mahogany (Cercocarpus montanus Raf.) was generally killed.

**Summary**

Propylene glycol butyl ether (PGBE) esters of 2,4,5-T and silvex were applied to Arizona chaparral at zero, one, two and four pounds per acre in the spring, spring-fall (of the same year), spring-spring, and spring-fall-spring, beginning in May, 1959. In a second experiment 2,4,5-T and silvex were applied at zero, two and four pounds as the alkanolamine salt, as PGBE esters in Kuron and Esteron form, and as PGBE esters of 2,4,5-T and silvex in Forron formulation in the spring of 1959 and 1960. All tests were made on replicated 25' x 50' plots.

The treatments resulted in varying degrees of topkilling of shrub live oak but most plants resprouted from the base or live branches. Treatment effects were recorded in terms of visual estimates of damage to tops of oak bushes as evidenced by dead leaves or lack of leaves. Silvex was generally slightly superior to 2,4,5-T.

The addition of five percent or more diesel oil emulsified in the water carrier increased effectiveness of 2,4,5-T in topkilling shrub live oak. When oil was included in the spray, there was no advantage in adding surfactant (above that in the formulated herbicide), but adding surfactant to sprays having no additional oil doubled the activity.

For any given schedule of retreatment, the higher application rates were more effective than the lower. However, the efficacy of the treatments was more related to frequency of retreatment than to total amount of herbicide applied. At any rate of herbicide the effectiveness of the treatment increased with the number of applications made. When two treatments were applied, there was no difference between fall and spring retreatment.

There was no difference between PGBE esters of 2,4,5-T and silvex as Forron (in water) or standard (Kuron and Esteron in 1:7 oil/water emulsion) formulations; however, both were superior to alkanolamine salts of 2,4,5-T and silvex in aqueous solution.

**LITERATURE CITED**


1,183.


1Cooperative with Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture and the Utah Agricultural Experiment Station, Logan, Utah. Thanks to Francis McAllister, former student, for greenhouse work. Utah Agric. Exp. Sta. Journal Paper 284.

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**Competition and Water Requirements of Cheatgrass and Wheatgrasses in the Greenhouse**

A. C. Hull, Jr.

Range Conservationist, Crops Research Division Agricultural Research Service, U. S. Department of Agriculture, Logan, Utah

Cheatgrass (Bromus tectorum L.), a vigorous, introduced annual, covers millions of acres of abandoned cropland and depleted rangeland. Although cheatgrass provides considerable livestock feed, it varies greatly in production, dries up early, and is a fire hazard (Hull and Stewart, 1948). Plant hosts of the beet leafhopper such as Russian thistle (Salsola kali L. var. tenuifolia Tausch) occupy cheatgrass areas following mechanical or biological disturbances and fire (Piemel, 1938). Stewart and Hull (1949) stated that crested wheatgrass (Agropyron smithii Rydb.) once established, restricted cheatgrass growth because cheatgrass competes with perennial grass seedlings it must be reduced for successful range seedings.

Dillman (1931) determined the water requirement of crested wheatgrass and many other species in North Dakota. The weighted mean water requirement of crested wheatgrass was 653. Some other species for comparison were Russian thistle 224, smooth brome (Bromus inermis Leyss.) 784, and western wheatgrass (Agropyron smithii Rydb.) 1,183.

Hunt (1962) obtained significant differences in water requirements of genotypes of in-
termediate wheatgrass (*Agropyron intermedium* (Host) Beauv.) and Russian wildrye (*Elymus junceus* Fisch.). Intermediate wheatgrass had a lower water requirement and produced more forage than did Russian wildrye.

Keller (1953) found that orchardgrass (*Dactylis glomerata* L.) genotypes high in herbage yields were low in their water requirements and visa versa. Keller (1954) advised adhering to a single technique in water-requirement studies.

In the greenhouse Evans (1961) grew 18 plants of crested wheatgrass and four, 16, 64, and 256 plants of cheatgrass in containers one foot square and four feet deep. Cheatgrass at densities of 64 and 256 plants severely curtailed shoot and root growth and greatly increased mortality of crested wheatgrass. With 18 crested wheatgrass plants and 256 cheatgrass plants, soil moisture was depleted to 15 bars suction in nine weeks. The crested wheatgrass ceased growth after eight weeks and the cheatgrass after ten. These results suggest that cheatgrass is more efficient in the extraction of soil water or has greater drought resistance than crested wheatgrass.

The competitive ability of cheatgrass has been blamed for many unsuccessful crested wheatgrass seedings on cheatgrass-infested lands. The present study was to determine water requirements and some competitive relations of cheatgrass and wheatgrasses.

