Response of Sitanion hystrix (Nutt.) J. G. to Prescribed Burning

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ABSTRACT: This study reports the response of *Sitanion hystrix* (Nutt.) J. G. to a midsummer controlled burn. Vegetative, reproductive and physiological attributes of control and burned plants were evaluated in the year following treatment using yield per unit of active crown area. Burned plants responded positively to fire for all parameters measured; (1) shoot biomass—.52 vs. .09 $g \cdot cm^{-2}$ (burn vs. control); (2) root biomass—.36 vs. .24 $g \cdot cm^{-2}$; (3) inflorescence biomass—.26 vs. .02 $g \cdot cm^{-2}$; (4) total shoot density—2.87 vs. 1.95 shoots $\cdot cm^{-2}$; (5) reproductive shoot density—2.14 vs. .28 shoots $\cdot cm^{-2}$; and (6) total nonstructural carbohydrates of roots and crowns—6.66 vs. 5.29 $g \cdot cm^{-2}$. The results contradict previous reports which indicate a period of 1 to several years before preburn levels of annual production are regained.

Direct effects of fire on quiescent bunchgrasses result from heat damage of crown meristematic tissue and subsequent reduction of active crown area. However, crown area of marked *Sitanion* plants was unchanged as a result of burning. Indirect effects of fire derive from alteration of the effective environment of treated plants. Growth of *Sitanion* appears to be related to fire-induced changes in the physical environment and competitive relations within the annual plant-dominated community.

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INTRODUCTION

Sitanion hystrix (Nutt.) J. G., a short-lived, perennial bunchgrass, occupies a variety of habitats throughout semiarid regions of the western United States. Although *Sitanion* is a component of many climax plant communities (*sensu* Whittaker, 1953), one of its outstanding characteristics is the ability to increase abundance during secondary succession (Hironaka and Tisdale, 1963). In the Intermountain shrub-steppe Hironaka and Sindelar (1973) reported *Sitanion* to be the only bunchgrass capable of natural establishment in *Bromus tectorum* L. and *Taeniatherum asperum* Nevski communities. Sites dominated by these two annual grasses are frequently subject to disturbance by wildfire (Wright and Bailey, 1982).

Past work has evaluated response of *Sitanion* to wildfire (Countryman and Cornelius, 1957; Barney and Frischknecht, 1974) and in combustion chambers (Wright and Klemmedson, 1965; Britton and Clark, 1978). This species is one of the most fire-tolerant bunchgrasses. This status is primarily a function of growth form: loosely clustered, coarse stems with minimum leafy materials burn rapidly with little heat transferred downward into meristematic tissue (Wright, 1971). Although burning in a dry year can reduce basal area, most observations indicate fire only slightly damages *Sitanion,* which recovers to preburn levels of annual production in 1-3 years following burning (Wright and Bailey, 1982).

No two fires are the same due to differences in fuel quantity, moisture content, and arrangement (including live vegetation), weather and phenological status of plants. Ten- to thousandfold variations in fireline intensity, the rate of energy release per unit length of flaming front, are observable among burns characterized as low, moderate or high intensity (Alexander, 1982). Similarly, time-temperature relations in the soil-plant-atmosphere continuum may vary greatly between different fires. Thus, variable plant response is observed as fire conditions change over time and space (Britton and Wright, 1971).

Most prescribed fires are conducted to maintain low- to moderate-intensity fires. Whereas previous research considers fire effects in combustion chambers and following wildfires, this study provides data on the response of *Sitanion* to a moderate-intensity controlled burn. Specific parameters evaluated include: (1) crown area; (2) above- and belowground biomass; (3) shoot density; (4) reproductive shoot density, and (5) total nonstructural carbohydrates (TNC) of the root and crown fractions.

METHODS

Study area. —The study area is located within the northern portion of the Basin and Range Province, approximately 65 km SE of Burns, Oregon. The site is occupied by an annual plant community composed of *Bromus tectorum,* the sole dominant, and lesser amounts of annual forbs including *Sisymbrium altissimum* L. and *Descurainia pinnata* (Walt.) Britt. The perennial bunchgrasses *Sitanion hystrix* and *Poa sandbergii* Vasey occur throughout the community, but account for less than 1% of aboveground live biomass (Young and Miller, 1983). Although it is impossible to reconstruct the recent history of this site, the extant plant community represents a low seral stage of a shrub-grassland type. The potential shrub dominant is indicated by scattered individuals of *Artemisia tridentata* Nutt. spp. *wyomingensis* Beetle and Young. Evidence of former dominants of the herbaceous union is found on similar adjacent sites where remnant individuals of the long-lived bunchgrasses *Agropyron spicatum* (Pursh) Scrib. and Smith and *Stipa thurberiana* Piper occur. The present community of exotic annual species is stable and self-perpetuating and is found throughout the Intermountain West. It is likely the result of past disturbance from overgrazing by domestic livestock, periodic fire and/or dryland agriculture.

