Effects of 2,4-D on Emergence and Seedling Growth of Range Grasses[1]

G. J. KLOMP AND A. C. HULL, JR.[2]

Range Scientists, Crops Research Division
Agricultural Research Service, U.S.D.A.
Reno, Nevada and Logan, Utah

Highlight

In a tarweed infested soil in the greenhouse, intermediate and crested wheatgrass and smooth brome seedlings growing with tarweed were sprayed with 2,4-D at 0.5, 1, 2, and 4 lb/A when seedlings had 1 to 2, 2 to 4, or 5 to 10 leaves. Tarweed was controlled at all rates. With simulated fall seeding, the higher the rate of 2,4-D and the younger the grass, the greater the injury to the grass. With simulated spring seeding, all rates of 2,4-D damaged the grass, but spraying at 0.5 or 1 lb/A of 2,4-D just after seeding resulted in the least damage. The field study indicated that .5 lb/A 2,4-D killed 90% of the tarweed; 1 lb/A killed 95% and 2 lb/A killed 99%. Rate of spraying had little effect on survival of the grass.

Herbicides have been widely and successfully used to control undesirable vegetation when seeding rangelands. Major advantages of herbicides are: (1) selectivity, (2) quick kill, (3) low cost (4) usable on steep and rocky areas, (5) do not expose the soil to erosion. When used at certain times and concentrations, however, herbicides damage the desirable plants. However, as many plants are susceptible to injury only at certain growth stages, injury may be reduced by controlling herbicidal concentrations and by proper timing. Klingman (1961) points out that susceptibility coincides with periods of active growth. For example, small grains may be very susceptible to 2,4-D in the germinating and seedling stages, tolerant in the fully tillered stage, and again susceptible in the jointing and heading stage. Though most plants become more tolerant with age, others remain susceptible.

Teel (1952) noted injury to grass seedlings during the 1- to 3-leaf stage with 0.75 lb/A of 2,4-D. Watson (1949) found that normal amounts of 2,4-D caused malformation and serious injury to 28-day-old seedlings of bentgrass (*Agrostis canina* L.). Phillips (1949) found that three warm-season grasses and three cool-season grasses were damaged when sprayed with an amine form of 2,4-D at 0.5 and 1 lb/A at emergence, but that they were not injured at 2, 4, and 8 weeks after emergence. Cool season species were affected less than warm season species and the rate of damage on all species decreased at later dates and lower rates. However, Klingman (1959) reported no lasting herbicidal damage to seedlings of warm or cool season grasses.

In addition to the foliar sprays, grass seedlings may also be damaged by herbicides carried to the plant by surface water or leached downward to germinating seed or to the roots. Dunham (1965) states that 2,4-D has killed grass seedlings when applied to the soil in large amounts.

Our previous work indicates that young grass seedlings have been killed or damaged by spraying 2 lb/A of 2,4-D. In contrast, some workers indicate that up to 2 lb/A of 2,4-D has had no adverse effect upon seedlings at any stage of growth.[3] This study was initiated because herbicidal control of weedy vegetation offers considerable promise, and because results differ on possible damage to seeded grasses by herbicides.

Treatments and Procedures

Greenhouse studies were conducted at Utah State University. Soil for the greenhouse flats was obtained from Franklin Basin, 35 mi northeast of Logan, Utah. This is a typical high-elevation tarweed area with abundant tarweed (*Madia glomerata* Hook.) seeds in the soil.

The simulated fall-seeded flats were planted on January 4. These flats and those to be seeded later which would simulate spring seeding were then put outside the greenhouse for exposure to winter weather conditions apparently necessary for germination of tarweed. All flats were left out for 50 days, with 49 days of freezing temperatures. Soil in the flats was frozen solid on February 23 when brought into the greenhouse. Tarweed began to emerge within 2 days and soon averaged 119 plants per ft^2 (Fig. 1). Grass emergence began in 6 days. Treatments designed to simulate fall and spring seeding were as follows:

Simulated fall seeding and spring spraying

1. Sprayed at the 1- to 2-leaf stage.
2. Sprayed at the 2- to 4-leaf stage.
3. Sprayed at the 5- to 10-leaf stage.
4. Check (seeded before outdoor treatment, not sprayed, not weeded).
5. Check (ditto to number 4, but handweeded).