**Procedures**

Four studies with cheatgrass and wheatgrasses were carried out in the greenhouse:


2. Same as study 1 except different seedling combinations of cheatgrass and crested wheatgrass.

3. Water use of cheatgrass and crested wheatgrass in different combinations in gallon cans with eight replications.

4. Top and root growth of cheatgrass and crested wheatgrass in different combinations in glass-faced boxes with three replications.

Soil was dried on greenhouse benches and 3,740 grams put in each can. The percent moisture was ascertained and thereafter water was added after weighing each can to determine water needs. Gypsum moisture blocks in some cans also helped determine moisture potential. Enough water was added to keep the plants growing well, but drainage was avoided.

The soil was a sandy loam obtained near Bliss, Idaho, with the following characteristics:

- **pH (paste)**: 7.3
- **Sat. ext. (EC x 10³)**: 1.0
- **Organic matter (percent)**: 1.1
- **P₂O₅ lbs/A**: 114.0
- **Moisture (percent)**: 38.0
- **½ atm.**: 15.6
- **15 atm.**: 7.3

Seeds were pregerminated and put in cans or boxes and covered with one-fourth inch of soil. Cheatgrass commenced germination in two days and germinated 100 percent in four days. The wheatgrasses started to germinate in four days and reached 80 percent in eight days. To get all seedlings started growing at the same time, germination of the wheatgrasses was started two days earlier than that of cheatgrass.

A plastic sheet was placed over all cans and boxes for three days after seeding to reduce water loss. Cans had a surface area of 0.20 square feet and boxes 0.24 square feet. Cans and boxes were rotated weekly. A board as high as the cans shaded the outer rows. Air temperatures at the plant level ranged from 60° to 88° F. during the day and 38° F. during the night.

![Figure 1](image-url)

**Figure 1.** Top growth of plants from different combinations in the plant-competition study. The entire roots are not shown. Crested wheatgrass (Ade) is on the right and cheatgrass (Bie) on the left in the three combinations. Numerals represent the number of plants per can.
Table 1. Air-dry weight of tops and roots and water requirements for cheatgrass and wheatgrasses in competition and water-requirement studies.

<table>
<thead>
<tr>
<th>Number of plants</th>
<th>Wheatgrasses</th>
<th>Cheatgrass</th>
<th>Wheat-grass</th>
<th>Cheat-grass</th>
<th>All roots</th>
<th>Water requirement (Grams water/grams herbage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Competition study</td>
<td>5 0</td>
<td>3.9a1</td>
<td>-</td>
<td>5.1a</td>
<td>836a</td>
<td></td>
</tr>
<tr>
<td>5 10</td>
<td>.6b</td>
<td>7.5a</td>
<td>14.0b</td>
<td>436b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 40</td>
<td>.4bc</td>
<td>8.0a</td>
<td>20.3c</td>
<td>502b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 160</td>
<td>.2c</td>
<td>7.9a</td>
<td>21.9c</td>
<td>527b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Competition study</td>
<td>10 0</td>
<td>4.9a</td>
<td>-</td>
<td>9.1a</td>
<td>818a</td>
<td></td>
</tr>
<tr>
<td>8 10</td>
<td>1.0b</td>
<td>7.4a</td>
<td>18.7b</td>
<td>486b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 20</td>
<td>.4c</td>
<td>7.5ab</td>
<td>18.2b</td>
<td>519b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 30</td>
<td>.1c</td>
<td>9.3bc</td>
<td>18.9b</td>
<td>450b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 40</td>
<td>-</td>
<td>10.1c</td>
<td>17.7b</td>
<td>445b</td>
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<td></td>
</tr>
<tr>
<td>3. Water-requirement study</td>
<td>5 0</td>
<td>4.6a</td>
<td>-</td>
<td>4.8a</td>
<td>582a</td>
<td></td>
</tr>
<tr>
<td>5 5</td>
<td>1.5b</td>
<td>6.2a</td>
<td>10.0b</td>
<td>417b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 5</td>
<td>-</td>
<td>8.1b</td>
<td>10.9b</td>
<td>385b</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1A highly significant (one percent) difference exists between two means not followed by the same letter.
2Agropyron cristatum and 3A. sibiricum. All other wheatgrasses are A. desertorum.

to 58°F at night during the study.

When seedlings in the water-use study were one inch high, the soil surface was covered with one-half inch of fine gravel to reduce evaporation. The cans were then covered with a plastic sheet, perforated for each plant. However, the plastic caused heat damage and was removed after three days. A row of alfalfa plants in gallon cans and clipped to the same height as the grass plants formed a buffer strip for the outer rows.

Studies were begun February 27, 1961. Heights were measured weekly. By mid-April top and root growth had ceased in cans which had a high density of cheatgrass plants. Studies were ended on April 26 before roots commenced dying. Soil was carefully washed from the roots and air-dry weights of tops and roots were obtained. Significance of results at the one-percent level was determined by Duncan's (1955) multiple range test.

