Annual Grassland Response to Fire Retardant and Wildfire

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Abstract

Diammonium phosphate (DAP), air-dropped in early autumn 1974 to contain a wildfire on the San Joaquin Experimental Range in California, applied high levels of nitrogen and phosphorus to foothill annual grassland. The DAP drop and fire provided 4 treatments for the study—unburned + DAP, burned + DAP, burned and unburned (control). In the first year both of the DAP treatments, with yields of more than 12,000 kg/ha produced twice that of the unburned (control). First-year forage yields for the unburned and burned plots were not significantly different. The second year the burned plot yielded almost twice that of the unburned. The second year, the unburned + DAP plot produced about 4200 kg/ha, the highest yield of all 4 plots, and significantly higher than the burned + DAP plots. Annual and seasonal weather patterns and soil moisture affected herbage composition more than treatments. Although forbs usually increase in annual grassland after fire, and nitrogen fertilizer favors grasses, grasses nonetheless dominated on all 4 treatments in the first year. Forbs were dominant the second year. The difference in relative percent composition of grasses and forbs was greater between years than between treatments.

Foothill annual grasslands and associated oak woodlands are California's largest and most important range types. The annual grasses and forbs germinate after the first effective rain in autumn, grow slowly through the winter, and then grow rapidly with warmer temperatures in early spring. In late spring plants quickly flower, set seed, and dry (Bentley and Talbot 1951). During late spring and summer, however, the vegetation, in addition to providing food and cover for domestic animals and wildlife, becomes a potential wildfire hazard.

Many studies have been done on the effects of burning oak woodland-grasslands. Vegetation grows more slowly the winter after burning (Hervey 1949), production is often less (Hervey 1949, Graham 1956), and composition changes (Graham 1956). Varying intensities of fires result in differential seed mortality (Burcham 1957) and alter chemical, physical, and biological properties of soils (Vogl 1974). Too, many soils of California are deficient in nitrogen (N), phosphorus (P), and sulfur (S), in varying degrees and combinations. Studies done on fertilization of these rangelands report that grass is stimulated by N fertilization (Duncan 1974, Martin and Berry 1970); P will often increase legumes if sufficient N is present (Heady 1975, Jones 1976, McKell et al. 1960); and the N produced by the legumes will, in turn, produce more grasses (Jones and Evans 1960). Of all the ecosystems they described, encompassing the entire United States, Garrison et al. (1977) said "...annual plants with their short life cycle and rather shallow root system, have probably shown the most consistent and profitable response to range fertilization."

To contain a wildfire, fire retardants are sometimes air-dropped on a burning woodland-grassland. One of these, diammonium phosphate (DAP), contains high levels of nitrogen and phosphorus. None of the studies cited earlier, however, has reported on the fertilizer effects of air-dropped DAP on California annual grasslands. Trade-offs between effects of fire and effects of fire retardant need to be quantified and evaluated. Other studies of air-dropped DAP have, thus far, concentrated on ecological problems (George et al. 1976). In the future, as increasing numbers of people move into the foothills, the benefits or disadvantages to range, wildlife, watershed resources and home protection need to be evaluated to obtain a more balanced assessment of this fire-fighting practice.

On October 5, 1974, a wildfire burned through woodland-grass across part of the San Joaquin Experimental Range in Madera County, 45 km northeast of Fresno, Calif. Aerially applied Phos-Chek XA[1] fire retardant (DAP) helped contain the fire. We took advantage of the fire and air drop of DAP to study their effects on forage yield, species composition, soil moisture, and grazing use by cattle. This paper reports the results of our study from October 1974 to May 1976.

Methods

The study area on the San Joaquin Experimental Range is at an elevation of 350 m and has been described as an "open, rolling slope" site (Bentley and Talbot 1951). Such sites have a long-term potential yield of about 2250 kg/ha/yr (Duncan and Woodmansee 1975). The slope is 5% with an easterly aspect. Scattered blue oak *(Quercus douglasii)*, buckbrush *(Ceanothus cuneatus)*, and granitic rock outcrops are seen in the general area (Fig. 1).

