Effects of Rest Following Defoliations on the Recovery of Several Range Species

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Highlight: Seven range species, western wheatgrass (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), fourwing saltbush (*Atriplex canescens*), antelope bitterbrush (*Purshia tridentata*), fringed sagewort (*Artemisia frigida*), scarlet globemallow (*Sphaeralcea coccinea*), and little rabbitbrush (*Chrysothamnus vicidiflorus*) were heavily defoliated once to remove 90% of the foliage during each of four different phenological stages. Defoliation effects were evaluated in the fall after the defoliated plants had received from 14 to 26 months of rest. Western wheatgrass, little rabbitbrush, and scarlet globemallow made good recovery in herbage yield, vigor, and total nonstructural carbohydrates (TNC) after a single heavy defoliation followed by 14 to 26 months of rest. Vigor and TNC levels of defoliated blue grama plants were similar to those of the control plants after the rest period, but the rest period was insufficient for the recovery of herbage yield. Herbage yield, vigor, and TNC levels of antelope bitterbrush and fourwing saltbush plants were still less than those of the control plants after the rest period when plants had been previously defoliated during the seed shatter or near maturity phenological stage. A 14- to 26-month rest period was insufficient for complete recovery of herbage yield, vigor, and TNC levels of fringed sagewort subjected to a single heavy defoliation at any phenological stage.

After 26 months of rest, antelope bitterbrush and fourwing saltbush previously subjected to three heavy defoliations during quiescence, fruit developing, and fall regrowth showed some recovery. However, six heavy defoliations were detrimental and plants made little recovery in herbage yield, vigor, and TNC even after more than 2 years of rest. Blue grama plants that received three heavy defoliations made fair recovery after 2 years of rest. However, more than 2 years of nonuse would be necessary before blue grama plants subjected to six heavy multiple defoliations could completely recover. Scarlet globemallow subjected to either three or six heavy defoliations and then given 26 months of rest had herbage yields, vigor, and TNC levels that were fairly similar to that of the control plants.

Unwise grazing practices can easily lead to a reduction of desirable plant species and subsequent range deterioration. The multiple use of rangelands for livestock production, wildlife habitat, watershed, and recreation requires a great deal of understanding of the ecological factors that influence structure and function of the range ecosystems. Management systems should include a consideration of how grazing systems affect the vegetation resource. Therefore, it is desirable to know tl period of rest that may be required before defoliated plants ca restore adequate total nonstructural carbohydrates (TNC), her age production, and vigor following foliage removal.

Previous studies have shown that herbage yield, vigor, ar TNC levels of plants are drastically reduced by intensi defoliations (Smith and Silva 1969; Cook 1971; Trlica and Coo 1971 and 1972; Bokhari and Singh 1974; Owensby et al. 1974 Cook and Stoddart (1953) concluded that the ability of a speci to resist clipping or grazing depended largely on its ability regenerate foliage tissue. Therefore, rangelands may requi several years of rest to fully recover following heavy grazin Cook and Child (1971) determined that more than 7 years nonuse was required for several salt desert species to rega normal vigor after cessation of various defoliation treatment McLean and Tisdale (1972) reported that deteriorated rang would require 10 to 20 years of rest to reach excellent conditio Little information of this kind is currently available on tl recovery of defoliated range plants. Therefore, the present stuc was initiated to provide information on herbage yield, vigo and TNC levels of seven range species as influenced by sho periods of rest following intensive defoliations.

Description of Study Locations

The study was carried out from 1970 through 1974 at two locatio in northern Colorado: the Central Plains Experimental Range (CPER located about 50 kilometers northeast of Fort Collins, and the Maybe location, about 6 kilometers west of Maybell.

The CPER location is typical of the shortgrass type of the Centr Great Plains region. The vegetation at the CPER location w dominated by blue grama (*Bouteloua gracilis*) and is typical of tl shortgrass prairie (Klipple and Costello 1960). Climate at the CPE Site is semiarid with warm summers and cold winters. Precipitation highly variable but generally ranges from 25 to 28 cm per annu (Hyder et al. 1975). Summer precipitation is chiefly in the form light thundershowers with occasional intense thunderstorms. The thundershowers account for more than 50% of the total annu precipitation.

Soils at the CPER are typical of the dark brown and brown soils the semiarid grasslands of the central Great Plains region (Klipple an Costello 1960) and belong to the Lithosol group. In general, CPE soils are loams, ranging from clay loams to sandy loams.

