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Clipping effects on growth dynamics of Japanese brome

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Abstract

Japanese brome (*Bromus japonicus* Thunb.) has invaded many northern mixed prairie communities. Understanding how defoliation affects the life cycle of this species is critical for proper grazing management of communities infested with this annual. The objective of this study was to determine the effect of defoliation on growth of Japanese brome. Treatments included no clipping or clipping to 75- or 150-mm stubble height weekly or biweekly for 65 to 70 days in a greenhouse. Response of Japanese brome tiller numbers, leaf height, and above- and below-ground biomass were measured in 1991, 1992, and 1997. Clipping vegetative plants in 1991 reduced tiller numbers and leaf heights, whereas clipping plants with reproductive shoots in 1992 and 1997 increased tiller numbers and reduced leaf heights. Herbage accumulated during clipping, above-ground and total biomass were similar in 1991 and 1997, but lower in 1992. Accumulated herbage was reduced by reducing stubble height from 150 mm to 75 mm on a biweekly frequency and increasing the frequency of clipping from biweekly to weekly at either the 150-mm or 75-mm stubble height. Reducing the stubble height also reduced above-ground and total biomass. Increasing frequency of clipping did not generally affect total biomass. Some inflorescences were produced with even the most severe clipping treatment.

Key Words*: Bromus japonicus*, controlled environment, clipping intensity, clipping frequency

Resumen

"Japanese brome" (*Bromus japonicus* Thunb.) ha invadido muchas comunidades septentrionales de pradera mixta. El entender como la defoliación afecta el ciclo de vida de esta especie es crítico para llevar a cabo un manejo adecuado del apacentamiento de comunidades infestadas con esta especie anual. El objetivo de este estudio fue determinar el efecto de la defoliación en el crecimiento del "Japanese brome". El estudio se realizó en invernadero y los tratamientos evaluados fueron: no defoliación y defoliación a 75 mm y 150 mm de altura del rastrojo remanente con frecuencias de defoliación semanal y cada dos semanas. La respuesta del "Japanese brome" a la defoliación respecto al número de hijuelos, altura de la hoja y producción de biomasa áerea y subterránea fue medida durante 1991, 1992 y 1997. En 1991, la defoliación de plantas en estado vegetativo redujó el número de hijuelos y altura de la hoja, mientras que en 1992 y 1997 la defoliación de plantas con tallos reproductivos incrementó el número de hijuelos y redujó la altura de la hoja. El forraje acumulado durante la defoliación y la biomasa total y áerea fueron similares en 1991 y 1997, pero menores en 1992. En la frecuencia de defoliación de cada dos semanas, el forraje acumulado se redujó al reducir la altura del rastrojo remanente de 150 mm a 75 mm. El incrementar la frecuencia de defoliación de dos a una semana también disminuyó el forraje acumulado tanto en 150 mm como en 75 mm de altura del rastrojo remanente. Reducir la altura del rastrojo también redujó la biomasa áerea y total. El incrementar la frecuencia de defoliación generalmente no afectó la biomasa total. Algunas inflorecencias se produjeron aun con el tratamiento más severo de defoliación.

Invasion of Japanese brome (*Bromus japonicus* Thunb.), an introduced annual weedy grass, may negatively impact the forage base and grazers of many mixed prairie communities in the Northern Great Plains (Whisenant 1990, Haferkamp et al. 1993). Perpetuation of Japanese brome in these communities requires completion of its life cycle, beginning with seed germination and terminating with plant maturation and dissemination of viable seed. Reduction of Japanese brome will require interruption of this life cycle.

Reducing seed production by grazing or clipping is an effective method of interrupting the life cycle of annual plants, including bromes (Stewart and Hull 1949, Hulbert 1955, Laude 1957, Finnerty and Klingman 1962, Young and Tipton 1990). Grazing also can indirectly reduce annual brome biomass by reducing the amount of mulch on the soil surface. The mulch benefits germination and seedling establishment of Japanese brome (Whisenant 1990) and downy brome (*Bromus tectorum* L.) (Evans and Young 1970). Pfeifer (1985) found clipping Japanese brome to a 50-mm stubble height in the

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field reduced subsequent plant height growth and above-ground biomass, while tiller density increased. These results differ from her greenhouse studies wherein clipping increased above-ground biomass, but did not affect tiller density. Competitive interactions with annual bromes vary also by species and season (Tausch et al. 1990). Grazing at different times of the year may shift the competitive balance between annual bromes and other species in the community.