In addition to diammonium phosphate, DAP contains additives to reduce corrosion, enhance flow characteristics, and improve adherence to fuels. A water-soluble coloring agent in the retardant clearly delineated the affected area. Two parallel drops of DAP were made. Liquid released totalled 7728 liters (Henson, pers. commun.)[2] Each drop formed an elliptic pattern that covered a total area of about 0.4 ha resulting in an estimated application rate of 381 kg/ha N and 408 kg/ha P.

The wildfire burned about 5 ha before it was slowed by the DAP drop and contained by ground crews. A burned-only treatment area about 84 m^2 was selected downslope as near to the DAP drop as constraints of trees, rocks, and swales allowed; a control area of equal size was selected upslope. Plots were located in open grassland to minimize variance caused by shade from overstory, litter effects, and soil moisture. Plot locations were limited also to a minimum soil depth of 30 cm with no dung or indication of gopher activity.

Patterns of the wildfire and air-dropped DAP determined 3 of the 4 treatments. Combinations sampled included the control or unburned, unburned + DAP, burned, and burned + DAP. Ten 0.093 m^2 plots per treatment were sampled at random to estimate

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[1]Trade names and commercial enterprises or products are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

[2]Roy Henson, air coordinator, California Department of Forestry, Sanger, Calif. 93657.

Fig. 1. *Open-rolling foothill-woodland with trees, shrubs, and granite outcrops.*

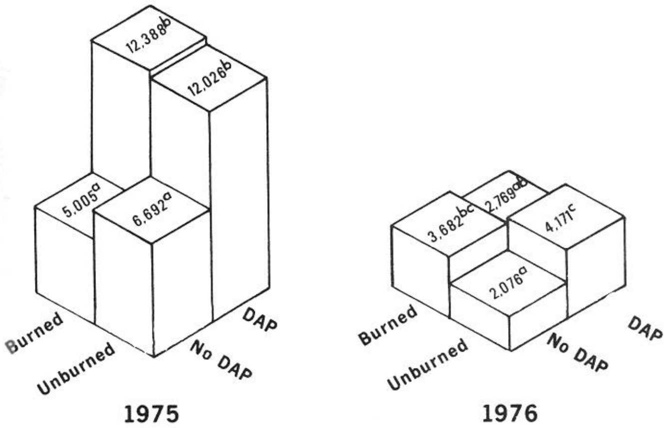

Fig. 2. *Herbage yield (kg/ha) 1975 and 1976 growing seasons. Treatment yields within years followed by a common letter are not significantly different (P<0.05).*

forage production. Data on yield were analyzed by a one-way analysis of variance and Tuckey's multiple range test.

Wire net cages were used to protect forage from grazing animals. At peak production these ungrazed plots were hand-clipped 1.3 cm above ground and yield calculated from air-dried weight of herbage. Percent species composition was calculated by hand-sorting the samples into 4 major species—soft chess *(Bromus mollis)*, ripgut brome *(B. diandrus)*, foxtail fescue *(Vulpia megalura)*, and broadleaf filaree *(Erodium botrys)*, and 2 groups— miscellaneous legumes and miscellaneous forbs (Table 1).

Soil water content was assessed by the gravimetric method at 3 depths (0–10, 10–20, and 20–30 cm) each month of the growing season. Two 5-cm diameter soil cores per treatment were taken at random just outside the caged sampling areas. Data were analyzed by analysis of variance. The official weather station at the San Joaquin Experimental Range headquarters about 1.6 km east of the study area provided weather records.

Forage utilization (yearlong grazing by cows and calves) was visually classified as light, medium, or close (Bentley and Talbot 1951).

Results and Discussion

Forage Yields

The unburned and burned treatments receiving DAP produced about 12,000 kg/ha of herbage in 1975, about twice that produced on the control and burned-only treatments (Fig. 2). Differences were statistically significant ($P<0.05$). No differences between burned and unburned treatments without DAP were observed.

The 1976 forage yield on control plots (2,076 kg/ha) was about 10% below the long-term mean and about 70% lower than production the year before. The burned and the unburned + DAP treatments both produced significantly more forage than the control. But production on the burned + DAP treatment did not differ significantly from the control or burned-only treatments (Fig. 2).

In terms of yield, therefore, an early fall application of air-dropped DAP resulted in much more forage the first year after treatment whether burned or unburned. The next year, however, carryover effects of DAP were detected only on unburned plots. Burning alone did not decrease production the first year, and second year yield on the burned-only plot was 1.8 times that on the control (Fig. 2).

