Relation of Certain Vegetative Characteristics of Stipa spartea to Survival from Defoliation

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Edited by

J. E. Potzger
The Butler University Botanical Studies journal was published by the Botany Department of Butler University, Indianapolis, Indiana, from 1929 to 1964. The scientific journal featured original papers primarily on plant ecology, taxonomy, and microbiology. The papers contain valuable historical studies, especially floristic surveys that document Indiana’s vegetation in past decades. Authors were Butler faculty, current and former master’s degree students and undergraduates, and other Indiana botanists. The journal was started by Stanley Cain, noted conservation biologist, and edited through most of its years of production by Ray C. Friesner, Butler’s first botanist and founder of the department in 1919. The journal was distributed to learned societies and libraries through exchange.

During the years of the journal’s publication, the Butler University Botany Department had an active program of research and student training. 201 bachelor’s degrees and 75 master’s degrees in Botany were conferred during this period. Thirty-five of these graduates went on to earn doctorates at other institutions.

The Botany Department attracted many notable faculty members and students. Distinguished faculty, in addition to Cain and Friesner, included John E. Potzger, a forest ecologist and palynologist, Willard Nelson Clute, co-founder of the American Fern Society, Marion T. Hall, former director of the Morton Arboretum, C. Mervin Palmer, Rex Webster, and John Pelton. Some of the former undergraduate and master’s students who made active contributions to the fields of botany and ecology include Dwight. W. Billings, Fay Kenoyer Daily, William A. Daily, Rexford Daudenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daubenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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RELATION OF CERTAIN VEGETATIVE CHARACTERISTICS OF *Stipa spartea* TO SURVIVAL FROM DEFOLIATION

By John F. Pelton, Butler University

INTRODUCTION

If it were possible to find readily observable morphological features by which survival of grasses subjected to overgrazing might be predicted it would doubtless be of considerable use in range management practice and research. Reliability of estimates of the condition of the range would thereby be appreciably increased, a much needed goal in the management of grasslands. This paper is a report on experiments designed to test the correlation between several readily measurable criteria of size and apparent vegetative vigor of individual bunches of porcupine grass, *Stipa spartea* Trin., and their survival from defoliation.

The experiment was planned to test the hypothesis that those individual bunches which are vegetatively moderately vigorous compared to the obviously less thrifty individuals, and at the same time are larger than a certain minimum size limit, would best tend to survive severe defoliation. In order to reduce the subjectivity involved in estimates of size and vegetative vigor these were measured quantitatively as described below. Size and vigor were based on characteristics which could be readily determined in most species of bunch grasses, namely basal area, shoot number, and shoot weight.

Porcupine grass is a medium to large sized bunch grass conveniently adapted to a study of this sort. Certain aspects of its ecology not here discussed have been described by Weaver and Fitzpatrick (6, 7), Weaver and Albertson (8, 9), R. J. Weaver (11), and Robertson (4).

1 It is a pleasure to express my indebtedness to Dr. and Mrs. Donald B. Lawrence of the University of Minnesota, Dr. W. E. Gorden of the Nashville School of Social Research, Dr. L. Ellison of the Intermountain Forest and Range Experiment Station, and especially to my wife, Jeanette S. Pelton, for invaluable assistance during the course of this investigation.
The experiment was performed on a relatively undisturbed site of prairie vegetation (locally known as Bunker Prairie) 17 miles north of Minneapolis, Minnesota, in Anoka County, and lasted from early spring of 1947 through the spring of 1948. Plots were established on the gently southwest facing windward slope of one of the numerous and now stabilized dune ridges characterizing the general locality, the physiographic history of which has been described by Cooper (2).

The soil on the experimental area is a uniform and deep fine sand, classified in the Hinckley series by Smith, et al (5). The plants near the lower part of the ridge were in a relatively moister situation, but nowhere was the soil on the experimental area sufficiently moist to support trees or large shrubs. *Stipa spartea* dominated the site but with a scattered admixture of *Koeleria cristata* (L.) Pers., *Calamovilfa longifolia* (Hook.) Scribn., *Poa pratensis* L., *Carex pensylvanica* Lam., *Andropogon scoparius* Michx. and *A. gerardi* Vitman, *Aster spp., Solidago spp*, and others.

