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Effects of 2,4-D on a *Populus tremuloides* community in the western United States—22 years after treatment

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EFFECTS OF 2,4-D ON A *POPULUS TREMULOIDES* COMMUNITY IN THE WESTERN UNITED STATES—22 YEARS AFTER TREATMENT

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Abstract.— Quaking aspen (*Populus tremuloides* Michx.) stands were accidentally sprayed with 2,4-D in a sagebrush control program in western Wyoming in 1958. We visited the site during the summer of 1981 to evaluate the long-term effect on the aspen trees and the associated vegetation. Initially, some observers believed that the aspen had been "destroyed." Subsequent data indicate just the opposite—aspen stocking appeared to have been improved by the treatment. On two of the sampled clones, 22 years after spraying, there were approximately 17,000 more suckers/ha on the sprayed than on the unsprayed plots. These are adequate numbers to restock the site to pretreatment densities. Although undergrowth vegetation appeared to be changed as a result of the treatment, this cannot be attributed solely to the herbicide because heavy grazing, mostly by domestic livestock, has occurred on the grazing allotment. A similarity index was calculated between sprayed and unsprayed portions of the same aspen clones. Forbs were still less on the sprayed areas, whereas grasses were similar on the sprayed and unsprayed areas. Spraying apparently does not have as adverse an effect on aspen communities as some conservationists originally thought.

The aspen (*Populus tremuloides* Michx.) ecosystem, widespread throughout North America (Little 1971), is a major forest type in the Rocky Mountains. This system produces multiple resources including wildlife habitat, wood fiber, and summer grazing for domestic livestock.

Through the process of natural plant succession many aspen forests in the West are succeeding to either conifer- or shrub-dominated communities. Such conversions are a concern to the resource manager because valuable forage and wildlife habitat is lost in the process.

Understanding the role of disturbance (e.g., herbicides) as a tool for altering succession in the aspen ecosystem will contribute toward our understanding the functioning of the system and serve as a basis for developing sound management alternatives. The two most practical management alternatives for aspen lands at present are: (1) permit aspen-to-conifer succession to proceed in seral communities, or (2) manipulate the system (i.e., burning, cutting, spraying) to set back plant succession and perpetuate aspen communities. Usually, both of these alternatives are imposed in conjunction with grazing pressure from domestic livestock. Such perturbations and subsequent plant succession causes changes in resource values and other alterations in the ecosystem. The short- and long-term responses must be quantified, where possible, to serve as the basis for sound land management decisions.

Although spraying of herbicides is a means of manipulating the aspen system, it has seldom been used in the western United States because of anticipated "adverse" environmental consequences. This study sought information from an aspen site that was accidentally sprayed with herbicides, and it should give us a better understanding of the system's response to such disturbance. This knowledge should result in more meaningful management recommendations and will serve as a basis for developing future studies on proposed spray sites in the Bridger-Teton (Wyoming) and Caribou (Idaho) national forests.

In 1958, an extensive spraying operation to control sagebrush was carried out on the Mosquito Lake Unit of the Upper Green River Allotment, Bridger National Forest, in western Wyoming. Approximately 3640 ha of big sagebrush (*Artemisia tridentata* Nutt.) was treated by aerial application of low volatile 2,4-D ester. With respect to range im-

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provement, the project was deemed a total success (Lester 1972). However, large tracts of quaking aspen and a few conifers were killed or injured during the operation. The Forest Service's sagebrush control program then fell under severe criticism by many conservationists, including Justice of the Supreme Court William O. Douglas. At the time, the Forest Service's sagebrush-spraying operation was curtailed on the Upper Green River Allotment and the region reassessed its methodology and changed from fixed-wing to helicopters for applications of herbicides (William F. Davis, pers. comm.).

Only one other report of the use of phenoxy herbicides on aspen in the Intermountain West was found. This was a Forest Service administrative study done by the Fishlake National Forest in central Utah. Between 1965 and 1967, 190 ha were repeatedly sprayed (up to 6 times during the growing season) in an attempt to convert the deep-rooted aspen and associated communities to a more shallow-rooted grass type to increase water production (Robinson 1971). Aspen were virtually eliminated from the site and grass production increased approximately 10 times. However, other problems arose as a result of the elimination of forest cover, including mass slumping, accelerated erosion, and some damage to wildlife habitat. Robinson (1971) further indicated that "massive applications of herbicides to aspen and associated plant communities are not recommended at present since the full ecological impact of such treatment is not known."

