# Time and Rate of Paraquat Application for Curing Meadow Vegetation for Winter Grazing[1]

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### ABSTRACT

Winter grazing of paraquat (1,1· dimethyl-4,4· bipyridinium ion)-cured meadow vegetation has been shown to hold potential as an alternative to the conventional cut-stack-feed practice in the Great Basin meadowlands. Additional information was needed to define (i) the minimum levels of paraquat required for curing; (ii) the best application time; (iii) the comparative effectiveness of above-canopy spray release with within-canopy spray release.

Plots were treated with paraquat at rates from 0.06 to 0.56 kg/ha in July of 2 years. Paraquat applied in the morning, midday, and evening hours evaluated plant maturity, illumination, temperature, relative humidity, and surface soil moisture in relation to the chemical's effectiveness to arrest the loss of herbage N.

Vegetation was satisfactorily cured with 0.11 kg/ha paraquat. Crude protein concentrations of meadow vegetation exceeded 7% in July, and treatments in that month maintained concentrations above 5.5% for 160 days; naturally cured vegetation then contained less than 4%. Yield losses in treated plots 90 days after treatment ranged from 22 to 30% but were no greater than those in control plots. Dispensing the spray above the canopy was more efficient than dispensing it within the canopy, but the difference is believed to be a result of poor spray coverage from the within-canopy treatments. Morning, midday, and evening applications did not produce significantly different treatment means. Crude protein concentration was higher in vegetation treated on sunny days than on overcast days, but this was due to sunny day effect rather than an increase in effectiveness of paraquat. Paraquat residue at 100 days after treatment at the rate of 0.34 kg/ha or less ranged from 3 to 15 ppm.


*Additional index words:* Chemical curing, Meadow hay.

PARAQUAT[3] (1,1′ dimethyl-4,4′ bipyridinium ion) satisfactorily cures grasses on rangelands (Sneva, 1967; Kay and Torell, 1970; Sneva et al., 1973). However, paraquat has not received clearance from the Environmental Protection Agency for this use. Rapid increases in costs of harvesting, storing, and feeding hay in the mid-1970's prompted investigation of winter grazing by beef cows on chemically cured meadow vegetation as an alternative for these conventional practices. Results of such winter grazing trials in 1974-75 and 1975-76 suggested that chemical curing followed by winter grazing of these meadows was a practical alternative for wintering the beef cow (Sneva and Turner, 1977).

In this paper we present and discuss the results of studies conducted to ascertain (i) the minimum level of paraquat necessary for satisfactory plant curing; (ii) the time of application for best curing; (iii) the spray release position for greatest effectiveness.

## MATERIALS AND METHODS

Plots of meadow vegetation were treated with paraquat at 0.0, 0.22, 0.34, 0.45, and, 0.56 kg/ha on 28 July 1975 and new plots at 0.0, 0.06, 0.11, 0.22, and 0.34 kg/ha on 25 July 1976. In 1975, herbage samples for N determinations were collected at 0, 42, 67, and 100 days after treatment. Herbage samples from plots treated at 0.22 and 0.56 kg/ha were collected at 100 days for paraquat residue determinations. In 1976, herbage samples for N determination were collected only at 63 days after treatment. On the same date herbage for chemical residue was collected from plots treated at 0.06 and 0.22 kg/ha and at 100 days after treatment from all plots.

The effect of date of paraquat application was evaluated by treating plots of meadow vegetation at 0.34 kg/ha paraquat as a canopy spray in the evening hours on 8, 16, 23, and 30 July 1976. Herbage yield and N concentration of the herbage were determined from three 1-m² quadrats per plot harvested at ground level on the treatment dates and on 17 and 30 August, 22 September, 3 November, and 2 January. Yields are expressed as weights of oven-dried herbage.

The time of application was evaluated on two sunny days (28 and 29 July 1976) and two overcast days (30 July and 13 August) with 0.22 kg/ha paraquat applied between 0500 to 0700, 1300 to 1500, and 1700 to 1900 hours. Herbage N was determined from a composite of grab samples within each plot on the treatment date and again on 24 September 1976.

