(Hyer, et al. 1950). They indicate that more attention should be paid in northwest Oklahoma and the Southern Great Plains to seed production of blue grama and other native grasses.

Conclusions

Blue grama seed production under irrigation could be highly profitable to a diversified crop and livestock operation in northwest Oklahoma. Efficient use of the forage produced would tend to pay most of the production costs, leaving the seed as a cash crop. Since irrigation farmers in the area have been shifting from cash grain crops to marketing of irrigated produce through livestock, this crop would fit in particularly well.

Even though use of dieldrin insecticide would mean added production costs and impose some limitations on use of forage remaining after seed harvest, increased seed sets obtained would give appreciable extra net returns per acre when seed is sold on a quality basis.

Summary

Estimates of net dollar returns per acre were made using blue grama seed and forage production data obtained during the years 1954-1959 from an experimental field at Woodward, Oklahoma.

Forage value estimated in terms of grazing rental and off-farm sale of hay made an appreciable contribution to gross returns. An operator utilizing all the forage produced would probably be able to pay his annual operating costs from forage alone.

Estimated net returns per acre to land, labor, management, and capital from seed and forage over the 6-year period ranged from a net loss of $1 to a profit of $131. Average net return was $76.

Where all recommendations except insect control were followed, the range was from $1 to $110 profit with an average return of $62.

LITERATURE CITED


Relation of Selected Measurements to Weight Of Crested Wheatgrass Plants

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One of the most useful criteria for judging the condition of grassland is herbage production. A common way of determining production is by clipping herbage on sample plots. Though this method is considered the most accurate, it has two serious disadvantages: (1) It is time consuming, and (2) it affects the vigor, growth, and physiological processes of the plant.

Clipping often causes long-lasting damage to perennial bunchgrasses growing under arid or semiarid conditions (Parker and Sampson, 1931; Lang, Barnes and Rauzi, 1956). Consequently, different plots should be clipped each year.

This procedure introduces a great deal of variation and requires a large sample.

An ideal method from the standpoint of both range and watershed management, would provide for a continuous measurement of changes in herbage weight during periods of rapid and slow growth as well as dormancy. Such measurements would not cause changes in soil or vegetation. The herbage capacitance meter developed by Fletcher and Robinson (1956) solves this particular problem. Unfortunately, the capacitance meter does not separate production by species. It measures only the plant mass (grass, weeds, and brush combined) on a given area. Moreover, moisture content of plants and soil may affect the measurements. A more promising approach, one that is less subject to these outside variables, is the measurement of individual plants.

Many range technicians have considered using height as an index of gross volume or weight. The widely used height-weight and height-volume tables are based on this assumption. Several investigators (Caird, 1945; Clark, 1945) have shown that the weight of an individual grass plant is not strictly a function of height but rather a function of several variables, depending on

1 This paper is based on a thesis submitted in partial fulfillment of the requirements for the Degree of Master of Science at the University of California, Berkeley, California.
2 Central headquarters maintained in cooperation with Colorado State University. Research reported here was conducted from the University of New Mexico, Albuquerque, New Mexico.
growth form. Growth form of individual crested wheatgrass (Agropyron desertorum (Fisch.) Schult.) plants has been shown by the author\(^3\) to vary widely according to site conditions.

Studies were conducted on crested wheatgrass at three areas in New Mexico in 1957 to seek relationships that would permit a range manager to determine herbage production from measurements of individual plants. Since weight of individual plants is correlated with volume, linear measurements related to volume can be correlated with individual plant weight. This will indicate the relative merit of each measurement individually and in association with others as it affects plant weight.

**Description of Study Areas**

Laguna Seca experimental pastures were about 40 miles northwest of Cuba, New Mexico, at an elevation of 7,400 feet. The long-time average precipitation approximates 16.5 inches but in 1957, the year of this study, the total annual precipitation was 22.7 inches. Before 1957, cattle grazed the area to an average of 20 percent utilization by weight, an amount considered to be light grazing.

Experimental pastures at the No Agua site were located 5 miles north of Tres Piedras, New Mexico, at an elevation of 8,300 feet. No Agua has an average annual precipitation of 13.3 inches; in 1957 it was 18.7 inches. Before 1957, cattle grazed the area to an average of 20 percent utilization by weight, an amount considered to be light grazing.

The Cebolla Mesa experimental pastures were 20 miles north of Taos, New Mexico, at an elevation of 7,450 feet, with an average annual precipitation of 12.5 inches. In 1957 annual precipitation was 18.3 inches. Spring grazing by cattle before the study averaged 0 (none), 40 (light), 54 (medium) and 70 (heavy) percent utilization.