The Maybell location is in the intermountain sandhills region western Colorado. This location is characterized by gently rolling hil with occasional steeper slopes. The climate is semiarid with war summers and cold winters. Summer precipitation is chiefly in the for of light thundershowers and accounts for less than one-half of the tot annual precipitation. The ground is normally covered with snow in la fall and winter.

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Soils at the Maybell study location are brown to dark brown, grading into shades of yellowish brown or gray with depth (Cunningham 1971) and belong to the Regosol group. Soils at both the CPER and Maybell locations have low organic matter content. Vegetation at the Maybell location was dominated by antelope bitterbrush (*Purshia tridentata*) with big sagebrush (*Artemisia tridentata*) being dominant in many lowland areas.

Methods and Procedures

Three exclosures of about 0.4 hectare in size were built at each of the study locations in the summer of 1970 before initiation of the study. Plants within the exclosures were subjected to defoliations at 90% intensity of foliage removal during each of several different phenological stages. The following four species were studied at the CPER site: blue grama, western wheatgrass (*Agropyron smithii*), fourwing saltbush (*Atriplex canescens*), and scarlet globemallow (*Sphaeralcea coccinea*). Three species, antelope bitterbrush, fringed sagewort (*Artemisia frigida*), and little rabbitbrush (*Chrysothamnus vicidiflorus*) were studied at the Maybell location.

Three plants of fourwing saltbush, antelope bitterbrush, and little rabbitbrush within each exclosure were clipped under each treatment. Eight plants of fringed sagewort within each exclosure were clipped under each treatment. Blue grama, western wheatgrass, and scarlet globemallow within 1.0 m² plots were clipped at each exclosure site at the CPER. Two plots per treatment within each of three exclosures were clipped for each species. Plants in the single defoliation experiment were clipped once at four phenological stages from the fall of 1970 through the late summer of 1971. The defoliation treatment effects were then evaluated in the fall of 1972 after defoliated plants had received from 14 to 26 months of rest. The same defoliation treatments were again repeated on different plants from the fall of 1971 through late summer of 1972. These treatments were then evaluated in the fall of 1973 after defoliated plants had again received 14 to 26 months of rest. Therefore, the single defoliation experiment was replicated through time.

Blue grama, fourwing saltbush, fringed sagewort, and scarlet globmallow were clipped during quiescence (November 5–20), early growth (April 15–20), rapid growth (June 1–10), and near maturity (August 1–15) phenological stages. Western wheatgrass was clipped during quiescence (November 5–20), early growth (April 15–20), rapid growth (June 1–10), and the boot stage (August 1–15). Antelope bitterbrush plants were clipped during quiescence (November 5–20), early growth (April 15–20), fruit developing (June 1–10), and seed shatter (August 1–15) stages. Little rabbitbrush was clipped during quiescence (November 5–20), early growth (April 15–20), rapid growth (June 1–10), and the flower developing stages (August 1–15).

In the multiple defoliation experiments, blue grama, fourwing saltbush, antelope bitterbrush, and scarlet globemallow were all subjected to either three multiple defoliations from the fall of 1970 through the summer of 1971, or plants were clipped six times from the fall of 1970 through the late summer of 1972. All species were clipped to remove 90% of the foliage at each phenological stage. The phenological stages during which plants were defoliated in these experiments were: quiescence (November 5–25), rapid growth or fruit developing (June 1–10), near maturity or seed shatter (August 1–15), and fall regrowth (September 1–15). The defoliation treatment effects were then evaluated after clipped plants had received 14 and 26 months of rest.

Herbage yield, vigor, and total nonstructural carbohydrates (TNC) were used to evaluate the recovery of defoliated plants. Herbage yield for blue grama was the total aboveground biomass adjusted to 100% basal cover per 1.0 m². Herbage yields were reported as grams per plant for the other species studied. Herbage yield and vigor for antelope bitterbrush, fourwing saltbush, and little rabbitbrush were obtained from the average plant within each treatment at each exclosure site. Herbage yield of the browse species represented the total dry weight of all leaves (seeds included in samples of fourwing saltbush only). Herbage yield and vigor measurements for western wheatgrass and scarlet globemallow were obtained from 80 and 40 plant samples, respectively, from each treatment in each exclosure. All eight plants within each treatment were used to determine herbage yield and vigor of fringed sagewort. All herbage samples were oven dried at 70°C and then weighed.

