Responses of Crested Wheatgrass and Russian Wildrye to Water Stress and Defoliation

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Abstract

Crested wheatgrass (*Agropyron desertorum,* Fisch Schult) and Russian wildrye (*Elymus junceus,* Fisch) plants were subjected to three levels of water stress (13, 2.6, and 1.8% soil moisture), in interaction with 4 defoliation levels (0, 40, 60, and 80% defoliation). Plants were clipped biweekly using the height-weight ratio method to determine the assigned defoliation level and leaf water potential (Ψ_1) was measured by pressure bomb. Following the final clipping at ground level a 40-day recovery period was allowed while maintaining plants at field capacity (13% soil moisture). Leaf water potential measurements showed significant differences between species, among three water stress levels, and within four defoliation levels. Water stress and defoliation levels significantly affected foliage yield, root biomass, and plant recovery. Heavy defoliation (80%) resulted in a 100% death loss for both species at wilting point (1.8% soil moisture). Light defoliated (40% at field capacity) produced more total dry matter than undefoliated plants maintained at field capacity or wilting point. Maximum root biomass was found in undefoliated plants of crested wheatgrass grown at field capacity. Significant differences in root production were also found among water stress and defoliation treatments. No plant recovery occurred among plants maintained at wilting point and defoliated at 80%. However, plants defoliated at 40 and 60% under 13 and 2.6% soil moisture exhibited considerable regrowth. In general crested wheatgrass out-yielded Russian wildrye in every treatment and was more resistant to defoliation and water stress.

Studies have been conducted to determine the effects of different levels of defoliation on chemical composition and dry matter yield of forage crops (Cook 1966, Buwai and Trlica 1977). Research has also characterized the effects of water stress on the growth and survival of certain plants showing that herbage yields, vigor, and total nonstructural carbohydrate levels were drastically reduced by intensive defoliations (Slatyer 1967, Kramer 1969, Stout 1976). Cook and Child (1971) determined that more than 7 years of non-defoliation were required for several salt desert species to regain normal vigor after cessation of various defoliation treatments. In foothill ranges in Utah, Russian wildrye produced significantly more herbage than crested wheatgrass when clipped at intensities of 25, 50, 75% (Drawe et al. 1972).

Dwyer (1969) in a greenhouse study reported that clipping at either the 3 or 5 cm level aboveground each 10 days for 102 days was too severe for maximum growth of blue grama *(Bouteloua gracilis).* However, in an earlier study Gay and Dwyer (1965) found that nitrogen fertilized tall grass prairie in excellent range condition clipped once at ground level during the growing season produced more dry matter than that not clipped and fertilized. McGinnies (1973) found that seedlings of crested wheatgrass from spring plantings clipped to a 1.3 cm stubble reduced survival by 13% but clipping to ground level reduced survival by 61%. Dwyer et al. (1963) suggested that both tops and roots were replaced in numbers proportional to the severity of shoot removal. They also reported that frequent defoliations greatly reduced herbage yields of several Oklahoma range grasses.

In addition to the physiological factors, environmental factors such as season, climate, and temperature have direct influence on the plant's resistance to water stress. Ellern (1976) found that efficiency of water use by ricegrass *(Oryzopsis hymenoides)* generally increased with increasing moisture tension, density, and seedling age. Mott and McComb (1975) grew *Helichrysum cassinianum, Helipterum craspedioides,* and *Aristida contorta* in a soil with 15, 10, and 7% moisture levels. High moisture stress reduced plant dry weight, number of flowers, and seeds. Field progressions of leaf water potential (Ψ_1) measured with a pressure chamber decreased rapidly from -7, -4, and -6 bars at sunrise to minimal values of -18, -22, and -15 bars near midday in maize, sorghum, and tobacco, respectively (Turner 1974). The increase in water stress was attributed to the rise of temperature at midday as compared to temperature at sunrise. Sanchez-Diaz and Kramer (1973) grew corn and sorghum for 40 days in controlled chambers and then withheld water until wilting. The stressed plants were then rewatered. The average Ψ_1 of well-watered corn was -4.5 bars and that of sorghum was -6.4 bars. The lowest Ψ_1 in stressed sorghum and corn at a water saturation deficit of 29 and 45% was -15.7 and -12.8 bars, respectively.