Studies are lacking that quantify the effect of intensity and frequency of clipping on above- and below-ground biomass of Japanese brome. The objective of this greenhouse study was to determine the response of Japanese brome, as measured by tiller number, leaf height, and above- and below-ground biomass, to varying intensities and frequencies of clipping.

Materials and Methods

Japanese brome seedlings were grown in 30 greenhouse boxes (inside dimensions of 10.2 cm wide, 32.8 cm long, and 73.7 cm deep) in 1991 and 1992 (Haferkamp and Currie 1973) and 45 PVC tubes (80 cm tall and 20 cm diameter) in 1997. Each container was uniformly packed with soil (Typic Ustochrepts, fine-silty, mixed, frigid). Seedlings were grown from seed collected on the Fort Keogh Livestock and Range Research Laboratory located near Miles City, Mont. (Haferkamp et al. 1994b). Seeds were germinated on paper towels in the bottom of aluminum trays in a germinator with controlled environment of alternating 12-hour periods of 8 and 23° C with light supplied by cool-white fluorescent bulbs (PAR = 30 umoles m^{-2} sec^{-1}) during each 12-hour 23°C period (Haferkamp et al. 1994a). Soil was added to each tray when seedlings were about 10 mm tall, and trays were moved into the greenhouse. When emerging seedlings were about 25 mm tall, several were transplanted in late winter into each container. When fully established, populations were hand-thinned to 2 healthy seedlings per container. Plants were watered to maintain active growth during the study. Natural light regimes were used, except that illumination from an exterior night light was evident within the greenhouse in 1991. This light was removed before beginning the 1992 and 1997 studies. Air temperatures were maintained near 10°C in the winter and below 38°C during spring and summer.

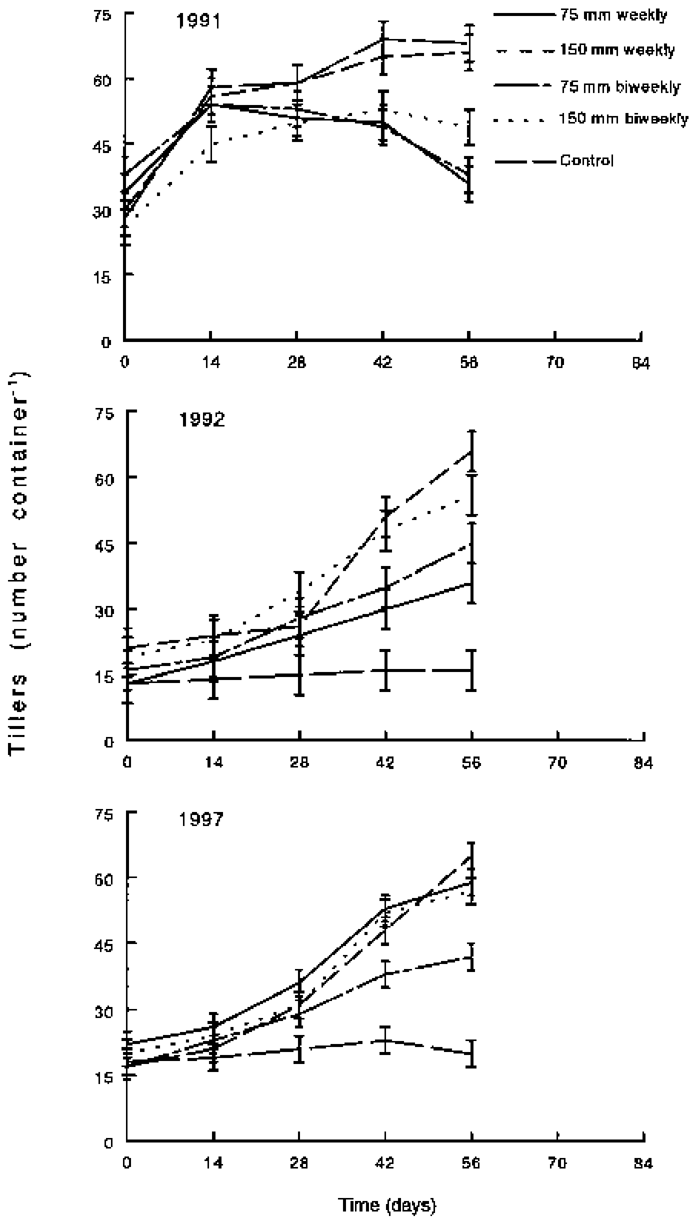

Fig. 1. Least square means of tiller counts ± standard errors for a significant 3-way interaction of year by treatment by date for Japanese brome plants.