Simulated spring seeding and spraying

6. Sprayed 2 hours before seeding.
7. Sprayed 2 hours after seeding.

[1] Cooperative research investigations of Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, and the Utah Agricultural Experiment Station. Utah Agr. Exp. Sta. Journal Paper 643.

[2] The authors thank Dayton Klingman and Wesley Keller who made helpful comments on the study and reviewed the manuscript, and E. James Koch who made the statistical analyses.

[3] Personal communication with C. Wayne Cook.

FIG. 1. Germination of tarweed commenced 2 days after flats were removed to the greenhouse and reached average of 119 plants/ft². Photo taken when grass seedlings had 1 to 2 leaves; tarweed plants 4 to 6 leaves.

8. Sprayed after seeding with seed uncovered in open furrows.
9. Check (seeded after outdoor treatment, not sprayed, not weeded).
10. Check (ditto to number 9, but handweeded).

The following grasses with symbols used in the tables were seeded on each date:

Agin—Intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv.)

Agde—Crested wheatgrass (*A. desertorum* (Fisch. ex Link) Schult.)

Brin—Smooth brome (*Bromus inermis* Leyss.)

Grasses were seeded 0.5-inch deep, in 2 rows each, in greenhouse flats. As grass reached the planned growth stages, the herbicide was sprayed with a hand-sprayer fitted with a nozzle which delivered a fan pattern. At each growth stage, there were 4 rates of 2,4-D iso octyl low volatile ester (0.5, 1, 2, 4 lb/A acid equivalent), except that 0.5 lb was not used in all applications. A spraying was planned when grass plants were in early boot, but it was abandoned because tarweed produced seed prior to this stage.

There were 3 replicate blocks; and within these blocks the 10 dates and 4 rates of spraying were randomized with the 3 species randomized within each treatment. All tables are on the basis of 10 possible plants per foot of row. Significance of results at the 5% level was determined by Duncan's (1955) multiple range test.

Results

Fall Seeding

Grass plants on simulated fall seedings were counted before and after spraying, and one week later. They were again counted and clipped for air-dry weight on April 21, 53 days after grass emergence (Table 1).

Table 1. Numbers of grass plants per linear foot and grams of air-dry grass per plot from various fall-simulated treatments and different rates of 2,4-D.

Treatment	2,4-D (lb/A)	Agin	Agde	Brin
		PLANTS PER FOOT		
Check, hand weeded	0	9.8^{ab1}	10.0^{a}	9.5^{ab}
Check, not weeded	0	9.7^{b}	9.7^{ab}	9.2^{ab}
Hand weeded, 1–2 leaf	0	10.0^{a}	9.5^{ab}	9.0^{ab}
Sprayed, 1–2 leaf	1	10.0^{a}	9.8^{ab}	9.2^{ab}
Sprayed, 1–2 leaf	2	10.0^{a}	9.7^{ab}	7.7^{c}
Sprayed, 1–2 leaf	4	9.2^{c}	9.2^{b}	7.2^{c}
Hand weeded, 2–4 leaf	0	10.0^{a}	10.0^{a}	9.3^{ab}
Sprayed, 2–4 leaf	1	10.0^{a}	10.0^{a}	9.5^{ab}
Sprayed, 2–4 leaf	2	10.0^{a}	9.3^{ab}	8.3^{bc}
Sprayed, 2–4 leaf	4	9.7^{b}	9.3^{ab}	7.7^{c}
Hand weeded, 5–10 leaf	0	10.0^{a}	10.0^{a}	10.0^{a}
Sprayed, 5–10 leaf	1	10.0^{a}	9.8^{ab}	9.7^{ab}
Sprayed, 5–10 leaf	2	10.0^{a}	9.8^{ab}	9.0^{ab}
Sprayed, 5–10 leaf	4	9.8^{ab}	9.8^{ab}	7.3^{c}
		GRAMS AIR-DRY GRASS PER PLOT		
Check, hand weeded	0	6.4^{ab}	5.9^{a}	3.2^{abc}
Check, not weeded	0	4.2^{ab}	2.9^{c}	2.5^{abc}
Hand weeded, 1–2 leaf	0	8.1^{a}	4.8^{abc}	3.9^{ab}
Sprayed, 1–2 leaf	1	5.9^{ab}	3.7^{bc}	2.7^{abc}
Sprayed, 1–2 leaf	2	5.9^{ab}	3.8^{bc}	3.2^{abc}
Sprayed, 1–2 leaf	4	4.5^{b}	3.1^{c}	1.2^{c}
Hand weeded, 2–4 leaf	0	6.7^{ab}	4.5^{abc}	4.1^{a}
Sprayed, 2–4 leaf	1	6.9^{ab}	4.9^{abc}	4.0^{ab}
Sprayed, 2–4 leaf	2	6.3^{ab}	5.0^{abc}	3.9^{ab}
Sprayed, 2–4 leaf	4	4.4^{b}	3.5^{c}	2.2^{abc}
Hand weeded, 5–10 leaf	0	5.1^{b}	5.7^{ab}	2.7^{abc}
Sprayed, 5–10 leaf	1	6.5^{ab}	4.6^{abc}	4.2^{a}
Sprayed, 5–10 leaf	2	5.4^{ab}	3.9^{bc}	1.4^{c}
Sprayed, 5–10 leaf	4	4.5^{b}	3.9^{bc}	2.1^{bc}

