IOWA STATE JOURNAL OF RESEARCH
TABLE OF CONTENTS
Volume 51
(August, 1976-May, 1977)

No. 1, August, 1976

No. 2, November, 1976

Iowa State Humanities Symposium
MYTHS and MINDS: Games People Think

No. 3, February, 1977

No. 4, May, 1977

IOWA STATE JOURNAL OF RESEARCH / FEBRUARY, 1977
Vol. 51, No. 3 249-254

USE OF A MOISTURE-STRESS INDEX FOR EXAMINING CLIMATE TRENDS AND CORN YIELDS IN IOWA[1]

R. H. Shaw[2]

ABSTRACT. A weighted stress index was calculated for three stations, one in western, one in central, and one in eastern Iowa, for the years 1933-36 and for 1947. A comparison of these indexes with those calculated for 1954-75 shows that 1934, 1936, and 1947 were more severe drought years than 1974 and 1975. The year 1936 was the most severe drought year of those examined. Groups of stress years occurred about every 20 years, about the same length period as the 20-year sunspot cycle.

An examination of the yearly pattern of the stress index from 1954 to 1975, weighted by acres of corn grown in the counties where soil-moisture sites were located, shows the most severe index occurred in 1955-56. The index for 1974 and 1975 was considerably less. The comparison between the actual corn yield inthe counties where soil-moisture sites were located and the yield calculated from the stress index and adjusted for technology showed a good relationship. Yields in 1970 were lower than predicted. How much of this was due to the corn blight in that year could not be estimated. Yields in 1974 were predicted close to the actual yield when adjusted for effects of late planting and of the late summer and early fall freezes. The pattern of stress in 1975 showed no reduction due to stress by July 1, a 314 kg/ha reduction by August 1, and a 753 kg/ha reduction by September 1.

INTRODUCTION

Following the two extremely high corn-yield years in Iowa during 1972 and 1973, the seasons of 1974 and 1975 showed significant decreases in yield per acre. Severe moisture stress occurred in western Iowa in 1974, and late planting and late summer and early fall freezes further reduced the yield. Moisture stress was more general across the state in 1975, but it did not reach the severe local conditions of 1974. Questions have been raised as to how severe the droughts of 1974 and 1975 were compared with those that occurred in the mid-30's, and in 1947. Questions also have been raised as to whether our climate is changing, or whether the dry mid-70's only conform to a cyclic pattern predicted by sunspot activity (Thompson, 1973).

A moisture-stress index developed by Shaw (1974) will be used to compare the droughts of the mid-30's and 1947 with those of recent years and to show the yearly stress pattern since 1954. The index also will be used to show the monthly development of stress in 1975.

LITERATURE REVIEW

Shaw (1963) previously reported on a program to predict daily soil-moisture values under corn. Subsequently, Dale (1968) examined the climatology of soil-moisture stress and nonstress days in Iowa for corn. Corsi and Shaw (1971) examined several stress indexes to determine which one correlated best with corn yields. Shaw and Felch (1972) reported on the climatology of a moisture-stress index in Iowa and its relationship to corn yields. Shaw

---

[1] Journal Paper No. J-8529 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa 50011. Project No. 1989.
[2] Professor, Agricultural Climatology, Agronomy Department, Iowa State University, Ames, Iowa.

(1974) reported on a weighted moisture-stress index. In this index the degree of stress each day is determined by the reduction in actual evapotranspiration compared with the potential rate for the day. The index is determined for the 85-day period from 40 days before silking to 45 days after silking. Weighting factors are applied to each 5-day period according to the sensitivity of the plant to moisture stress during the period.

Shaw (1976) used this index to estimate the yield reduction due to stress in each county in 1974 where soil-moisture sites were located. The part of the reduction in yield in 1974 that was not explained by stress in each county also was determined. This reduction was believed due largely to the combination of late planting and of late summer and early fall freezes, but no attempt was made to separate the individual factors.

PROCEDURES AND RESULTS

Comparison of the index in the mid-30's, and 1947, with that since 1954

Comparison at three locations

The first, class-A evaporation pan to be located in Iowa was installed near Ames in 1932. This was the only evaporation pan in operation in Iowa until 1948. Evaporation-pan data are a necessary input to the soil-moisture and stress-index programs. Use of evaporation-pan data from Ames for western and eastern Iowa may underestimate the evaporation in western Iowa and overestimate it in eastern Iowa, but because they were the only data available, the Ames evaporation data were used for all three locations. Soil-moisture data were not systematically collected in Iowa until 1954. However, estimated spring soil-moisture data are available for the Monona, Story, and Johnson county areas for each year during the 1933-54 period.[3] Stress-index values for the 1954-75 period are available for west-central Iowa from the Western Iowa Experimental Farm in Monona County; for central Iowa, from experimental farms near Ames in Story County from 1954 to 1965 and from the Agronomy and Agricultural Engineering Research Center in Boone County from 1965 to 1975; and in eastern Iowa, from near Cedar Rapids in Linn County. Environmental Data Service rainfall data from Onawa, Ames, and Cedar Rapids were used to calculate the stress index for the years 1933-36, and also for 1947. Onawa data were used for that period because the Western Iowa Experimental Farm was not established until some years later.

The stress-index values calculated for the 1933-36 period were ranked relative to stress-index values that occurred from 1954 to 1975. The most severe 13 stress years of the 26 years tested are shown in Table 1 for each location. If the stress years are ranked by the most severe one-fourth and the most severe one-half of the stress years and if the values are randomly distributed (no cyclic pattern or trends), the numbers of these that should be expected to occur in a 4-year period, such as 1933-36, are one in the most severe one-fourth and two in the most severe one-half. For the 4-year period of 1933-36, these occurrences were as follows: in western Iowa 2 and 4; in central Iowa, 3 and 4; and in eastern Iowa, 2 and 4. The occurrence of stress years in the 4-year period was more frequent than would be expected by random chance. The next most severe stress period was the 1954-57 period when more stress years occurred than would be expected by chance. The 1970-75 period also had more stress years than expected in western and central Iowa. The spacing of these periods follows approximately the major 20-year sunspot cycle.

One severe drought year occurred in the 1940's, in 1947. This occurred near what is called the minor sunspot minimum. The stress-index value for 1947 was 39.7 for western Iowa, 43.3 for central Iowa, and 61.6 for eastern Iowa. In terms of the 1933-36 and 1954-75 periods, this year ranked 8th in drought intensity in western Iowa, 4th in central Iowa, and 1st in eastern Iowa.

Comparison at soil-moisture sites

Sampling sites have been located in from 11 to 37 counties scattered over the state since soil-moisture sampling commenced in 1954. The following procedure was used to compute

[3] R. F. Dale, 1967. Unpublished data, Iowa State University.

Table 1. Ranking and stress index values for the 13 most severe moisture stress years out of the 26 years 1933-36 and 1954-75.

Western Iowa			Central Iowa			Eastern Iowa		
Year	Rank	Index	Year	Rank	Index	Year	Rank	Index
1936	1	100*	1956	1	64.6	1936	1	52.3
1955	2	84.2	1936	2	63.6	1957	2	37.2
1970	3	69.5	1934	3	61.8	1934	3	33.4
1934	4	60.5	1933	4	32.4	1955	4	31.4
1956	5	41.5	1966	5	31.1	1975	5	26.6
1974	6	40.8	1975	6	31.1	1966	6	19.2
1975	7	40.2	1971	7	29.9	1958	7	17.0
1971	8	33.0	1955	8	29.1	1935	8	16.5
1933	9	30.5	1954	9	21.9	1933	9	15.6
1959	10	30.4	1935	10	21.6	1964	10	15.1
1968	11	30.4	1970	11	20.9	1965	11	13.6
1935	12	26.8	1965	12	20.4	1960	12	11.2
1967	13	24.6	1967	13	19.7	1963	13	10.0

* Indicates crop failure

an average, weighted-stress index for each year. The stress index for each site was multiplied by the county corn acreage obtained from reports of the Iowa Department of Agriculture, Annual Farm Census (annually). These values were summed over all sites and divided by the total acres of corn in the counties involved. The result is a weighted, stress-index per unit area of corn. These values are plotted in Figure 1 and should indicate the relative effect of the stress on the state corn yields. The values for 1933-36 also are plotted, on the assumption that each of the three stations used in Table 1 had equal weight. The year 1947 is not plotted. The weighted value for that year was 48.2. Again, the mid-30's stand out as severe-stress years, with 1936 the most severe-stress year of all. The overall statewide stress index in 1974 and 1975 was much less than in the severe-stress years of 1934 and 1936. The year 1947 was the third most severe-stress year. The years 1955 and 1956 were also more severe-stress years than 1974 and 1975. The mid-30's and mid-50's follow approximately the 20-year sunspot cycle, but the 1970s' conformance to this pattern is not clear. The year 1970 was a relatively high severe-stress year, in addition to being a severe corn blight year, and 1971 had an index comparable to 1975. The sunspot cycle would predict severest droughts in the mid-70's.

Comparison of estimated and actual county yields

An index per unit area has been calculated. A yield per unit area for the counties involved in moisture sampling was computed as follows. The average yield in bushels per acre for each county was multiplied by acres of corn harvested in the county. Both these values are available from reports of the Iowa Department of Agriculture, Annual Farm Census. These products were summed over the counties where moisture samples were taken, and the sum was divided by the total acres of corn harvested in the sampled counties, giving a yield per acre of corn. These values were then converted to kg/ha. A graph of the index per hectare compared with the yield per hectare showed a definite progression of yield with time due to increasing technology. To adjust for technology, a technology trend relationship developed by Thompson[4] was used. This trend is 0.79 bu/acre (49.5 kg/ha) for the period before 1961 and $2.77X - 0.06X^2$ bu/acre starting in 1961, where X = year, with 1961 = 1, 1962 = 2, . . . 1973 = 13. This trend was used through 1973, with all values converted to kg/ha. Because of changing prices of nitrogen fertilizer, availability of fertilizer, and expanding corn acreage, the nitrogen used per acre declined in 1974 and 1975. Use was 123 kg/ha in

[4] Private communication. 1976. L. M. Thompson, Iowa State University.

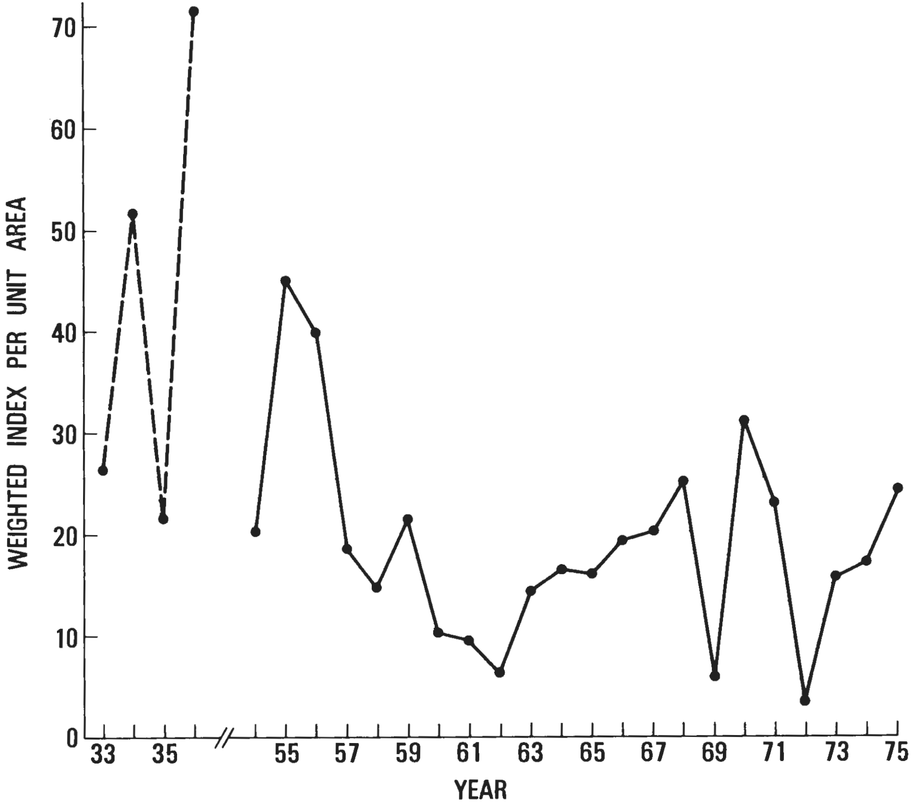


Figure 1. Weighted moisture-stress index per unit of land area in corn in counties where moisture sites were located from 1954 to 1975 and average value of three sites in 1933-36.