Clipping treatments were applied during a 65- to 70-day period from 20 June to 30 August 1991, 4 May to 8 July 1992, and 1 May to 8 July 1997. We measured leaf heights, from the soil surface to the tip of the longest leaf, and counted tiller numbers weekly before and after clipping treatments began. Due to variation in duration of clipping and final harvest periods, we chose day 52 as the final date for leaf height measurements and tiller counts and day 84 as the final harvest date. Five treatments included an unclipped control and plants clipped to either a 75- or 150-mm stubble height either weekly or biweekly. When clipping treatments began, leaf heights averaged 30 cm in both 1991 and 1992 and 38 cm in 1997. Tiller numbers averaged 32 per container in 1991, 16 in 1992, and 19 in 1997. Inflorescences emerged soon after treatment periods began in both 1992 and 1997. Sixty-six percent of the plants produced inflorescences 14 days after clipping began in 1992, whereas 80% produced inflorescences 14 days after clipping was initiated in 1997. More than 90% of the plants had exerted inflorescences on each measurement date after day 14 during these 2 studies.

As plants were processed at the end of each study (assigned day 84 in figures), herbage was clipped to the designated stubble height of 75 or 150 mm for the 2 clipping treatments or at the soil surface for control plants. The stubble remaining from the 75- and 150-mm treatments was clipped at the soil surface. Roots and crowns were washed from the soil over a 6-mm screen, and roots were clipped from crowns. All plant material including herbage accumulated during weekly or biweekly clippings and above- and below-ground biomass collected at the end of each study were dried for 48 hours at 60°C and then weighed.

Treatments were factorially arranged in a randomized complete-block design with 6 blocks in 1991 and 1992 and 9 blocks in 1997. Before treatments began, plants were rearranged within the greenhouse to provide uniform plant size within each block. Analysis of variance was used to test the effect of clipping intensities (stubble height) and frequencies on total root, shoot, and crown biomass and herbage accumulated during clipping by date of harvest. A repeated measures analysis of variance was used to test the effect of clipping intensities or frequencies on tiller counts and maximum leaf heights. Main effects of year and treatment and their interaction were tested with the residual variation blocks within year and treatment; effects of date and interactions of date with year and treatment were tested with residual intrablock variation. The Least Significant Difference (LSD) method ($P \leq 0.05$) protected by a prior F-test ($P \leq 0.05$) was used for comparing means. All differences discussed are significant at the $P \leq 0.05$ level unless otherwise noted.

