cantly lower than top weights of plants subjected to the 70° and 85° temperatures. As stated before, final top weights of seedlings subjected to the 55° temperatures cannot be directly compared as they were allowed a ten-week recovery period.

**Final Root Weight**

Final root weights follow a similar pattern as final top weights. Analysis of variance for final root weight shows temperature, stage of growth, species, and the interactions of these variables to be significant at the 0.01 level (Table 1). Final root weight was greatest at the 85° regime and this value was highly significantly different from all other values for root weight. This apparently was a reversal of the trend immediately following temperature treatment where root growth exhibited an optimum growth at 100°. Six weeks after treatment, root growth for the 85° regime was 9.16 mg., about double that for the 100° regime (4.72) (Table 2). Mean values for the 100°, 115°, and the 70° regimes were not significantly different. The final root weight for the 55° regime should not be compared because of the difference in recovery period. Six weeks after temperature treatment, there appeared to be complete masking of the immediate root stimulation at the higher temperature regimes; plants subjected to the 85° regime produced maximum root production. In some instances, as with beardless wheatgrass at the oldest stage of growth, the effects of the temperature stimulation in the growth chamber were still evident six weeks after removal.

**Summary And Conclusions**

Results of germination analysis on beardless bluebunch wheatgrass, hard fescue, big bluegrass, and orchardgrass indicated that germination is inhibited or greatly reduced at temperatures above 100° or below 70°. Germination was fair between 70° and 100°. Orchardgrass germinated best at the lower temperature and beardless wheatgrass, hard fescue, and big bluegrass at the higher temperatures. No apparent detrimental carry-over effects from extreme temperatures were observed after returning seeds to greenhouse conditions.

A pronounced increase in top production was exhibited as the temperature was increased from 55° to 85°. The 85° regime resulted in the greatest top growth over all stages of growth. Little growth occurred at 55°. A sharp decline in top production took place at 115°.

In contrast to the decline in top growth from 85° to 100°, root growth as measured by elongation was greatest at 100°. The stimulation of root elongation at 100° was followed by an over-all decrease in both top and root production during the six-week recovery period.

**LITERATURE CITED**

Crocker, W., and Barton, L. V., 1953. Physiology of seeds. 267 pp., illus. Waltham, Mass., Chronica Botanica Co.


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**Variable Plot, Square Foot Plot, and Visual Estimate for Shrub Crown Cover Measurements**

H. G. Fisser

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Range management procedures often require an estimation of shrub cover for complete evaluation of vegetation characteristics. Survey studies conducted over large areas necessitate rapid estimation. However, procedures associated with reduced time requirements are often inexact and variable. Since the inherent characteristics of a survey study often require evaluation by several workers with varying degrees of ability and experience, an acceptable cover estimation method must be accurate, rapid, and consistent among individuals.

The study reported here was conducted in the Big Horn Basin of western Wyoming by University of Wyoming personnel. Three men evaluated three types of shrub cover with three methods of estimation—visual estimate, square-foot plot, and variable plot. The object of this evaluation was to compare the three methods and to appraise the re...
relationship of data acquired by different personnel.

Review of Literature

Estimates of vegetation cover for range inventory studies were originated in 1907 by Jardine. His method, known as the reconnaissance method, was used on a team basis and consisted of estimating percentage of ground cover and the percentage composition of the species in the vegetation (Pickford, 1940). Although widely adopted, the method has been criticized, since accuracy of results depended largely upon the judgment and observational powers of the individuals using it (Smith, 1944).

A number of plot sizes have been developed for cover estimation procedures (Brown, 1954). Armstrong (1907) used a frame one square foot in area and subdivided into 144 square inches by cord stretched across the frame. He counted squares of bare surface and squares occupied by vegetation. With practice and care, he was able to obtain accurate estimates of cover by examining 6 to 10 frames on a representative portion of turf. However, the method is not altogether satisfactory since estimation of tall plants is difficult and location by “random” throws tends to be biased (Greig-Smith, 1957).

The variable plot method was first proposed by Bitterlich (1948) in Austria. By this system, timber-volume estimates were obtained without establishing plot boundary lines. Basically, the procedure consisted of viewing all trees visible from a given point and counting all those whose diameters appeared greater than a hand-held angle gauge. The total count divided by the number of sampling points, multiplied by a constant derived for a given angle, gave an estimate of average basal area per acre. Grosenbaugh (1952) introduced the method to American foresters. Subsequent modifications have been developed to permit use of the method on shrub and grass types.