The accidentally sprayed site in western Wyoming offered an excellent opportunity to monitor the response of aspen to herbicides. Although 22 years have elapsed since the spraying occurred, useful information is still available because of the reproductive strategies of aspen. Generally, aspen reproduces profusely by root suckers after a disturbance. Current levels of aspen reproduction should indicate the degree of "damage" the aspen actually did sustain. These data will be particularly useful now because of the renewed interest in using herbicides to manipulate aspen forests, especially on lands not conducive to treatment by burning or cutting.

The two main objectives of this study were:

1. To determine the suckering response of aspen in the sprayed clones. Sucker density should be an adequate indicator of the ability of the clone to regenerate after disturbance. Measuring the juvenile individuals should give us a better understanding as to whether or not the aspen on the site were "destroyed" by this accidental spraying operation.

2. To determine the long-term change in undergrowth. Initial changes in the undergrowth vegetation are not available. However, long-term differences can be assessed by comparing sprayed and unsprayed portions of the same clones. If such differences are still detected in the understory vegetation, this could indicate where the successional process is in returning the site to pretreatment conditions.

Study Area

The Mosquito Lake Grazing Unit, at the north end of the Bridger National Forest, is presently administered as part of the Bridger-Teton National Forest (Fig. 1). The unit is approximately 56 km north of Cora, Wyoming, in the northwest part of the state. The 5261 ha grazing unit is subdivided into four pastures. Geographically, the study site lies in several sections of Townships 39 and 40 North, range 110 West, at an elevation of approximately 2760 m. The climate consists of short, cool summers and long, severe winters, with average yearly precipitation of about 46 cm (Lester 1972).

The Mosquito Lake Grazing Unit is a high mountain grassland with adjacent woody communities. In the south central portion of the unit the open grasslands are interspersed with shrubby and woody vegetation. Aspen is the dominant woody species with an understory consisting of species such as bush cinquefoil (*Potentilla fruticosa* L.), mountain snowberry (*Symphoricarpos oreophilus* Gray), and bearberry (*Arctostaphylos uva-ursi* [L.] Spreng.). A few small lodgepole pine (*Pinus contorta* Dougl.) also occur. Reed (1971) designated this type as a *Populus tremuloides*/*Symphoricarpos oreophilus* association.

Methods

Sampling was limited to those areas that had aspen. Aspen clones were selected that

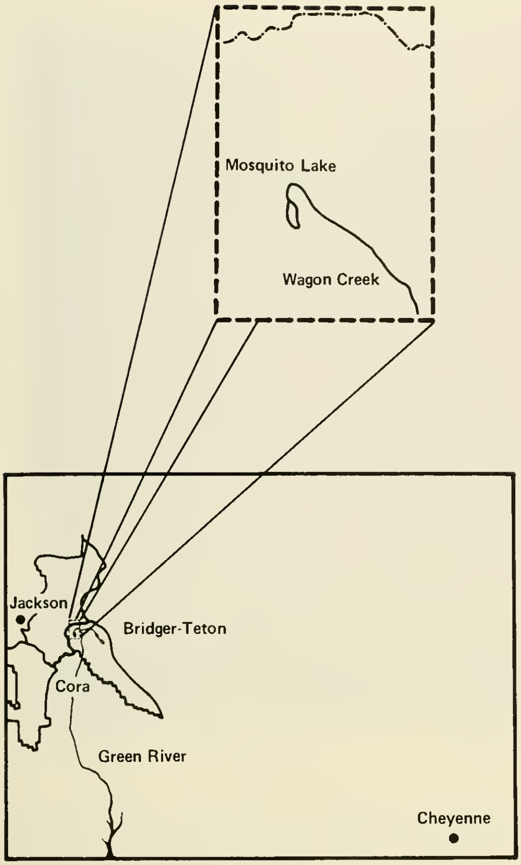

Fig. 1. Map of the Mosquito Lake study area in relation to the Green River system in Wyoming.

appeared to have been on the edge of the sprayed area, resulting in one portion of the clone having been treated with herbicides and the other portion missed. Thus, treated and untreated (control) plots were selected from a single clone. Three aspen clones were located that met the above criteria, and six sampling plots were established within these clones.

The selected clones apparently occupied different sites both because of site physiography and the differences observed in the undergrowth vegetation. Site 1 would probably be classified as POTR/BERE c.t., site 2 is clearly a POTR/SYOR c.t., and site 3 is a POTR/ARTR c.t. (Youngblood and Mueggler 1981).

Aspen suckers were counted on three transects per treatment and classified as to current year or older. These transects were 30 m long and 2 m wide and were selectively located so they would fall within the clone. Suckers were categorized as follows: < 0.5 m tall, 0.5–2 m tall, and > 2 m tall and < 5.1 cm diameter at breast height (dbh). Three representative suckers per height class were cut and aged. Also, conifer reproduction was noted.