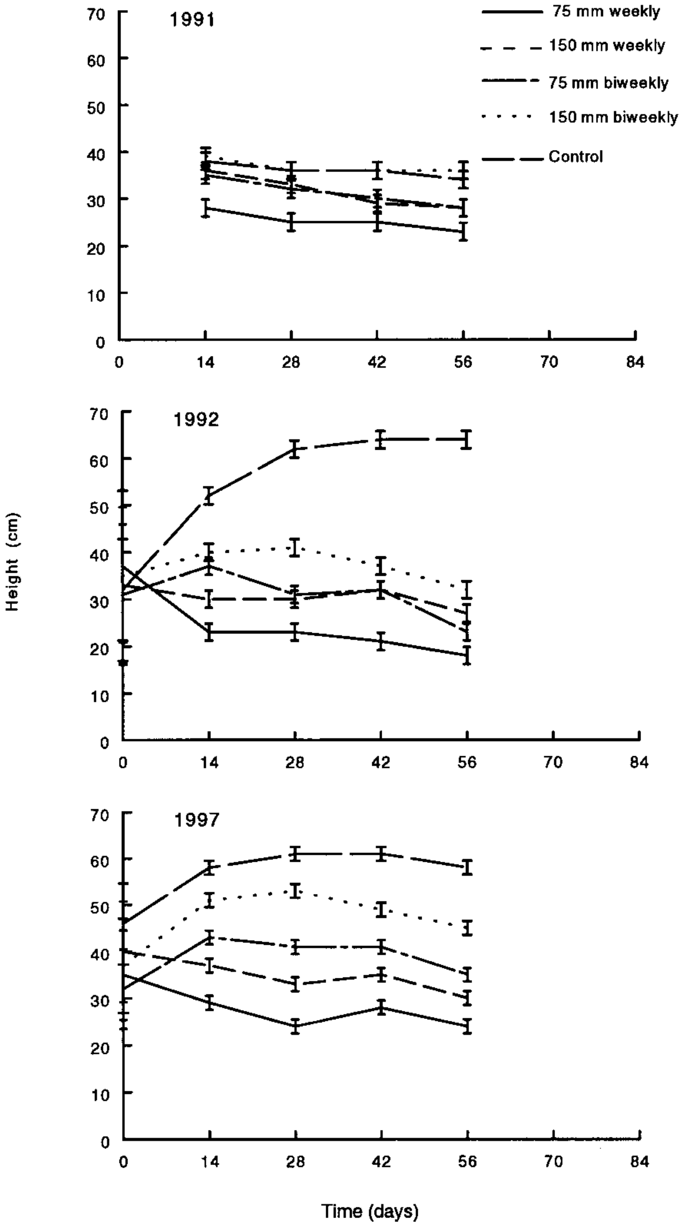

Fig. 2. Least square means of leaf heights ± standard errors for a significant 3-way interaction of year by treatment by date for Japanese brome plants. Leaf heights were not measured until day 7 in 1991.

Results

Tiller Numbers

Treatment differences in tiller numbers were not obvious until 42 days after clipping began each year (Fig. 1). On days 42 and 56, maximum numbers were produced by unclipped controls and plants clipped to 150 mm weekly in 1991; plants clipped to 150 mm weekly and biweekly in 1992; and plants clipped to 75 and 150 mm weekly and 150 mm biweekly in 1997. Within treatments, tiller numbers increased by day 14 and remained relatively constant or in some cases decreased in 1991, whereas in 1992 and 1997, tiller numbers increased during the study period for all treatments except unclipped controls.

Leaf Heights

Clipping significantly affected leaf heights by 14 days after treatments began each year. Greater leaf heights on unclipped controls in 1992 and 1997 compared to 1991 reflect the internode elongation of reproductive shoots produced in both 1992 and 1997. Maximum leaf heights were maintained on the unclipped controls and plants clipped to 150 mm biweekly in 1991, and unclipped controls in 1992 and 1997 (Fig. 2). Leaf heights tended to decrease over time in 1991 for plants clipped weekly to 75 and 150 mm and those clipped biweekly to 75 mm. Heights decreased significantly over time for all clipped plants in 1992 and 1997.

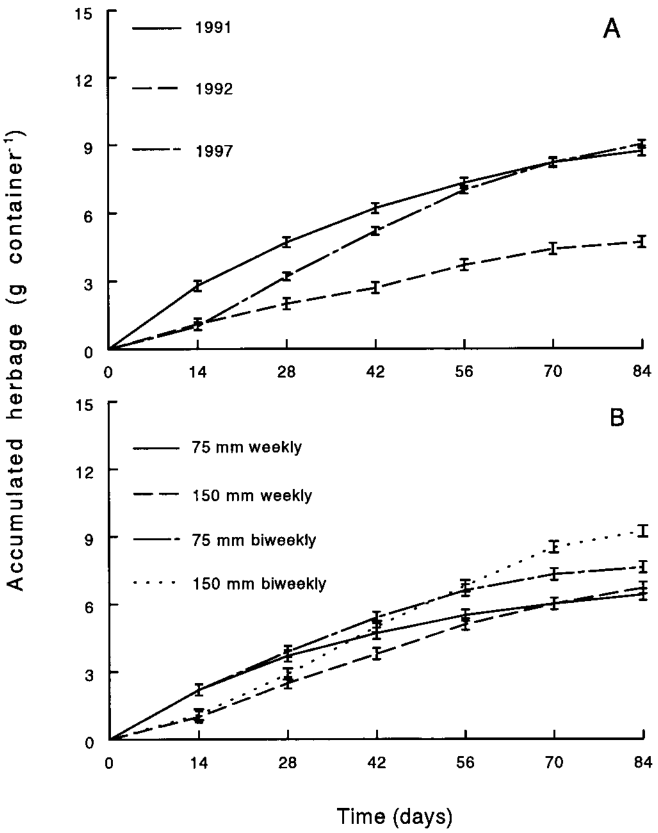

Fig. 3. Least square means for accumulated herbage ± standard errors for significant 2-way interactions of year by date (A) and treatment by date (B) for Japanese brome plants.