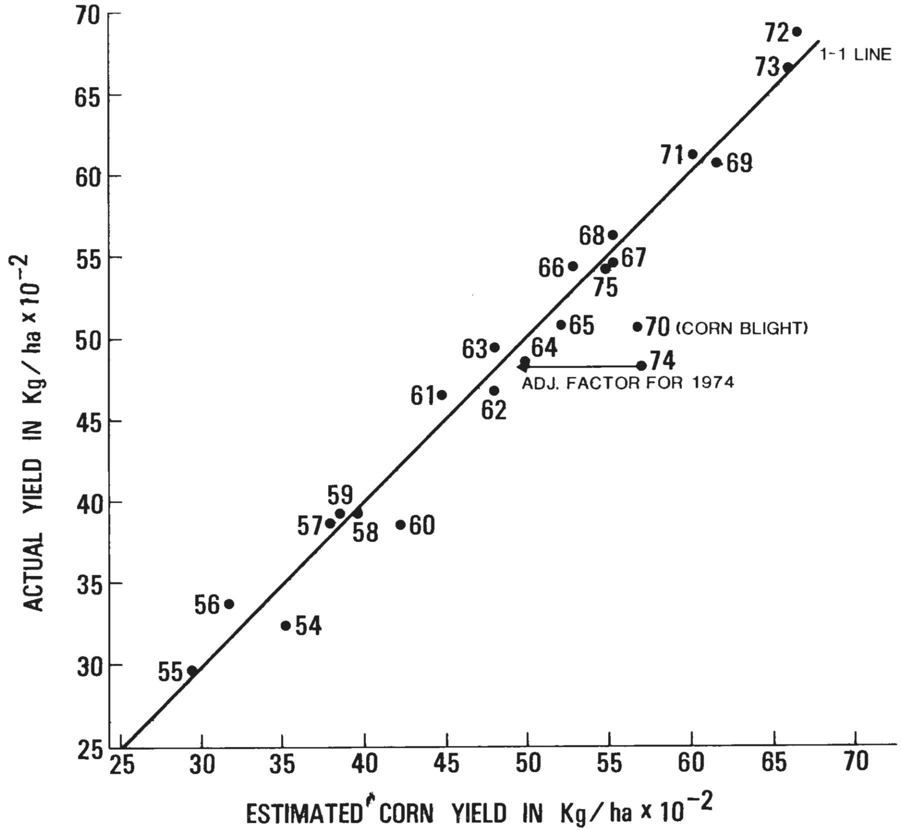


Figure 2. Comparison of estimated corn yields in counties where moisture sites were located with the actual corn yields harvested in those counties.

1972, 122 kg/ha in 1973, about 114 kg/ha in 1974,and less than 112 kg/ha in 1975. The nitrogen used in 1974 and 1975 was slightly less than the 116 kg/ha used in 1968. Inasmuch as other technology factors (variety, mechanization, etc.) would have increased since 1968 and would help compensate for the lower nitrogen levels used in 1974 and 1975 (compared with 1968), it was arbitrarily decided to use 1968 technology to represent the 1974 and 1975 levels of technology. The predicted yield was determined by using a regression analysis, where X_1 was the stress index, X_2 the technology factor, and Y the estimated yield. The multiple-regression equation calculated was

$$\hat{Y} = 63.36 - 0.42X_1 + 1.48X_2. \quad (1)$$

The yield estimated for each year from equation 1 and the Iowa Department of Agriculture yield in kg/ha for the sampled counties are compared in Figure 2. Most data points fall relatively close to the 1-1 line, but 1970 yields were predicted higher than actual. This should be expected because the effects of corn blight were not considered in the prediction model. The yield for 1974 also is overestimated. With use of the information provided by Shaw (1976), the estimated yield reduction in 1974 not explained by moisture stress was calculated as 771 kg/ha. It is believed that this reduction is attributable primarily to the combination of late planting and late summer and early fall freezes. The adjustment for the reduction is shown in Figure 2.

Seasonal development of stress

How much yield was lost from moisture stress at different periods during the 1975 season? An estimate of this can be obtained by accumulating the stress index for selected periods and then using equation 1 to estimate the yield. If the stress index is accumulated to the first of July, August, September, and October and a level of technology comparable to 1968 is assumed, the predicted yields on each date for the counties where moisture sites were located were:

July 1	6272 kg/ha	Sept. 1	5519 kg/ha
Aug. 1	5958 kg/ha	Oct. 1	5519 kg/ha

If no additional stress had occurred after August 1, the yield would have been 5958 kg/ha. Stress occurring in August reduced the yield to 5519 kg/ha. No stress occurred in September. An ideal yield prediction would have a range of estimated yields, to include average, better than average, and poorer than average weather in subsequent months, and might reduce the "ups" and "downs" that we now often see in yield estimates, because this range of weather conditions is not considered.

LITERATURE CITED

Dale, R. F. 1968. The climatology of soil moisture, evaporation, and nonmoisture stress days for corn in Iowa. Agricultural Meteorology 5: 111-118.

Corsi, W. C., and R. H. Shaw. 1971. Evaluation of stress indices for corn in Iowa. Iowa State Journal of Science 46: 79-85.

Shaw, R. H. 1963. Estimation of soil moisture under corn. Iowa Agricultural and Home Economics Experiment Station Research Bulletin 520.

Shaw, R. H. 1974. A weighted moisture-stress index for corn in Iowa. Iowa State Journal of Research 49: 101-114.

Shaw, R. H. 1976. Moisture stress effects on corn in Iowa in 1974. Iowa State Journal of Research 50: 335-343.

Shaw, R. H., and R. E. Felch. 1972. Climatology of a moisture-stress index for Iowa and its relationship to corn yields. Iowa State Journal of Science 46: 357-368.

Thompson, L. M. 1973. Cyclical weather patterns in the middle latitudes. Journal of Soil and Water Conservation 28: 87-89.

IOWA STATE JOURNAL OF RESEARCH / FEBRUARY, 1977
Vol. 51, No. 3 255-264

SPECTRAL ANALYSES OF PRECIPITATION DATA FOR IOWA AND KANSAS[1]

L. R. Alfred[2] and E. S. Takle[3]

ABSTRACT. Precipitation data from nine climatic regions for Iowa and nine climatic regions for Kansas have been subjected to spectral analysis. Results show evidence for a long-term (20-27 year) recurrence behavior in Kansas, which agrees with results from other investigations. Evidence, with even greater statistical significance, points to variations in precipitation having a period of approximately 3 years for Iowa and parts of Kansas.

INTRODUCTION

Scientists have long searched for trends and periodicities or recurring patterns in geophysical data series. Confirming the existence of such ordered behavior in climatic data would assist long-term forecasting and economic planning and improve our knowledge of atmospheric processes. Landsberg (1958) and Lamb (1972) have cited examples of studies in which many types of climatic data were used. Such parameters as lake levels, temperatures, precipitation, and winds have been studied. It is not surprising that evidence for cycles of many different periods have been found in these data. Because of data limitations, however, likely many of these cycles do not have physical bases but are attributable to statistical sampling errors.

It is noteworthy, however, that a few cycles are much more frequently observed, even over a wide range of climatic variables. Landsberg (1958) points out that periods near 2 1/3, 3 1/3, 5 to 6, 11 to 12, 19 to 24, and 30 to 35 years are found most often. Much longer periods appear with some regularity; but, because of the limited length of climatic data series in most instances, unambiguous identification of cycles with these longer periods is tenuous.

Several periodicities may be expected a priori in climatic data. Mitchell (1964) has stated that only four real oscillations occur in climatic data. The diurnal and annual variations are obvious responses to the regular 24-hr and yearly variations in solar radiation received at any one location. The semisynodic lunar cycle (with a period near 15 days) and the quasi-biennial cycle with a period near 2 years (Lindzen and Holton, 1968) also have physical bases. Periods of 20 to 22 years are attributed by some to sunspot periodicities, although no direct physical link has been demonstrated. Very few precipitation data sets are of sufficient length (10 or more periods) to test clearly this correlation.

This paper reports the results of a study of precipitation data for Iowa (Alfred, 1974) and Kansas. These states were selected because of the availability of relatively long (84-year) records of precipitation data. Spectral analyses were applied to the time series of monthly, areally averaged, precipitation amounts for climatic regions in each state. Iowa and Kansas each have nine climatic regions; thus, 18 separate time series were subjected to analysis.

---

[1] Journal Paper No. J-8482 of the Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Ames, Iowa 50011. Projects 1802 and 1852R.
[2] Meteorologist, Black and Veatch Consulting Engineers, Kansas City, Mo. 64114 (formerly graduate assistant, Departments of Agronomy and Earth Science, Iowa State University).
[3] Associate Professor of Climatology and Meteorology, Departments of Agronomy and Earth Science, Iowa State University, Ames, Iowa.

METHOD OF ANALYSIS

Initial data testing indicated that low-frequency periodicities were likely present and also that the distribution was skewed and could not be approximated by a normal distribution. The second result is not surprising for precipitation data. The raw data were transformed as suggested by Freeman and Tukey (1950) by defining

$$Y = (x)^{1/2} + (1 + x)^{1/2} \qquad (1)$$

where x is the total monthly precipitation. This transformation tends to normalize a skewed sample distribution.

Variance due to the annual cycle was removed by using a method similar to that of Landsberg et al. (1959). The expression is in the form

$$Z = Y - \bar{Y} + \bar{\bar{Y}} \qquad (2)$$

where Y is any monthly value, $\bar{Y}$ is the mean of Y in that particular month, and $\bar{\bar{Y}}$ is the overall mean of all months. Because $\bar{Y}$ was found time dependent over the total record, a 23-point running average of $\bar{Y}$ was used in equation (2).

Two methods for estimating variance spectra were used in this study: the Fourier transformation of the autocorrelation function (Blackman and Tukey, 1958) and direct estimation by application of the Fast Fourier Transform (FFT) to the initial time series (Welch, 1967). Both methods yielded very similar variance spectra from a test data series, although the spectrum from the Blackman and Tukey method was slightly smoother (Alfred, 1974).

The calculation of autocorrelation coefficients with the necessary time lags from a long time series can be very costly in terms of computation time. Therefore, a method that directly estimates spectra was used in the analysis of complete time series from each climatic region (84 x 12 = 1008 months per series). The data from each climatic region also were subdivided into 12 data series, one for each calendar month. The Blackman and Tukey method was used to analyze these shorter data sets (84 months per series).

The autocorrelation coefficients were defined as

$$\rho(\tau) = \frac{\frac{1}{N-\tau} \sum_{i=1}^{N-\tau} (x_{i-\tau} - \bar{x})(x_i - \bar{x})}{S_x^2}, \quad \tau = 0,1,\ldots,m \qquad (3)$$

where $\bar{x}$ and S_x^2 are the mean and variance of the time series, τ is the lag, and m is the maximum lag being considered.

The appropriate expression for the Fourier transform of the autocorrelation coefficients is

$$S(f_n) = \frac{2\delta}{m} \sum_{\tau=0}^{m} \rho(\tau) \cos \frac{\pi f_n \tau}{m} \qquad (4)$$

where

$$\delta = \begin{cases} 1/2 \text{ when } \tau = 0,m \\ 1 \text{ when } 0 < \tau < m \end{cases}$$

and $S(f_n)$ is a spectral estimate at frequency f_n. These estimates are smoothed by means of a Hanning window:

$$S'(f_0) = 0.50\,S(f_0) + 0.50\,S(f_1)$$
$$S'(f_n) = 0.25\,S(f_{n-1}) + 0.50\,S(f_n) + 0.25\,S(f_{n+1}) \quad (5)$$
$$S'(f_m) = 0.50\,S(f_{m-1}) + 0.50\,S(f_m).$$

The values $S'(f_n)$ are the final spectral estimates at the frequency f_n.

The direct-estimation method involves the subdivision of the time series of length N into overlapping subgroups, all of length L. Each group is modified by weighting terms defined as

$$W(j) = 1 - \left[\frac{j - \frac{L-1}{2}}{\frac{L+1}{2}}\right]^2, \quad j = 0,1,\ldots,L-1. \quad (6)$$

The result is nearly the same as one would produce by applying a Hanning smoother later to the spectral estimates.

The modified subgroups are then transformed by using the Fast Fourier Transform (FFT) to obtain the values $C_k(n)$ where $k = 1,2,\ldots K$. These are converted to spectral estimates simply by averaging the values from each subgroup across common frequencies by using

$$S(f_n) = \frac{1}{K}\sum_{k=1}^{K}\left[\frac{2L\,C_k^2(n)}{U}\right] \quad (7)$$

where

$$U = \frac{1}{L}\sum_{j=0}^{L-1} W^2(j).$$

The statistical significance of each spectral estimate can be determined through the use of the chi-square divided by degrees-of-freedom statistic and either a white noise or red noise spectrum as a null hypothesis.

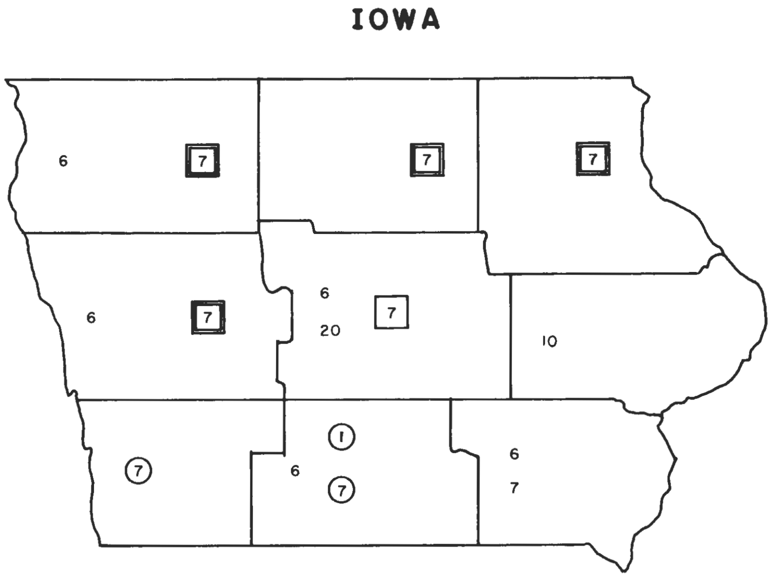
Details of the basic procedures used in this study, as well as the limitations of analyses of this type, have been presented elsewhere, including Blackman and Tukey (1958), Eddy et al. (1968), Panofsky and Brier (1958), and Welch (1967). More specific information on the application of these procedures is available in Alfred (1974).