[1] A significant (5%) difference exists between two means not followed by the same letter.

Species.—Comparing plant numbers and herbage yields of the three grasses, intermediate wheatgrass was highest, crested wheatgrass next, and smooth brome lowest in their resistance to injury from 2,4-D.

Growth stage.—Differences are not statistically significant, but in general, the earlier the stage of growth at which grass seedlings were sprayed, the greater the reduction in numbers and yields. Spraying 2,4-D at 0.5 to 1 lb/A when grass had 2 to 4 leaves and tarweed 6 to 8 leaves, killed most of the tarweed with little injury to the grass. When all species and rates were averaged, the plots sprayed when grass had 1 to 2 leaves yielded 3.8 g of grass per plot as compared to 4.6 for spraying at 2 to 4 leaves and 4.1 at 5 to 10 leaves.

Rates.—All rates of 2,4-D readily killed tarweed in the 2 to 4- and 6 to 8-leaf stages. At this time, the grass had 1 to 2 and 2 to 4 leaves. When grass was in the 5 to 10-leaf stage, tarweed averaged 2 blossoms per flower cluster. At this stage, 2 or 4 lb/A of 2,4-D killed 100% of the tarweed, 1 lb/A killed 96%, and 0.5 lb/A killed 83%. In general,

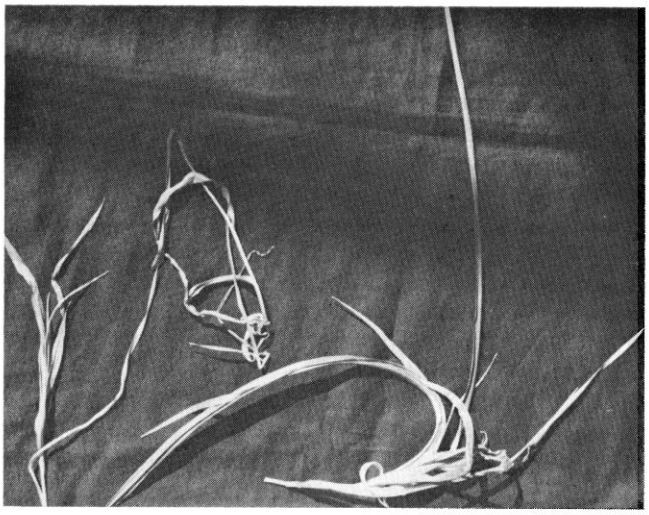

FIG. 2. Smooth brome sprayed at 2-leaf stage with 2 lb/A of 2,4-D acid equivalent. Plants were malformed with rolled blades and leaf tip often remained in the sheath. Photo 40 days after spraying.

the higher the rate of 2,4-D the greater the reduction in number and yield of grass plants. Averaging all species when sprayed at the 1- to 2-leaf stage, the plots sprayed with 4 lb/A of 2,4-D yielded 2.9 g, as compared to 4.3 g at 2 lb/A, 4.1 at 1 lb/A, and 5.6 for the check.