A conventional tractor-mounted boom-type field sprayer was used to apply the chemical. The effect of spray position release (above the vegetation canopy vs. within the canopy) was also evaluated in the two rate and the one time-within-day study. In those experiments one-half of the boom was rigged with 46-cm drop tubes (Fig. 1) and the boom mounted and carried to release the spray above and within the canopy simultaneously. Tractor speed, boom pressure, orifice tip size, and carrier volume were constant within a study but differed among studies. Operating speeds varied from 3.2 to 4.8 km/hour with boom pressures of 2.8 to 3.5 kg/cm² and total spray volume

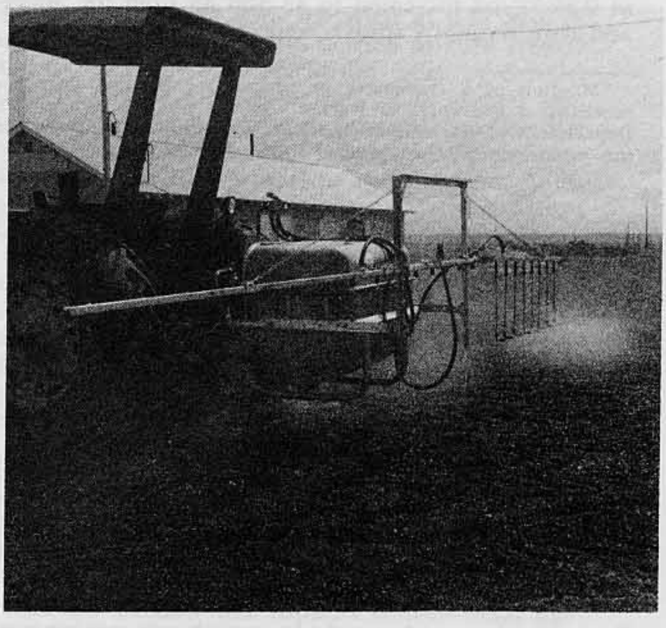

Fig. 1. Commercial spray boom with half of the boom rigged with 46-cm drop tubes.

[1] The research is a cooperative investigation of the AR, SEA, USDA, and the Oregon State Agric. Exp. Stn.. Squaw Butte Exp. Stn., Burns. Oregon Agric. Exp. Stn. Technical Paper No. 4790. Received 18 Sept. 1978.

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[3] This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation by the USDA nor does it imply registration under FIFRA.

ranging from 102.9 (1975) to 177.6 l/ha (1976). Water was used as a carrier with the surfactant X-77[4] added at the rate of 0.5% of the total solution volume.

Experimental designs consisted of randomized block and variations of the split plot with three to five replications. Standard analysis of variance was used to evaluate treatment-mean differences.

Paraquat residue values reported are single determinations of 1.4-kg herbage samples obtained from multiple points within treatment plots and composited over similarily treated plots. Residue analyses were conducted by independent laboratories but purchased by Chevron Chemical Co.

Maximum and minimum daily temperature, daily precipitation, and incoming solar radiation at canopy level (measured with a recording actinograph) were monitored at the headquarters 0.4 km away. Relative humidity was continuously monitored with a hygrothermograph set at ground level in a nearby undisturbed meadow. Illumination above and at 15 cm above ground level was measured with a lux meter in an undisturbed meadow. Ten light readings at random positions were taken at 0900, 1300, and 1700 hours on each treatment date for the time-of-day study. Soil moisture in the upper 5 cm of meadow at each application date of the date-within-season study was estimated from five, random, 1.9-cm-diam cores per control plot.

The meadow vegetation is that which is typical of the wild flood meadow at high elevations in western U. S. Dominant plant species are rush (*Juncus* spp.) and sedge (*Carex* spp.) with only small amounts of true grasses present.

## RESULTS

### Rate Studies

Paraquat at rates of 0.22, 0.34, 0.45, and 0.56 kg/ha satisfactorily arrested crude protein loss (Fig. 2). Meadow vegetation on control plots lost about half of its crude protein concentration from 28 July to 5 November 1975. No difference in effectiveness was detected between paraquat sprays released above the canopy and those released within the canopy. Paraquat residue in meadow vegetation 100 days after treatment at 0.22 kg/ha were 15 and 11 ppm for above- and within-canopy sprays, respectively. Paraquat residues in the vegetation 100 days after paraquat was sprayed at 0.56 kg/ha increased to 48 and 35 ppm for above- and within-canopy sprays, respectively.

[4] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may be suitable.