Vigor for fourwing saltbush, antelope bitterbrush, little rabbitbrush, and fringed sagewort was measured in terms of live crown cover and seedstalk length (or twig length). Plant height and fall regrowth were used to measure vigor of scarlet globemallow and western wheatgrass. Seedstalk length was the only vigor measurement obtained on blue grama plants.

Plants were excavated by digging around the perimeter of the plants to a depth of 30 cm. Plants and soil were then removed together, and the soil was carefully removed by hand shaking and washing with cold water. The TNC levels were determined in both tap roots and live basal stems (0.5 to 1.0 cm diameter) of antelope bitterbrush and fourwing saltbush. Roots and crowns of blue grama, fringed sagewort, little rabbitbrush, western wheatgrass, and scarlet globemallow were used to determine TNC levels. Rhizomes were included with the root samples of western wheatgrass and scarlet globemallow. For little rabbitbrush, only lateral roots were included in the root samples. Only one sample of each storage organ for each species from each exclosure and for each treatment was used to determine TNC levels. Total nonstructural carbohydrates were extracted from a 0.5-g plant sample with 0.2N sulfuric acid (Smith et al. 1964). Aliquots of the extracts were then used to determine TNC levels on a glucose equivalent basis (Heinze and Murneek 1940; Association of Official Agricultural Chemists 1965; Trlica and Cook 1971).

All data were analyzed using standard analysis of varance techniques (Steel and Torrie 1960). Significant differences were accepted at the 0.05 level of probability. When significant *F*-values were found, Duncan's new multiple range test was utilized to separate significant ($P < 0.05$) mean differences.

Results and Discussion

Single Defoliation and Rest

Data on herbage yield, vigor, and TNC levels were obtained on clipped plants and were compared with unclipped control plants to determine plant recovery during a 14- to 26-month rest period. Differences in growing conditions during the study years resulted in significant differences among years for some of the measurements of the seven species studied. Differences in precipitation amounts and distributions probably account for some of the observed differences in response during the study.

Western Wheatgrass

After 14 to 26 months of rest, all defoliated western wheatgrass plants had herbage yields, vigor, and TNC levels that were similar to the control plants (Table 1). All defoliated plants were still slightly shorter and made less fall regrowth than the control plants. It appeared that a quiescence defoliation had the least effect on herbage yield. Most defoliated western wheatgrass plants had slightly less TNC than did the underfoliated plants (Table 1). However, there were only small differences in TNC levels among plants from the various defoliation treatments.

A 14- to 26-month rest period appeared to be sufficient for the recovery of western wheatgrass from a single heavy defoliation. Cook and Child (1971) found that Indian ricegrass (*Oryzopsis hymenoides*) made good recovery from previous defoliations after 1 year of rest. However, Mueggler (1975) found that Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum*) in low vigor may require more than 6 to 8 years of protection to approach normal vigor.

Blue Grama

All defoliated blue grama plants had seedstalk lengths and TNC levels similar to those of undefoliated plants (Table 1).

Table 1. Average herbage yield, vigor, and total nonstructural carbohydrates (TNC) for three herbaceous species subjected to a single defoliation during various phenological stages. Measurements and collections were made in the fall after defoliated plants had received 14 to 26 months of rest.

Species and phenological stage when defoliated	Vigor: Plant height (cm)	Vigor: Seedstalk length (cm)	Fall regrowth (cm)	Herbage yield (g/plant)	TNC (mg/g): Roots	TNC (mg/g): Crowns
Western wheatgrass						
Control	32 a[1]		9 a	0.5 a	145 a	122 a
Quiescence	25 a		7 a	0.4 a	139 a	110 a
Early growth	25 a		6 a	0.3 a	147 a	118 a
Rapid growth	23 a		6 a	0.3 a	134 a	128 a
Boot stage	23 a		7 a	0.3 a	139 a	111 a
Scarlet globemallow						
Control	14 a[1]		2 a	0.8 a	170 a	151 a
Quiescence	13 a		2 a	0.5 a	167 a	147 a
Early growth	10 a		2 a	0.4 a	167 a	139 a
Rapid growth	10 a		2 a	0.4 a	181 a	141 a
Near maturity	10 a		1 a	0.4 a	170 a	155 a
Blue grama						
Control		38 a[1]	—	731 a[2]	59 a	79 a
Quiescence		31 a	—	547 ab[2]	52 a	65 a
Early growth		23 a	—	406 b[2]	52 a	66 a
Rapid growth		29 a	—	417 b[2]	50 a	71 a
Near maturity		24 a	—	338 b[2]	52 a	72 a

[1]Means in the same column followed by a similar letter are not significantly different at the 0.05 level of probability.
[2]Grams/m^2 expressed on a basis of 100% basal cover.