Since the area was located in a state game refuge grazing by livestock had been prevented for some time, and deer were scarce. Fire had not passed over the area for at least several years. Some grasshopper injury, however, occurred during the course of the study, but since it occurred rather uniformly and not excessively over the entire experimental area the results of the experiment were probably not appreciably altered.

Eight rows of plots were located in an area about 80 feet long and 30 feet wide. Each plot was one meter wide and of variable length chosen to include exactly twenty *Stipa* bunches, one meter being left between successive plots in a given row. Each individual *Stipa* was marked with a numbered stake, a total of 760 bunches being included in the study. Genetic differences between individuals were probably at a minimum because of the small area and population involved and the relatively uniform habitat.

Size of the individual clumps of *Stipa* was measured by three methods: (1) Total number of live shoots, (2) Total dry weight of live shoots, (3) Basal area of the clump. These were determined by clipping all the overwintered dead foliage from the plants at a
height of one inch in very early spring before growth had started. The numbers of live shoots were determined by counting all shoots possessing any green tissue within the dead outer leaf sheaths of the preceding year. This procedure was possible owing to the live shoot bases of this species normally remaining green throughout the winter.

Dry weight was determined from the dead foliage thus collected from each plant and oven dried in individual numbered paper bags. That this previous year's foliage was highly correlated as a measure of relative size with the growth of the current season was shown by clipping twenty plants later in the spring and weighing this new leafage. The rank correlation coefficient between the dead and living foliage used in this way as relative measures of size was 0.97 in this test.

Basal area was obtained by tracing the outline of the bunch at ground level (as estimated at the clipping height of one inch) on a glass plate with a wax pencil. The form thus obtained was traced again onto a sheet of paper and its area later measured with a planimeter. Approximately 3% of the plants on the plots were doubtful as to individuality because of the gradual breaking up of an original clump into several, or the fusion of two adjacent clumps, and these were omitted from the study.

Three criteria of relative vegetative vigor of the bunches were utilized, all derived from the above types of measurements of plant size. These were: (1) Number of live shoots per square inch of basal area, (2) Dry weight of live shoots per square inch of basal area, (3) Average shoot weight for a given clump. The first criterion is based on the idea that the more vegetatively vigorous plants will have denser shoots and foliage, as measured at ground level. Sparse and scattered shoots would then suggest low vigor. The weight of foliage per unit of basal area also is a measure of its density as well as of other characteristics such as average shoot size. The third criterion, average shoot weight, is assumed by this theory to indicate that the bunches of greater vegetative vigor will have heavier than average shoots.

After the plants had been classified according to size and vigor as based upon the growth of the previous season, defoliation treatments by means of clipping were instituted. The experimental popu-
lation was divided into two groups of 380 plants each, alternating sets of twenty clumps being placed in a group. One group was clipped so frequently that by the following spring (May 2) 74.6% were dead. The other group, clipped less frequently, suffered a 19.8% mortality. All clipping was done at a height of one inch, and only the frequency and season were varied. The experiment was not designed to distinguish between the relative importance of frequency and season of defoliation in causing the mortality observed.

The frequently clipped group was cut six times between May 20 and June 30 at about weekly intervals. It was then seen that the mortality rate would be excessively high if clipping were not stopped. Consequently, the plants were not cut again until October 25 at the end of the growing season. The infrequently clipped group was allowed to grow until seed had matured, about July 13, before cutting. They were not again clipped until August 28, and finally on October 25.

Apparent time of death was recorded for each bunch individually. Complete loss of all green leaves and green leaf bases was the criterion for recording a clump as dead. No plant recorded as dead in the fall was observed to recover the following spring, although about 15% of additional clipped plants died during the winter. That these winter fatalities were at least indirectly due to clipping is shown by the observation that no unclipped plants died during either the summer or winter in the study area.

RESULTS

An analysis of the relation between the vegetative characteristics used and survival was made by the Chi-square technique of testing significance. The results are summarized in Table I. Large size, as measured either by total shoot weight or total number of shoots, favored survival to a statistically significant extent in only the less frequently clipped plants. The association between size and survival was weak or non-existent where size was measured by basal area, reaching a significance level of only 0.10. The association of size and percentage survival in the less severely cut group is readily seen in graphic form in figure 1. The general trend of better survival with increasing size appears to be fairly consistent.
Fig. 1. Survival as related to total weight and number of shoots under the less frequent clipping treatment. The classes are in the order of increasing magnitude.