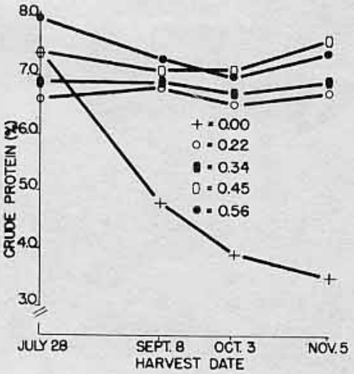


**Fig. 2. Trends in crude protein concentrations in meadow vegetation treated with paraquat on 28 July 1975 at the rates indicated (kg/ha).**

In 1976, paraquat at 0.11, 0.22, and 0.34 kg/ha arrested the loss of crude protein similarly. Crude protein retention was significantly ($P < 0.05$) higher in vegetation treated at these rates than in vegetation treated at 0 and 0.06 kg/ha. Spray release position interacted significantly ($P < 0.05$) with application rate (Fig. 3); the release position made little difference in retention of crude protein in vegetation treated at the 0.06 kg/ha but in vegetation treated at higher rates, retention of crude protein was greater with above-canopy than within-canopy sprays. Paraquat residues in the vegetation 100 days after treatment at 0.06, 0.11, 0.22, and 0.34 kg/ha, were 0.74, 3.77, 4.17, and 5.40 ppm, respectively. Residues the day after application of paraquat at 0.22 kg/ha were 9.0 and 0.16 ppm for sprays released above and within the canopy, respectively.

### Date Study

Surface soils were saturated on 8 and 16 July (125 and 111% soil moisture concentration, respectively). Soil moisture concentration dropped to 94 and 82%, respectively, in the subsequent 2 weeks.

Dry matter concentration of the herbage from control plots ranged from 29 to 34% between 8 and 30 July 1976 with no discernible trend. Dry matter concentration of the paraquat-treated vegetation increased 16 and 3% at the end of the 1st and 2nd weeks, respectively.

Herbage yield declined similary on plots treated with paraquat and on those not treated (Fig. 4). On 3 November, herbage yields were 90, 67, 80, and 74% of yields harvested on the respective starting dates of 8, 16, 23, and 30 July.

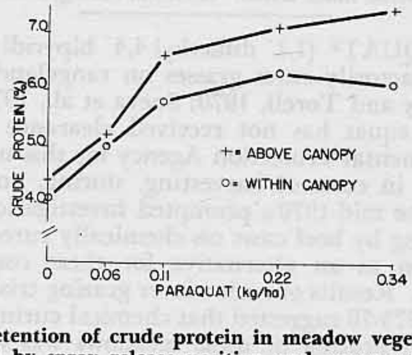


**Fig. 3. Retention of crude protein in meadow vegetation as influenced by spray release position and paraquat application rate in 1976.**

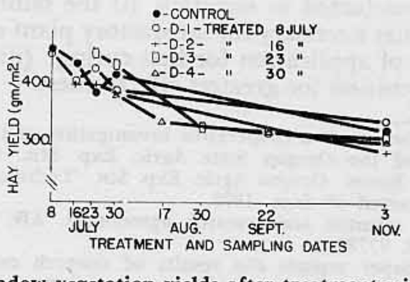


**Fig. 4. Meadow vegetation yields after treatment with paraquat at 0.34 kg/ha on four dates (8, 16, 23, and 30 July 1976),**

Crude protein concentrations of herbage was 7.0% or higher at all initial spray dates (Fig. 5). Crude protein concentrations of herbage from control plots began to decline after 16 July reaching 4.2% by 3 November and decreasing to 3.2% by 2 January. Paraquat at all application dates significantly ($P < 0.05$) arrested the decline of herbage crude protein so that levels of 6.2% or higher were retained by 3 November and 5.6% by 2 January (Fig. 6). Differences among treatment means for dates of application were not significant, as determined by the analysis of variance of data from 3 November samples.

Crude protein concentrations increased during the 2nd week after the 8 July application, in both the 1st and 2nd week after the 16 July application, and in the 1st week after the 23 and 30 July application of paraquat. These increases were small (>0.7%) but differences in crude protein means for 30 July for treatment means were significant ($P < 0.05$); crude protein concentration of herbage treated on 8 and 16 July was significantly higher than that of control herbage treated on 30 July. Paraquat residues in herbage treated 30 July were 15.4, 6.1, and 7.9 ppm at 1, 3, and 4 weeks after treatment with paraquat at 0.34 kg/ha.

### Time Study

Crude protein concentrations in meadow vegetation about 50 days after treatment with paraquat at 0.34 kg/ha were 6.8, 7.0, and 7.2% for morning, midday, and afternoon treatments, respectively. These differences were not significant ($P > 0.05$). Meadow vegetation treated on 2 overcast days contained less crude protein (7.4 and 7.5%) than that treated on two sunny days (8.3 and 8.0%), but the differences were not significant ($P > 0.05$). Crude protein concentrations of vegetation treated by release of the spray above the canopy was significantly ($P < 0.05$) higher (7.2%) than that of vegetation treated by release of the sprays within the canopy (6.8%).