RESULTS

Analysis of total data series

The data series consisting of 1008 monthly precipitation values for each region were subjected to spectral analysis by using the method of direct estimation with the aid of the FFT. The FFT subroutine used required that the number of data points being transformed be a power of 2. For this study the total data series was divided into six overlapping subgroups, each consisting of 256 points. The transform subroutine then gave 128 spectral estimates, the first corresponding to one cycle per 256 months, or a period of 21.3 years. The relationships between periods and harmonic numbers, together with the spectral estimates, are given in Figure 1 for Iowa. The harmonic numbers of the peaks of the spectra for each region are displayed, with the statistical significance level given in the legend. Because our present interest is primarily in longer periods, only harmonic numbers corresponding to periods of greater than 1 year are shown.

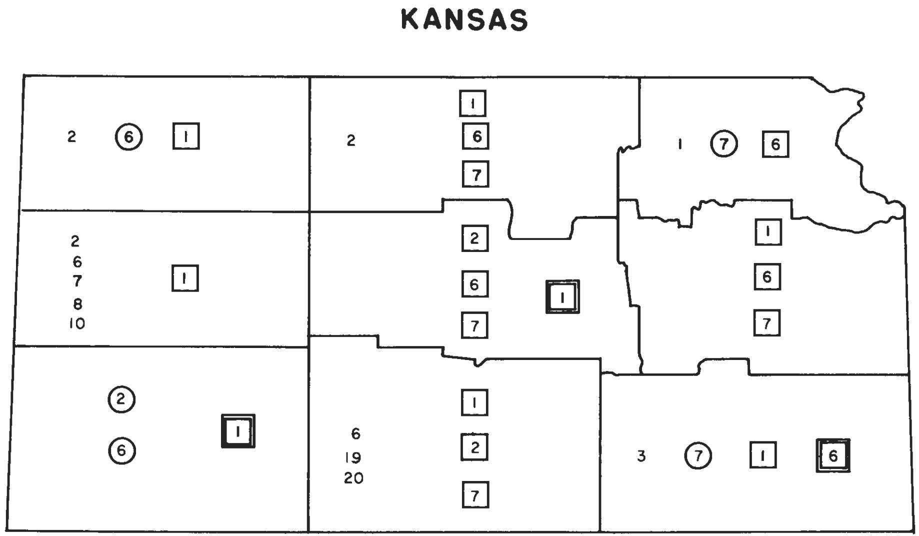
Comparing the results for Iowa with those for Kansas (Figure 2) reveals significant differences between the states and some general patterns across each state. Iowa shows considerable tendency, particularly in the north and west, toward a quasi-3-year recurrence (harmonics 6 and 7). The only harmonic less than 6 appearing anywhere in Iowa is harmonic 1,



HARMONIC No.	1	2	3	4	5	6	7	8	9	10	11	12	20
PEROID (yrs.)	21.3	10.7	7.1	5.3	4.3	3.6	3.0	2.7	2.4	2.1	1.9	1.8	1.1

SIGNIFICANCE LEVELS: 95 %: 7 97 %: (7) 99 %: [7] 99.9 %: [[7]]

Figure 1. Results of spectral analyses of time series consisting of 1008 consecutive monthly precipitation totals for each climatic region in Iowa.



HARMONIC No.	1	2	3	4	5	6	7	8	9	10	11	12	19	20
PERIOD (yrs.)	21.3	10.7	7.1	5.3	4.3	3.6	3.0	2.7	2.4	2.1	1.9	1.8	1.1	1.1

SIGNIFICANCE LEVELS: 95 %: 7 97 %: (7) 99 %: [7] 99.9 %: [[7]]

Figure 2. Results of spectral analyses of time series consisting of 1008 consecutive monthly precipitation totals for each climatic region in Kansas.

which appears only once and at the 97.5% level. This strongly suggests a lack of any periodicities greater than 4 years in Iowa precipitation.

Kansas, by comparison, shows considerable long-term variation in precipitation. The spectral power of harmonic 1 exceeds the 95% level in every region and exceeds the 99.9% level in the SW. The statistical significance of the peak increases from NE to SW in a fairly orderly pattern. Harmonic 2 also occurs in all but the eastern regions. Harmonic 3 appears only once, with 95% significance, and 4 and 5 are absent. In contrast to the Iowa data, the Kansas data give strong evidence for the existence of periodicities with periods greater than about 7 years. The enhanced spectral power assigned to harmonic 1 includes spectral power from a wide range of possible periods and does not necessarily imply the existence of a 21-year period. Marshall (1972) and Borchert (1971) have identified the 20-year drought cycle in the high plains states. The results of this study agree with (or at least do not contradict) the results of previous studies.

Harmonic 6 occurs in every region in Kansas with statistical significance decreasing from east to west. Harmonic 7 shows a similar statewide variation with slightly less amplitude than 6. The quasi-3-year variation that dominated the Iowa spectra also is quite evident in the Kansas data. Almost more remarkable than the strong evidence for harmonic 7 in Iowa and for 1, 2, 6, and 7 in Kansas is the nearly total absence of any other harmonics with periods greater than 1 year at the 95% level or above. The exceptions to this general statement do not show sufficient areal coverage to support the possible existence of real oscillations. Figures 1 and 2 give no indication of a biennial oscillation in either the Iowa or Kansas precipitation data.

Only harmonics corresponding to periods greater than 1 year were considered. The spectra did show peaks at harmonics higher than those listed in the figures. However, only two regions for each state gave high-frequency peaks exceeding the 99% level; neither of these was supported by the presence of similar peaks in adjacent regions. The one high harmonic that did show some consistency among regions was harmonic 122 for Iowa. This corresponds to 2.1 months and appears in six of the nine regions at the 97.5% level. This peak did not appear in the Kansas data. Harmonic 25 did appear in the Kansas data, but to considerably less extent than did harmonics 1, 2, 6, and 7.

Analysis of monthly data series

Agricultural production is more sensitive to precipitation during the growing season because, as occurred in 1974 in Iowa, localized drought can occur in a year with above-average precipitation if there is a deficiency during a critical time in the growing season. Thompson (1973) determined that the year-to-year variation in July and August temperatures (considered to be the growing season) taken over the Corn Belt states from 1900 to 1971 seemed to be nearly periodic, with a period close to that of the so-called double sunspot cycle (about 20 years). The average annual temperatures, however, do not show this tendency toward a 21-year variation (L. M. Thompson, private communication). This indicates to us that seasonal precipitation from year to year might relate to agricultural production better than the total precipitation record. To explore the seasonal differences, a time series was generated for each month and for each climatic region. The series for each month would then have 84 values, one for each year of the total record. The relationships between the periods and harmonic numbers for this study, together with the spectral results, are given in Figure 3 for Iowa and Figure 4 for Kansas. The spectra produced in this study have greater frequency resolution than the spectra described in analysis of total data series because the Blackman and Tukey method was used rather than the Welch method. This increased resolution allows for a more definitive analysis of low-frequency recurrences. The spectral results for each month shown in Figures 1 and 2 give the dominant harmonics for each region, with the legend of the figure indicating the statistical significance level. This form of representation allows us to observe both areal and seasonal nature of any possible cyclic precipitation behavior.

The dominant feature of Figure 3 is the 99% significance of harmonic 25 in November for every region, some of which exceeded even the 99.9% level. Harmonics 24 and 26 also appear in several regions in November, with 24 being significant at the 99% level in the SE and EC regions. November is a relatively dry month in Iowa, with precipitation over the state taveraging just over 2 in. in the SE to about 1 in. in the NW (Shaw and Waite, 1964). The concentration of spectral power around harmonic 25 also decreases from SE to NW. Harmonics 24, 25 and 26 occur in November in Kansas also (Fig. 4), with significance levels generally

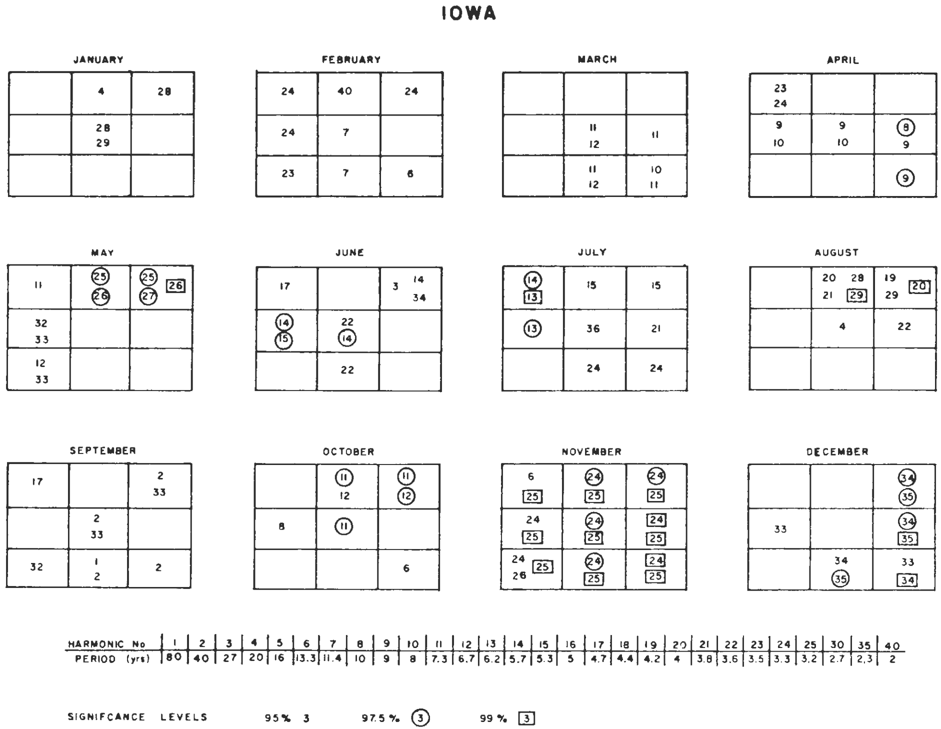
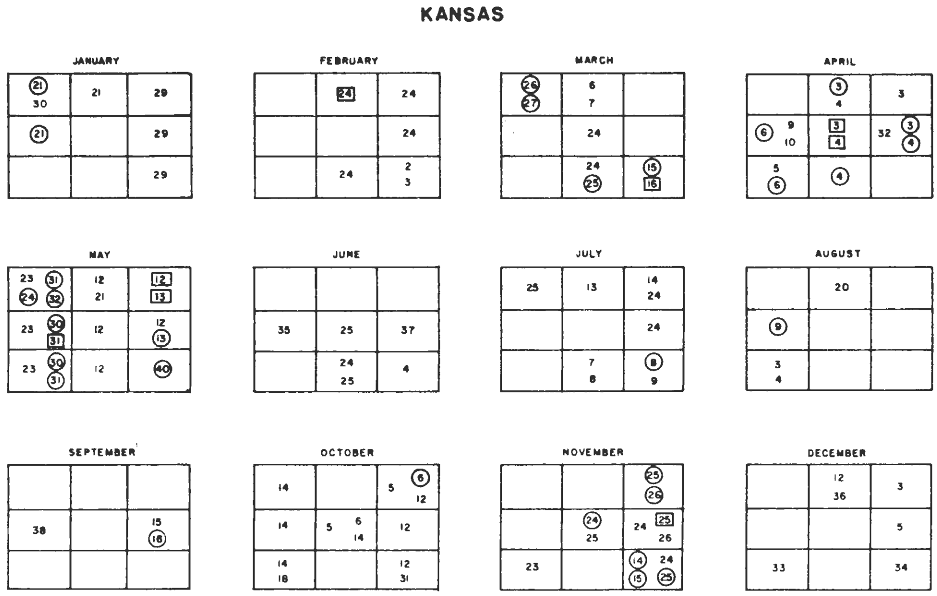


Figure 3. Results of spectral analyses of time series consisting of 84 precipitation totals for each month in each climatic region of Iowa.



HARMONIC No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30	35	40
PERIOD (yrs)	80	40	27	20	16	13.3	11.4	10	9	8	7.3	6.7	6.2	5.7	5.3	5	4.7	4.4	4.2	4	3.8	3.6	3.5	3.3	3.2	2.7	2.3	2

SIGNIFICANCE LEVELS 95% 3 97.5% (3) 99% [3]

Figure 4. Results of spectral analyses of time series consisting of 84 precipitation totals for each month in each climatic region in Kansas.

decreasing from E to W, the western three regions showing no November peaks above 97.5%. Therefore, the November 3-year spectral power correlates with mean precipitation in both states. The eastern part of Iowa also shows some evidence of a 2.2- to 2.4-year (harmonics 33, 34, and 35) recurrence in December. This behavior is not as strong as the November phenomenon and does not appear in Kansas.