**Methods**

Data were collected in each pasture at all three study locations during the growing season (June and July) of 1957. Linear measurements, accurate to the nearest 2 inch, were made on 923 ungrazed crested wheatgrass plants as follows:

1. Basal diameter
2. Crown diameter
3. Leaf height
4. Culm height
5. Compressed crown diameter
6. Compressed leaf length
7. Compressed culm length

The first four measurements were taken on undisturbed plants in their natural field condition. Basal diameter measurements of the plants were taken near ground level (Figure 1). Crown diameter, leaf height, and culm height were measured on undisturbed plants in their natural field position. Other measurements were taken after foliage and culms were compressed and raised to the maximum vertical position and grasped together by hand at average leaf height (Figures 2 and 3). After measurements were taken, each plant was clipped at ground level, oven dried and weighed to the nearest hundredth of a gram.

Correlations (Goulden, 1956) of weight with all seven variables were computed by individual study areas or sites, individual pastures within sites, four intensities of use and overall or combined sites. Multiple correlations involving the best independent variables were then computed.

**Results**

Intensity of past use had no apparent effect on the ranking of the correlation coefficients of plant measurements with weight of individual plants. When intensities of use were combined for all locations, there was less variation in the correlation coefficients than between different uses within a site.

Site also had no apparent effect on the ranking of correlation coefficients between plant measurements. There was some variation between values for pastures within an area, but when all pastures were combined variations balanced out. This was
Table 1. Plant measurements ranked according to the sequence of their correlation with oven-dry plant weight by pasture, intensity of use, individual and combined location.

<table>
<thead>
<tr>
<th>Location</th>
<th>Grazing use</th>
<th>Relative rank</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laguna Seca</td>
<td>Light</td>
<td>CCD*</td>
<td>BD</td>
<td>CD</td>
<td>CLL</td>
<td>LH</td>
<td>CCL</td>
<td>CI</td>
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<tr>
<td>No Agua</td>
<td>None</td>
<td>CCD BD</td>
<td>CD</td>
<td>CLL</td>
<td>LH</td>
<td>CCL</td>
<td>CH</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Light</td>
<td>BD CCD</td>
<td>CLL</td>
<td>LH</td>
<td>CCL</td>
<td>CD</td>
<td>CH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cebolla Mesa</td>
<td>Medium</td>
<td>CCD BD</td>
<td>CD</td>
<td>LH</td>
<td>CLL</td>
<td>CH</td>
<td>CCL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy</td>
<td>CCD BD</td>
<td>CD</td>
<td>LH</td>
<td>CLL</td>
<td>CH</td>
<td>CCL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All Uses</td>
<td>CCD BD CD</td>
<td>CLL</td>
<td>LH</td>
<td>CCL</td>
<td>CH</td>
<td>CCL</td>
<td>CH</td>
<td></td>
</tr>
<tr>
<td>No Agua</td>
<td>None</td>
<td>CCD BD</td>
<td>CD</td>
<td>CLL</td>
<td>LH</td>
<td>CCL</td>
<td>CH</td>
<td></td>
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<tr>
<td>Cebolla Mesa</td>
<td>Light</td>
<td>BD CCD</td>
<td>CLL</td>
<td>LH</td>
<td>CCL</td>
<td>CH</td>
<td>CCL</td>
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<tr>
<td></td>
<td>Medium</td>
<td>BD CCD</td>
<td>CLL</td>
<td>LH</td>
<td>CCL</td>
<td>CH</td>
<td>CCL</td>
<td>CH</td>
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<tr>
<td></td>
<td>All Uses</td>
<td>CCD BD CD</td>
<td>CLL</td>
<td>LH</td>
<td>CCL</td>
<td>CH</td>
<td>CCL</td>
<td>CH</td>
<td></td>
</tr>
</tbody>
</table>

* Plant measurements were basal diameter (BD), crown diameter (CD), compressed crown diameter (CCD), leaf height (LH), compressed leaf length (CLL), culm height (CH), and compressed culm length (CCL).

also true when all three study locations were combined.

Values of individual measurements were ranked according to the numerical sequence of simple correlation coefficients with ovendried plant weight (Table 1). There were slight differences in the ratings of measurements between pastures and intensities of use. When either pastures or sites were combined, the relative rank of plant measurements in their contribution to weight was always in the order of: (1) Compressed crown diameter, (2) basal diameter, (3) crown diameter, (4) compressed leaf length, (5) leaf height, (6) compressed culm length, and (7) culm height.

Simple correlation coefficients between measurements of compressed and uncompressed plants were extremely high because of the close relation between the two values. Compressed measurements always gave higher correlation coefficients with plant weight than uncompressed measurements.

When all the independent variables were combined, a multiple correlation coefficient of 0.924 was obtained. Thus, 85.4 percent of the variation in individual plant weight was accounted for by these seven measurements.