Insolation on sunny days ranged from 420 to 480 ly as compared with a range of 316 to 360 ly on overcast days. Illumination on overcast days at the canopy level was 69, 52, and 48% less than that on sunny days at 0900, 1300, and 1700 hours, respectively. Within-canopy measurements estimated that there was 87% less illumination than that received at the canopy level. Midday illumination within the canopy on dull days was 57% of that on sunny days, but in the morning and evening illumination was greatest on overcast days. On sunny and overcast days, 35 and 14%, respectively, of midday illumination was present at the canopy level at 0900 hours, with 53 and 43%, respectively, at 1700 hours.

Maximum sheltered air temperature exceeded 32 C on sunny days but was 28 C or lower on overcast days. A total of 1.5 cm rain was received from 2 to 15 August. Wind speed averaged 3.4 km/hour from 27 July to 17 August. The mean diurnal ambient air temperature and relative humidity within the meadow sward during the 4-week application period of the time of season study are shown in Fig. 6. Only in the week following application on 30 July was the temperature particularly different; weekly mean daytime, but not nighttime, temperature was about 11 C lower than in the previous 3 weeks.

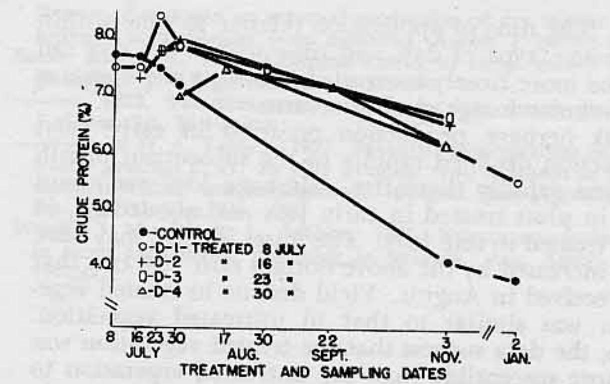


**Fig. 5. Crude protein concentrations in meadow vegetation after treatment with paraquat at 0.34 kg/ha on four dates (8, 16, 23, and 30 July 1976).**

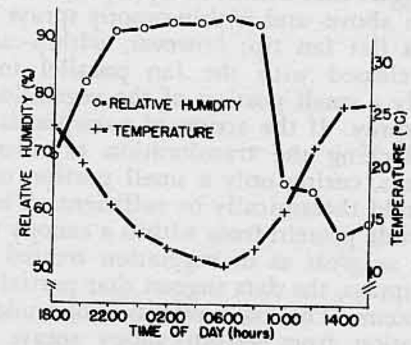


**Fig. 6. Trend of daily temperature and relative humidity in an undisturbed meadow 9 to 30 July 1976.**

## DISCUSSION

Meadow vegetation in these studies responded to paraquat similarilary as did range grasses growing in a more xeric environment (Sneva, 1967). However, this meadow vegetation yielding 2.2 to 4.5 metric tons/ha was satisfactorily cured with paraquat at 0.11 to 0.22 kg/ha whereas 0.34 kg/ha was needed to cure crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult) yielding 1.1 metric tons/ha or less. The greater sensitivity of meadow vegetation to paraquat may be due to the different species or to the more mesic environmental conditions that prevail in the meadow. Additional testing of these rates at other locations within the Great Basin are needed for confirmation; however, such testing can not be justified until paraquat's status as an agricultural chemical has been decided through the Environmental Protection Agency's Rebuttable to Presumption against Registration Program.

Paraquat satisfactorily cured meadow vegetation at all application dates which spanned the normal period for hay harvest with conventional machinery. On 8 July, conventional swathers first began to operate in a nearby field, but the operation ended because the ground was too soft. Cooper (1956) and Rumburg et al. (1964) have shown that the best time to harvest this meadow to maximize cattle gains generally is 1 to 2 weeks before peak herbage yield and prior to the time that the meadow will support conventional harvesting equipment. Chemical curing, which does not require heavy equipment, is, therefore, less restricted by soil conditions and can be applied rapidly to large areas. The time of application relative to time within the season, type of day, and time within the day can thus be more closely controlled, allowing the operator to maximize forage quality returns.

Peak herbage production occurred in early July; production declined rapidly in the subsequent month and less rapidly thereafter. Herbage loss was about 30% in plots treated in early July and about 22% in plots treated in late July. The losses in 1976 may have been increased by the above normal rain (5.0 cm) that was received in August. Yield decline in treated vegetation was similar to that in untreated vegetation. Thus, the data suggest that the treated vegetation was no more susceptible than the untreated vegetation to shattering and to the disappearance of dry matter.