In addition to treatment differences resulting from fertilizer and burning, weather during the study period obviously contributed significantly. Rainfall for the period September 1, 1974, to August 31, 1975, was 48.0 cm, an amount that compares to a 41-year mean of 48.5 cm. But because of colder-than-normal spring weather, growth of forage, especially forbs, was retarded for a longer-than-normal time. Unusually heavy, late spring rains (Fig. 3) were, however, early enough to stimulate the maturing plants so that forage yields were above average.

Rainfall for the 1976 growing season was below average, and a drought period with many frosty nights occurred in December and January. These harsh conditions not only retarded growth, but in many instances, killed the young plants on the shallower soils. Start of an adequate green grazing season was delayed until March

Table 1. Effect of wildfire and air-dropped DAP, alone and in combination, on species composition (% air-dry wt.) on California annual range land.

	Grasses			Forbs			Total	
Year and treatment	*Bromus mollis*	*Bromus diandrus*[1]	*Vulpia megalura*	*Erodium botrys*	Misc. legumes[2]	Misc. forbs[3]	All grasses	All forbs
1975								
Unburned	35	5	40	10	8	2	80	20
Burned	66	8	0	15	4	7	74	26
Unburned + DAP	23	38	19	19	0	1	80	20
Burned + DAP	33	42	21	4	0	0	96	4
1976								
Unburned	7	7	13	61	2	10	27	73
Burned	32	7	0	59	0	2	39	61
Unburned + DAP	3	8	13	37	0	39	24	76
Burned + DAP	7	3	21	67	0	2	31	69

[1]Includes minimal amount of red brome *(Bromus rubens)* and slender wild oats *(Avena barbata)*.
[2]*Trifolium* spp. and *Lupinus bicolor*.
[3]Primarily popcorn flower (*Plagiobobothrys nothofulvus*) and smooth catsear (*Hypochoeris glabra)*, except for unburned + DAP 1976, which was nearly all popcorn flower.

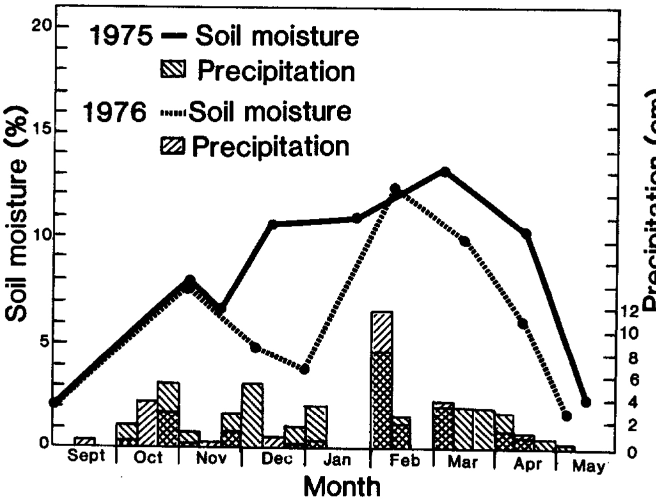

Fig. 3. *Percent soil moisture, 0–30 cm by month, and precipitation, as 10-day means, 1975 and 1976 growing seasons, San Joaquin Experimental Range.*

1. Late spring rains, however, stimulated the stressed plants and the season ended with average yields.

Species Composition

Instead of forbs being dominant the first year after the fire as expected (Graham 1956, Hervey 1949), grasses represented 80% of the air-dry weight (Table 1). The differences in percentages of grass species indicate either that fire increased the percent soft chess, or that foxtail fescue was inhibited by fire or was simply not present in the burned treatment. Foxtail fescue was equally abundant in the DAP treatments whether burned or unburned. Ripgut brome is known to respond to nitrogen fertilization and this was apparent in the first growing season in the DAP treatments. But ripgut brome did not respond to the carryover effects during the second growing season. Although DAP doubled yields, on both burned and unburned plots the first year following application, it did not appear to affect the grass-to-forb ratio. Legumes germinated but did not mature with the high nitrogen levels resulting from the DAP treatments.