Average seedstalk lengths were somewhat shorter for plants that received a single heavy defoliation during early growth, rapid growth, or near maturity stages than they were for plants defoliated at quiescence or for the control plants.

Most single defoliation treatments drastically reduced herbage yields of blue grama below that of the control plants, even after 14 to 26 months of rest (Table 1). However, herbage yields were generally least affected by a quiescence defoliation.

Scarlet Globemallow

Herbage yield, vigor, and TNC levels of all defoliated scarlet globemallow plants were similar to those of the control plants after at least 14 months of rest (Table 1). However, most defoliated scarlet globemallow plants had lower herbage yields and were somewhat shorter than the undefoliated plants after the rest period. A single heavy defoliation at quiescence had less effect on plant height than a heavy defoliation at any other phenological stage. All defoliated scarlet globemallow plants had made good recovery in both root and crown TNC levels, and all previously defoliated plants had TNC levels similar to those of undefoliated control plants.

It appears that scarlet globemallow had almost completely recovered from a previous heavy defoliation at any phenological stage after at least 14 months of nonuse. Only small differences between control and defoliated plants were detected for any measurement of plant welfare.

Fourwing Saltbush

It was observed that most fourwing saltbush plants had not recovered from previous defoliation treatments after the 14- to 26-month rest period (Table 2). After at least 14 months of rest, plants that had earlier received a single heavy defoliation at a near maturity phenological stage had shorter seedstalks than did undefoliated fourwing saltbush plants. However, fourwing saltbush plants defoliated at quiescence, early growth, or rapid growth had seedstalk lengths similar to those of the control plants. Live crown cover of defoliated fourwing saltbush plants

Table 2. Average herbage yield, vigor, and total nonstructural carbohydrates (TNC) for two browse species subjected to a single defoliation during various phenological stages. Measurements and collections were made in the fall after defoliated plants had received 14 to 26 months of rest.

Species and phenological stage when defoliated	Vigor: Seedstalk or twig length (cm)	Vigor: Live crown cover (%)	Herbage yield (g/plant)	TNC (mg/g): Tap roots	TNC (mg/g): Basal stems
Fourwing saltbush					
Control	13 a[1]	88 a	148 a	78 a	57 a
Quiescence	12 ab	61 b	136 a	79 a	47 ab
Early growth	11 ab	63 b	87 ab	68 a	52 ab
Rapid growth	11 ab	61 b	109 ab	67 a	49 ab
Near maturity	8 b	46 b	33 b	76 a	44 b
Antelope bitterbrush					
Control	12 ab[1]	100 a	57 a	70 a	68 a
Quiescence	15 a	68 b	40 ab	64 a	53 ab
Early growth	14 ab	68 b	36 b	62 a	56 ab
Fruit developing	11 b	47 c	33 b	59 a	50 ab
Seed shatter	13 ab	50 c	23 b	63 a	44 b

[1]Means in the same column followed by a similar letter are not significantly different at the 0.05 level of probability.

was still less than that of the control plants after 14 to 26 months of rest. Herbage yield was still below that of the control plants when plants had been heavily defoliated during a near maturity phenological stage and then allowed 14 months of rest.

Tap roots TNC levels of defoliated fourwing saltbush plants were similar to those of undefoliated control plants after 14 to 26 months of rest (Table 2). However, basal stem TNC levels were reduced the most by a near maturity defoliation. Therefore, most measurements of plant welfare indicated that a near maturity defoliation was most detrimental.

Antelope Bitterbrush

Most defoliated antelope bitterbrush plants made good recovery in twig lengths during the rest period (Table 2). Plants that received a single heavy defoliation during the fruit developing phenological stage had shorter twigs than did plants defoliated at other phenological stages. Antelope bitterbrush twigs were often longer for plants that had received a defoliation than they were for the control plants, but the differences were not significant. Shepherd (1971) also found that defoliated antelope bitterbrush produced longer twigs than did undefoliated plants.

Live crown cover following the rest period was still less than that for the control plants when antelope bitterbrush plants had been defoliated at any phenological stage (Table 2). Late season defoliations at the fruit developing or seed shatter stages appeared to affect cover greatly. Average herbage yields showed that plants defoliated only during quiescence made fair recovery during the rest period.