The site is located at approximately 1300 m elevation, is level and the climate is semiarid. Annual precipitation averages 23.0 cm with 40-50% as rain or snow in the winter (November-February) and 35-40% as rain in the spring to early summer growing season (March-June). Mean January and July temperatures average -0.1 C and 18.5 C, respectively. Winter precipitation for 1980-1981 (6.45 cm) was 34.2% below mean long-term levels. However, spring to early summer precipitation for 1981 (14.61 cm) was 66.6% above normal.

Experimental design. —Two treatments, unburned control and burned, were applied to 25 x 50 m units arranged in a randomized complete block design with three blocks. In July 1980, prior to the burn treatment, 72 individual *Sitanion* bunchgrasses were randomly located within each of the two treatments (24 plants per treatment per block = 144 total). Each plant was permanently marked and its crown area measured as follows: Longest crown axis and longest dimension perpendicular to this length were measured. The area of an ellipse was calculated from these dimensions. Final crown area was determined by subtracting the area of any dead portions within the crown. Aboveground standing crop biomass was harvested in 25, 0.25 m^2 quadrats in each block to estimate preburn fuel load.

Prescribed burn. —The prescribed burn was conducted on 19 July 1980. Weather conditions had been warm and dry for more than 2 weeks prior to this time. Annual plants had completed growth and were fully senesced. Perennial bunchgrasses, including *Sitanion,* had entered summer quiescence with no green shoot material evident. Soils of the rooting zone were dry. Fuel load averaged $223.8 \pm 106.3\ g \cdot cm^{-2}$ over the study area. Burning was initiated at 10:30 AM and was completed ca. 1:00 PM. Fine fuel (less than 0.64 cm diam) moisture at these respective times was 6 and 4% (expressed on an oven-dry basis). Ignition was conducted using a combination of backing and strip head fires (Wright and Bailey, 1982). Weather conditions and behavior of strip head fires observed at the time of the burn are summarized in Table 1. Values for fireline intensity, a measure of the rate of energy released per unit time per unit length of fire front, indicate a burn of moderate intensity (Alexander, 1982).

Postburn sampling. —Each *Sitanion* plant was relocated in early June 1981. At this time anthesis was complete but disarticulation of inflorescences had not begun. Each plant was sampled as follows: (1) crown area was remeasured as in 1980; (2) total shoot density and density of floral reproductive shoots (hereafter referred to as reproductive shoots) were counted; (3) current year's inflorescences were harvested; (4) remaining shoot biomass was harvested. Vegetative and reproductive biomass samples were subsequently oven-dried (60 C) and weighed.

A subset of 30 plants in each treatment (10 plants per block) was randomly selected and excavated for further analysis. A volume of soil 30 cm x 30 cm centered around each plant and 30 cm deep was removed. Samples were washed, oven-dried (100 C), separated into roots and crowns, and weighed. Subsamples were ashed to determine ash-free weights. Root and crown materials were analyzed for percentage total nonstructural carbohydrates (TNC) (Smith, 1969).

Community-level sampling consisted of harvesting standing crop biomass in 25, 0.25 m^2 quadrats in each treatment-block. Samples were separated into the following categories: (1) current year's standing crop of (a) *Bromus,* (b) forbs, and (c) perennial grasses; and (2) litter. Density of *Bromus* and of forbs was also enumerated within each quadrat.

Data analysis. —Change in basal area from 1980 to 1981 was evaluated within each treatment using paired t-tests. Notes concerning shape and dead portions within crowns were compared between years for both treatments, to ascertain if interiors of bunchgrasses sustained damage due to prolonged burning after passage of the flaming front (Wright and Klemmedson, 1965; Wright, 1971). Analysis of variance was used to test differences in treatment means for the various biomass components and shoot density of individual plants, the ratio shoot:root biomass and the weight of TNC in the combined fractions of roots and crowns. Treatment differences of community-level parameters were similarly evaluated using analysis of variance.