Cooper (1957) conducted variable plot studies on shrub types of southern Arizona. Modifications were developed for the direct conversion of shrub counts to percent cover data through division-factor constants for various sighting angles as projected by different crossarm lengths. A comprehensive derivation of variable plot principles and factor equations was presented. Variable plot studies were compared with direct shrub cover measurements and line interception data in three vegetation types. The variable plot estimates closely approximated the other methods in shrub stands of less than 35 percent cover and were much less time consuming.

Kinsinger, et al. (1960) compared different vegetation types of northern Nevada to evaluate variations of line interception, variable plot, and loop methods of shrub cover estimation as developed by different observers. Differences between observers and between plots of a vegetation type were negligible by variable plot analysis. Individual shrubs were difficult to distinguish when cover was more than 20 percent.

Hyder and Sneva (1960) constructed an apparatus of angle iron for application of variable plot studies on bunchgrass range of Oregon. Basal cover estimates were significantly greater by variable plot than by line intercept; however, the differences were not consistent among species. Differences between observers were slight. Reduction of reading time appeared to be the greatest advantage of the variable plot method.

Procedure

Crown cover studies were conducted on three shrub types—Nuttal saltsage (Atriplex nuttallii S. Wats.), big sagebrush (Artemisia tridentata Nutt.), and greasewood (Sarcobatus vermiculatus (Hook) Torr.). The sites were relatively uniform over an area approximately 200 feet in diameter and typical of much of the rangeland of western Wyoming. Saltsage (Figure 1) is a half-shrub, rarely over a foot in height with well defined plant units. The sagebrush (Figure 2) in this area is about 2.5 feet tall, while the greasewood (Figure 3) ranges from three to five feet in height. Individual bushes of the latter two species are, in many cases, not well defined.

Three observers collected individual data by three methods. Visual estimates were determined on a reconnaissance basis while standing in the study site and recorded in units of 5-percent crown cover. Cover data were obtained from transects of 10 frames, each a square foot in area. Each observer located plots independently of the others but within the general study area. Variable plot estimates were conducted from a single location point within each of the study sites.

A wooden angle gauge (Figure 4) was constructed similar to that described by Cooper (1957). The overall length, or the distance from eyepiece to crossarm, was 30 inches. Peephole diameter of the eyepiece was 5/32 of an inch. Four lengths of crossbar with division constants of 1, 2, 4, and 6 were used and individual readings obtained by each of the angles. The crossbars were easily exchanged but were held firmly in the cross lap cuts.

Before the reported study, survey procedures with the three methods were conducted throughout the region for two weeks. All observers were thus able to estimate shrub cover with reasonable uniformity. Emphasis was placed upon the concepts of recognizing the influence of plant growth form and height upon visual and square foot plot estimations. Variable
plot determinations involved the study of delineating plant units of various species.

**Results and Discussion**

Mean values of percent crown cover by shrub type as evaluated between methods and between observers are presented in Table 1. Differences between cover values of shrub types are not related and are of little importance as a measure of variation in this study. Determination of cover by visual estimate were equal by the three observers on the saltsage site but were extremely variable on the other two sites. This would appear to be a function of the growth form and height of the different species. Visual estimation must, of necessity, be considered a gross procedure with an expected high degree of variability between observers unless intensive training and checking procedures are conducted. Cover estimates from transects of square foot frames appear to be of little value for shrub cover determinations. Observer differences were great and the overall averages of cover by this method were much less than those by the other methods. It seems obvious that this method cannot be successfully applied to shrub cover determinations.

Mean cover values of variable plot data as presented in Table 1 indicate relatively close estimates between observers on given sites. Further evaluation of the data by standard statistical procedures (Ostle, 1956) yields interesting sources of variation. Mean squares for relation of variance to shrub types, gauge angles as determined by crossarm lengths, and observers are presented in Table 2. Shrub types introduced an expected highly significant variation in cover estimates. Other sources of significant variation in mean squares were crossarm lengths, observers, and the interaction between shrub types and gauge angles.