The differences in TNC levels among plants of antelope bitterbrush from the defoliation treatments were small after 14 to 26 months of rest (Table 2). Defoliated antelope bitterbrush plants had similar tap root TNC levels as the undefoliated control plants. However, plants that received a seed shatter defoliation still had lower basal stem TNC levels than did the undefoliated plants. Therefore, recovery of TNC levels was probably adequate for all plants except those that were defoliated at the seed shatter stage.

A rest period of 14 to 26 months was not sufficient for complete recovery of vigor, herbage yield, and TNC levels of antelope bitterbrush, especially if defoliated during the latter part of the growing season. Cook and Child (1971) reported that heavily defoliated browse species required several years of nonuse for complete recovery.

Little Rabbitbrush

Little rabbitbrush made fair recovery from previous defoliation treatments during the 14- to 26-month rest period. Seedstalk lengths and herbage yields were similar among defoliated and undefoliated little rabbitbrush plants (Table 3). It appeared, however, that little rabbitbrush plants defoliated at the rapid growth stage would require a longer period of rest before complete recovery of herbage yield could be attained. Reductions in live crown cover and TNC levels in roots were still evident among defoliated and control plants after the rest period.

Defoliation of little rabbitbrush during the rapid growth stage severely reduced the recovery of live crown cover and root TNC levels, even after at least 14 months of rest (Table 3). Plants defoliated at quiescence, early growth, or the flower developing phenological stages made fair recovery in crown cover and root TNC levels. The TNC levels of crowns of all defoliated plants were similar to those of undefoliated plants after the rest period. Willard and McKell (1973) also found that defoliated little rabbitbrush plants made good recovery in TNC levels after one year of rest.

Table 3. Average herbage yield, vigor, and total nonstructural carbohydrates (TNC) for two species subjected to a single defoliation during various phenological stages. Measurements and collections were made in the fall after defoliated plants had received 14 to 26 months of rest.

Species and phenological stage when defoliated	Vigor: Seedstalk length (cm)	Vigor: Livecrown cover (%)	Herbage yield (g/plant)	TNC (mg/g): Roots	TNC (mg/g): Crowns
Little rabbitbrush					
Control	16 a[1]	60 a	18 a	104 a	80 a
Quiescence	16 a	58 a	15 a	83 ab	79 a
Early growth	14 a	44 ab	13 a	92 ab	72 a
Rapid growth	15 a	28 b	7 a	67 b	51 a
Flowers developing	17 a	54 ab	13 a	111 a	91 a
Fringed sagewort					
Control	22 a[1]	74 a	4.8 a	126 a	50 a
Quiescence	7 b	15 b	1.8 b	48 b	22 b
Early growth	5 b	9 b	1.0 b	36 b	20 b
Rapid growth	3 b	3 b	0.7 b	18 b	25 b
Near maturity	4 b	12 b	1.5 b	48 b	20 b

[1]Means in the same column followed by a similar letter are not significantly different at the 0.05 level of probability.

Fringed Sagewort

All the defoliation treatments affected recovery of herbage yield, vigor, and TNC levels of fringed sagewort (Table 3). All defoliated plants had shorter seedstalks and less live crown cover after 14 to 26 months of rest than the control plants. Herbage yield of fringed sagewort was drastically reduced by any single heavy defoliation. Herbage yield was reduced by at least 50% by any heavy defoliation, even after a minimum of 14 months of rest. All defoliated plants had much lower TNC levels in both roots and crowns after the rest period than did the undefoliated control plants. Defoliated plants had at least 40% less TNC than did the control plants. The rest period was, therefore, not sufficient for recovery of live crown cover, seedstalk lengths, herbage yields, and TNC levels of heavily defoliated fringed sagewort plants. Defoliation at any phenological stage was detrimental to plant welfare.

Cook and Child (1971) reported that as a result of previous defoliations, vigor of several salt desert species required several years of nonuse before full recovery. Robertson et al. (1970) concluded that 1 year of rest was insufficient for the recovery of vigor of heavily grazed plants. The present study showed that intensive utilization of fringed sagewort would necessitate several years of rest before recovery of plant growth, vigor, and carbohydrate reserves could be expected.