RESULTS AND DISCUSSION

Sitanion plants in burned areas adjacent to the experimental units were inspected immediately following passage of the flaming front. Centers of bunchgrasses were cool to the touch and showed no charring and thus no visual damage to meristematic tissue within the crowns. The prescribed fire reduced total aboveground standing crop phytomass to less than 1% of preburn levels.

Crown area of *Sitanion* did not change for either control or burned plots between the 1980 (pretreatment) and 1981 growing seasons. However, *Sitanion* responded to fire with changes in yield and morphology (Table 2). Total live biomass (above- and belowground portions) averaged 1.21 $g \cdot cm^{-2}$ for burned and .56 $g \cdot cm^{-2}$ for unburned plants ($p < .10$).

Both shoot biomass and density, per unit crown area for burned plants, increased dramatically over control levels. Shoot biomass and density of burned plants was 5.8 and 1.5 times greater per unit crown arma, respectively, than unburned plants ($p < .01$). Mean shoot biomass of burn and control plants are .180 g and .048 g, respectively. *Sitanion* produced more and larger shoots following the burn treatment. In con-

TABLE 1. —Weather conditions and resulting fire behavior of strip head fires for the prescribed burn conducted on 19 July 1980. Time of initiation and completion of burning was 10:30 AM and 1:00 PM, respectively

Time	Temperature (C)	Relative humidity (%)	Wind speed ($km \cdot h^{-1}$)	Rate of spread ($m \cdot s^{-1}$)	Fireline intensity[1] ($kW \cdot m^{-1}$)
10:30 AM	24	25	8-11	.250	1046
1:00 PM	31	16	13-16	.667	2790

[1] Fireline intensity was calculated using a basic value of 187000 $kJ \cdot kg^{-1}$ for low heat of combustion following Alexander (1982)

trast, Willms *et al.* (1980) found shoot density of *Agropyron spicatum* (Pursh) Scrib. and Smith burned in the autumn equal to control plants; and mean shoot biomass of burned plants to be less than the control. Whereas, we observed increased yield of *Sitanion* in the 1st year after burning, other researchers have reported intervals of 1-10 years for bunchgrasses of this region to return to preburn levels of production (for a review, *see*, Wright and Bailey, 1982). Prior to this, yields reported were less than preburn levels.

We found burning increases root biomass of *Sitanion* plants 49% per unit crown area ($p < .01$). There is a paucity of information concerning fire effects on root biomass. In addition to providing an understanding of belowground processes, data of this nature permit evaluation of the differential response to treatment by shoots and roots. This can be summarized in the ratio of shoot biomass to root biomass (shoot:root). Shoot:root ratios of burned and unburned plants are 1.73 and .43, respectively. Therefore, although both shoot and root biomass are greatest for burned plants, production of shoots is favored. Hadley and Kieckhefer (1963) found root biomass of *Andropogon gerardi* Vitman and *Sorghastrum nutans* (L.) Nash communities in Illinois increased in the year after burning by 37% and 21%, respectively. Our findings are consistent with their observation of proportionally greater increases in aboveground production. Shoot:root ratios derived from their data provide values of 1.09 (burned) vs. .34 (unburned) for the *Andropogon* community and 1.55 vs. .63 for the *Sorghastrum* community. In contrast, Old (1969), also working in tallgrass prairie of Illinois, found a 10% reduction in root biomass in the 1st year after burning; this despite a slight increase in aboveground production in the burned area.

One of the largest differences observed is the proportion of reproductive culms. Reproductive shoots of burned plants account for 74.8% of all shoots compared to 14.3% for unburned plants ($p < .01$). Inflorescences of burned plants were 49.8% of the total shoot biomass, as compared to 19.9% for control plants ($p < .01$). Inflorescence weight and number of reproductive shoots is a useful index to reproductive effort. Ridder *et al.* (1981) stated that roots should be included in biomass values used to calculate reproductive effort. Following their example, inflorescence biomass as a proportion of total biomass is .213 and .034, respectively, for burned and control *Sitanion* plants. Similarly, burned plants produced more shoots per unit crown area, and a larger proportion of those shoots developed inflorescences, relative to control plants.