Studies have not generally evaluated the combined effects of water stress and defoliation on the foliage yield, especially for range plants. Burzlaff and Harris (1969) suggested that changes in botanical composition and forage production were affected more by yearly climatic differences than differences in stocking rates. Often there is a positive correlation between soil water stress and plant growth. Baker and Hunt (1961) studied the influence of clipping on the growth of intermediate wheatgrass and pubescent wheatgrass under drought stress. They found significant differences in dry matter yield between the plants maintained at field capacity and those maintained just above wilting point. There was a significant interaction between clipping levels and water use on dry matter yield. With the increase in clipping height the number of tillers, total herbage yield, and water used per gram of forage produced were increased. Crested wheatgrass and Russian wildrye are noted for their resistance to heavy grazing, heat, drought stress and disease (Pepper et al. 1953, Drawe 1970). They are also well known for their long life, productivity, and palatability (Cook and Harris 1952). However, data are not available that quantitatively evaluate the response of these grasses to various levels of defoliation under water stress.

In this study an attempt has been made to find the combined effects of water stress, and intensity and frequency of defoliation on forage yield, plant recovery, and root biomass of crested wheatgrass and Russian wildrye.

Methods and Procedures

Seeds of crested wheatgrass and Russian wildrye were sown in plastic pots with soil mixed at three parts sand:one part loam and the pots kept at field capacity until transplanting the seedlings.

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Fertilizer (NPK, 18:18:24) was applied at 5 grams/pot at 10-day intervals to stimulate growth. After a 4-month establishment period, three water stress levels (13, 2.6 1.8% soil moisture) and four defoliation levels (control, 40, 60, and 80% defoliation) were applied.

A soil water potential curve for the soil was found using standard laboratory procedures. The soil moisture percentages 13, 2.6, and 1.8 corresponded with -0.3, -5, and -15 bars soil water potential for field capacity, intermediate stress, and wilting point, respectively. These moisture levels were maintained throughout the experiment by weighing the pots each 24-hour period and adding the amount of water lost through evapotranspiration during that period.

A height-weight ratio technique (Pieper 1973) was used to obtain 80 (heavy), 60 (moderate), and 40% (light) defoliation levels. This corresponded to 2, 4, and 6 cm stubble height for crested wheatgrass and 2, 4, and 7 cm for Russian wildrye. Plants were harvested every 2 weeks and the material oven-dried and weighed. On final sampling all plants were clipped at ground level. Following this last clipping, all plants were given a 40-day recovery period with all pots being maintained at field capacity. After 40 days, the regrowth produced was clipped and weighed and root biomass for each treatment was determined by washing the roots, oven drying, and weighing at the termination of the experiment.

A pressure chamber instrument was used to determine the leaf water potential (Ψ_1) of both species under each treatment. The first determination was at the beginning of the study when water stress and defoliation treatments were first applied. The second determination was taken at the midpoint of the study and the final Ψ_1 was taken just before the final clipping.

A factorial analysis of variance computer program was used to analyze the data. Statistical significance ($P<0.05$) was determined for each treatment by means of a standard F test. Fisher's Least Significance Difference Test (LSD) of multiple comparison (Ott 1977) was applied to determine differences among treatment means.

Results

Leaf Water Potential Responses

No significant decrease in Ψ_1 occurred among defoliations over time. The effects of water stress and Ψs were significant in both species (Table 1). Among interactions, only species × water stress was significant ($P<0.05$). Differences in Ψ_1 treatment means were significant within water stress levels but there was no difference between the undefoliated and 40% defoliated plants or between 60 and 80% defoliated plants.

There were significant differences between species when field capacity was compared with wilting point, but no difference was found between the two species in Ψ_1 at wilting point, suggesting that crested wheatgrass and Russian wildrye have similar wilting points (Table 1).

Table 1. Treatment mean comparisons of leaf water potential (Ψ_1) for crested wheatgrass (CWG) and Russian wildrye (RWR) under water stress, defoliation, and combination of species × water stress (-bars).

Treatment	Mean[1] (Ψ_1)	Treatment	Mean[1] (Ψ_1)
Water stress		Species × water stress	
-15 bars	27.7a	CWG -15 bars	28.3a
-5 bars	10.8b	RWR -15 bars	27.1a
-0.3 bars	4.6c	CWG -5 bars	12.4b
Defoliations		RWR -5 bars	9.1b
0%	25.3a	CWG -0.3 bars	5.2b
40%	19.0a	RWR -0.3 bars	4.2b
60%	14.2b		
80%	13.5b		

[1]Treatment means followed by different letters are significant at 0.05 level of probability.