Cyclic precipitation patterns in November and December would not likely have any significant influence on agricultural production. Of more interest is the possible presence of recurrences between April and August. Significant peaks appearing in more than one region in Iowa include harmonics 8 for April, 25 and 26 for May, 14 for June, 13 for July, and 20 and 29 for August. The nearly total absence of harmonics 3,4, and 5 suggests a lack of long-term cyclic summer precipitation behavior for Iowa.

The clustering of similar or adjacent harmonics in neighboring climatic regions also is noteworthy. For example, March displays a preponderance of spectral power in harmonics 10, 11, and 12 for the four regions in the SE, whereas October has harmonics 11 and 12 significant in the C, NE, and NC regions. This may be an expression of the lack of independence of the data sets from adjacent regions that experience common mesoscale precipitation events.

The Kansas results differ considerably from those from Iowa. Spectral power estimates at harmonics 3 and 4 in April are very strong, particularly in the central, north, and east. In May the pattern shifts to harmonics 12 and 13 in the east and to 23, 24, 30, 31, and 32 in the west. June, July, and August show only a scattering of spectral harmonics, none being significant at the 99% level. The only other significant harmonics include 24, 25, and 26 for November, as was mentioned, and a scattering of harmonics 15, 16, 25, 26, and 27 in March. A clustering of adjacent harmonics in adjacent regions also is evident in the Kansas data.

CONCLUSIONS

Spectral analyses of areally averaged precipitation data for two midwestern states give some indication of long-term ordered behavior. From the results of the analyses on the total data sets of 1008 menthly values for each region, harmonics 7 in Iowa and 1 in Kansas were the dominant features. These results are supportive evidence for the quasi-3-year variation in Iowa precipitation and the long-term (greater than about 15 years) variation in Kansas.

The results of the analyses of the series of 84 values for each month for each region indicate that periodicities in seasonal precipitation amounts also differ between the two states. All nine regions in Iowa and the eastern regions of Kansas showed very strong recurrences of period 3.2-3.3 years in November. The Kansas data show strong evidence of long period (20-27 years) recurrences of April precipitation in the NC, C, and EC regions, and shorter term (2.5-3.0 years) recurrences in May precipitation in the west.

It is noteworthy that some spectra had peaks consisting of more than one harmonic (e.g., April for the C region of Kansas, which has both 3 and 4). The statistical significance of such peaks is higher than for peaks resulting from isolated harmonics because the degrees of freedom on the contributing harmonics are summed, resulting in a lowering of the relative variance establishing each significance criterion. This consideration was not included in determination of statistical significance levels for any of the figures presented. Allowing for this significance enhancement gives further credence to the reality of those periods identified in the previous paragraph.

In summary, we wish to stress that no claim is made of a definitive identification of all periods contributing to the precipitation records for Kansas and Iowa. Rather, we can only say that, when subjected to spectral analyses, the time series of precipitation for these climatic regions show tendencies for the periods listed. A number of harmonics would likely exceed the given significance levels purely by chance. From the evidence presented here, however, it is difficult to discount the 20-27 year and 2.5-3.0 year recurrences in Kansas and the quasi-3-year recurrence in Iowa as being chance occurrences. The long-term cyclic pattern in Kansas agrees with results of other studies. The shorter-term variations, which stand out with more statistical significance, have not previously been reported for these regions of the Midwest, although they have appeared in spectral studies from other areas.

REFERENCES

Alfred, L. R. 1974. Spectral Analyses of Precipitation Data for Iowa. M.S. Thesis, Iowa State University, Ames. 78 p.

Blackman, R. B., and J. W. Tukey. 1958. The Measurement of Power Spectra from the Point of View of Communications Engineering. Dover Publications, Inc., New York.

Borchert, J. R. 1971. The dust bowl in the 1970s. Annals of the Association of American Geographers 61: 1-22.

Eddy, A., C. E. Duchon, and J. A. Alamazan. 1968. Variance Spectrum Analysis. Report 8, University of Texas, Austin.

Freeman, M. F., and J. W. Tukey. 1950. Transformations related to the angular and square root. Annals of Mathematical Statistics 21: 607-611.

Lamb, H. H. 1972. Climate: Present, Past and Future. Vol. 1. Methuen & Co., Ltd., London.

Landsberg, H. E. 1958. Physical Climatology. Gray Printing Co., Inc., DeBois, PA.

Landsberg, H. E., J. M. Mitchell, Jr., and H. I. Crutcher. 1959. Power spectrum analysis of climatological data from Woodstock College, Maryland. Monthly Weather Review 87: 283-298.

Lindzen, R. S., and J. R. Holton. 1968. A theory of the quasi-biennial oscillation. Journal of the Atmospheric Sciences 25: 1095-1107.

Marshall, J. R. 1972. Precipitation Patterns of the United States and Sunspots. Ph.D. Thesis, University of Kansas, Lawrence. 124 p.

Mitchell, J. M., Jr. 1964. A critical appraisal of periodicities in climate. Weather and Our Food Supply, Report 20. Center for Agricultural and Economic Development, Iowa State University, Ames.

Panofsky, H. A., and G. W. Brier. 1958. Some Applications of Statistics to Meteorology. Pennsylvania State University, University Park.

Shaw, R. H., and P. J. Waite. 1964. The Climate of Iowa. III. Monthly, Crop Season, and Annual Temperature and Precipitation Normals for Iowa. Iowa Agriculture and Home Economics Experiment Station Special Report 38. 31 p.

Thompson, L. M. 1973. Cyclical weather patterns of the middle latitudes. Journal of Soil and Water Conservation 28: 87-89.

Welch, P. D. 1967. The use of Fast Fourier Transform for the estimation of power spectra: A method based on time averaging over short, modified periodograms. IEEE Transactions on Audio and Electroacoustics. Au-15(2): 70-73.

IOWA STATE JOURNAL OF RESEARCH / FEBRUARY, 1977
Vol. 51, No. 3 265-270

DIFFERENCE IN GROWTH RESPONSE TO LIGHT INTENSITY BY *Populus x euramericana* CLONES[1]

F. E. Fasehun[2] and J. C. Gordon[3]

ABSTRACT. Controlled-environment experiments were conducted to determine the effect of three light intensities obtained by artificial shading (37%, 75%, and 100% of full light) on the growth, distribution of photosynthate, and root-system configuration of four *Populus* x *euramericana* clones. Individual plants were started from rooted tip cuttings, and nutrients and water were maintained near optimum for the 8-week period.

Total dry weights of all clones increased with increasing light intensity from 37% to 100%, but the clones differed significantly in their height growth and distribution of dry-weight responses to the different light intensities. Clone 5321 had the best growth under the lowest light intensity. Clones 5326 and 5328 grew best under 100% full light, whereas clone 5323 had consistently good growth under all light intensities. All clones showed a direct relationship between amounts of shoot and root growth, but differences occurred also in root system configuration among the clones.

INTRODUCTION

Intensive culture of *Populus* hybrids for the production of wood fiber may soon be a large-scale industrial reality. Although many persons have indicated the dangers of monoclonal cultures, little is known about the physiology of clonal mixtures. As a first step toward identifying culturally important differences in physiology among fast-growing *Populus* x *euramericana* clones, we have measured growth and dry-weight distribution responses to shade in four clones known to exhibit differences in growth in full sunlight. Although studies on several woody species have shown marked differences in growth and growth distribution in response to light intensity (e.g., Björkman and Holmgren, 1963; Bourdeau and Laverick, 1958; Gordon, 1969; Loach, 1967; Zelawski and Kinelska, 1967), little is known about differences within the genus *Populus*, all populations of which are generally thought to be "intolerant," light-demanding species. Understanding their growth response to shade will help in choosing clones that better tolerate some shading; such clones could be intermixed with less tolerant but more productive clones, thus decreasing genetic uniformity within the stand and perhaps ensuring better utilization of sunlight. Differences in photosynthate allocation to roots and in root system configuration probably will be particularly important in choosing clones for intermixture in the same stand.

The objective of this study was, therefore, to determine the effect of light intensity (shading) on the growth, distribution of photosynthate, and root-system configuration of four hybrid poplar clones chosen to exhibit genetically conditioned differences in growth rate in full sunlight. We present evidence that these clones respond quite differently to shading and probably would behave differently in mixed stands.

---

[1] Journal Paper No. J-8247 of the Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Ames, Iowa 50011. Project 2034.
[2] Formerly graduate student, Department of Forestry, Iowa State University. Present address: School of Agriculture, College of Science and Technology, P.M.B. 5080, Port Harcourt, Nigeria.
[3] Professor, Department of Forestry, Iowa State University, Ames, Iowa.

MATERIALS AND METHODS

On the basis of controlled-environment growth trials, four clones of similar genetic origin but differing in juvenile growth rate (Wray, 1974) were chosen for this study. The clones are *Populus deltoides* x *Populus nigra* hybrids designated *Populus* x *euramericana* by the International Poplar Commission. For convenience we will refer to them by their North Central Forest Experiment Station numbers: 5321, 5323, 5326, and 5328.

The experiment was set up in the greenhouse by using a randomized split-plot design, in which two replicates served as blocks. Within each block three light intensity levels (37%, 75%, and 100% of full light) were established by use of Seran[4] shade cloth. Three individuals of each clone were randomly assigned to each light intensity within a block.

Apical cuttings of the poplar clones were planted in plastic pots containing greenhouse mix (2:1 Jiffy Mix[4] and Perlite[4]) on March 1, 1973, and rooted under mist. After rooting (on March 29, 1973), potted plants of the same height and approximately the same number of leaves were chosen from each clone and randomly assigned to treatment within each block. Subsequently, for the duration of the experiment, moisture content of the pots was maintained near field capacity by watering as necessary, and a soluble 20:20:20 fertilizer was added to each pot twice weekly.

Light intensities at noon under each shade level were recorded four times a week by using a Lambda L1-185 photometer. Average light intensities for 37%, 75%, and 100% full light were, respectively, 375, 820, and 1,324 μ Einsteins m^{-2} sec^{-1} PAR. The range of temperatures in the greenhouse was from 22°C (at night) to 24°C (day), and the range of humidity was 66% (at night) to 63% (day).

Height was measured weekly and plants were harvested from each treatment combination at 2-week intervals throughout the experiment. The first harvest was on May 7, 1973; the third was on June 4, 1973. At each harvest three potted plants of each clone were carefully uprooted, substrate was cleaned from the roots, and the shoots and roots were carefully washed in water. The root system was then separated from the shoot and photographed. Each plant part was then dried in the oven at 70°C for 24 h, cooled in a desiccator and weighed. The growth data were analyzed according to the experimental design.

RESULTS

Height growth differed among clones at the various light intensities and harvests. With increasing light intensity and time spent under each light intensity, height of all clones increased (Table 1). Clone 5321 grew taller and had a greater total dry weight under 37% full light, but under 100% full light, was smaller than all other clones. Clone 5323 had consistently good height growth under all light intensities, especially at 75% and 100% full light, whereas clones 5326 and 5328 were appreciably shorter at 37% full light than were 5321 and 5323.

Clone 5323 was second to clone 5321 in total dry weight at the lowest light-intensity levels. Clone 5328 had the greatest dry-matter production of all clones grown at 100% full light, even though clones 5326 and 5328 both had a slow initial growth rate.

Shoot:root ratio differed among clones at all harvest times (Table 1), as did root-system size and configuration (Fig. 1). In general, clone 5321 had the best-developed root system (more lateral roots, heaviest roots) at the lowest light intensity, and the poorest-developed root system at the greatest light intensity.

With more time under each light intensity, the differences among the clones became more evident. Thus, at final harvest (i.e., 10 weeks after the application of light treatment) total dry weight (Tables 1 and 2), height (Tables 1 and 3), and shoot:root ratio (Tables 1 and 4) differed significantly among the clones.

DISCUSSION

Growth and distribution of photosynthate in young hybrid poplars were affected markedly by light intensity. This finding is similar to the results reported in literature for other species. For example, Phares (1971) grew red oak seedlings at 10%, 30%, and 100% full

[4] Use of trade names does not imply endorsement by Iowa State University.

Table 1. Height, total dry weight, and percentage of total dry weight in roots of *Populus* x *euramericana* clones grown under 37, 75, and 100% full sunlight. Harvest times were (1) 6, (2) 8, and (3) 10 weeks after application of light treatments. Each clonal value is the mean of 2 observations.