To characterize the aspen clones, plots that were 100 m^2 (10 x 10 m) in size were established. Within these plots, all mature trees (>5.1 cm dbh) were tallied, and height, dbh, and age were measured using standard techniques for five of the largest trees.

Undergrowth production was measured at or near its peak during the first week of August 1981. Total production was obtained and expressed on a dry weight basis. Measurements were made using three sets of five, 0.5 m^2 circular quadrats that were randomly distributed within the 100 m^2 macroplot in each treatment. The current year's biomass was estimated on each of four quadrats as a percent of the fifth one. The reference quadrat (fifth) was clipped of all vegetation to ground level, dried in an oven at 70 C till it reached a constant weight (at least 48 hours), and weighed. The percentage estimates were converted to weights and the average weights of the 15 quadrats were expressed as kilograms dry weight per hectare. When sampled, the pasture was being grazed by cattle, so total production figures are lower than they would have been under nongrazing conditions.

The four pastures in the grazing unit are managed in a rest-rotation system—each pasture is grazed for three years and rested one. Comparison of the sampled pasture to the rested pasture allowed us to estimate use as approximately 75%. Grazing, however, appeared to be uniform across each clone sampled.

A list of all major plant species was developed from observations made within the 100 m^2 plot. The following cover class assignments were used to quantify various species and species groups on the plot:

Class	*Percent*
1 =	Trace–1
2 =	1–5
3 =	5–15
4 =	15–25
5 =	25–50
6 =	50–100

Fig. 2. General views of the three study sites: A, site 1. B, site 2. C, site 3 (next page). Note the sharp contrast between the sprayed and unsprayed portion of each clone.

Results and Discussion

Aspen Trees

The aspen responded to spraying essentially as we had anticipated. The aboveground portion of the overstory trees was almost totally killed by the accidental application of 2,4-D, and there was a release of aspen suckers. But these findings need to be put in proper perspective: all measurements were made 22 years after the site was treated, and no initial or intermediate sampling was carried out on the aspen sites. However, the junior author worked on the sagebrush-grassland portion of this grazing allotment 10 years after treatment and observed that considerable damage had been done to the aspen. He (1972) stated that "large tracts of quaking aspen and a small number of conifers were eliminated or injured during the operation."

A distinct difference was observed between the sprayed and unsprayed portion of the clones sampled (Fig. 2). After 22 years, we found essentially no mature trees on the sprayed portion of the clones. We did encounter one tree in the 10.2 to 15.2 cm category on one of the transects in site 2. On the same site we found almost 600 suckers/ha that were larger than our biggest reproduction category, e.g., greater than 5.1 cm dbh and more than 2 m tall. We assumed these individuals were not more than 22 years old. We thus concluded that most of the aboveground portion of the trees and reproduction were completely killed by the herbicide and all died shortly after application. The unsprayed portion of the clones were considered to represent pretreatment conditions. The stands measured were multistoried (Table 1) and ranged in density from 1600 to 3700 trees/ha. These densities are equal to or more than double those reported by Schier (1975) for 80-year-old, healthy clones in northern Utah.

No distinct patterns emerged from the descriptive data obtained from the five largest trees in each clone (Table 1). However, the aspen trees on site 2 are shorter, smaller in diameter, and have less basal area even though these trees are not the youngest of the three sites. According to Baker's (1925) classi-

Fig. 2 continued: C, site 3.

fication, the site quality would be site IV for all three areas, which is a poor site with little chance of producing aspen wood products other than firewood.

The basal areas calculated for the three sampled clones appear to be large when compared with other western aspen sites (Baker 1925, Jones and Trujillo 1975, Schier 1975, and Harniss and Harper 1982). However, our values lie at the upper end of the range reported by Mueggler and Campbell (1982) for aspen forests in southern Idaho.

Table 1. Stand values for density, diameter at breast height (dbh), and basal area of mature aspen trees and height and age of the five largest aspen trees on the unsprayed plots for three sites.

	Numbers/ha		
Values	Site 1	Site 2	Site 3
Density			
5.1–10.2 cm	1,000	1,200	—
10.3–15.2 cm	1,300	1,500	300
15.3–20.3 cm	600	1,000	600
20.4–25.4 cm	400	—	400
25.5–30.5 cm	100	—	300
Total	3,400	3,700	1,600
dbh (cm)	13.8	12.5	20.0
Basal area (m^2/ha)	58.7	49.5	53.7
Ht (m)	10.6	8.9	14.1
Age (years)*	54.0	56.3	82.8

*Base of tree was used to determine age.

