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ABSTRACT. An area burned by prescription in 1977 and a nearby unburned area were measured in 1974 and 1980 to determine effects of the burn on herbage and forage production. Herbage production on the burned area increased significantly in 1980 over its 1974 level, in addition to being greater than the 1980 control production. However, the proportion of forage production to total herbage production in 1980 on the burned area decreased after the burn, and was significantly less than the control area forage production. This reduction in forage production can be attributed to the increase of nonforage species, notably bracken fern.

Increases in total herbage production on both burned and unburned areas between 1974 and 1980 are attributed to a number of factors, including increased soil moisture availability during the 1980 growing season which had 50 percent more precipitation than the historical average. FOREST SCI. 30:22–25.

ADDITIONAL KEY WORDS. *Pinus ponderosa,* forage production.

FIRE SUPPRESSION in southwestern ponderosa pine has been blamed for a host of negative environmental impacts including decreased forage production, increased fuel loads, and increased severity and destructive potential of wildfires (Weaver 1974). In an attempt to alleviate the wildfire severity problem, land managers are using prescribed burning to reduce these heavy fuel loads.

Little is known about the impact of prescribed fire on understory production in southwestern ponderosa pine. Ffolliott and others (1977) found a 13 fold increase (from 3.4 to

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44.8 kg/ha) 11 years after a prescribed fire on volcanic soils in northern Arizona. Harris and Covington (1983) found that understory production increased overall during the first growing season following a prescribed fire on basalt soils near Flagstaff, Arizona. However, Gaines and others (1958) found a first year decline in understory density following a prescribed fire in east central Arizona.

This paper reports the results of a study of differences in herbage and forage production between an unburned area and a burned area 3 years after the prescribed burn on sedimentary soils near Flagstaff, Arizona.

Study Area

The study area is located 30 km southwest of Flagstaff, Arizona, within the Coconino National Forest. The topography is a rolling plateau surface with a relief of 25 m or less. Slopes range from 0 to 20 percent. The elevation of the area is between 1,900 and 2,060 m. Soils are predominantly sandy loams in the Hoggs, McVickers, and Soldier series over Kaibab limestone and Coconino sandstone bedrock.

The average daily temperature of the study area is approximately 6°C and average annual precipitation is 49 cm at the nearest weather station at Flagstaff, Arizona.[1] Most of the precipitation occurs during the winter.

The overstory vegetation is almost entirely ponderosa pine (*Pinus ponderosa*), with scattered white fir (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), Gambel oak (*Quercus gambelii*), and alligator juniper (*Juniperus deppeana*) (nomenclature follows Kearney and Peebles 1964). The understory is made up of grasses and herbaceous plants.

In 1971 and 1972, the area to be burned was thinned to release saplings growing in dense thickets. The study area was burned[2] on October 18 and 19, 1977. Skies were clear both days. Relative humidity ranged from a high of 100 percent to a low of 23 percent, while temperatures ranged from a low of −3°C to a high of 26°C. Winds were from the southwest at 8–16 km/h on October 18 and calm from the southeast on October 19. Backing fires and short strip head fires were used to burn the area.

Fuel inventories conducted by U.S.F.S. personnel indicated that fuel loads generally varied between 16 and 27 t/ha before burning. Estimates of fuel consumption ranged from 50 to 75 percent of preburn levels. Generally the fire was cool enough that regeneration was not killed; however, isolated patches of saplings, generally less than 0.1 ha, were killed. No mortality occurred in the vicinity of our sample plots.

Methods

In 1974, as a part of a study of a nearby wildfire, understory vegetation was sampled on the area to be burned by prescribed fire as well as a nearby control area (Fitzhugh and Beaulieu,[3] Beaulieu[4]). Four vegetation quadrats (0.89 m^2) were established perpendicularly 7.1 m from the center of each of 25 timber plots (total number of quadrats in each study area = 100). These same plots were measured in 1980 in our study. Two vegetation quadrats around each timber inventory plot were used for collecting data. The number of stems was counted by species. Stem was defined as the entire plant above the root collar. The data from the two quadrats were combined and analyzed as one result.

In previous studies in the area, harvesting was excluded from the plots. In this study the two plots counted were clipped at ground level by species, and averaged for each timber inventory plot. The clipped material was ovendried under forced air for 24 hours at 105°C.

The areas were sampled in late July and early August. Total herbage and forage production for each of the 25 plots was calculated.

Herein, forage is defined as all plant species except those not utilized by range animals;

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[1] National Oceanic and Atmospheric Administration. 1980. Local climatological data, annual summary with comparative data. Flagstaff, Arizona. Unpublished report.

[2] Fernow Burn Report. On file Flagstaff District Office, Coconino National Forest.

[3] Fitzhugh, E. Lee, and J. T. Beaulieu. 1976. Wildfire effects on plant and animal communities in Arizona ponderosa pine forests. Unpublished report.