Results

Competition Between Cheatgrass and Three Wheatgrasses

Each treatment had five wheatgrass plants growing with 0, 10, 40, or 160 cheatgrass plants (Table 1). Only crested wheatgrass was grown alone and with ten cheatgrass plants. Five crested wheatgrass plants growing alone produced 3.9 grams of herbage but in competition with 10 cheatgrass plants only 15 percent of that amount was produced (Figure 1). Roots could not be accurately separated, but by observation cheatgrass competition reduced wheatgrass root yield as much as it reduced top yield. Differences in growth and water use among crested, fairway, and siberian wheatgrasses growing in competition with 40 cheatgrass plants were not significant.

Cheatgrass used water more efficiently than the wheatgrasses. Since there was more exposed soil in the cheatgrass cans there may have been slightly greater evaporation which would have increased the water requirement. Water requirement is the weight of water used divided by the weight of herbage produced. Soil in cans with no plants and no gravel cover used 24 to 33 percent as much water as soil with plants and no cover.

Competition Between Cheatgrass and Crested Wheatgrass

Results were similar to those in study 1. As cheatgrass plant numbers increased, the yield of crested wheatgrass decreased. Crested wheatgrass growing with 0, 10, 20, and 30 cheatgrass plants per can yielded .49, .13, .08, and .04 grams of herbage per plant. Cheatgrass used 54 percent as much water as did crested wheatgrass.

Water Use by Cheatgrass and Crested Wheatgrass

Five plants each of cheatgrass and crested wheatgrass were grown alone and in combination (Table 1). Five plants of crested wheatgrass without cheatgrass produced 4.6 grams, three times

Table 2. Top and root yields and growth of cheatgrass and crested wheatgrass in glass-faced boxes.

<table>
<thead>
<tr>
<th>Number of plants</th>
<th>Wheatgrasses</th>
<th>Cheatgrass</th>
<th>Air-dry weight (Grams)</th>
<th>Root length (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 0</td>
<td>4.9a1</td>
<td>-</td>
<td>7.0a</td>
<td>16.7a</td>
</tr>
<tr>
<td>10 10</td>
<td>.9b</td>
<td>4.6a</td>
<td>9.9ab</td>
<td>16.1ab</td>
</tr>
<tr>
<td>10 80</td>
<td>.2b</td>
<td>7.0a</td>
<td>12.3bc</td>
<td>12.2bc</td>
</tr>
<tr>
<td>10 640</td>
<td>.1b</td>
<td>13.0b</td>
<td>13.0c</td>
<td>9.3c</td>
</tr>
</tbody>
</table>

1A highly significant (one percent) difference exists between two means not followed by the same letter.
as much herbage as five plants competing with five plants of cheatgrass. Crested wheatgrass produced 43 percent less top growth and 56 percent less root growth than cheatgrass (Figure 2).

Cheatgrass required 66 percent as much water to produce a gram of dry matter as did crested wheatgrass. Evaporation from soil in cans with a one-half inch gravel cover and no plants was ten percent that of the combined use and loss from soil with a gravel cover and plants. Evaporation was ignored in calculating water requirements.

Figure 2. A. General view of water-use study with border rows of alfalfa removed. B. Typical top growth of plants. The entire roots are not shown. Crested wheatgrass (Ad) on left. Cheatgrass (Bt) on right. Numerals represent the number of plants per can.

Top and Root Growth of Cheatgrass and Crested Wheatgrass

Ten plants of crested wheatgrass were grown with 0, 10, 80, and 640 cheatgrass plants in 2 x 17 x 36-inch glass-faced boxes (Table 2). Ten plants of crested wheatgrass yielded 4.9 grams of tops. Ten plants of crested wheatgrass growing with ten plants of cheatgrass yielded 0.9 gram of tops. Increasing cheatgrass plants to 80 and 640 per box further reduced wheatgrass yields.

Root length of wheatgrass plants decreased significantly as the number of cheatgrass plants increased. Cheatgrass roots elongated more rapidly and were longer, finer, and spread wider than wheatgrass roots (Figure 3).

Discussion

Cheatgrass is a severe competitor with other grasses. Even a small number of cheatgrass plants reduced growth of wheatgrass to between 1/7 and 1/3 of that produced without cheatgrass. Cheatgrass is also a strong competitor with itself. Increasing plant numbers decreased the weight of individual plants. Where cheatgrass numbered 10, 40, and 160 plants per can, individual plants weighed .75, .20, and .05 grams.

Cheatgrass seeds germinated more rapidly and the tops and roots elongated faster than those of crested wheatgrass. It could thus compete severely with crested wheatgrass for light and moisture. Cheatgrass roots occupied a wider and deeper soil area and the roots were finer with more roots for a given weight than for crested wheatgrass. Cheatgrass could thus absorb water and plant nutrients from a larger soil volume than could crested wheatgrass seedlings. Studies by Evans (1961) suggested that cheatgrass is more efficient in the extraction of soil water than crested wheatgrass.