Fig. 2. Survival as related to average shoot weight of both frequently and infrequently clipped plants. The classes are in the order of increasing magnitude.
Two of the measures of vegetative vigor, number of shoots per square inch and weight of shoots per square inch, had no measurable correlation with survival under either clipping treatment. Average shoot weight, on the other hand, seemed definitely associated with survival under both treatments. The results in this case, however, are conflicting. Among the frequently clipped plants those with heavy shoots tended to have a lower survival rate than clumps with lighter weight shoots, while the reverse relation seems to hold under the less frequent cutting treatment (Fig. 2).

In view of some of these conflicting results a further analysis of the interrelations of the various measures of size and vigor would seem desirable. The frequencies of the measure used are shown in figure 3. The three measures of size are all seen more or less to agree in the large number of small plants. Of the measures of vegetative vigor, both weight and number of shoots per unit of basal area appear to follow a frequency pattern which is similar to those of the measures of size. That is, plants which have a small number or weight of shoots per square inch of basal area predominate in numbers. Average shoot weight, however, more nearly approaches the normal curve in its distribution although there is still a larger proportion of plants with light-weight shoots than with heavy shoots. If each measure of size and of vegetative vigor is plotted against every other measure of size and vigor used in this study a total of fifteen possible combinations may be obtained. Three examples representing the general patterns that were obtained in this fashion are illustrated in figures 4, 5, and 6. In order to reduce the size of the charts the outer extreme one per cent of the cases is omitted, although these were included in calculating the regression line.

The trend represented by figure 4 approaches a straight line with a strongly positive slope. It was characteristic of all charts where one measure of size was plotted against any other measure of size, and also where weight per square inch and number of shoots per square inch were plotted against one another. It is apparent from the scatter in figure 4 that the degree of correlation is not high, although it is greater where weight and number, or area and number, are plotted. Field observations had previously suggested that close correlation between basal area and weight or number of shoots should not be expected, for it frequently occurred that clumps which pos-
Fig. 3. Frequencies of the characteristics used in estimating size and vegetative vigor. The classes are in the order of increasing magnitude.

Fig. 4. Scatter diagram of basal area and total shoot weight.

Fig. 5. Scatter diagram of total number of shoots and average shoot weight.

Fig. 6. Scatter diagram of basal area and weight of shoots per square inch.
sessed large basal areas often exhibited few and scattered shoots of small total weight. In fact, the decision to use the number or weight of stems per unit of basal area as measures of relative vegetative vigor was largely prompted by this observation.

Figure 5 illustrates the general trend and scattering which resulted whenever average shoot weight was included as one of the variables. In general the slope is positive but slight or even horizontal in several cases, and the scatter is considerable. The slope is greater, however, where average shoot weight is plotted against total shoot weight, suggesting even more than does figure 5 that as the size of the plant increases so does the average weight of the individual shoots. This relationship is almost non-existent, however, where size is measured by basal area.

A distinctive type of relationship is that represented by figure 6, one in which the trend is at least initially strongly negative and curvilinear, and in which the scatter is small. Such a curve resulted whenever either weight per square inch or number of shoots per square inch were plotted against any of the measures of size, with one exception (weight per square inch times total shoot weight) in which a linear and horizontal trend was obtained.

DISCUSSION

The inconsistencies apparent in the results described above raise some fundamental problems concerning the existence of other plant characteristics which might be more reliable in indicating resistance to defoliation than those here used. The results of this experiment suggest that if these exist they will in all likelihood not be conveniently observed or measured properties. Useful characteristics will most likely be such difficult to measure morphological features as the depth and spread of the root system or the root-shoot ratio, or physiological characteristics such as the amount of reserve foods in roots and shoot bases. The time-consuming though promising method of measuring vigor described by Weaver and Darland (10) uses several morphological measures, but there is no evidence that plants classified as vigorous by this method are actually able to withstand grazing better. The potentialities of chemical analysis in estimating survival ability is suggested in the work of Rather and Harrison (3) in which it was found that the food reserves of alfalfa
plants in a pasture subjected to grazing were a measure of their survival and recuperative vigor. Ability to reproduce satisfactorily over a period of time has been used as a criterion of vigor in a broad sense, as by Braun-Blanquet (1). In this usage reproduction by either vegetative means or by the production of seeds could be used as a measure of vigor.