Plant Defoliation Responses

Generally under all treatments, crested wheatgrass produced more dry matter than Russian wildrye. Total foliage yield associated with increasing levels of defoliation showed a sharp decline under intermediate water stress (Table 2). Though there was 500% less soil moisture at the intermediate level of soil water potential (2.6%) and 722% less soil moisture at wilting point (1.8%) than at field capacity (13%), the foliage yield as a result of this water stress was decreased only about 100% when all three soil moisture treatments were defoliated at the same level.

Table 2. Treatment mean comparison of total foliage yield by species, water stress levels, defoliation levels, and combinations of species × water stress, species × defoliations and water stress × defoliations for crested wheatgrass (CWG) and Russian wildrye (RWR).

Treatment	Mean[1] (grams)	Treatment	Mean[1] (grams)
Species		Species × defoliations	
CWG	32.8a	CWG 40%	42.3a
RWR	28.6b	RWR 40%	38.0b
		CWG 0%	34.7c
Water Stress		CWG 60%	29.0d
Field capacity (-0.3 bars)	41.4a	RWR 0%	28.4d
		RWR 60%	27.0e
Intermediate (-5 bars)	29.1b	CWG 80%	25.2f
Wilting point (-15 bars)	21.6c	RWR 80%	21.0g
		Water stress × defoliation	
Defoliations		-0.3 bars 40%	51.8a
40%	41.0a	-0.3 bars 0%	42.1b
0%	31.6b	-0.3 bars 60%	42.1b
60%	28.0c	-5 bars 40%	37.3c
80%	23.1d	-15 bars 40%	31.0d
		-0.3 bars 80%	29.6e
Species × water stress		-5 bars 0%	29.5e
CWG -0.3 bars	39.3a	-5 bars 60%	29.8f
RWR -0.3 bars	36.6b	-5 bars 80%	23.2g
CWG -5 bars	29.3c	-15 bars 0%	23.0g
RWR -5 bars	26.1d	-15 bars 80%	16.3h
CWG -15 bars	21.7e	-15 bars 60%	16.1h
RWR -15 bars	21.2e		

[1]Means followed by different letters are significant at 0.05 level of probability.

The effect of intensity of defoliation levels on foliage production was highly significant (Table 2). Defoliation of both species at 40% on the bi-weekly schedule resulted in the greatest production followed by unclipped, 60, and 80% foliage removal. The amount of foliage produced by 40% defoliation was 43% more than for unclipped plants of both species. Sixty and 80% defoliation reduced yield by 13 and 38%, respectively, compared to the unclipped plants of both species.

The interactions of species × water stress and species × defoliations were significant at 0.05 level (Table 2). The treatment mean comparisons showed significant differences ($P<0.05$) between species, among water stresses, and among defoliations. Interaction of species × water stress was significant at field capacity and intermediate water stress but no species difference was found at wilting point. All the interactions of species × defoliation were significantly different except in unclipped plants of crested wheatgrass and 60% defoliated Russian wildrye plants.

The interaction of water stress × defoliation showed that yield obtained from 40% defoliated plants maintained at field capacity was 75 and 125% greater than the yield from unclipped plants maintained at intermediate and wilting point, respectively (Table 2). Production under 40% defoliation and intermediate and wilting point was 63 and 36% more than unclipped plants maintained at wilting point. There was no production difference between 60%

defoliation and undefoliated plants maintained at field capacity. Plants defoliated at 80% and maintained at field capacity produced as much as undefoliated plants at the intermediate water stress level. Forty percent defoliation under intermediate and wilting point stress levels gave significantly more yield than unclipped plants at intermediate or wilting point levels.

Plant Recovery

Following the 40-day recovery period, measurements used indicated that the influence of past water stress was prominent in resultant growth response to both species. The amount of regrowth was inversely related to the increased water stress to which the plants had been previously subjected as well as to the increase in levels of defoliation. Prior water stress and defoliation treatments significantly affected growth during recovery. Undefoliated and 40% defoliated plants at field capacity and intermediate water stress produced more foliage during recovery than 60 and 80% defoliated plants maintained at field capacity (Table 3). All other combinations were nonsignificant. It can be concluded that plants continuously defoliated at 40 and 60% will regrow if soil moisture stress does not exceed -5 bars.

Table 3. Treatment means comparison of growth recovery yield (grams) of crested wheatgrass (CWG) and Russian wildrye (RWR) obtained at the end of the 40-day recovery period with all plants maintained at field capacity.