Heights of unclipped control plants remained stable in 1991 and 1997 but increased toward the end of the sampling period in 1992.

Accumulated Clipped Herbage

Accumulated herbage was greater in 1991 than in 1992 or 1997 for the first 42 days (Fig. 3A). Thereafter, accumulated herbage was greatest in 1991 and 1997 and least in 1992. Herbage accumulation was greater for the first 28 days when plants were clipped at the 75-mm stubble height (Fig. 3B). However, by day 56 more herbage was accumulated by clipping biweekly to 150 mm than clipping weekly to 75 mm. Maximum herbage was accumulated from plants clipped biweekly to 150 mm. More herbage was accumulated from plants clipped biweekly to 75 mm than from plants clipped weekly to 75 or 150 mm.

Above- and Below-ground Biomass

Total and above-ground biomass yields were greater in 1991 and 1997 than in 1992 (Fig. 4A). Total and above-ground biomass were greatest for unclipped control plants, intermediate for plants clipped to 150 mm, and least for plants clipped to 75 mm (Fig. 4B). Below-ground biomass varied significantly among years within treatments (Table 1). Biomass production was similar among years for most clipping treatments, but was greater in 1997 than 1992 for plants clipped biweekly to 150 mm and greater in 1991 than in 1992 or 1997 for unclipped controls. Below-ground biomass was greater for unclipped controls than all other treatments in 1991; similar among clipping treatments in 1992; and greater for plants clipped biweekly to 150 mm than for control plants or those clipped weekly or biweekly to 75 mm in 1997. Frequency of clipping did not significantly affect above-ground ($P = 0.057$), below-ground ($P = 0.910$), or total ($P = 0.111$) biomass.

Discussion

Reproductive Status

Baskin and Baskin (1981) suggested vernalization was not an absolute requirement for Japanese brome to flower as reported by Hulbert (1955); rather they found exposure to short days prior to exposure to long days stimulated flowering. This study supports Baskin and Baskin (1981) in that our plants did not flower in 1991 when exposed to the almost continuous light provided by natural day light and an exterior night light.

Morphological Status

Observed responses for tiller number and leaf height in 1991 are characteristic of plants producing culmless vegetative shoots with apical meristems maintained near the soil surface while grown in a fertile well-watered environment. Hyder (1974) reported culmless vegetative shoots are well adapted to frequent mowing and grazing. He reported leaf growth stops during unfavorable conditions, but cell division and expansion resume in both apical and intercalary meristems upon the resumption of favorable conditions (e.g., temperature and soil water). Culmless vegetative shoots remain active in producing leaf

Table 1. Below-ground biomass produced by Japanese brome plants treated with 1 of 5 clipping treatments during 3 years.

Year	weekly 75mm	weekly 150mm	biweekly 75mm	biweekly 150mm	control
	(g container^{-1})				
1991	$_{a}2.5^{C}$	$_{a}6.2^{B}$	$_{a}4.0^{BC}$	$_{ab}5.1^{BC}$	$_{a}10.0^{A}$
1992	$_{a}1.2^{A}$	$_{a}3.6^{A}$	$_{a}1.2^{A}$	$_{b}2.3^{A}$	$_{b}3.1^{A}$
1997	$_{a}3.1^{C}$	$_{a}5.9^{AB}$	$_{a}3.7^{BC}$	$_{a}6.6^{A}$	$_{b}3.6^{BC}$

Means within a year followed by the same upper case superscript or within a treatment preceded by the same lower case subscript are not significantly ($P \geq 0.05$) different.