The highly significant variation in different crossarm lengths appeared to result from the higher average cover estimation values of the next to the longest crossarm length—that of 4-15/64 inches (Table 3). Interaction effects of the saltsage data tend to modify the deviation but appear to be of slight significance. Computation of the least significant difference (L. S. D.) shows the average crown cover value by this length to be significantly different from all others at the
5-percent probability level. The others are uniform and indicate little variation.

Effective sampling radius becomes larger with a smaller angle and thus, if a change in estimation occurs, one would expect it to be downward. This follows from the concept that, as the distance of measurable plants from the observer increases, the probability increases that hidden bushes will not be counted and that separate plant units will be combined into single counting units. Confirmation of this hypothesis is noted in the observed lower estimates of the shorter crossarms on the sagebrush and greasewood sites (Table 3).

The low estimates by the longest crossarm indicate other agents that can cause variation. The basic concept of the variable plot technique assumes a crown measurement procedure on a horizontal plane. This is virtually impossible in field application, since the observer must usually be above the bushes to be able to see and distinguish them. This difference in observer and plant height increases the measuring distance to the shrubs. For a given gauge angle, the greater the sighting distance, the greater the shrub diameter must be to be counted. Since this effect is most pronounced near the observer, proximate bushes could easily be ignored and not counted.

Therefore, subject to the interaction effects of plant height, it would appear that a crossarm of 4-15/64 inches will develop the greatest accuracy for the vegetation under study. Interestingly enough, this concept results from the fact that cover data by this length crossarm are significantly

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**Table 1. Means of percent cover of three shrub types as determined by three methods by three individuals.**

<table>
<thead>
<tr>
<th>Shrub Types</th>
<th>Nuttall Saltsage</th>
<th>Pig Sagebrush</th>
<th>Greasewood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate</td>
<td>Vari-</td>
<td>Vari-</td>
<td>Vari-</td>
</tr>
<tr>
<td>Ft. Plot</td>
<td>able Plot</td>
<td>able Plot</td>
<td>able Plot</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Observer</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Average:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>15.0 7.9 12.98</td>
<td>30.0 5.2 22.18</td>
<td>15.0 3.5 14.38</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>15.0 .9 12.25</td>
<td>20.0 8.7 20.12</td>
<td>10.0 6.0 11.15</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>15.0 7.8 12.05</td>
<td>15.0 14.4 24.08</td>
<td>5.0 5.1 18.75</td>
<td></td>
</tr>
<tr>
<td>Average:</td>
<td>15.0 5.5 12.43</td>
<td>21.7 9.4 22.13</td>
<td>10.0 4.9 13.09</td>
<td></td>
</tr>
</tbody>
</table>

1Each figure is an average of cover estimates with four different angles as determined by four crossarm lengths.
The significant observer variation in the analysis of variance of Table 2 results from a very interesting sample bias situation. It will be noted in Table 1 that the average variable plot cover estimate of salt sage by observer "B" was lower than the other, and the estimate of observer "B" to underestimate is also noted in Table 3. Least significant difference (L. S. D.) at the 5-percent probability level is less than the differences between observer "B" and the others.

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<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Degrees of Freedom</th>
<th>Mean Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>(S) Shrub Type</td>
<td>2</td>
<td>332.28**</td>
</tr>
<tr>
<td>(C) Crossarm Length</td>
<td>3</td>
<td>31.33**</td>
</tr>
<tr>
<td>(O) Observer</td>
<td>2</td>
<td>16.99*</td>
</tr>
<tr>
<td>S x C</td>
<td>6</td>
<td>8.96*</td>
</tr>
<tr>
<td>O x S</td>
<td>4</td>
<td>5.63*</td>
</tr>
<tr>
<td>C x O</td>
<td>6</td>
<td>.96*</td>
</tr>
<tr>
<td>Error (S x C x O)</td>
<td>12</td>
<td>2.83</td>
</tr>
</tbody>
</table>

*Significant at the 5-percent probability level.
**Significant at the 1-percent probability level.

Summary and Conclusions

Range survey methods of shrub crown cover measurements must be rapid, accurate, and consistent among individuals. Studies were conducted to compare percent crown cover estimates from three methods of evaluation on three shrub types by three observers.

Cover values obtained by the visual estimation technique were variable. However, data indicated that relatively accurate determinations could be obtained with intensive training and repeated checks.