In 1975 releasing the spray within the canopy was as effective as releasing it above the canopy, but the 1976 results suggest that within-canopy sprays were less effective. Both above- and within-canopy sprays were ejected from a flat fan tip; however, within-canopy sprays were released with the fan parallel to the ground, so only a small portion of the vegetation intercepted the spray. If the action of paraquat is simply one of blocking the translocation of nutrients within the plant, curing only a small portion of the lower stem would theoretically be sufficient. Though retention of crude protein from within a canopy treatment was not as great as in vegetation treated with above-canopy sprays, the data suggest that partial stem blocking did occur. The lower retention of crude protein concentration from within-canopy sprays most likely results from incomplete coverage of the vegetation due to spray pattern interference from vegetation immediately adjacent to the spray nozzle tip. The effectiveness of within-canopy sprays may be increased by substantially increasing the operating pressure or the number of nozzles or by using a fogging or misting technique. Releasing the spray within the canopy would markedly reduce off-target site drift and permit operation under adverse conditions. If suitable coverage can be obtained, partial stem blocking should permit a reduction in the amount of herbicide used, because less vegetation must be treated than in full cover sprays.

A significant herbage crude protein concentration increase was observed 1 and 2 weeks after paraquat treatment. Since the amount of N compounds in paraquat cannot account for such an increase, it is evidently the result of an accumulation of N that follows a disruption of physiological processes in the plant. Increased plant N after herbicide treatment has been documented; in some plants the levels of nitrate N have reached toxic levels and animals have been poisoned (Wright and Davison, 1964). Though levels of $NO_3$-N were not examined in this study, no indication of nitrate toxicity was evident in test animals that grazed paraquat-treated range or meadow vegetation (Sneva, 1967; and Sneva and Turner, 1977). However, because grazing of cured vegetation is delayed 3 to 5 months after treatment, the likelihood of nitrate poisoning is substantially reduced.

Temperature, relative humidity, illumination, and the sequence of light or dark periods after treatment with paraquat have been shown to influence activity of the chemical. These factors, and others, have been discussed in a comprehensive review of paraquat by Calderbank (1968). Not all of the factors have been studied in the field. Evans et al. (1967) reported that evening applications of paraquat were more effective than morning applications for weed control. However, Sneva (1967) found no differences between morning and evening applications for arresting the loss of crude protein in crested wheatgrass. While crude protein concentrations of meadow vegetation did not differ significantly with the time of day applications there was an increase in concentrations from morning to midday and from midday to evening applications. This trend was not consistent with daily trends of relative humidity, temperature, or illumination. It does support the findings of Putman and Ries (1968) that the effectiveness of paraquat is increased when application is followed by a dark period and then a light period. However, in our study the results are confounded with the daily pattern of crude protein in the plant, and our sampling procedure unfortunately did not provide for clarification of such an effect if, indeed, one exists. Thus, the higher crude protein concentrations in vegetation from evening than from midday or morning applications of paraquat may be resulting from naturally higher occurring levels of crude protein concentrations in the plants as the day progresses.

Similarly, crude protein concentrations at the time of treatment was higher on sunny days than on overcast days, although differences again were not significant. Yet, 60 days later, crude protein concentrations between vegetation treated on sunny or overcast days had decreased similarly. Thus, it appears that the advantage of spraying on sunny days was not to any greater effectiveness of the chemical on such days, but rather to a higher level of crude protein concentration in the vegetation on sunny than on overcast days

The high cost of determining paraquat residue in plants permitted only a limited number of such analyses. The data suggest that at 100 days after treatment of 0.11 and 0.22 kg/ha paraquat residue lies somewhere between 3 to 15 ppm. Paraquat residues were consistently lower in vegetation treated by sprays released within the canopy than from sprays released above the canopy. However, the extreme low residue value of 0.16 ppm 1 day after the within-canopy treatment in 1976 can not be adequately explained. Permissable levels of paraquat residue in forages grazed by cattle have yet to be set and the use of paraquat for this purpose has yet to be approved by the Environmental Protection Agency. Calderbank et al. (1968) reported no evidence of toxicity in cattle that consumed forage containing paraquat at 400 to 170 ppm over a 35-day period. Similarly, Sneva and Turner (1977) found no visible evidence of toxicity in pregnant cows winter-grazed on meadow vegetation treated with paraquat at 1.1 kg/ha and containing 16 to 21 ppm paraquat. The calves born showed no treatment influence, and all cows were subsequent bred and settled without evident treatment differences.

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Reprinted from AGRONOMY JOURNAL
Vol. 71, July–August 1979, p. 634–638