Many sprayed grasses were malformed and damaged. The blades were rolled and the tip of the blade often did not emerge from the sheath. This retarded the growth of such plants (Fig. 2).

Spring Seeding

The flats which simulated spring seeding were sprayed and seeded on March 1 when tarweed averaged 2 to 4 leaves. Grasses emerged in 6 days. Grass seedlings were counted and marked daily for 1 week, every 3 days for 3 weeks, and on the 40th day after seeding. Sixty days after initiation of emergence, plants were again counted and also clipped for air-dry weight (Table 2).

Species.—Averaging all spraying treatments, intermediate wheatgrass had the greatest plant numbers and yields, followed by crested wheatgrass and smooth brome.

Seedbed phase.—Spraying when grass seed was not covered in the open furrow reduced plant numbers and yielded as compared to covered seed. When all species and rates were averaged, plots sprayed with 2,4-D after seeding yielded 7.9 g of grass. Those sprayed before seeding also yielded 7.9 g and those sprayed with seed in the open furrow yielded 5.8 g (Fig. 3).

Rates.—All rates of spraying killed all the tarweed plants. Though the differences were not statistically significant, increasing the amount of 2,4-D decreased the survival and yield of grass plants. Averaging all species and treatments, the plot sprayed at 1 lb/A of 2,4-D yielded 9.0 g of grass as compared to 7.0 and 5.5 g for 2 and 4 lb/A, respectively. The check yielded 9.4 g and the handweeded 11.5 g.

Spring drilling and spraying resulted in more and greater physical malformations of grasses than did spraying on fall seeding.

Table 2. Grass plants per foot and grams air-dry grass per plot from various spring-simulated treatments.

Treatment	2,4-D (lb/A)	Agin	Agde	Brin
		PLANTS PER FOOT		
Hand weeded	0	8.3[a1]	8.9[a]	7.0[a]
Not weeded	0	7.4[abc]	7.8[abc]	5.6[b]
Spray after seeding	1	7.5[abc]	8.0[ab]	5.8[ab]
Spray after seeding	2	6.7[cd]	6.1[de]	2.3[ef]
Spray after seeding	4	7.1[abc]	6.7[bcd]	3.4[de]
Spray before seeding	1	6.2[cd]	8.6[a]	5.0[bc]
Spray before seeding	2	7.4[abc]	4.9[e]	3.8[cd]
Spray before seeding	4	6.5[bcd]	5.4[de]	1.5[fg]
Spray in open furrows	1	7.8[ab]	6.3[cde]	4.5[bcd]
Spray in open furrows	2	7.3[abc]	6.3[cde]	3.3[de]
Spray in open furrows	4	5.5[cd]	2.2[f]	.6[g]
		GRAMS GRASS PER PLOT		
Hand weeded	0	12.6[ab]	12.3[a]	9.5[ab]
Not weeded	0	11.4[abc]	9.6[abc]	7.1[bc]
Spray after seeding	1	13.2[a]	7.8[bcd]	11.1[a]
Spray after seeding	2	12.2[ab]	5.4[de]	3.5[de]
Spray after seeding	4	10.0[abc]	4.2[de]	3.8[de]
Spray before seeding	1	8.9[bc]	10.6[ab]	7.3[bc]
Spray before seeding	2	11.3[abc]	7.2[bcde]	7.3[bc]
Spray before seeding	4	9.7[abc]	5.9[cde]	2.8[de]
Spray in open furrows	1	10.1[abc]	6.5[cde]	5.7[cd]
Spray in open furrows	2	7.4[c]	6.6[cde]	3.4[de]
Spray in open furrows	4	8.5[bc]	3.4[e]	.7[e]

[1]A significant (5%) difference exists between two means not followed by the same letter.

FIG. 3. In treatments simulating spring seeding, spraying with 1 lb/A 2,4-D after seeding as in photo, gave better germination and emergence, less injury to grass seedlings, and greater yields than spraying seed in open furrows. Tarweed plants in photo were affected by 2,4-D and most of them died.