Weather appears to have been the dominant variable influencing species composition. Colder-than-normal weather during the winter growing season favored grasses, and late spring rains decreased the competitive advantage forbs show over grasses when moisture is limiting (Talbot et al. 1939). Also, these late spring rains, coupled with the dense grass herbage, produced a microclimate with high relative humidity that favored an unidentified thin, white powdery mycelium, which reduced the number of filaree plants (pers. obs. Larson). Lush green foliage associated with postburn conditions may favor certain fungi and bacteria (Vogl 1974).

The second season after the first was a "forb year" for all treatments, with forbs comprising about 70% and grass about 30% of the forage crop. Filaree was by far the most abundant broadleaf plant except in the unburned + DAP treatment where popcorn flower *(Plagiobothrys nothofulvus)*, an early growing broadleaf that was heavily utilized by cattle, comprised 50% of the total forbs (Table 1). The winter drought definitely gave the forbs an advantage and, in combination with the long period of cold weather, resulted in many of the stressed grasses being frosted back or killed.

Production of native legumes on the San Joaquin Experimental Range has been shown to be positively correlated with late spring rains (Duncan and Woodmansee 1975). The differences between years on the unburned treatments also suggest this correlation. The fertilizer effect of N can also be a limiting factor in legume production (Table 1).

Utilization

Early in the 1975 green grazing season, observations suggest that the cows preferred grazing in the area that received DAP. The exact reasons for preferential grazing in areas that have been burned or fertilized have yet to be quantified, but such use frequently occurs (Heady 1975, Vogl 1974).

Close utilization was observed on the burned + DAP plots throughout both growing seasons. The unburned + DAP plots were utilized slightly less, perhaps indicating a positive interaction effect between burning and DAP as related to use. The burned plots were grazed at a moderate rate, only slightly more than the unburned.

The heavy utilization of the DAP areas probably affected the lack of fertilizer response the next year and seemed to delay the next green grazing season. Close utilization delays growth the next winter and reduces total yields in the spring (Bentley and Talbot 1951).

Fire retardant containing ammonium phosphate or sulfate should not cause toxicity problems (Dodge 1970). The close utilization of the bulk of the forage on the DAP areas did not produce toxic symptoms in cows and calves. This area, however, was only a small portion of the total grazing unit.

Differences in weather between the 2 years of this study were reflected in the results of soil moisture tests (Fig. 3). Each year a significant difference ($P<0.05$) in soil moisture was observed between the 0- to 10-cm depth and the lower depths for all treatments, except for the first and last samples of each season. But no significant difference was observed between depths of 10 to 20 cm or of 20 to 30 cm or between treatments. The differences, therefore, were in the upper 10-cm portion of the soil where from 75 to 80% of the roots of winter annuals are found (Duncan 1975).

Range Readiness

Annual range was considered ready for grazing without supplement when plants reached heights of 5 to 8 cm and plant growth was likely to stay ahead of cattle grazing. Range readiness occurred about February 11 on all treatments in 1975, except the burned area, which was not range ready until about 4 weeks later. The delayed growth in the burned-only area probably was related to the absence of litter that would have altered the microclimate near the ground and afforded some protection for the seedling plants from the colder-than-normal early growing season. Sampson (1944) found that forage is often green longer than normal on burned areas, but is shorter in height. The burned area developed slower phenologically, thereby producing a longer green season. Plant height was not reduced, however.

In 1976, all treatments were range ready by late February except the burned + DAP treatment, which was delayed until late March because of the abundance of broadleaf filaree that was semiprostrate as a result of cold weather.

Management Implications

This 2-year study demonstrates that a complexity of variables determines herbage yield and composition. Long-term studies by Duncan (1974) and Martin and Berry (1970) point out the need to evaluate annual grassland treatments for at least 10 years to obtain a realistic picture over time.

Reported responses (cited above) to fire and fertilizer in many areas of California have given similar results. Although our results apply only to the study area, they may be applicable to similar sites at other locations.

Results of this study suggest that prescribed fall fires should be studied as a means of increasing production on annual grasslands. A fall aerial drop of DAP markedly increased forage production on the annual grassland, but depressed native clover production for 2 years. Heavy preferential forage utilization on the fertilized areas probably reduced fertilizer carryover effects and subsequent production. Where no fertilizer was involved, the fall wildfire had little effect on forage yield or composition the first growing season after the fire, but yield was almost doubled the second year.

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