Physiological response of *Sitanion* to fire was evaluated by measuring total pools of TNC in roots and crowns. We found total amount of TNC available to plants in roots and crown, per unit crown area, higher in the burned treatment (p. $< .10$). Nonstructural carbohydrates are necessary for respiration during dormant periods, initiation of spring growth, and to some degree regrowth after defoliation (White, 1973). It has been suggested that concentrations of TNC can be used as an index of relative health or

TABLE 2.—Mean weight ($g \cdot cm^{-2}$) and shoot density ($no. \cdot cm^{-2}$) of parameters measured on burned and control *Sitanion* plants, June 1981. All values are expressed as quantity per unit plant crown area

Plant parameter	Burn	Control
Shoot biomass[1] (n = 72)	.52 b[2]	.09 a
Inflorescence biomass (n = 72)	.26 b	.02 a
Root biomass (n = 30)	.36 b	.24 a
Crown biomass (n = 30)	.33 b	.23 a
Shoot biomass:root biomass (n = 30)	1.73 b	.42 a
Total shoot density (n = 72)	2.87 b	1.95 a
Reproductive shoot density (n = 72)	2.14 b	.28 a
Total nonstructural carbohydrates (n = 30)	6.66[3]	5.29

[1] Includes all aboveground parts

[2] Means within a row followed by different letters are significantly different at the .01 level

[3] Means of total nonstructural carbohydrates were significantly different at the .10 level

vigor of plants (Cook, 1966). Total amounts of TNC, however, are likely a better indicator of physiological status.

Direct effects of fire on dormant bunchgrasses such as *Sitanion* are limited to heat damage of crown meristematic tissue. Translocated heat injury to roots is negligible in grassland fires as soil temperatures increase little below 64 mm, with marked temperature rises limited to the upper 10 mm of soil, regardless of soil texture (Norton and McGarity, 1965). In the present study, lack of injury to live crown tissue is supported by both postburn inspection of plants (immediately following burning) and comparison of preburn and postburn (1981) measurements of basal area. As stated earlier, crown area of *Sitanion* did not change for either control or burned plots. Wright and Klemmedson (1965), burning *Sitanion* in a combustion chamber, found little detrimental effect on plants with basal area diam less than 7.5 cm. Crown areas of plants greater than 8.75 cm were reduced in the year after burning. Mean diam of plant crown area in this study is 4.1 cm (range = 0.6-7.6 cm). Little change occurred in crown area of *Sitanion* 1 year after a July wildfire (Countryman and Cornelius, 1957). Britton *et al.* (1978), however, reported 30% mortality and crown area reduction of 73% when *Sitanion* was burned in a combustion chamber in mid-May of a drought year. Burning in mid-October reduced crown area 48%.

Fire indirectly affects plants by altering their physical and biotic environment. Treatment effects at the community level, including response of major plant groups are shown in Table 3. The greater total phytomass production of the burn treatment is due to higher forb production, with no difference in production of *Bromus*. Forb density is greatest in burned areas, whereas density of *Bromus* is greatest on the unburned control. Mean plant weight of both *Bromus* and forbs is greater in the burned treatment.

Changes in community composition might result in differential competition through availability of water, light and nutrients. Community total aboveground primary production, an index of competition to *Sitanion,* increased as a result of prescribed burning. Despite this, productivity of *Sitanion* improved in response to fire in all the measures we employed. Density of *Bromus* decreased with burning. This is the expected result of: (1) direct loss of seed reserves by heat damage, and (2) loss of favorable microsites for germination and overwinter survival due to removal of the protective litter cover (Evans and Young, 1972). Winter annuals such as *Bromus* compete heavily for soil water with the later developing bunchgrasses (*e.g., Sitanion*) of this region (Harris, 1967). Most annual forbs of this study site initiate growth and develop at the same time as *Sitanion.* Poor overwinter soil moisture recharge in combination with above normal spring to early summer rainfall might favor production of forbs and *Sitanion,* relative to *Bromus.* In the unburned control, however, the dense sward of *Bromus* responded by producing a second crop of shoots, thus limiting growth of both forbs and *Sitanion.* Our results indicate that burning opens this annual community by reducing *Bromus* density, allowing forbs and *Sitanion* to successfully compete for growing season precipitation. Increased yield of *Sitanion* in burned areas suggests it can readily compete with forbs in this community.

TABLE 3.—Mean aboveground production ($g \cdot m^{-2}$) and density ($plants \cdot m^{-2}$) of community level parameters for burn and control treatments, June 1981. N = 75 per treatment

Plant parameter	Burn	Control
Total production	199 b[1]	141 b
Annual grass production[2]	112 a	113 a
Forb production	80 b	1 a
Annual grass density	83 b	1789 a
Forb density	39 b	5 a

[1] Means within a row followed by different letters are significantly different at the .01 level

[2] *Bromus tectorum* constitutes the sole annual grass species

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