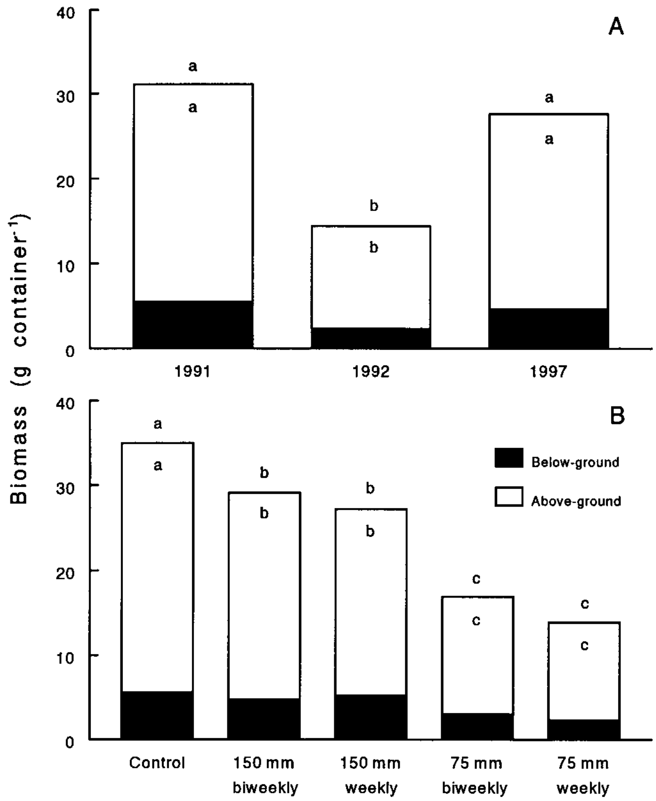

Fig. 4. Least Square Means for above- and below-ground biomass for significant main effects of year (A) and treatment (B). Similar lower case letters above total biomass and within aboveground biomass denote lack of significance (P≥0.05) between years or treatments.

tissue unless the shoot apex becomes reproductive or death occurs. Plants studied in 1992 and 1997 responded as plants initially with culmless vegetative shoots that eventually differentiated into culmed reproductive shoots. Few tillers were produced by unclipped plants, but once reproductive shoots were clipped, plants tillered rapidly within the greenhouse environment.

The reduction in below-ground biomass with all clipping treatments in 1991 was probably the result of removing actively photosynthesizing leaves. Tiller density was high for all plants when clipping began on actively growing vegetative tillers. Removal of leaf material, thus, probably reduced the amount of carbohydrate available for root growth. In contrast, clipping increased tiller numbers in 1992 and 1997. Findings in 1997 suggest below-ground biomass increased most with the least intensive and frequent clipping schemes that allowed the greatest accumulation of leaf area. Lack of differences among below-ground biomass values in 1992, as well as reduced above-ground biomass production, suggest plants may have suffered environmental stress from high temperature, lack of soil water, or insects. Reduced leaf area would have impacted the response of below-ground biomass to clipping regimes.

Management Implications

These findings relate to situations where soil water is adequate for regrowth of Japanese brome plants after defoliation. The environmental conditions near Miles City (Fig. 5) would allow regrowth during spring in many years. Care must be exercised in extrapolating from greenhouse findings to field environments. Briske and Richards (1995) suggest environmental variables which promote growth, (e.g., favorable temperature, irradiance, water and nutrient availability), generally promote tillering as well. Pfeifer (1985) found Japanese brome plants stopped growing as the growing season advanced in Kansas due to reduced soil water availability and high temperatures. Whole plot shading reduced the heat load and allowed plants to keep growing. In contrast, unshaded plants produced the most tillers during the duration of the greenhouse study where water and temperatures were controlled for optimum growth. She also found clipping intervals of 2, 3, or 4 weeks best for regrowth of Japanese brome in the field, but regrowth was similar among all intervals in the greenhouse. Difference in above-ground biomass between unclipped and clipped plants reportedly resulted from differences in number of tillers and not weight of tillers. The lack of a consistent tillering response often found between different years or controlled environments and the field is due to the apparent complexity of the physiological mechanisms regulating axillary bud growth (e.g., apical dominance) and the large number of potentially intervening factors, (e.g., environmental variables, species specific responses, stage of phenological development, and frequency and intensity of defoliation) (Briske and Richards 1995).

The 1991 findings relate to situations where Japanese brome seeds were disseminated on spring dates too late for optimum vernalization and photoperiod response. Baskin and Baskin (1981) proposed a scenario where Japanese brome seed remains on dead erect plants until spring when habitat temperatures are too high for induction of secondary seed dormancy or vernalization. Non dormant seed would germinate if soil water was sufficient, but the resulting plants would not flower until the following spring after they received vernalization and the transition from short days to long days during winter and spring. Baskin and Baskin (1981), however, found only a few newly germinated seeds in the spring. Similarly, Karl (unpublished data) found only a few seedlings emerging in the spring on our study locations.