Three Defoliations and Rest

In this multiple defoliation experiment, blue grama, fourwing saltbush, antelope bitterbrush, and scarlet globemallow were defoliated at a heavy intensity (90%) during three phenological stages in 1970 and 1971. Scarlet globemallow and fourwing saltbush were clipped during quiescence, 1970; and rapid growth and seed shatter, 1971. Blue grama plants were clipped during quiescence, 1970; rapid growth and fall regrowth, 1971. Antelope bitterbrush was clipped during quiescence, 1970; and fruit developing and fall regrowth, 1971. Herbage yield, vigor, and TNC data were taken in the fall of 1972 after 14 months of rest, and again in the fall of 1973 after 26 months of rest. Analyses of variance were conducted on differences between control plant responses and defoliated plant responses to determine recovery of the defoliated plants.

Little recovery in herbage yield, vigor, and TNC levels of both storage organs of defoliated blue grama, antelope bitterbrush, fourwing saltbush, and scarlet globemallow plants was noted among plants that had received either 14 or 26 months of rest (Table 4). Herbage yields of all defoliated species were still lower than the undefoliated control plants after 26 months of rest. However, differences in herbage yields between control and clipped plants of blue grama and fourwing saltbush after 14 months of rest were more than twice as great as those obtained after 26 months of rest. In contrast, both scarlet globemallow and antelope bitterbrush showed little change in recovery of herbage yields after 14 or 26 months of rest.

Vigor of defoliated blue grama, fourwing saltbush, antelope bitterbrush, and scarlet globemallow plants was not greatly different after 14 months and 26 months of rest (Table 4). Recovery in live crown cover of fourwing saltbush and antelope bitterbrush was greater after 26 months of rest than after 14 months of rest. However, both browse species had at least 30% less live crown cover than the undefoliated control plants even after 26 months of rest. Seedstalk lengths of defoliated blue grama plants were shorter than those of the control plants after either 14 or 26 months of rest. The rest periods had little effect on twig lengths of scarlet globemallow. Fourwing saltbush had longer seedstalks after 14 months of rest than did the control plants. Twig lengths of defoliated antelope bitterbrush were slightly longer than those of the control plants after either 14 or 26 months of rest. Shepherd (1971) also found defoliated antelope bitterbrush had longer twigs than did undefoliated plants.

Vigor of several salt desert species were found to require several years of non-use before full recovery (Cook and Child 1971). Robertson et al. (1970) concluded that one year of rest was insufficient for the recovery of heavily grazed plants. Mueggler (1975) found that several years of rest were required to restore vigor of Idaho fescue and bluebunch wheatgrass. The present study also showed that several years of rest would be necessary after intensive heavy defoliations before herbage yield and vigor of defoliated plants could be restored to levels similar to those of the control plants.

Table 4. Average difference (control minus defoliated) for several vigor measurements of four species subjected to three defoliations at three phenological stages during 1970 and 1971. Measurements and collections were made during the fall of 1972 and 1973 after defoliated plants had received 14 or 26 months of rest.

Measurement and species	Rest period: 14 months	26 months
Herbage yield		
Blue grama (g/m^2)	464 a[1]	204 a
Scarlet globemallow (g/plant)	0.3 a	0.4 a
Fourwing saltbush (g/plant)	157 a	59 a
Antelope bitterbrush (g/plant)	26 a	40 a
Seedstalk or twig length (cm)		
Blue grama	10 a	19 a
Scarlet globemallow	4 a	4 a
Fourwing saltbush	–6 a[2]	4 a
Antelope bitterbrush	–3 a	–1 a
Live crown cover (%)		
Fourwing saltbush	70 a	30 a
Antelope bitterbrush	63 a	50 a
TNC (mg/g)		
Roots		
Blue grama	13 a	7 a
Scarlet globemallow	–22 a	–31 a
Fourwing saltbush	1 a	20 a
Antelope bitterbrush	18 a	–1 a
Crowns		
Blue grama	16 a	3 a
Scarlet globemallow	–4 a	–3 a
Basal stems		
Fourwing saltbush	10 a	17 a
Antelope bitterbrush	25 a	30 a

[1]Means in the same row followed by a similar letter are not significantly different at the 0.05 level of probability. Blue grama herbage yield was expressed on a basis of 100% basal cover.

[2]A negative sign indicates that clipped plants surpassed the control plants.