Treatment	Mean[1]	Treatment	Mean[1]
Species		Defoliations	
CWG	2.2a	0%	3.4a
RWR	1.9a	40%	2.5b
Water Stress		60%	1.4c
-0.3 bars	3.3a	80%	1.1c
-5 bars	2.4b		
-15 bars	0.5c		

[1]Means followed by different letters are significant at the 0.05 level of probability.

Plant Root Biomass Responses

Crested wheatgrass produced significantly more root biomass than Russian wildrye under the same water stress levels (Table 4). Generally there was a sharp decline in root yield from plants maintained at the intermediate water stress level compared to those maintained at field capacity. However, reduction in root biomass was less sharp between intermediate water stress and wilting point at both grass species. Highly significant ($P<0.01$) differences in root biomass were found among all levels of defoliation. The highest production of root biomass occurred in undefoliated plants followed by 40, 60, and 80% defoliated plants.

The influence of water stress on root production was more prominent than the intensity of defoliation. Crested wheatgrass showed more resistance to water stress than Russian wildrye perhaps due to higher rates of root extension, root density, and fine root hairs as observed during root washing. The root biomass of undefoliated plants at field capacity was nearly three times the root yield from plants at wilting point and 80% defoliation.

The analysis shows that all levels of defoliation tested have a detrimental effect on the root growth (Table 4). However, defoliation becomes more critical under water stress conditions. Sixty and 80% defoliation of plants maintained under intermediate and wilting point water stress levels decreases root growth more than 80% defoliation of plants and maintained at field capacity. Forty percent defoliation at field capacity and no defoliation at the intermediate water stress level were not significantly different in root production. However, both of these combinations produced significantly more root biomass than plants defoliated at 40% and maintained at intermediate water stress.

Table 4. Treatment mean comparisons of root biomass for species, water stress levels, defoliation levels, and combinations of water × defoliation of crested wheatgrass (CWG) and Russian wildrye (RWR).

Treatment	Mean[1] (grams)	Treatment		Mean[1] (grams)
Species		Water stress × defoliation		
CWG	11.4a	-0.3 bars	0%	18.1a
RWR	10.1b	-0.3 bars	40%	14.6b
Water stress		- bars	0%	14.0b
		-5 bars	40%	12.1c
-0.3 bars	13.5a	-0.3 bars	60%	12.0c
-5 bars	10.2b	-15 bars	0%	11.2c
-15 bars	8.5c	-0.3 bars	80%	9.4d
		-15 bars	40%	8.7de
Defoliations		-15 bars	60%	7.8ef
0%	14.4a	-5 bars	60%	7.7efg
40%	11.8b	-5 bars	80%	7.1fg
60%	9.2c	-15 bars	80%	6.3g
80%	7.6d			

[1]Means followed by different letters are significant at the 0.05 level of probability.

Conclusions

The following conclusions have been drawn as a result of this research.

1. Crested wheatgrass produced more foliage than Russian wildrye under all treatment combinations of water stress and defoliation.
2. With an increase in soil water potential, leaf water potential also increases. However, the variation in leaf water potential of both species diminished at the wilting point.
3. Light defoliation (40%) under field capacity (-0.3 bars soil water potential) resulted in greater plant production than in undefoliated plants maintained at either field capacity intermediate water stress or wilting point. Crested wheatgrass and Russian wildrye were more productive, even under severe water stress, when defoliated at 40% than undefoliated plants under the same severe stress.
4. Undefoliated and 40% defoliated plants at field capacity and intermediate water stress were able to recover when soil moisture was raised to field capacity. All other combinations were nonsignificant.
5. Generally there was a sharp decline in root yield from plants maintained at the intermediate water stress level when averaged across defoliation treatments compared to those at field capacity. Reduction in root volume became less sharp from intermediate water stress to wilting point (-15 bars) in both species.
6. The influence of water stress has more effect on reducing root production than the intensity of defoliation. Forty percent defoliation under intermediate water stress and 60% defoliation at field capacity produced equal amounts of root biomass.

In attempting to relate the results of this study to actual grazing it is speculated that production and survival of both crested wheatgrass and Russian wildrye are enhanced, even during periods of water stress, if grazed at levels which are near 40% defoliation. This is in conflict with reasoning that grasses would do best during drought if left ungrazed. Perhaps light to moderate defoliation by decreasing the amount of transpiring surface reduces the negative impact of water stress on plant growth and survival. The data also support the contention that 40% defoliation is not detrimental to root growth under moderate moisture stress even though the greatest root biomass was produced by undefoliated plants. These conclusions are based on the water stress and defoliation data only.

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