Heavy grazing or intensive clipping, as reported in this and other studies, reduces above- and below-ground biomass and seed production. Thus seedling density is reduced with a reduction in the amount of seed, as well as, mulch or litter. A dense litter cover reduces evaporation of soil water and thus provides an optimum environment for germination and seedling emergence. Vallentine and Stevens (1994) and Mosley (1996) sug-

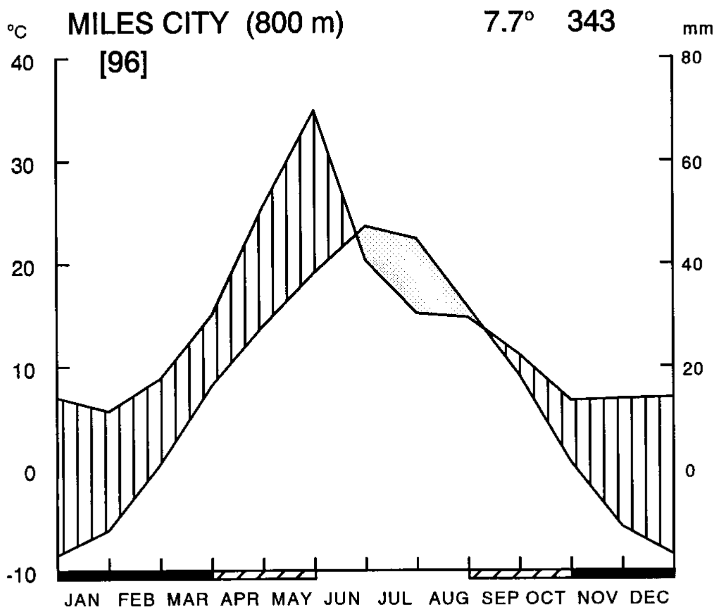

Fig. 5. Climate diagram for Miles City, Mont. Mean monthly precipitation (mm) and temperature (°C) for 96-year period indicate mesic spring, early summer, and fall periods interrupted by late summer and early fall drought (stippling). Winter precipitation occurs as snow. Months shaded in black have average minimum temperatures <0°C. Those with diagonal lines have absolute minimum temperatures <0°C. Figure follows standard form of Walter (1985).

gest there is a rather narrow early spring window when grazing can suppress downy brome growth, seed production, and mulch buildup. This approach would require high-density grazing for a short duration, during which time downy brome would be closely defoliated and/or seed production prevented. Precisely timing grazing to reduce selection of perennial grasses or allowing them adequate time to recover from defoliation before the end of the growing season is challenging.

Defoliation early in the growing season is critical for controlling annual bromes. Hulbert (1955) found downy brome was difficult to eliminate by mowing at the purple stage. Seeds were already sufficiently developed to germinate at a later date. Haferkamp et al. (1996) also found Japanese brome seed germinates in June when it is still green. Finnerty and Klingman (1962) found mowing about 1 week after inflorescences emerged was the most appropriate time to control downy brome. Even this treatment did not eliminate downy brome plants from plots; a few young tillers always emerged from mowed plants. Defoliation does not always reduce annual brome production. Ganskopp and Bedell (1979) found grazed downy brome plants produced more forage than ungrazed plants when soil water was available for regrowth.

The tillering response reported for downy brome by Finnerty and Klingman (1962) could occur with grazed or mowed Japanese brome plants in the Northern Great Plains. Terminating grazing or mowing when soil water is available for regrowth of associated perennial grasses may also prove advantageous for annual bromes. It is unlikely all plants and tillers will be grazed. Thus, there will always be some annual brome plants producing viable seed to replenish the seed bank. Whisenant (1990) suggests greater reduction of annual bromes can be expected when precipitation is below normal following the year of burning or in our case clipping or grazing. This phenomena is a result of reduction in litter accumulation, which will reduce annual brome recruitment, seed production, and seed banks. As water becomes limiting, litter becomes more important in population dynamics. As suggested by Vallentine and Stevens (1994), sufficient information probably does not presently exist for developing the precise grazing plan needed for exerting biological control, but further research seems warranted.

Literature Cited

Baskin, J.M. and C.C. Baskin. 1981. Ecology of germination and flowering in the weedy winter annual grass *Bromus japonicus*. J. Range Manage. 34:369–372.

Briske, D.D. and J.H. Richards. 1995. Plant response to defoliation: A physiologic, morphologic and demographic evaluation, p. 635-710. *In:* D.J. Bedunah and R.E. Sosebee (eds.), Wildland plants: Physiological ecology and developmental morphology. Soc. Range Manage. Denver, Colo.