Aspen Suckers

After 22 years, there were still sufficient numbers of aspen suckers (Table 2) to restore the sites to densities that existed prior to treatment. In 1981, there were between 18,000 and 24,000 suckers/ha on the sprayed sites and between 3,000 and 20,000 on the unsprayed areas. Only site 1 had no significant statistical differences between the number of suckers on the treated and the un treated portion of the clones. Such reproduction on the control plots would indicate that the three clones were self-regenerating.

Disturbances (burning or cutting) of the aspen forest in the West can result in sucker densities of between 5,000 and 45,000/ha (Jones and Trujillo 1975). Generally, the number of suckers peak the first year after disturbance (Sampson 1919, Baker 1925, Smith et al. 1972, Jones 1975) and then decline over several years until the numbers stabilize at a level comparable to what was

Fig. 2 continued: C, site 3.

on the site before treatment. The aspen regeneration at the Mosquito Lake study area had not stabilized at pretreatment densities after 22 growing seasons. This lack of stability can be attributed in part to use by both domestic livestock and wildlife. Jones (1976) has indicated that 50,000 to 75,000 suckers/ha in the first year after disturbance is not excessive because of the natural thinning that occurs in aspen stands. The suckers had probably peaked at a higher number and have since declined to the numbers observed.

The tremendous suckering ability of western aspen has been substantiated by several studies. Mueggler and Bartos (1977) and Bartos and Mueggler (1982) reported 20-fold increases in sucker numbers (up to 50,000/ha) in both southern and northern Utah after aspen had been clearcut. On another northern Utah site that was cut, Smith et al. (1972) de-

TABLE 2. Current year aspen suckers and those two years old and older presented for three size classes. Also given are the mean ages for the various size suckers.

Site	Current suckers	<0.5 m tall suckers		0.5–2 m tall suckers		>2 m tall and < 5.18 cm dbh		Total number of suckers,
	Numbers/ha	Numbers/ha	Years	Numbers/ha	Years	Numbers/ha	Years	Numbers/ha
SITE 1								
Sprayed	889	4,278	5	7,389	9	6,222	19	18,778
Unsprayed	1,278	10,611*	5	6,389	10	1,389*	14*	19,667
SITE 2								
Sprayed	444	7,556	4	3,444	8	12,278	17	23,722
Unsprayed	333	4,611*	5	889*	14	278*	18	6,111*
SITE 3								
Sprayed	111	5,444	4	5,611	9	8,167	15	19,333
Unsprayed	278	1,944*	8	389*	11	56*	12	2,667*

*Statistical difference between the sprayed and control plots (P>.90).

termined there were between 74,000 and 124,000 suckers/ha. Jones (1975) found 35,000 suckers/ha on aspen clearcuts in Arizona. In southwestern Colorado Hittenrauch (1976) reported from 15,000 to 25,000 suckers/ha.

The aspen suckers varied in age from 1 year (current) to 22 years. Within the constraints of our limited sample size and because no suckers were found to be over 22 years old, we assume that virtually all the pretreatment reproduction was killed in the spraying operation. Drift from the herbicide application might even have affected the unsprayed portions of the sites. However, it is more likely that other factors (e.g., animal use, suppression by mature trees) are responsible for the absence of suckers older than 22 years. No conifer reproduction was found on our transects, although some lodgepole pine seedlings were observed within the clones.

Undergrowth Production

Although undergrowth production was determined at peak growth, grazing by domestic livestock was intense in this pasture during the summer of 1981. Production values, therefore, are distorted and are at least 75% below actual production.

Table 3 shows the measured undergrowth production for the three aspen clones. On all three sites there were significant differences in standing herbage between the sprayed and unsprayed portion. The sprayed areas on both sites 2 and 3 had approximately twice the undergrowth as their respective control areas. It was just the opposite on site 1. These inconsistencies do not appear related to environmental or edaphic factors. A strong positive relationship exists between sucker numbers and undergrowth production on the unsprayed portions of the three clones. This increase in production can be attributed to the aspen reproduction restricting use by animals. No clear pattern emerges to indicate whether or not spraying has a detrimental effect on undergrowth production.

The aspen understory communities in this area have been designated by Reed (1971) as a POTR/SYOR association, and the community types for the three sites are POTR/BERE (site 1), POTR/SYOR (site 2), and POTR/ARTR (site 3), according to Youngblood and Mueggler (1981).