Percentage of full light	Harvest Time	Average Height 1	Average Height 2	Average Height 3	Average Total Dry Weight 1	Average Total Dry Weight 2	Average Total Dry Weight 3	Percentage Total Dry Weights in Roots 1	Percentage Total Dry Weights in Roots 2	Percentage Total Dry Weights in Roots 3
			(cm)			(g)			(%)	
	Clone									
37 (375[a])	5321	23.8	35.0	61.0	1.65	1.96	6.31	19	21	16
	5323	23.8	27.3	59.0	1.43	1.56	5.54	17	17	12
	5326	14.0	17.8	42.5	0.74	0.94	2.73	18	16	12
	5328	13.0	15.5	31.5	1.52	1.95	4.46	19	21	16
	means	18.7	23.9	48.5	1.33	1.60	4.76	18	18	14
75 (820[a])	5321	29.5	37.8	72.0	2.36	3.99	13.43	17	21	19
	5323	34.0	60.8	87.3	2.70	9.44	15.65	16	17	15
	5326	26.8	46.8	72.0	1.82	5.41	10.75	16	17	14
	5328	27.3	17.0	47.0	4.12	2.11	10.36	19	19	16
	means	29.4	40.6	69.5	2.75	5.23	12.54	17	18	16
100 (1325[a])	5321	28.0	34.0	77.3	2.69	5.26	15.56	22	23	18
	5323	41.0	49.0	96.5	4.27	6.63	26.12	22	20	18
	5326	31.5	42.8	89.8	2.57	5.47	22.22	16	19	15
	5328	26.3	19.8	77.3	3.98	2.09	31.68	23	17	19
	means	31.7	36.4	85.2	3.37	4.86	23.89	20	19	17

[a]Average light intensity μ Einsteins m^{-2} sec^{-1} PAR taken at noon four times weekly.

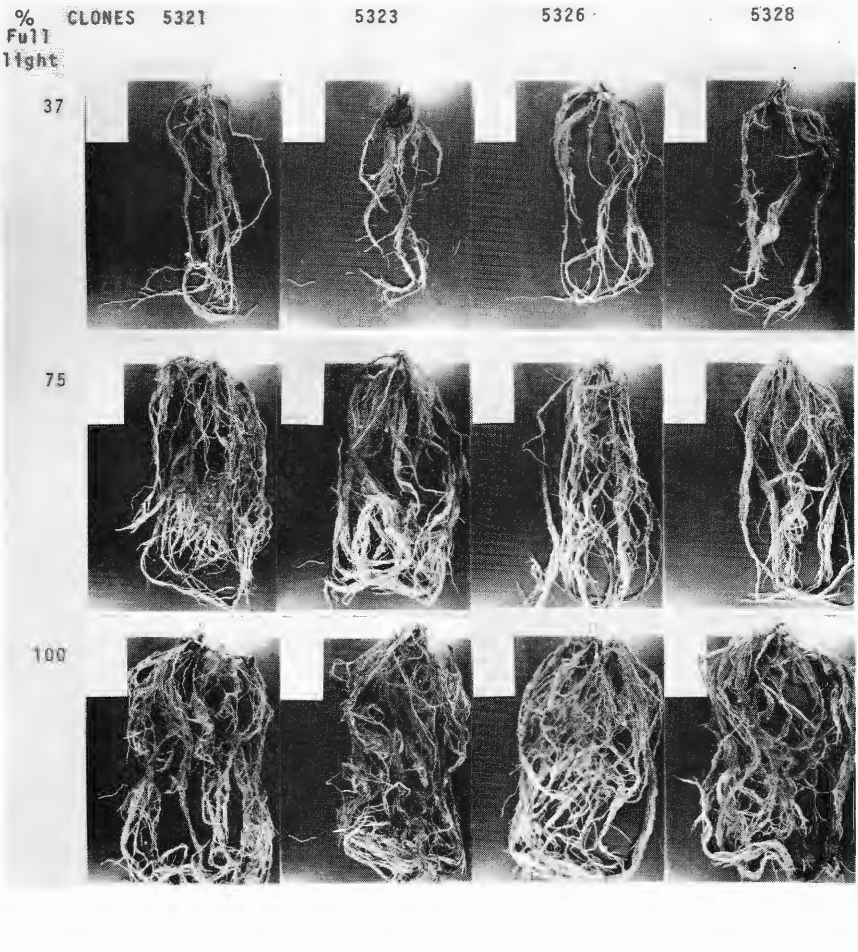


Figure 1. Roots of *Populus* x *euramericana* grown under different light intensities (375, 820, and 1325 μEinsteins m^{-2} sec^{-1}PAR)[a] 10 weeks after application of light treatments,

[a]Average light intensity taken at noon four times weekly.

light and found that dry weight increased with light intensity. This increase in growth with increased light intensity can be attributed to increased photosynthesis in the whole plant under full light. Although individual poplar leaves probably reach light saturation at about one-third of full sunlight, more leaf surface is exposed to saturating light at greater light intensities.

Table 2. Effect of light intensity and clone on total dry weight 10 weeks after application of light treatments.

Source of variation	d.f.	mean square	F-value	Prob > F
light intensity	2	749.21	615.08	0.0014
clone	3	30.91	3.65	0.0568
light intensity x clone	6	40.01	4.72	0.0194

Differences in growth among the clones at the same light intensity and developmental stage probably are due to differences among the clones in photosynthetic efficiency. Tonzig and Marre (1964) also reported differences among *Populus* x *euramericana* in photosynthetic activity, as did Gatherum et al. (1967) for naturally occurring, aspen-poplar, hybrid clones. Photosynthetic response to increasing light intensity may also account for differences among clones in patterns of dry-weight response to increasing light intensity. Probably, clones 5323 and 5321 have greater photosynthetic rates per-plant at low light intensities than do clones 5326 and 5328. This may be due to clonal differences in crown structure, leaf structure, leaf physiology, or to a combination of all three.

Table 3. Effect of light intensity and clone on height, 10 weeks after application of light treatments.

Source of variation	d.f.	mean square	F-value	Prob > F
light intensity	2	2711.65	46.47	0.0189
clone	3	697.88	3.29	0.0720
light intensity x clone	6	217.75	1.02	0.4676

The shaded seedlings had a lower percentage of their total dry weight in the roots than did those grown in full light. Similar results have been reported in experiments with other species (Loomis, 1953; Logan, 1965; Logan and Krotkov, 1969; Gordon, 1969).

The results of this experiment can be used as a guide for selection of clones to be used in the field. The differences among the clones in growth and distribution of photosynthate suggest that clone 5323 may have a metabolically superior genotype, capable of responding well to a wide range of light conditions; therefore, it would be especially useful in dense stands or in admixture with clones, such as 5328, that are superior at high light intensities. Clone 5321, on the other hand, does relatively well at low light intensities; it might also be useful in mixtures or as replacement stock in established stands. Field experiments to test effects of

Table 4. Effect of light intensity and clone on shoot/root ratios (dry weight basis), 10 weeks after application of light treatments.

Source of variation	d.f.	mean square	F-value	Prob > F
light intensity	2	5.34	79.60	0.0105
clone	3	4.27	13.05	0.0017
light intensity x clone	6	0.55	1.67	0.2333

root-zone competition or growth response of these clones will be necessary before definite planting recommendations can be made. Controlled-environment experiments, however, will allow the efficient design of such field trials, and will reduce the time and effort needed for them by indicating which clonal mixtures to test first.

LITERATURE CITED

Björkman, O., and P. Holmgren. 1963. Adaptation of photosynthetic apparatus to light intensity in ecotypes from exposed and shaded habitats. Physiologia Plantarum 16: 889-914.

Bourdeau, P. F., and M. L. Laverick. 1958. Tolerance and photosynthetic adaptability to light intensity in white pine, red pine, hemlock and ailanthus seedlings. Forest Science 4: 196-207.

Gatherum, G. E., J. C. Gordon, and B. F. S. Broerman. 1967. Effect of clone and light intensity on photosynthesis, respiration and growth of aspen-poplar hybrids. Silvae Genetica 16: 128-132.

Gordon, J. C. 1969. Effect of shade on photosynthesis and dry weight distribution in yellow birch *(Betula alleghaniensis* Britton*)* seedlings. Ecology 50: 924-927.

Loach, K. 1967. Shade tolerance in tree seedlings: leaf photosynthesis and respiration in plants raised under artificial shade. New Phytologist 66: 607-622.

Logan, K. T. 1965. Growth of tree seedlings as affected by light intensity. 1. White birch, yellow birch, sugar maple and silver maple. Canadian Department of Forestry Publication 1121. 15 p.

Logan, K. T., and G. Krotkov. 1969. Adaptations of photosynthetic mechanism of sugar maple *(Acer saccharum)* seedlings grown in various light intensities. Physiologia Plantarum 22: 104-116.

Loomis, W. E. 1953. Growth and differentiation: an introduction and summary. p. 1-17. *in* W. E. Loomis (ed.) Growth and differentiation in plants. Iowa State College Press, Ames, Iowa.

Phares, R. E. 1971. Growth of red oak (*Quercus rubra* L.) seedlings in relation to light and nutrients. Ecology 52: 669-672.

Tonzig, S., and E. Marre. 1964. Comparative studies on the photosynthetic efficiencies of poplar hybrids with investigation on limiting factors. First Annual Report, Institute of Plant Sciences, University of Milano, Italy.

Wray, P. H. 1974. Peroxidases and growth in hybrid poplar. Unpublished Ph.D. dissertation, Iowa State University Library, Ames, Iowa.

Zelawski, W., and J. Kinelska. 1967. Photosynthesis and respiration of Scotch pine (*Pinus silvestris* L.) seedlings of various provenance grown under different light conditions. Acta Societatis Botanicorum Polonial 36: 713-723.

IOWA STATE JOURNAL OF RESEARCH / FEBRUARY, 1977
Vol. 51, No. 3 271-278

SYRINGEAL HISTOLOGY. VI. Icteridae: Red-wing, *Agelaius phoeniceus*, and bobolink, *Dolichonyx oryzivorus*.[1]

Charles J. Ellis [2]

ABSTRACT. Histological details of two icterid species, *Agelaius phoeniceus* and *Dolichonyx oryzivorus* are reported. These features are compared with two other icterid species, *Sturnella magna* and *S. neglecta* (meadowlarks). The specimens for this study were recovered in a campaign to salvage carcasses of migrating birds killed in collision with a nearby television transmitting tower.

INTRODUCTION

This report is the second in this series (Ellis, 1973a, 1073b, 1976; Ellis and Thome, 1975a, 1975b) to concern icterids; the first described *Sturnella magna* and *S. neglecta.* Histology of syringes salvaged from birds killed in collision with a television transmitting tower is presented. Though only one specimen of each species was obtained, these descriptions are offered as part of a plan to salvage information from many birds killed in these collisions. New histological data are offered, for the syringeal histology of neither species has been described.

MATERIALS AND METHODS

Syringes from one male red-wing and one male bobolink were cut frontally at about 5 μm. Four to six sections were affixed to each microscope slide. Every other slide was stained with hematoxylin and eosin; remaining slides were stained with a trichrome modification of the Pantin method in which acid fuchsin, orange G, and aniline blue were used (Matson, 1975[3]). Slides were prepared by Matson, Milltown, Montana. Figures were drawn with the aid of a microprojector. No photographs of gross syringes were available.

Results

Though the time between the birds' deaths and freezing of the tissue is unknown, it likely is considerable. Therefore, cellular structure can not be reported with certainty, but histological details will be presented.

To simplify comparisons in this report, red-wing is abbreviated RW and bobolink BOL. The number of syringeal rings was determined by designating as ring #1 that from which the syringeal tube projected cranially as seen in midfrontal section. Five rings were observed in both birds.

Antepessular Region

Tracheosyringeal boundary. This border was marked by the junction of the syringeal tube and the caudalmost tracheal ring. This demarcation was not easy to see in sections. If detected, it coincided with the first discontinuity of the tube cranial to syringeal ring # 1.

Epithelium. Because of poor cytological detail, this layer was not described in either bird.

Lamina propria. This tissue was very thin. Details were not studied.

[1] This work was done at the Howard K. LaFlamme Memorial Research Laboratory, Department of Zoology, Iowa State University, Ames, Iowa 50011.
[2] Associate Professor, Department of Zoology, Iowa State University, Ames, Iowa.
[3] Personal Communication.

Rings. No rings existed in this area.

Syringeal tube. This tube extended cranially from syringeal ring #1 in midfrontal section. It was about 13 μm thick in both birds.

Outer layer. This layer consisted of striated muscle and its epimysial covering.

Antepessular - pessular boundary. Cilia were not seen in the epithelia of either bird. Consequently, the border between the two cranial syringeal regions was not determined histologically. However, for this report, this boundary was assumed to lie at the junction of the syringeal tube and syringeal ring #1, as viewed in midfrontal syringeal section.

Pessular Region

Pessulus. The dominant feature of this region was the dorsoventrally aligned, bony pessulus. In midfrontal syringeal section this structure included five parts in BOL, two cartilaginous and three bony; in RW it had only one part with no cartilaginous wings. It was triangular in cross-section and small in RW but ovoid in similar sections of BOL. At its dorsal and ventral terminations, the pessulus melded with syringeal rings #1 and the syringeal tube (Figs. 1, 2). Between these terminations and its midregion, the pessulus was V-shaped, with the open portion facing caudally in both species. At other levels, cartilage was included in the V-shaped, BOL pessular wings.

Epithelium. The condition of this tissue layer in these birds was similar to that in the antepessular region, hence it was not described. However, pessular epithelium was a continuation of antepessular epithelium because the pessulus melded with the laterally situated syringeal rings at certain levels (Figs. 1, 2).

Lamina propria. This tissue associated with the pessulus was thicker than that underlying the syringeal tube. Such a condition would have been abnormal. On the lateral walls of the syringeal complex this tissue was very thin and seemingly nonexistent on its medial walls.