Evans, R.A. and J.A. Young. 1970. Plant litter and establishment of alien annual weed species in rangeland communities. Weed Sci. 18:697–703.

Finnerty, D.W. and D.L. Klingman. 1962. Life cycles and control studies of some weed bromegrasses. Weeds 10:40–47.

Ganskopp, D.C. and T.E. Bedell. 1979. Cheatgrass and its relationship to climate: A review. Spec. Rep. 562, Ore. Agr. Exp. Sta., Corvallis, Ore.

Haferkamp, M.R. and P.O. Currie. 1973. Effects of fertilizer on root strength of Sherman big bluegrass. Agron. J. 65:511–512.

Haferkamp, M.R., M.G. Karl, and M.D. MacNeil. 1994a. Influence of storage, temperature, and light on germination of Japanese brome seed. J. Range Manage. 47:140–144.

Haferkamp, M.R., M.D. MacNeil, and M.G. Karl. 1996. Induction of secondary dormancy in Japanese brome (*Bromus japonicus*), p. 3-4. *In:* N.E. West (ed.), Proc. 5th Int. Rangeland Congress. Soc. Range Manage., Denver, Colo.

Haferkamp, M.R., J.D. Volesky, M.M. Borman, R.K. Heitschmidt, and P.O. Currie. 1993. Effects of mechanical treatments and climatic factors on the productivity of Northern Great Plains rangelands. J. Range Manage. 46:346–350.

Haferkamp, M.R., J.A. Young, E.E. Grings, M.G. Karl, R.K. Heitschmidt, and M.D. MacNeil. 1994b. Japanese brome in the Northern Great Plains, p. 396-401. *In:* S.B. Monsen and S.G. Kitchen (compilers), Proc.-Symposium on ecology and management of annual rangelands, 18–21 May 1992, Boise, Ida. USDA For. Serv. INT-GTR-313.

Hulbert, L.C. 1955. Ecological studies of *Bromus tectorum* and other annual brome grasses. Ecol. Monogr. 25:181–213.

Hyder, D.N. 1974. Morphogenesis and management of perennial grasses in the U.S., p. 89–98. *In:* Plant morphogenesis as the basis for scientific management of range resources. USDA Misc. Publ. 1271. Wash. D.C.

Laude, H.M. 1957. Growth of the annual grass plant in response to herbage removal. J. Range Manage. 10:37–39.

Mosley, J.C. 1996. Prescribed sheep grazing to suppress cheatgrass: A review. Sheep & Goat Res. J. 12:74–81.

Pfeifer, T.A. 1985. The effects of defoliation, density, and light intensity on the regrowth, biomass, and tiller production of Japanese brome *(Bromus japonicus* Thunb.). M.S. Thesis, Fort Hays State Univ., Hays, Kan.

Stewart, G. and A.C. Hull. 1949. Cheatgrass (*Bromus tectorum* L.), an ecologic intruder in southern Idaho. Ecol. 30:58–74.

Tausch, R.J., R.S. Nowak, A.D. Bruner, and J. Smithson. 1990. Effects of simulated fall and early spring grazing on cheatgrass and perennial grass in western Nevada, p. 113–119. In: S.B. Monsen and S.G. Kitchen (compilers), Proc.-Symposium on ecology and management of annual rangelands, 18–21 May 1992, Boise, Ida. USDA For. Serv. INT-GTR-313.

Vallentine, J.F. and A.R. Stevens. 1994. Use of livestock to control cheatgrass-A review, p. 202-206. *In:* S.B. Monsen and S.G. Kitchen (compilers), Proc.-Symposium on ecology and management of annual rangelands, 18–21 May 1992, Boise, Ida. USDA For. Serv. INT-GTR-313.

Walter, H. 1985. Vegetation of the earth and ecological systems of the geobiosphere. Third, Revised and Enlarged Edition. Translated from the Fifth, Revised German Edition by O. Muise. Springer-Verlag, New York, N.Y.

Whisenant, S.G. 1990. Postfire population dynamics of *Bromus japonicus*. Amer. Midl. Natur. 123:301–308.

Young, J.A. and F. Tipton. 1990. Invasion of cheatgrass into arid environments of the Lahontan Basin, p. 37–40. *In:* E.D. McArthur, E.M. Romney, S.D. Smith, and P.T. Tueller (compilers), Proc.-Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management, 5–7 April 1989, Las Vegas, Nev. USDA For. Serv. INT-276.