Youngblood and Mueggler found undergrowth production values to vary between 800 and 1500 kg/ha; however, they made no reference to the amount of grazing they encountered. Our values are somewhat comparable to theirs, particularly when one considers that approximately 75% of the production had been utilized.

Species Composition

Composition of the undergrowth in these aspen forests was only moderately complex. Only 15 species of plants were sufficiently abundant to individually constitute at least 1% of the undergrowth production on any of the study sites.

In general, it is difficult to say whether spraying changed the species composition. No general trends are readily obvious, but this could be attributed in part to the extensive grazing on these sites during the 1981 grazing season and in previous years. More forbs were found on the unsprayed plots than on the sprayed areas, which agrees with observations made in Canada by Hilton and Bailey (1974), who found increases in grass and grasslike species, and by Bowes (1978), who reported forbs were reduced as a result of spraying.

The only two forbs that occurred on all sampled sites were sticky geranium (*Geranium viscosissimum* F. & M.) and Nuttall aster (*Aster perelegans* Nels. & Macbr.). The geranium was the most abundant. Other important forbs that contributed to the overall makeup were showy frasera (*Frasera speciosa* Dougl.), strawberry (*Fragaria vesca* L.), and northern sweetvetch (*Hedysarum boreale* Nutt.). The proportion of graminoids in the undergrowth varied from a trace to 20%.

Table 3. Peak herbage present on plots in heavily grazed aspen clones on the Upper Green River Allotment.

	Kg/ha		
	Sprayed		Unsprayed
Site 1	446.4	°	767.4
Site 2	481.8	°	260.4
Site 3	577.5	°	294.9

°Statistical difference between the sprayed and control plots ($P > .999$).

Slender wheatgrass (*Agropyron caninum* [L.] Beauv.), sedge (*Carex* spp. L.), Idaho fescue (*Festuca idahoensis* Elmer), and Letterman needlegrass (*Stipa lettermani* Vasey) were most abundant. Letterman needlegrass contributed most to the graminoids overall and in particular on the sprayed plots. No consistent trends were observed in the shrubs encountered. Big sagebrush, woods rose (*Rosa woodsii* Lindl.), and mountain snowberry were by far the most abundant shrubs. The target species in the spraying operation was big sagebrush, which was abundant on two of the sprayed portions of the sites. This abundance might indicate that sagebrush is not as susceptible to 2,4-D when it occurs under an aspen canopy.

To facilitate understanding the overall divergence of undergrowth composition caused by spraying, we computed Sorensen's community coefficient (Mueller-Dombois and Ellenberg 1974) as an index to the similarity between sprayed and unsprayed plots. The data used in this comparison were percentage composition based on cover of the undergrowth species rather than actual production. Thus, the index compares proportions of species irrespective of differences in total undergrowth production. Aspen reproduction was excluded from the analysis. An index value of 1.00 indicates identical matching of species and composition on the compared areas. A value of 0.00 would indicate that the areas have no species in common.

When all species were used, the similarity index (S.I.) between the sprayed and unsprayed plots for sites 1, 2, and 3 was 0.24, 0.50, and 0.34, respectively. Because after 22 years these values indicate dissimilarity in species composition on the treated and control plots for the three sites, it will probably be a considerable length of time before these areas return to their pretreatment similarity. An S.I. was also calculated for forbs, shrubs (minus aspen reproduction), and grasses on the treated and untreated portion of the clones. Extremes in S.I. were found in the shrub category with 0.08 on site 2 and 0.78 on site 1. Higher S.I. were found for grass and grasslike species (site 1 = 0.19, site 2 = 0.68, and site 3 = 0.57) than for forbs (site 1 = 0.40, site 2 = 0.31, and site 3 = 0.24). These results substantiate that grasses are not harmed appreciably, but forbs are harmed by 2,4-D.

Conclusions

The accidental spraying of aspen that occurred on the Upper Green River grazing allotment appeared to be an excellent opportunity to evaluate the long-term effects of herbicides on the aspen system. Although the treatment occurred 22 years before, we decided that valuable information could still be gathered because of the growth response of aspen. We found that the aboveground portion of the aspen trees and reproduction was almost totally killed as a result of the single spraying with 2,4-D. Sprayed areas had approximately 20,000 suckers/ha, which for two of the three sites sampled was almost six times more than the tree densities on the control plots. Treatment by herbicides appears to have aided the aspen by promoting suckering.

Undergrowth production under heavy grazing was low, with approximately 500 kg/ha being recorded. The shrub and forb component appeared to be most adversely affected by the treatment, but the graminoids were somewhat favored.

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