Medial tympanic membranes. These membranes were trilaminar. The three layers—intercrural epithelium, crural epithelium, and intermediate connective tissue—were discernible but details could not be perceived. These membranes were quite long (in syringeal frontal section) and extended caudally between the dorsal and ventralmost portions of the pessular region. In fact, they extended below the ventral bony termination of the pessulus in BOL.

Lateral tympanic membranes. These membranes were not present.

Medial syringeal valves. These structures extended between the pessular base and the cranial end of the medial tympanic membranes. Compared to tympanic membranes they were thicker and composed of loose connective tissue, with a denser portion in the core of each valve (Fig. 1). The luminal epithelia of these valves were intact and slightly keratinized. The cells were squamous.

Lateral syringeal valves. These thick valves, lying mostly between the third and fourth syringeal rings, were of the same composition as the medial syringeal valves, although the latter included two areas, dense and loose, which the former did not display. The luminal epithelia of these valves were intact and but slightly keratinized.

Rings. The rings in this pessular region were bone with no signs of cartilage in syringeal midfrontal sections. At their ventral terminations in BOL and RW rings were surrounded by striated muscle (Fig. 3). The bone marrow in BOL only lacked myeloid elements. The marrow cavities included only networks of fine strands of tissue in BOL. The fourth ring in RW did not extend ventrally as far as the other syringeal rings in frontal section.

Fifth rings. At most levels the fifth syringeal rings were indistinguishable morphologically from crural rings. However, they occupied positions immediately caudal to the fourth syringeal rings with their lateral syringeal valves. At ventral levels the fifth rings assumed a shape different from that of crural rings (Fig. 2); hence they were recognizable. They had medial portions in both birds, but only at certain levels. These fifth rings were elongated in midfrontal section with their long axes at an angle to the airway. They did include a medial bony-cartilaginous portion, which was not as persistent in all tissue sections as similar portions of crural rings.

Interannular space. This space between rings 3 and 4 in frontal section was wide compared to all other interannular spaces. Furthermore, this space was filled with dense connective tissue upon which intrinsic, striated muscle inserted (Fig. 2). Adluminally, in some sections, part of the lateral syringeal valve was situated in this space.

In some frontal sections crural interannular spaces displayed areas void of tissue. These areas were outlined with what appeared to be epithelia or where epithelia might have been. Therefore, these voids resulted from evaginations of crural walls between crural rings being cut (Fig. 4).

In both species these spaces were filled with loose and dense connective tissue. The latter was indented from the outer layer towards the crural lumina. These indentations were not noticeable at all levels, but, when they existed, the outer syringeal layer followed the conformation of the connective-tissue indentations.

Intercrural diverticulum. This extensive structure included subdiverticula extending cranially and caudally from the main one. Though cytological details were damaged, the lining of the lumen of this diverticulum resembled that of birds reported earlier.

Part of the wall forming this structure in RW and BOL was occupied by intrinsic, striated musculature; part by the bronchidesmus/esophagus in BOL. In the latter structure subdiverticula were formed by the intrusion of the esophagus and bronchidesmus in syringeal frontal section (Fig. 2).

Intercrural bridge. This structure connected the medial walls of the syringeal crura in many, but not all, frontal sections. It formed part of the caudal aspect of the intercrural diverticulum.

Bronchidesmus. This structure was a thick, collagenous tissue sheath between syrinx and esophagus. It formed part of the caudal wall of the intercrural diverticulum.

Outer layer. Part of the syringeal complex was covered by striated musculature and associated epimysium. However, syringeal ring 5 was not so covered; instead, a simple squamous outer layer was present.

Pessular-postpessular boundary. Although this border was not marked clearly, it seemed to lie in midfrontal section at the caudal end of the medial tympanic membranes and to coincide with the position of the intercrural bridge.

Postpessular Region

Epithelium. This tissue could not be described for reasons already cited.

Lamina propria. Descriptions of this tissue would be inaccurate because of abnormalities.

Crural rings, medial. Grossly, crural rings were C-shaped with the open portions facing medially. The open parts were filled with craniocaudally oriented membranous connective tissue lying in a parasagittal plane. These membranous structures were contiguous with the medial tympanic membranes in the pessular region. Cross-sections of these cartilaginous rings were not seen in syringeal midfrontal section.

Crural rings, lateral. These C-shaped rings were bony on the lateral aspects and cartilaginous dorsoventromedially. Their cross sections reflected this composition.

Syringeopulmonary boundary. Though not seen in this study because of lack of tissue, the boundary was presumed to lie in intact birds at the sites where syringeal crura joined the lungs.

DISCUSSION

Many cellular details were not detectable in this study; nevertheless, new material was examined and reported. The RW pessulus was relatively small, perhaps the smallest of any described in this series. In many sections of this study the pessulus in both birds formed an isosceles triangle except at the dorsal termination where it became V-shaped, with its wings serving as sites of origin for intrinsic striated muscle. These wings in RW and BOL were bone, not cartilage.

The significance of the five-part termination of the pessulus in BOL is that this bird's pessulus was flatter than that of RW. A gross study of this pessulus should be made to confirm this conclusion as well as to note its detailed configuration.

The intercrural diverticulum extended farther vertically (in syringeal frontal section) in RW than any other so far reported in this series. More important, perhaps, is that this diverticulum extended far dorsoventrally, possibly because the medial tympanic membranes were present farther caudally than in other birds.

In previously offered descriptions concerning the epithelium of the antepessular region and the pessular epithelium (Ellis, 1973a, 1973b; Ellis and Thome 1975a, 1975b), similarity between the two epithelia was reported. Reason for this similarity was seen in the present study. The antepessular epithelium was continuous with that on the sides of the pessulus (Figs. 1,2). The lateral syringeal valves in RW were thick and particularly obvious.

Similarity between histology of BOL and meadowlarks *(Sturnella magna, S. neglecta)* (Ellis, 1973b) was noted. *S. neglecta* had a five-part pessulus as well as one that was ovoid at certain frontal levels. In addition, all icterids so far described possessed a syringeal tube extending cranially from syringeal ring 1.

Like meadowlark, BOL has a thick section of tissue in the interannular space between syringeal rings 3 and 4. The fifth syringeal ring of BOL resembled that of meadowlark. The latter was figured but not described or labelled. (Ellis, 1973b, Fig. 5, upper portion).

The icterid species described in this series of syringeal histology had typical passerine anatomy. All lacked lateral tympanic membranes, but they had medial tympanic membranes contiguous with and cranial to medial syringeal valves.

The presence in these two species, as well as other birds, of the dense connective tissue indentations in the interannular spaces provides evidence for potential expansion, lengthwise, of this portion of the airway. Such extension would follow the contraction of intrinsic muscles and would affect any sound produced by the bird.

The lack of myeloid elements in the marrow cavities of BOL is not a species difference and is not offered here as such.

Reference to keratinization of epithelia refers to visual observations and not to histochemical tests.

ACKNOWLEDGEMENTS

Personnel of the Fisheries and Wildlife Biology section of the Department of Animal Ecology furnished bird specimens for this study. Drs. Wing and Best were particularly helpful in their advice and service. Mr. Darwin Mossman of Ankeny delivered dead birds to the laboratory. The Iowa Academy of Science generously provided funds for the production of the microscope slides.

LITERATURE CITED

Ellis, C. J. 1973a. Syringeal histology. I. Japanese quail, *Coturnix coturnix japonica.* Iowa State Journal of Research 48: 7-47.

Ellis, C. J. 1973b. Syringeal histology. II. Meadowlark *(Sturnella magna, S. neglecta)* Iowa State Journal of Research 48: 175-191.

Ellis, C. J., and Peter Thome. 1975a. Syringeal histology III. House-wren, *Troglodytes aedon.* Iowa State Journal of Research 50: 1-16.

Ellis, C. J., and Peter Thome. 1975b. Syringeal histology. IV. Parulidae: Oven-bird, *Seiurus aurocapillus,* and mourning warbler, *Oporornis philadelphia.* Iowa State Journal of Research, 50: 153-172.

Ellis, C. J. 1976. Syringeal histology. V. Thraupidae: yellow-rumped tanager, *Ramphocelus icteronotus,* and scarlet tanager, *Piranga olivacea.* Iowa State Journal of Research 50: 357-362.

Fig. 1

Figure 1. Frontal section (left side of figure more dorsal) of red-wing syrinx near ventral level.

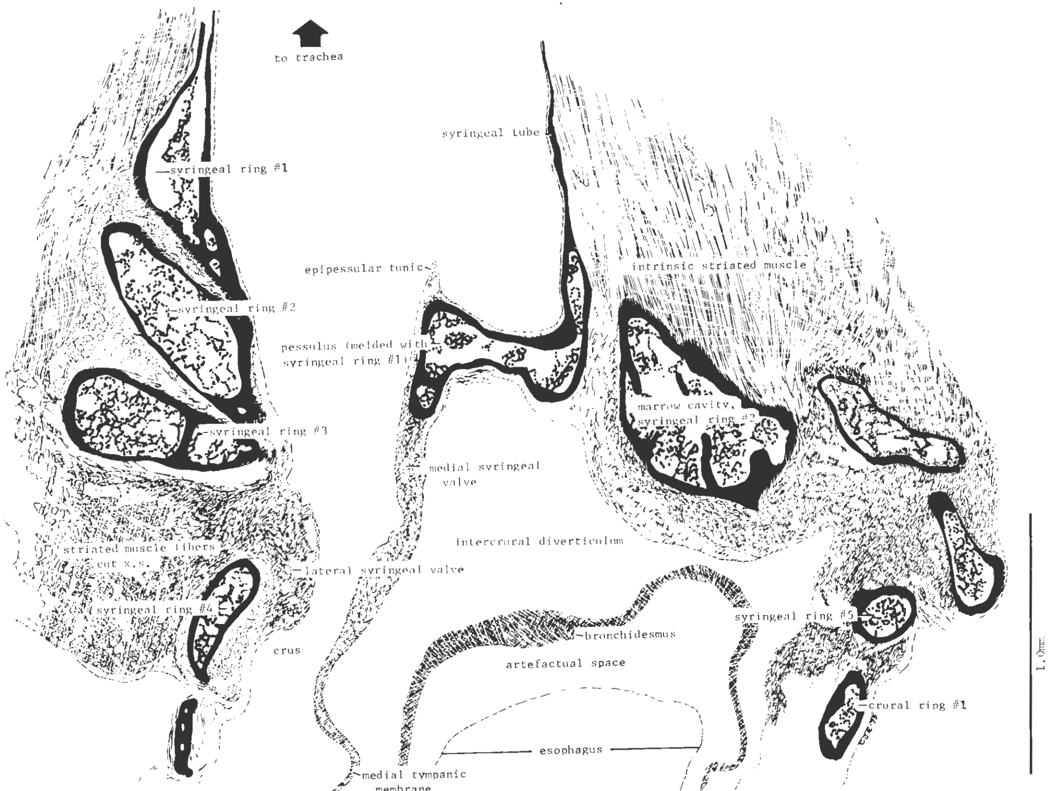


Fig. 2

Figure 2. Frontal section (right side of figure more ventral).

Figure 3. Frontal section through ventral muscle mass of bobolink syrinx.

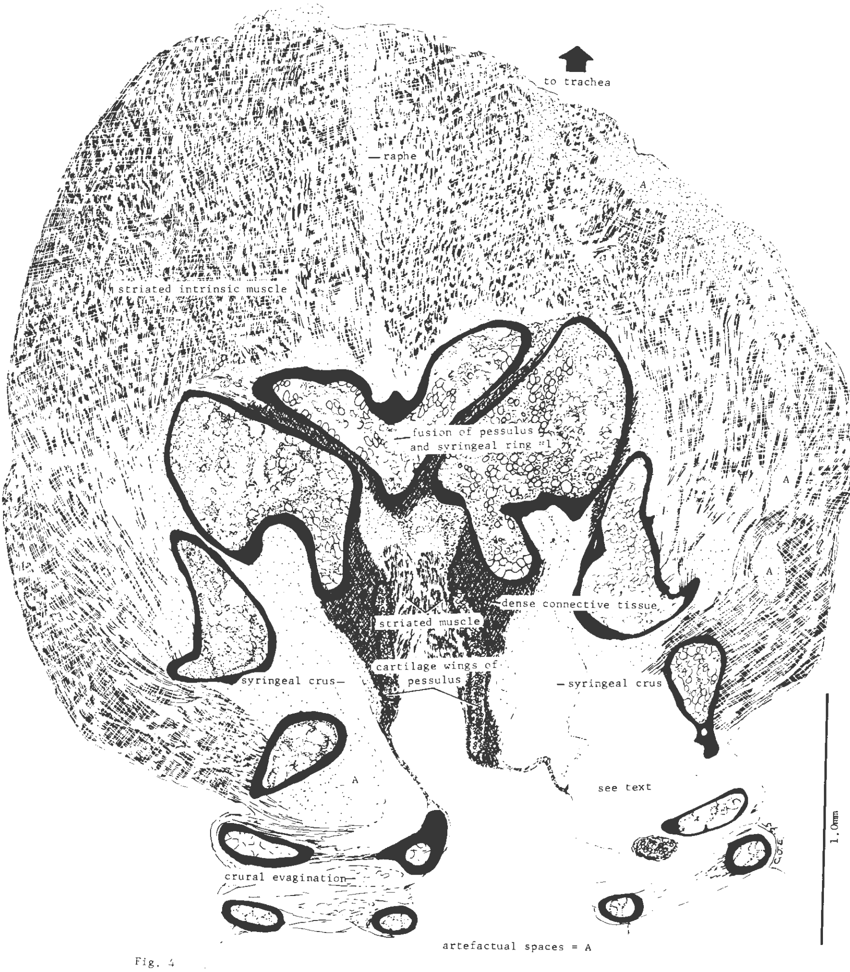


Figure 4. Similar to Figure 3 only cut more dorsally.