In the water-requirement study crested wheatgrass re-
quired 582 grams of water to produce a gram of dry matter. Cheatgrass required 385 grams or 66 percent as much as crested wheatgrass. Efficiency in water use or water extraction might make a major difference in plant growth and competition. In the competition studies crested wheatgrass required 836 and 818 grams to produce a gram of dry matter. The lower amount of 582 grams in the water-requirement study was undoubtedly the result of a half-inch gravel layer on top of the soil. Mulches and shading by plants reduce evaporation from the soil surface, which in turn may be of great importance to plants competing for soil water.

Summary

Cheatgrass, a vigorous annual, is a strong competitor with perennial grass seedlings and often causes failures of range seedings. Cheatgrass and three wheatgrasses were grown together in gallon cans and in glass-faced boxes in the greenhouse. The shoots and roots of cheatgrass elongated more rapidly than those of crested wheatgrass. Also cheatgrass roots were finer, spread more, and occupied the soil mass more completely than did crested wheatgrass roots.

Cheatgrass grown in varying densities with wheatgrasses reduced the top growth of wheatgrass to between 1/7 and 1/3 of that produced without cheatgrass. Although roots were not separated, the root growth of the wheatgrasses appeared to have been reduced by a similar amount.

Cheatgrass produced up to twice as much top growth and required only 66 percent as much water to produce a gram of dry matter as did crested wheatgrass.

Differences in top and root growth and water use among the three wheatgrasses growing with cheatgrass were not significant.

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Effect of Fertilization on Yield on an Irrigated Mountain Meadow

ROSS W. LEAMER


Ranchers utilizing mountain ranges in the Rocky Mountain region usually have areas of valley land on which they produce hay for winter feed. Approximately 3,800,000 acres of such land in the 11 Western States is classified as mountain meadows (Rouse et al. 1955). Commonly these meadows are pastured in the spring, cut for hay in the summer while the cattle are on higher ranges, and pastured again in the fall. Grasses predominate in these high altitude valleys.

Burton and DeVane (1952) reviewed the literature on the effect of nitrogen fertilization on growth and chemical composition of grasses in pastures in the southeast and Willhite et al. (1955) studied grasses in mountain meadows in Colorado. They all agreed that nitrogen on pure stands of grass increased the yields on most soils. Generally, yield increases were accompanied by increases in protein content.

Shipley and Headley (1948), working on the high altitude meadow areas of Nevada have shown that late harvesting reduced the nutritive value of hay. Miller et al. (1955) found that highest protein yields were obtained when the first harvest was at the end of June. Willhite et al. (1955) found that, in high mountain valleys in Colorado, hay cut the first of August was superior in feeding value to hay cut in early September. In their experiment, one pound of 43 percent crude protein cake supplement per animal per day was required to raise the feeding value of late cut hay ration to equal early cut hay. They also found a direct relationship between pounds of crude protein in the daily ration and the rate of animal gain. Many ranchers cut hay in the early stages of maturity to maintain the high protein content and then use the fall regrowth for pasture when the high mountain ranges are covered with snow.

This report summarizes a four-year study on an irrigated meadow in the Cimarron Valley one mile west of Cimarron in northern New Mexico. The valley at this location is 6500 feet above sea level. The average frost free period is 158 days (May 1 to October 11). The mean temperature for July is 70 degrees. Average annual precipitation is 15 inches. There is ample water for irrigation.

Materials and Methods

The field was leveled for irrigation in 1956 to a slope of 0.95 feet per 100 feet. Maximum cut in the experimental area was 1.10 feet; maximum fill was 0.70 feet. The soil was described as a well-drained, undifferentiated mountain alluvium. Barnyard manure, at the rate of five tons per acre, was spread on the whole field in 1956 following leveling. In 1957, 100 pounds of 8-32-0 and 100 pounds of 33-0-0 were spread, and the area was disk plowed. About July 1, 1957, a mixture of Kentucky 31 fescue (Festuca arundinacea), orchardgrass (Dactylis glomerata), tall wheatgrass (Agropyron elongatum), and Madrid sweetclover (Melilotus officinalis) was planted. The area was irrigated before planting, and good rains followed planting. The grasses emerged to a good stand. The field was sprayed with 2,4-D about the middle of August. Most of the weeds and clover were killed but a good stand of grasses remained.

The treatments were initiated in 1958 and terminated in 1961. The main variables were time and rate of application of nitrogen as ammonium nitrate. One application was made early in the spring when the first growth was apparent (March 1); another was made when growth was well started (April 15); and a third was made after the first cutting of hay had been removed (July 1). The amounts of fertilizer applied at the various dates are shown in Figures 1, 2 and 3. All rates were doubled the last year.