Root and crown TNC levels of defoliated blue grama plants had increased more after 26 months of rest than after 14 months of rest (Table 4). The influence of the rest duration was more pronounced in crown TNC levels of blue grama than in root TNC levels. Differences in TNC levels in both tap roots and basal stems of defoliated and undefoliated fourwing saltbush plants were greater after 26 months of rest than after 14 months of rest. Two years of rest appeared to be sufficient for the recovery of tap roots TNC levels of antelope bitterbrush, but basal stem TNC levels were still somewhat suppressed. The TNC levels in both roots and crowns of defoliated scarlet globemallow plants were higher than they were for the control plants after either 14 or 26 months of rest. Defoliated scarlet globemallow plants had slightly greater TNC levels in roots after 26 months of rest than after 14 months of rest.

Six Defoliations and Rest

In this experiment, blue grama, fourwing saltbush, antelope bitterbrush, and scarlet globemallow were all heavily defoliated six times from the fall of 1970 through the late summer of 1972. Blue grama, fourwing saltbush, and scarlet globemallow were defoliated during quiescence, 1970; rapid growth, seed shatter, and quiescence, 1971; and rapid growth and seed shatter, 1972. Antelope bitterbrush plants were defoliated during quiescence, 1970; fruit developing, fall regrowth, and quiescence, 1971; and fruit developing and fall regrowth, 1972. The effects of the defoliation treatments were evaluated in the fall of 1972 immediately following cessation of defoliation treatments and in the fall of 1974 after defoliated plants had received 26 months of rest.

The effects of the six heavy defoliations on herbage yield and vigor of blue grama, fourwing saltbush, antelope bitterbrush, and scarlet globemallow were still evident after defoliated plants had received 26 months of rest (Table 5). However, herbage yields of defoliated blue grama and scarlet globemallow showed some recovery during the rest period. The two browse species, fourwing saltbush and antelope bitterbrush, showed no significant improvement in herbage yields of defoliated plants that were given 26 months of rest.

Undefoliated control plants of scarlet globemallow, fourwing saltbush, and antelope bitterbrush had higher vigor than did defoliated plants. Twig lengths of defoliated scarlet globemallow plants recovered significantly during the 26 months of rest (Table 5). Differences in seedstalk lengths of defoliated fourwing saltbush and twig lengths of antelope bitterbrush were less after 26 months of rest than before the rest period, but the improvements were not significant. In addition, live crown cover of the two browse species was greater after defoliated plants had received 26 months of rest than before the rest period, but all defoliated plants had at least 70% less live crown cover than did the undefoliated conrol plants.

Albertson et al. (1953) found intensively defoliated buffalograss (*Buchloe dactyloides*) and blue grama would require more than 3 years of rest to fully restore plant vigor. Cook and Child (1971) have shown that plant vigor, as a result of previous defoliations, was reduced and required several years of nonuse before full recovery. They found that after 7 years of rest, black sagebrush (*Artemisia nova*), big sagebrush, and squirreltail grass (*Sitanion hystrix*) had not fully recovered from 90% defoliations. McLean and Tisdale (1972) reported that over-

Table 5. Average differences (control minus defoliated) for several vigor measurements of four species subjected to six defoliations from 1970 through 1972. Measurements and collections were made during the fall of 1972, and in 1974 after defoliated plants had received 26 months of rest.

Measurement and species	Rest period: No rest	26 months of rest
Herbage yield		
Blue grama (g/m^2)	748 a[1]	235 b
Scarlet globemallow (g/plant)	0.6 a	0.2 a
Fourwing saltbush (g/plant)	195 a	213 a
Antelope bitterbrush (g/plant)	36 a	115 a
Seedstalk or twig length (cm)		
Scarlet globemallow	11 a	1 b
Fourwing saltbush	8 a	5 a
Antelope bitterbrush	9 a	4 a
Live crown cover (%)		
Fourwing saltbush	97 a	80 a
Antelope bitterbrush	99 a	70 a
TNC (mg/g)		
Roots		
Blue grama	15 a	–1 a[2]
Scarlet globemallow	7 a	7 a
Fourwing saltbush	21 a	48 a
Antelope bitterbrush	17 a	23 a
Crowns		
Blue grama	23 a	24 a
Scarlet globemallow	33 a	1 a
Basal stems		
Fourwing saltbush	23 a	30 a
Antelope bitterbrush	36 a	28 a

[1]Means in the same row followed by a similar letter are not significantly different at the 0.05 level of probability. Blue grama herbage yield was expressed on a basis of 100% basal cover.

[2]A negative sign indicates that clipped plants surpassed the control plants.

grazed ranges might require 20 to 40 years of nonuse to reach excellent condition.