Field Studies

The applicability of the greenhouse studies to field conditions was determined by spraying plots in a tarweed infested area at Franklin Basin. In the spring of 1966, plots

of intermediate and slender wheatgrasses (*Agropyron trachycaulum* (Link) Malte) and smooth brome were sprayed with the iso octyl ester of 2,4-D at 0.5, 1, and 2 lb/A when the grass was seeded and when it had 1 to 2 and 2 to 4 leaves. At these three stages, tarweed had 2 to 4, 6 to 12, and 16 to 30 leaves. Tarweed was 90% in bud at the last spraying. The calendar dates were May 25, June 24, and July 11. There were four replications of each treatment.

In the field, as in the greenhouse trials, the heavier the rate of herbicide, the more tarweed was killed. There were 108 tarweed plants/ft^2 in the untreated check plots. Averaging all growth stages, spraying with 0.5 lb/A of 2,4-D killed 90% of the tarweed. The 1 lb/A rate killed 95% and the 2 lb/A rate 99%. The tarweed plants which did survive the spraying were generally stunted and apparently did not compete seriously with grass seedlings. Uneven spray distribution with a small hand sprayer undoubtedly allowed more tarweed plants to survive than if better spray equipment were used.

Grass seedlings in the field were little affected by the different rates of 2,4-D. Also as seedlings responded similarly to treatment, the species are averaged. Spraying at different plant growth stages caused some differences in grass seedling survival, but numbers varied greatly. Seedling survival may have been more affected by extremely adverse growing conditions than by spray treatments. At the time of the last spraying, there had been no precipitation for 22 days, and soil moisture was below the wilting coefficient. There was no effective precipitation for the next 23 days.

Averaging all rates of spraying and all growth stages, there were 6.4 grass seedlings/ft^2, which is adequate for a full stand of grass.

Discussion

These studies and field observations show that spraying tarweed infested lands with 2,4-D is an excellent method of removing plant competition to allow seedling establishment. However, when grass seedlings are sprayed either at susceptible growth stages, or with too heavy rates of 2,4-D, injury can result. If injury is not severe, plants outgrow it. If grass stands become infested with tarweed, they may be sprayed with 0.5 to 1 lb/A of 2,4-D in the spring when grass is at the 2 to 4 leaf stage, and when tarweed is at the 6 to 8 leaf stage.

Where spring seeding of tarweed infested lands is feasible, the best procedure is to drill early and follow by spraying with 0.5 to 1 lb/A of 2,4-D. This gave good weed control and minimal grass damage. Higher rates of 2,4-D are excessive, control only slightly more tarweed, and often damage the grass.

When undesirable plants, not easily killed with 2,4-D, are growing with tarweed, it may be necessary to spray as much as 2 lb/A to kill these weeds. In this case, spraying can be delayed until after the 2 to 4 leaf stage of grass seedlings to reduce damage to grass.

LITERATURE CITED

DUNHAM, R. S. 1965. Herbicide manual for noncropland weeds. U.S. Dep. Agr., Agr. Handbook No. 269. 90 p.

DUNCAN, DAVID B. 1955. Multiple range and multiple F tests. Biometrics 11:1–42.

KLINGMAN, D. D. 1949. Second year response of six cool-season grasses sprayed as seedlings with 2,4-D for weed control. Abst. Research Report, 6th Ann. NCWCC. p. 65.

KLINGMAN, G. C. 1961. Weed control; as a science. John Wiley and Sons, New York, 421 p.

PHILLIPS, W. M. 1949. Effect of 2,4-D on seedling grasses under greenhouse conditions. Abst. Research Report, 6th Ann. NCWCC. p. 65.

TEEL, M. R. 1952. 2,4-dichlorophenoxy–acetic acid as a herbicide for controlling broad-leaved weeds in grass seedings. M.S. Thesis. Univ. Nebr. 73 p.

WATSON, D. P. 1949. Anatomical changes of bentgrass (*Agrostis canina*) from soil treatment with 2,4-D acid. Abst. Research Report, 6th Ann. NCWCC. p. 66.