IOWA STATE JOURNAL OF RESEARCH / FEBRUARY, 1977
Vol. 51, No. 3 279-285

Helicotylenchus pseudorobustus AS A PATHOGEN ON CORN, AND ITS DENSITIES ON CORN AND SOYBEAN [1]

Don C. Norton [2]

ABSTRACT. No high degree of resistance to *Helicotylenchus pseudorobustus* was found among 10 corn and 18 soybean cultivars. The nematode was a mild pathogen on corn in greenhouse tests. The increase in population on corn followed the J-shaped curve, reaching 213,000 nematodes/1,500 cc of soil in 12 months.

* * *

INTRODUCTION

Helicotylenchus pseudorobustus (Steiner) Golden probably is indigenous to midwestern U.S.A., being found in native prairies of Kansas (Orr and Dickerson, 1966) and Iowa (Schmitt and Norton, 1972). The nematode is a frequent and abundant associate of field crops in the Midwest (Castaner, 1966; Ferris and Bernard, 1971; Norton et al., 1971). Densities vary between and within fields, and edaphic factors have been correlated with abundance (Ferris and Bernard, 1971; Norton et al., 1971). Taylor (1960) found that 94 of 127 cultivars were hosts, with alfalfa and flax being the two major field crops in the Midwest listed as nonhosts. Occurrence of the nematode with other parasitic nematode species makes evaluation of its importance difficult, evaluation that cannot be gained by autecological studies alone. Such investigations, however, provide baseline data for eventual determination of the importance of *H. pseudorobustus* in the agroecosystem.

MATERIALS AND METHODS

All nematodes used in greenhouse tests were reared on Pioneer 216 x 238 corn grown in sterilized soil. Fifteen-cm clay pots were used in all greenhouse tests. At nematode extraction time, water was withheld from the pots for one day to facilitate removal of the roots from the soil. The soil from each test pot was then thoroughly mixed by rolling and a 100-cc aliquot was removed for nematode extraction by the centrifugal-flotation method (Jenkins, 1964). All tests in the greenhouse were conducted between April 1973 and July 1975.

Susceptiblities of corn and soybeans

Soybeans are often rotated with corn, and it is necessary to know the susceptibilities of both plants to any parasitic nematode. Ten corn and 18 soybean cultivars representing wide genetic spectrums were tested for susceptibility to *H. pseudorobustus*. The soil used was a steam-sterilized greenhouse mix consisting of 89 3% coarse sand, 5.6% silt, and 5.1% clay. Inoculum for corn consisted of 95±8 nematodes pipetted into each of three holes 2-cm deep

---

[1] Journal Paper No. J-8480 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa 50011. Project 2119.
[2] Professor, Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa.
Appreciation is expressed to Dean Foley and Hideo Tachibana for supplying corn and soybean seeds, respectively.

in 15-cm pots, each pot holding 1,500 cc of soil. Inoculum for soybeans consisted of 88±11 for each of three similar holes/pot. One seed was planted per hole and there were three pots per cultivar. The pots were kept in the greenhouse under a 15-hr day. Tests were terminated in 84-90 days. All cultivars that supported fewer nematodes than the mean in the first test were tested a second time.

Pathogenicity on corn—first test

A steam-sterilized sandy soil obtained from the field and consisting of 90.7% fine sand, 6.9% silt, and 2.4% clay was used. There were three replications of three 15-cm pots, each with three holes 2-cm deep in which one seed of Pioneer 216 x 238 corn and 555±28 nematodes were placed in each hole. Controls were treated similarly, but no nematodes were added. Tops were removed and reseedings made without disturbance of the roots or nematodes at the end of 3 and 6 months. The experiment was terminated at 9 months when root and top dry weights and nematode counts were taken. Plants were fertilized with 6-10-4 N-P-K once every 3 months.

Pathogenicity on corn—second test

Steam-sterilized soil from the same mix as used in the susceptibility trials was used. Fifty±5 nematodes were pipetted into a hole 2-cm deep in the center of each of 36 15-cm pots. One seed of Pioneer 216 x 238 corn was planted in each hole. An equal number of pots without nematodes were used as controls. Three pots were removed each month for top and root weights and nematode counts. Plants for which readings were not made during the first 3 months were discarded and the soil was repotted and reseeded. This process was repeated for three additional 3-mo periods. Plants were fertilized with 6-10-4 N-P-K early in each 3-mo growth period. Soil temperatures were calculated every 2 hours from a continuous recording thermograph with the cable placed in a box containing a similar thickness of soil as was contained in the pots. The soil was planted to corn and placed on the greenhouse bench in the middle of the test pots.

To obtain insight into the magnitude of environmental resistance against population increase, specific growth rates ($\frac{\Delta N}{N \Delta t}$ where N equals the number of nematodes and t equals the time span) were calculated from control plots (no chemical added) in nematicide field tests (unpublished) and compared with growth rates in the greenhouse.

RESULTS

Susceptibilities of corn and soybeans

The figures for the greater mean recovery of *H. pseudorobustus* in two tests each around corn and soybeans are presented in Table 1. Significant differences in susceptibility among cultivars occurred although none were considered as highly resistant.

Pathogenicity on corn—first test

There were no significant differences between treatments in top weights after 3 mo, but inoculated plants had significantly (P = 0.05) less top weight at 6 mo compared to noninfested plants. At the end of 9 mo there were no significant differences in root weights, but top weights of infested plants were significantly (P = 0.01) less than those of noninfested plants (Fig. 1).

Pathogenicity on corn—second test

Mean densities of *H. pseudorobustus* and root and top weights of plants are provided in Table 2. The population growth curve of the nematode in the greenhouse is presented in Figure 2. Significant (P = 0.05) differences in dry weights usually occurred only at the third month of each growth period, possibly because of disturbance after each period and pot binding of roots at the end of each period. The nematode population growth pattern is the well-known J-curve, on the arithmetic basis, in which the asymptote evidently was not

Table 1. Greater mean numbers recovered and reproduction factor of *Helicotylenchus pseudorobustus* in two tests each on corn and soybeans 84-90 days after inoculation.

Cultivar	Nematodes recovered/ 1,500 cc soil[a]	Reproduction factor (P_f/P_i)
	Corn[b]	
Check (no seed)	55 a	0.2
B 73	980 ab	3.4
K 757	1,645 b	5.8
B 37	1,676 b	5.9
B 57	1,820 bc	6.4
C 103	1,920 bc	6.7
Pioneer 216 x 238	1,990 bc	7.0
B 66	2,150 bc	7.5
B 52	2,330 bc	8.2
N 7 B	2,640 c	9.3
H 88	3,205 c	11.2
	Soybeans[c]	
Check (no seed)	60 a	0.2
Harosoy	1,300 ab	4.9
Hark	1,400 ab	5.3
Marshall	1,450 ab	5.5
Ontario	1,510 ab	5.7
Acme	1,520 b	5.8
Kent	1,530 b	5.8
Hawkeye	1,700 bc	6.4
Steele[d]	1,750 bc	6.6
Flambeau[e]	1,800 bc	6.8
Wells	1,860 bc	7.0
Williams	1,950 bc	7.4
Wayne	2,000 bc	7.6
Chippewa '64	2,050 bcd	7.8
Merit	2,600 bcd	9.8
Calland	2,750 bcde	10.4
Richland	3,120 cde	11.8
Lincoln	3,500 de	13.3
Amsoy '71	4,200 e	15.9

[a]Figures followed by the same letter are not significantly different from each other at P=0.05.

[b]Initial infestation for corn was 285±24.

[c]Initial infestation for soybeans was 264±33.

[d]Plants were in poor condition at end of test.

[e]Plants matured early.

obtained (Figure 2). During the 52 weeks of the experiment, the absolute high and absolute low soil temperatures were 38 and 15 C, respectively; mean weekly highs and lows were 29 and 22 C. respectively. The yearly mean was 25 C.

Even though the nematode is capable of large increases in the greenhouse, much greater environmental resistance is encountered in the field and population growth is markedly less (Figure 3). Growth curves were much more erratic in the field during 4 mo after planting than for a corresponding period in the greenhouse. The highest specific growth rate during the growing season in the field from the initial density ranged from 0.4 to 34, although the specific growth rate at five of the six locations was 3.7 or less, less than that for the first month after planting in the greenhouse. The value of 34 at Independence in 1974 was due to a low initial density

Table 2. Numbers of *Helicotylenchus pseudorobustus*, and root and top weights of corn at monthly intervals for one year after inoculation with 50 nematodes per pot.

Month	Nematodes/ 1,000cc soil	Specific growth rate		Dry weight (g/pot)			
				Roots		Tops	
		Since inoculation	Since previous month	Check	Inoculated	Check	Inoculated
1	250	4	4.0	1.7	2.4	2.0	3.5
2	450	8	0.8	4.2	4.9	12.9	12.7
3	750	14	0.7	10.0	4.7*	26.9	21.6*
		Reseeded					
4	1,600	31	1.1	1.9	0.8	2.1	1.1
5	2,400	47	0.5	11.0	8.1	22.4	19.5
6	10,300	205	3.3	13.1	9.2	33.5	28.9*
		Reseeded					
7	15,500	309	0.5	0.5	0.6	0.6	0.6
8	22,050	440	0.4	3.3	2.6	13.4	9.7
9	54,000	1,079	1.4	17.2	9.5*	42.9	37.9*
		Reseeded					
10	59,650	1,192	0.1	0.5	0.4	0.5	0.6
11	87,900	1,757	0.5	5.6	6.1	9.9	10.9
12	213,450	4,268	1.4	13.6	8.3*	34.9	26.8*

*Significantly different from check at P = 0.05.

DISCUSSION

Taylor (1960) found 12 of 13 soybean cultivars, 2 cultivars of field corn, and 2 of 4 cultivars of sweet corn to be hosts for *H. pseudorobustus*. It is apparent from his results and those reported herein that corn and soybeans probably are generally susceptible to the nematode. The one soybean cultivar, Hawkeye, that Taylor classified as a nonhost was susceptible in my tests (Table 1). The fact that he tested nonhosts four times indicates that a different race of nematode was used or that his Hawkeye cultivar was different genetically from mine.

Taylor (1961) found that the life cycle of *H. speudorobustus* was at least 30 days at 32 C and about 35 days at 24 C. Thus, soil temperatures during the present experiment were such that the life cycle was completed in about 30-35 days, other factors being equal. The specific growth rate of 4,268 after 12 months (Table 2) probably is conservative, since it is not known how many of the original 50 neamtodes were functional in initiating the population, and the mortality during the entire experiment is unknown. The contrast between the growth curve in the greenhouse (Figure 2) and the ecological growth curves obtained in the field (Figure 3) is due to environmental resistance. Since the asymptote apparently was not reached during 12 mo in the greenhouse, the carrying capacity on the corn cultivar used is not known. A J-shaped curve similar to that on corn was obtained with the nematode on sycamore *(Platanus occidentalis)* by Churchill and Ruehle (1971), starting from 200 nematodes and increasing to

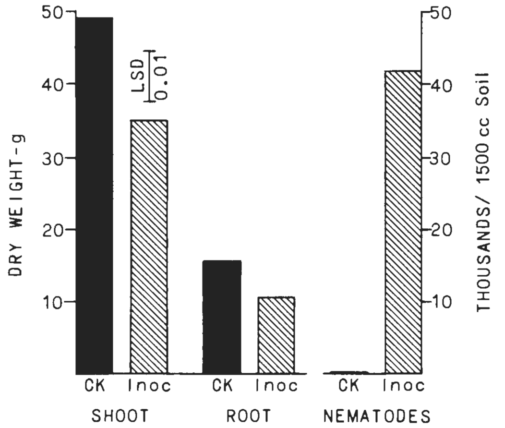


Figure 1. Dry weights of Pioneer 216 x 238 corn and densities of *Helicotylenchus pseudorobustus* 9 mo after inoculation. Initial inoculum was 1,665±84 nematodes/1,500 cc of soil.

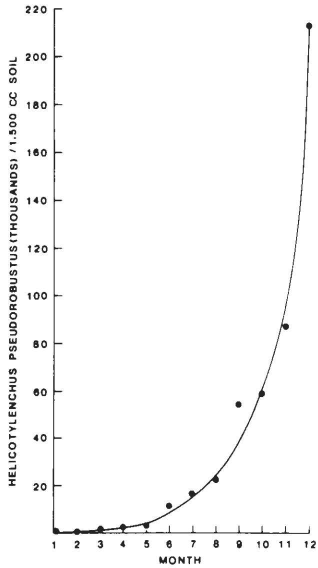


Figure 2. Growth curve of *Helicotylenchus pseudorobustus* on Pioneer 216 x 238 corn for 1 year.