Transects of square foot plots appeared to be of little value as a shrub cover estimation technique. Observer differences were great and crown cover values were markedly lower than those obtained by the other methods.

Variable plot studies were conducted with four gauge angles as determined by different crossarm lengths. Evaluation of the data by analysis of variance indicated significant differences in shrub types, crossarm lengths, observers, and the shrub type X crossarm length interaction.

Variation due to crossarm length appeared to be due to characteristics of plant height and growth form and to differences in effective sampling radius as reflected by the different

Table 3. Means of percent cover by variable plot estimation of crossarm lengths and observers among shrub types and crossarm lengths and shrub types among observers.

<table>
<thead>
<tr>
<th>Observer</th>
<th>Crossarm Length (inches)</th>
<th>Average¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-29/64</td>
<td>3.0</td>
</tr>
<tr>
<td>A</td>
<td>15.03</td>
<td>16.17</td>
</tr>
<tr>
<td>B</td>
<td>12.77</td>
<td>14.77</td>
</tr>
<tr>
<td>C</td>
<td>15.57</td>
<td>15.43</td>
</tr>
<tr>
<td>Average²</td>
<td>14.46</td>
<td>15.46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shrub Type</th>
<th>Crossarm Length (inches)</th>
<th>Average¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt sage</td>
<td>13.13</td>
<td>13.07</td>
</tr>
<tr>
<td>Sagebrush</td>
<td>19.07</td>
<td>21.77</td>
</tr>
<tr>
<td>Greasewood</td>
<td>11.17</td>
<td>11.53</td>
</tr>
</tbody>
</table>

¹L. S. D. of 1.49 at 5-percent probability level.
²L. S. D. of 1.72 at 5-percent probability level.
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gauge angles. The smaller the crossarm length, the greater the sampling radius, and when this distance becomes greater, the probability increases that the observer will underestimate the number of countable bushes. On sagebrush and greasewood the two shorter crossarm lengths consistently underestimated cover, but on saltsage they did not. The estimates from the longest crossarm appeared to underestimate cover because of the differential in observer and plant heights. The next to the longest crossarm (4-15/64 in.) appeared to provide the best estimate of cover subject to the shrub type interaction, which tended to modify the results.

As observer height above the bushes increases, fewer countable bushes will be overlooked. Observer “B” was 15 inches shorter than the others, and consistently estimated less cover on sagebrush and greasewood. However, his estimates on saltsage were intermediate between the others.

Field studies should be conducted to determine the most accurate gauge angle subject to shrub height and density before range survey use of the variable plot technique. In addition, inherent variations in data due to different observer heights must be evaluated. With a minimum of procedural control the variable plot method of shrub crown cover estimation appears to be a highly satisfactory tool for range surveys.

LITERATURE CITED


Utility of Soil Classification Units in Characterizing Native Grassland Plant Communities in the Southern Plains

ARNOLD HEERWAGEN AND ANDREW R. AANDAHL

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Environmental factors instrumental in the development of a native plant community and the soil on which it occurs have much in common and are interdependent in many respects. The nature of the relationship between kind of soil and kind of plant community is becoming more apparent as a result of joint field evaluations by soil scientists and range conservationists in connection with the National Cooperative Soil Survey.

Millions of acres of rangeland are now being mapped by this survey. In portions of the Plains states, sufficient adjoining counties have been mapped to provide contiguous soil maps for distances of several hundred miles. For example, detailed soils maps are available, with but few interruptions, from eastern Oklahoma to eastern New Mexico.

Within the next decade it is probable that most privately owned rangelands in the Southern Plains will be mapped by such surveys. Therefore, the contribution that these surveys make to rangeland resource inventories is of direct concern to rangeland users.

Relationship Between Soil Classification Categories and Native Grassland Plant Communities

Soil is the upper part of the earth’s mantle in which land plants grow. The lower limit of soil has not been clearly defined but it includes the material in which most of the plant roots grow.

The characteristics of the soil at any given point depend on the properties of the parent material from which it was formed, and the extent to which this material has been changed by nature. An extremely young soil has been altered very little. Most soils, however, have been appreciably altered by the environmental forces of nature.

The degree that parent material may be changed in the formation of a soil depends on (1) the resistance of the material to change, (2) climate, (3) vegetation and other biological activity, and (4) time. Relief or topography modifies the macro-