Differences between the roots TNC levels of defoliated and control plants of blue grama, scarlet globemallow, fourwing saltbush, and antelope bitterbrush that had received no rest and those plants that were given 26 months of rest were not statistically significant. However, root TNC levels of blue grama plants had been restored after 26 months of rest even though previously defoliated plants were still not producing as much herbage as the undefoliated control plants (Table 5). This may be related to a reduction of total root biomass in the defoliated blue grama plants as compared with the control plants. If this were the case, defoliated blue grama plants may have had less total reserves to restore aboveground biomass. The TNC levels in crowns of defoliated blue grass that had no rest were fairly similar to those that had received the rest. However, crown TNC levels of scarlet globemallow had made good improvement after the 26-month rest period. The TNC levels of basal stems of antelope bitterbrush showed some recovery after defoliated plants had received 26 months of rest. However, defoliated fourwing saltbush plants made no recovery in basal stems TNC levels during the rest period.

Summary and Conclusions

Seven important range species were heavily defoliated once to remove 90% of the foliage during each of four different phenological stages. Defoliation effects were evaluated in the fall of 2 years after the defoliated plants had received 14 to 26 months of rest. Western wheatgrass, little rabbitbrush, and scarlet globemallow made good recovery after a single heavy defoliation followed by 14 to 26 months of rest. Western wheatgrass and scarlet globemallow plants subjected to a single heavy defoliation and then given a rest period had herbage yields, vigor, and TNC levels similar to those of undefoliated control plants. Heavily defoliated little rabbitbrush plants had herbage yield, live crown cover, and TNC levels after 14 to 26 months of rest that were similar to those of the defoliated control plants except when the defoliation was made during the rapid growth phenological stage.

A 14- to 26-month rest period was insufficient for complete recovery of vigor and herbage yield of antelope bitterbrush and fourwing saltbush subjected to a single heavy defoliation at various phenological stages. Herbage yields, vigor, and basal stem TNC levels of these two browse species were still below those of the control plants after the rest period when plants had received a single defoliation during the fruit developing, seed shatter, or near maturity phenological stages.

Vigor and TNC levels in both storage organs of defoliated blue grama plants were similar to those of the control plants after the rest period. However, the rest period was insufficient for recovery in herbage yield of defoliated blue grama plants, except when the defoliation was made during the quiescence phenological stage.

Herbage yields, vigor, and TNC levels of fringed sagewort subjected to a single heavy defoliation at various phenological stages were still below that of the control plants after 14 to 26 months of rest. Defoliation to remove 90% of the foliage was extremely severe for this species and several years of nonuse would be required for recovery.

Blue grama, antelope bitterbrush, fourwing saltbush, and scarlet globemallow were subjected to three and six heavy defoliations at various phenological stages during 1970, 1971, and 1972. Plants that received three heavy defoliations from the fall of1970 through the late summer of 1971 were evaluated in the fall of 1972 and 1973 after defoliated plants had received either 14 or 26 months of rest. Recovery data of the defoliated plants during these rest periods were compared with data collected from unclipped plants to determine whether the rest periods were adequate to restore herbage yields, vigor, and TNC levels. Recovery of plants that received six heavy defoliations from the fall of 1970 through the late summer of 1972 were evaluated by comparing data for clipped and unclipped plants before rest and after 26 months of rest.

Herbage yield, vigor, and TNC levels of antelope bitterbrush and fourwing saltbush plants that received either three or six multiple defoliations were reduced below those of the undefoliated control plants even after 14 or 26 months of rest. Six heavy defoliations of antelope bitterbrush and fourwing saltbush appeared to be extremely severe for these species and continuous use at this frequency and intensity would probably kill the plants.

Blue grama was more resistant to damage by frequent heavy defoliations and made fair recovery after two years of rest from either three or six heavy defoliations. However, several years of rest might be required before heavily defoliated blue grama could completely recover. It is, therefore, not desirable to utilize this species at this intensity and frequency.

Scarlet globemallow given three heavy defoliations showed good recovery in herbage yield, vigor, and TNC levels after 14 and 26 months of rest. Both root and crown TNC levels of scarlet globemallow given three heavy defoliations were slightly greater than those of the control plants after the rest periods. However, scarlet globemallow plants that received six heavy defoliations had less TNC than did the undefoliated control plants. Scarlet globemallow appeared to be fairly resistant to damage by frequent, intensive defoliations.

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