The inconveniences of all these methods of estimating survival ability will, however, tend to prevent their routine use in range management practice. It is still quite probable that some easily measured morphological characteristics may be found to be usefully correlated with ability of the plant to survive overgrazing. If these occur, however, they may be expected to vary considerably with the species, with the habitat, and with the previous treatment to which the plants had been subjected, and hence would certainly have to be applied with caution.

It might be expected that excessive vegetative vigor might as well indicate susceptibility as resistance to defoliation, just as it often indicates susceptibility to cold injury. In the area of the present study, however, no plants of *Stipa spartea* seemed to fall into the category of unusual vegetative vigor owing to the infertile sandy soil of the locality. It would be most interesting to repeat the experiment in a region where a much greater range of vegetative vigor of *Stipa* is available.

Weaver and Albertson (8) observed that the first individuals of *Stipa spartea* to succumb to drought were the very young and the very old plants. Age was here undoubtedly estimated by size of the individual clumps. Age is, however, probably closely proportional to size only in an exceedingly uniform environment populated by one or only a few biotypes. In the present experiment the environmental conditions were probably varied enough so that size of the clumps was a very unreliable measure of age. If only plants of a given age were compared, a more consistent and dependable relation of size to survival would probably have been obtained. Unfortunately, age determinations of bunch grasses are generally impracticable under natural conditions after the first two or three years following germination.

Some of the inconsistencies in the relation of survival to those characteristics used in the present work are understandable in the
light of their relation to one another. Thus it is evident from figure 4 that a plant classified as large by basal area measurements might be considered small if weight were the criterion. Figure 6 shows that plants considered vegetatively vigorous by the criterion of weight of shoots per unit of basal area occur mainly in the smallest size classes. Yet if vegetative vigor is believed associated with high average weights of the individual shoots of a clump then the larger plants, as measured by number of shoots in figure 5, tend to be considered the more vigorous instead of the smaller ones. Thus average shoot weight appears to contradict both of the other two measures of vegetative vigor used in this study, weight or number of shoots per unit of basal area. These facts would seem to emphasize the need for clear and specific use of the terms size and vigor in referring to bunch grasses.

SUMMARY

The bunch grass *Stipa spartea* was utilized in an experiment designed to test the relation of size and vegetative vigor of individual naturally-grown plants to their survival from defoliation.

Three measures of clump size were used, basal area, number of shoots, and weight of shoots. Three criteria of vegetative vigor were obtained from these values, and expressed as number and weight of shoots per unit of basal area, and average shoot weight.

Two equivalent groups of plants were subjected to different intensities of defoliation: Frequent clipping which resulted in nearly 75% mortality, and less frequent removal of foliage causing less than 20% mortality.

The results of significance tests suggest that the larger plants tended to survive better than smaller bunches under the less severe treatment. No correlation of size and survival was obtained with more severe defoliation. The results with the measures of vigor indicate either no correlation at all, or an inconsistent one in the case of average shoot weight.

The necessity for clear and specific use of the terms size and vigor is emphasized by the lack of agreement present among several of the criteria commonly used in judging them. The potential value in estimating survival ability of some criteria not used in the present study is evaluated.
LITERATURE CITED


TABLE I

A summary of the relations of size and vegetative vigor to survival from defoliation. Those values marked with an asterisk (*) indicate statistically significant correlations at the 5% level of significance.

<table>
<thead>
<tr>
<th>Plant characteristic</th>
<th>Frequently cut plants</th>
<th>Infrequently cut plants</th>
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<tbody>
<tr>
<td>Total shoot weight</td>
<td>0.80</td>
<td>0.001*</td>
</tr>
<tr>
<td>Total number of shoots</td>
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<td>0.012*</td>
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<tr>
<td>Basal area</td>
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<td>0.10</td>
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<tr>
<td>Weight per square inch</td>
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<tr>
<td>Number shoots per square inch</td>
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<tr>
<td>Average shoot weight</td>
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<td>0.029*</td>
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