} for lightly grazed caucasian bluestem (*Bothriochloa caucasica* (Trin.) C.E. Hubb.) in late spring; Körner and Renhardt (1987) obtained values ranging from 0.0056 to 87.09 cm cm^{-2} for samples of 49 species in 2 contrasting elevational positions; and Kummerow (1980) measured values of 23.5 to 234.5 cm cm^{-2} for 4 southern California chaparral shrubs. Root length/leaf area ratios were calculated from data presented by Svejcar and Christiansen (1987) and Kummerow (1980). Certainly root length/leaf area ratios will be influenced by plant species, phenology, and environmental conditons; however, it appears that 60–80 cm cm^{-2} might be expected for fibrous rooted grasses during active growth. More research, however, will be necessary to evaluate this relationship.

To conclude, cheatgrass was more efficient (per unit of biomass) than crested wheatgrass in production of both root length and leaf area. The efficiency of cheatgrass is probably one of the factors contributing to the competitive advantage of this species over seedlings of perennial bunchgrasses. Thus, cheatgrass enjoys a growth advantage over and above its ability to germinate (Young and Evans 1985) and grow roots (Harris 1967) at lower soil temperatures than can bunchgrasses. Studies examining competitive relations based on biomass production alone may miss the more functional responses. The efficient annual growth form of cheatgrass allows it to establish and quickly use available soil moisture and nutrients.

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