[4] Beaulieu, J. T. 1975. Effects of fire on understory plant populations in a northern Arizona ponderosa pine forest. M S thesis, Northern Ariz Univ, Flagstaff. 36 p.

TABLE 1. Mean herbage production (kg/ha) of the study areas.

Year	Prescribed burn	Unburned area
1974	275[b,x]	139[b,x]
1980	490[a,y]	295[b,x]

[a,b] Significant ($p < 0.05$) differences between burned and unburned areas.
[x,y] Significant ($p < 0.05$) differences over passage of time.

herbage is all understory herbaceous species. In our study area the major nonforage species were *Pteridium aquilinum* and *Astragalus* spp. An analysis of variance was performed between the data from Beaulieu[4] and the data collected in 1980. This determined the variation as a result of the passage of time, as well as the prescribed burn. The results of the analysis were tested at 0.05 confidence level. The Student-Newman-Keuls Multiple Range test was used to determine which treatment means were different.

Results and Discussion

The mean herbage production for both burned and control areas is shown in Table 1. The analysis of variance showed that no significant difference existed in 1974, before the prescribed burn. However, by 1980 the burned area had increased significantly in herbage when compared to its 1974 level. Furthermore, the burned area was higher than the unburned area in 1980.

While there were no significant differences in forage production between years, in 1980 forage production on the unburned area was significantly higher than that on the burned area (Table 2).

Herbage production on both burned and unburned areas increased from 1974 to 1980. This increase could be the result of a variety of factors. In 1980, precipitation on the study area was 74 cm, almost 50 percent greater than the historical average. A linear relationship between increased precipitation and increased production was suggested in a study by Ffolliott and Clary (1974). Thus, some of the apparent increase in herbage production between 1974 and 1980 on the burned and unburned areas may be attributed to greater moisture availability. Increases of understory herbage production on the burned area when compared to the unburned area might also be due to fire-induced increases in soil moisture and nutrients (Ryan and Covington, unpublished[5]), decreases in allelopathy (Christensen 1977), and the reduction of forest floor depth (Clary and others 1968).

While forage species accounted for over 95 percent of total herbage production on the unburned area in 1974 and 1980, forage production on the burned areas was only 34 percent of the total herbage production in 1974 and 25 percent in 1980. This change is explained by the increased production of bracken (*Pteridium aquilinum*) after the prescribed burn.

Changes in species composition following prescribed burning were apparent. Three major species showed reductions in composition, while nine species showed increases (Table 3). Notable changes are decreases in *Muhlenbergia montana* and *Bromus* spp., both of which are important forage. However, other forage species (*Koeleria cristata, Lotus* spp., *Vicia*

[5] Ryan, Michael G., and W. Wallace Covington. Unpublished. Effect of a prescribed burn in ponderosa pine on inorganic nitrogen content of mineral soil.

TABLE 2. Mean forage production (kg/ha) of the study areas.

Year	Prescribed burn	Unburned area
1974	93[a,x]	137[a,x]
1980	123[a,x]	290[b,x]

[a,b] Significant ($p < 0.05$) differences between burned and unburned areas.
[x,y] Significant ($p < 0.05$) differences over passage of time.

TABLE 3. Species showing changes in composition following prescribed fire.

Species	1974 density	1980 density
	Stems/m^2	
Achillea lanulosa	1.11	1.48
Bromus spp.	0.05	0
Draba asprella	0.17	0.04
Muhlenbergia montana	1.01	0
Gayophytum nuttalli	0.46	8.30
Koeleria cristata	0	0.63
Lotus spp.	0.10	0.27
Poa spp.	0.87	36.78
Pteridium aquilinum	1.88	3.81
Senecio wootonii	0.70	1.35
Thermopsis spp.	0	1.35
Vicia americana	1.13	3.50

americana, and *Poa* spp.) increased in composition thus compensating, in part, for the decline in the others. The increase in *Pteridium aquilinum* composition following burning appeared to account for most of the increase in nonforage understory biomass.

As in all studies of fire effects, the causes for changes in understory composition must be interpreted with caution. In addition to mechanisms directly associated with the burning (mortality, injury, and effects on site), species composition may be altered by greater grazing and browsing pressure associated with fire-induced increases in nutritional value of understory vegetation (Handley 1969, Pearson and others 1972). Such increases in nutritional value in southwestern ponderosa pine following both prescribed burning (Harris and Covington 1983) and wildfire (Pearson and others 1972) have been demonstrated. Since our study area is part of a cattle allotment and is used heavily by both deer and elk, we suspect that some of the compositional changes we observed may be due to increased grazing pressure.

In summary, while herbage production increased by year 3 after this prescribed burn, forage production was not significantly affected. This is explained by the substantial increase in nonforage species, particularly bracken fern, following the burn.

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