Culm measurements, which had the lowest correlations, were eliminated. Crown diameter and leaf height were eliminated because: (1) Their dependence with the compressed measurements, and (2) their lower correlation values. This left basal diameter (which remains unchanged with compression), compressed crown diameter and compressed leaf length. Multiple correlations between these measurements and plant weight were computed for combinations of any two and for all three with the following results:

- **Portion of variation**
- **Correlation coefficient accounted for**
- **Plant Measurements (R)**
- **(R²)**

<p>| | | | | |</p>
<table>
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</thead>
<tbody>
<tr>
<td>CCL &amp; CLL</td>
<td>0.918</td>
<td>84.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BD &amp; CLL</td>
<td>0.882</td>
<td>77.8</td>
<td></td>
<td></td>
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<tr>
<td>BD &amp; CCD</td>
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</tr>
<tr>
<td>BD, CCD &amp; CLL</td>
<td>0.922</td>
<td>85.0</td>
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<td></td>
</tr>
<tr>
<td>All 7 variables</td>
<td>0.924</td>
<td>85.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On the basis of these relationships, the three measurements; basal diameter, compressed crown diameter, and compressed leaf length, provide an estimate of plant weight nearly equal to all seven combined measurements. Compressed crown diameter and compressed leaf length in combination were almost as good in this study, but might be expected to have less reliability under different conditions.

The following regression equation best represented the data:

\[ Y = -26.240 + 2.148 X_1 + 22.872 X_2 + 1.900 X_3 \]

Where \( Y \) = oven-dry weight of plant material

\( X_1 \) = basal diameter

\( X_2 \) = compressed crown diameter

\( X_3 \) = compressed leaf length

Evans and Jones (1958) accounted for 28.9 to 97.6 percent of the variability in yield on mixed annual ranges, using the product of plant height and ground cover. Hurd (1959), working with Idaho fescue and using leaf height, basal area, and number of flower stalks, accounted for 86 to 94 percent of the variability in plant weight.

Summary

During the 1957 growing season, 923 crested wheatgrass plants were measured, clipped at ground level, oven dried, and...
taken were basal diameter, crown diameter, leaf height, culm height, compressed crown diameter, compressed leaf length, and compressed culm length. Simple and multiple correlations were then calculated to determine the relative contribution of each measurement individually and in combination with others as it affects plant growth. Conclusions are as follows:

1. Intensity of past grazing use had no effect on the ranking of correlation coefficients between yields and each of the linear measurements.

2. Area or site conditions had no effect on the ranking of correlation coefficients.

3. Measurements of compressed plants were much more closely correlated with plant weight than those of uncompressed plants.

4. The combined seven measurements accounted for 85.4 percent of the variability in plant weight.

5. Measurement of basal diameter, compressed crown diameter, and compressed leaf length provides an estimate of plant weight nearly equal to that obtained from all seven measurements. Also, compressed crown diameter with compressed leaf length accounted for 84.3 percent of the variability in plant weight.

LITERATURE CITED


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Ground Cover and Plants Present on Grazed Annual Range As Affected By Nitrogen Fertilization

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In recent years there has been considerable interest in fertilization on California's annual range-land, not only for increased forage production, but also for increased quality of feed. Conrad (1950), Bentley and Green (1954), and Williams, et al. (1956), found that application of phosphorus and sulfur increased legumes and thereby substantially increased the succeeding crop of nonlegumes. Evans and Love (1956) reported that grasses such as soft chess (Bromus mollis), ripgut (B. rigida), wild oats (Avena spp.), and broadleaf filaree (Erodium botrys) increased with application of nitrogen especially in combination with phosphorus and sulfur, work by Jones and Evans (1960) indicated that changes in botanical composition resulting from the application of nitrogen and phosphorus were not the same on grazed as on ungrazed plots.

Beginning in 1953, Martin et al. (1954) (1956) (1957) (1958) reported the results of a number of large scale fertilizer trials on California's annual range using animal gains as a measure of results. The purpose of this present study was to survey the botanical composition of a number of these fertilizer trials which had been grazed by sheep or cattle, and which represented a wide range of soils and climatic conditions, to see if consistent changes resulted from the application of nitrogen fertilizers.

Procedure

Botanical composition was measured on previously nitrogen fertilized and unfertilized annual range-land at 11 locations in California. These areas were surveyed between March 23 and April 28, 1959 by a modification of the step-point method as described by Evans and Love (1957). About 400 points and 40 estimates of total ground cover were taken in each pasture-treatment along six to ten transects. The number of transects and the distance between each point along the transect was determined by the size and shape of the pasture. The percentage of a given species in a pasture was found by dividing the number of hits which occurred on the species in