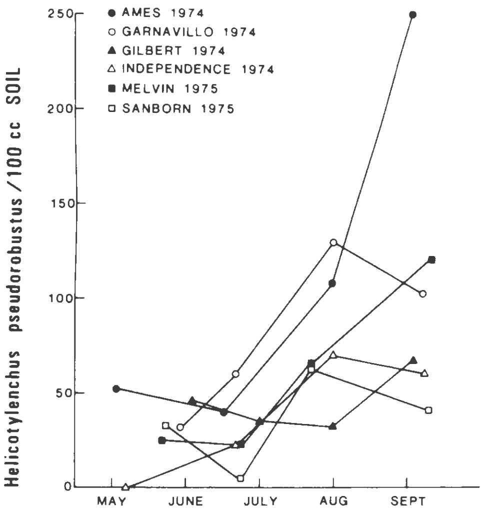


Figure 3. Densities of *Helicotylenchus pseudorobustus*/100 cc soil in nontreated chemical experiments in six corn tests in Iowa during 1974-1975.

70,000 in 9 mo. Calculation from their information indicates a specific growth rate of 349 after 9 mo compared with 1,079 that I obtained on corn for the same time span. Churchill and Ruehle used four times the inoculum that I did and this could account for the difference if host susceptibility or growth conditions do not. If the 250 nematodes that I obtained on corn after the first month is used as the P_i for a subsequent 9-mo period ending at the tenth month (Table 2), then the specific growth rate on corn is 238 for this period, a figure closer to that of Churchill and Ruehle (1971) with sycamore.

Taylor (1961) presented evidence that *H. pseudorobustus* when feeding as a semiendoparasite caused brown surface lesions involving 4-10 epidermal cells extending not more than four layers deep in corn. Taylor also found some nematodes in a truly endoparasitic habit in corn, but they were not found in the vascular system. It is generally recognized that nematodes feeding as ecto- or semiendoparasites are less damaging than true endoparasites, or at least those feeding in the vascular system, unless enormous numbers are present (Wallace, 1973). Results of my experiments in the greenhouse support this view. It is difficult to determine the comparative value of results in the greenhouse and field. The nematode caused a significant reduction in root surface area of sycamore after 9 mo but no root necrosis or reduction in top and root weights (Churchill and Ruehle, 1971). Large numbers of nematodes are frequently needed to cause significant yield reductions under conditions relatively free from adverse factors in the greenhouse. This is no reason to ignore the possible role of the nematode in plant growth in the field. Synecological studies will help solve this problem. Based on evidence presented here, *H. pseudorobustus* probably is only a moderate pathogen by itself, but along with other parasites, including nematodes, in the ecosystem, the nematode may be contributing to root necrosis and reduction of yields.

REFERENCES

Castaner, D. 1966. The relationship of numbers of *Helicotylenchus microlobus* to nitrogen soil amendments. Iowa State Journal of Science 41: 125-135.

Churchill, R. C., Jr., and J. L. Ruehle. 1971. Occurrence, parasitism, and pathogenicity of nematodes associated with sycamore (*Platanus occidentalis* L.). Journal of Nematology 3: 189-196.

Ferris, V. R., and R. L. Bernard. 1971. Effect of soil type on population densities of nematodes in soybean rotation fields. Journal of Nematology 3: 123-128.

Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Disease Reporter 48: 692.

Norton, D. C., L. R. Frederick, P. E. Ponchillia, and J. W. Nyhan. 1971. Correlations of nematodes and soil properties in soybean fields. Journal of Nematology 3: 154-163.

Orr. C. C., and O. J. Dickerson. 1966. Nematodes in true prairie soils in Kansas. Transactions of the Kansas Academy of Science 69: 317-334.

Schmitt, D. P., and D. C. Norton. 1972. Relationships of plant parasitic nematodes to sites in native Iowa prairies. Journal of Nematology 4: 200-206.

Taylor, D. P. 1960. Host range study of the spiral nematode, *Helicotylenchus microlobus.* Plant Disease Reporter 44: 747-750.

Taylor, D. P. 1961. Biology and host-parasite relationships of the spiral nematode, *Helicotylenchus microlobus.* Proceedings of the Helminthological Society of Washington 28: 60-66.

Wallace, H. R. 1973. Nematode ecology and plant disease. Arnold, London. 228 p.

IOWA STATE JOURNAL OF RESEARCH / FEBRUARY, 1977
Vol. 51, No. 3 287-321

A BIOSYSTEMATIC STUDY OF THE *Sporobolus asper* COMPLEX (GRAMINEAE)[1],[2]

Rhonda Riggins [3]

ABSTRACT. This study is concerned with the delimitation and relationships of the taxa in the *Sporobolus asper* complex. Morphological, cytological, anatomical, and distribution data obtained from population samples and herbarium material were used to delimit the taxa. Morphological variation within and among local population samples was assessed and analyzed by numerical techniques. The sources of variation are explained by studies of the breeding system and reproductive biology and by the responses of population transplants grown under uniform environmental conditions.

Four taxa are recognized: *Sporobolus asper* (Michx.) Kunth var. *asper, S. asper* var. *drummondii* (Trin.) Vasey, *S. asper* var. *macer* (Trin.) Shinners, and *S. clandestinus* (Biehler) Hitchc. The treatment includes a key to the taxa, and for each taxon a description, synonymy, illustration, and distribution data.

INTRODUCTION

The *Sporobolus asper* complex is a group of perennial grasses occurring in the continental United States and southern Canada. Previous taxonomic treatments of the complex, based on herbarium material, have resulted in the recognition of a varying number of taxa (Table 1).

The objectives of my research were to delimit the taxa and to determine their relationships. Morphological, cytological, anatomical, and distribution data obtained from population samples and herbarium material were used to delimit the taxa. Morphological variation within and among local population samples was assessed and analyzed by numerical techniques. The sources of variation are explained by studies of the breeding system and reproductive biology and by the responses of population transplants grown under uniform environmental conditions. The paper is primarily concerned with the numerical analysis and the resulting taxonomic treatment. Details of the transplant studies are largely excluded. Throughout the paper I refer to the taxa as I recognize them (Table 1). My procedure is for clarity and is not indicative of a priori judgments.

METHODS AND MATERIALS

Collections were made during 1970 and 1971 and consisted of three to twelve specimens randomly selected at each site. At most sites four living plants were obtained for transplant studies. Population samples, as well as Operational Taxonomic Units (OTU's) are specified by my collection numbers, except those of W. H. Duncan 23535 (WHD) and R. Q. Landers R-455 (RQL). Representative specimens are deposited in ISC.

---

[1] Journal Paper No. 8372 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 1833. The facilities of the Iowa State University Herbarium, supported by the Science and Humanities Research Institute, were used in the preparation of this paper.

[2] Based on a dissertation submitted to the Graduate College, Iowa State University, in partial fulfillment of the requirements for the Ph.D. degree.

[3] Biological Sciences Department, California Polytechnic State University, San Luis Obispo, California 93407.

Table 1. Disposition of the *S. asper* complex

Hitchcock (1951)	Shinners (1954)	Steyermark & Kucera (1961)	Riggins (1973)
S. asper (Michx.) Kunth	*S. asper*		*S. asper*
S. asper var. *asper*	=var. *asper*	=var. *asper*	=var. *asper*
S. asper var. *pilosus* (Vasey) Hitchc.	=var. *hookeri*	=var. *pilosus*	=var. *asper*
S. asper var. *hookeri* (Trin.) Vasey [sensu *S. drummondii* (Trin.) Vasey]	=var. *hookeri*	=var. *hookeri*	=var. *drummondii* (Trin.) Vasey
S. macer (Trin.) Hitchc.	=var. *macer* (Trin.) Shinners	not considered	=var. *macer*
S. clandestinus (Biehler) Hitchc. (=*S. canovirens* Nash)	=var. *clandestinus* (Biehler) Shinners =var. *canovirens* (Nash) Shinners	=*S. clandestinus* var. *clandestinus* =*S. clandestinus* var. *canovirens* (Nash) Steyerm. & Kucera	=*S. clandestinus*

Morphological variation was scored for 14 continuous variables, four ratios, three discrete variables, and six attributes from one culm of each specimen. Spikelet measurements were made after applying a softening solution (Pohl, 1965). Latitude and longitude for the collection sites were taken from Gerlack (1970). The variables are subsequently identified by number as follows:

1. Plant height from ground level
2. Culm width at first internode
3. Terminal blade length
4. Terminal sheath length
5. Terminal sheath width (folded)
6. Panicle length
7. Maximum panicle width
8. Number of primary panicle branches
9. Number of spikelets/cm^2
10. First glume length
11. Second glume length
12. Lemma length
13. Palea length
14. Floret width (folded)
15. Floret length/width
16. Number of lemma nerves
17. Presence or absence of lemma pubescence
18. Fruit length
19. Fruit width
20. Fruit length/width
21. Presence or absence of blade pubescence
22. Presence or absence of collar pubescence
23. Presence or absence of sheath pubescence
24. Presence or absence of rhizomes
25. Presence or absence of gelatinous pericarp
26. Latitude
27. Longitude
28. Terminal sheath length/width
29. Panicle length/width

Numerical analyses included several steps, all of which were carried out at the Iowa State University Computation Center.

1. For each population sample, the range, mean ($\bar{x}$), variance (s^2), and standard deviation (s) were determined for the continuous and discrete variables and the ratios. Within-population variability was estimated from these computations.

2. An analysis of variance (ANOVA) within and among populations was obtained for continuous and discrete variables and ratios. Significance was determined by F tests. Confidence limits were set at 5% for these and all other tests of significance in the study.

3. A variable x variable correlation matrix was computed and used to derive a factor matrix. Factors were extracted by the centroid method.

4. Input for cluster analyses was a character x OTU matrix based on standardized data. OTU's correspond to summarized data for the population samples. Correlation coefficients (r) formed the basis of a similarities matrix from which clusters were obtained by the unweighted, pair-group method using averages (UPGMA). The program of McCammon and Wenninger (1970) was used to plot the dendrograph. Three dendrographs were obtained. The first dendrograph of the 66 OTU's was based upon all 29 variables. A second dendrograph was based on 16 variables. Variables 1, 7, 10-14, 18, 19, 22, 28, and 29 were eliminated after other analyses indicated that they were of little taxonomic value. The third dendrograph was based upon 12 variables (2-5, 8, 9, 16-18, 20, 25, and 26) that contributed largely to the variance in factor 1 of the factor analysis.

5. F and t tests for significant differences between means of each variable were made after the samples were grouped by taxa.

Distribution data and selected morphological variables were recorded from herbarium specimens in ISC, or borrowed from F, FSU, GA, GH, IND, MIL, MO, NY, P, PH, SMU, TAES, TENN, TEX, US, and WIS.

Uniform environment studies were conducted with growth chamber and garden facilities. The garden site was located on an Iowa State University farm in Section 19, Washington Township, Story Co., Iowa. Survival patterns, growth responses, and flowering behavior were monitored. Morphological variation was scored for the garden-grown plants. These data were compared with data from wild populations by using F and t tests to detect differences.

Meiotic material was fixed in Newcomer's (1953) solution. Anther squashes were made in 45% aceto-orcein. Slides were made permanent by freezing with liquid CO_2 (Bowen, 1956). Voucher specimens for chromosome counts are deposited in ISC.

Anatomical material was fixed in FAA and dehydrated with a tertiary butyl alcohol series as prescribed by Jensen (1962). Leaf material was placed in a 10% hydrofluoric acid solution for 12 hours before dehydration (Metcalfe, 1960). The material was embedded in Tissuemat (mp 61 C) and sectioned at 10-12 μ. Sectioned material was stained with safranin and fast green according to a schedule modified from Sass (1958).

Leaf blades from dried specimens were cleared with 5% aqueous NaOH, followed by chloral hydrate, and dehydrated with a graded ethanol and xylene series (Shobe and Lersten, 1967). The material was stained with chlorozol black E and permanently mounted in Piccolyte. Lemmas were cleared through the chloral-hydrate stage.

Pollen from dehisced anthers was stained with lactophenol and cotton blue (Sass, 1958).

RESULTS

Anatomy

Members of the *Sporobolus asper* complex have uniform epidermal patterns that agree with Prat's (1932, 1934) description of *Sporobolus*. Cross sections of leaf blades of *Sporobolus* show the chloridoid type of anatomy (Brown, 1958). Few anatomical differences among taxa of the *S. asper* complex were observed. Blades of *S. asper* var. *macer* are more deeply furrowed than those of other taxa and sometimes have papillae on the abaxial surface.

The presence of lateral nerves on the lemmas of *S. clandestinus* was verified by clearings and cross sections. The lateral nerves may consist of a single tracheary element surrounded by sclerenchyma and parenchyma, or they may be entirely of sclerenchyma and parenchyma. The presence of one, two, or three lemma nerves was observed within the same panicle. Similar results have been reported for *S. vaginiflorus* (Torr.) Wood (Riggins, 1969).

Cytology

Brown (1950) recorded mitotic counts for *S. asper* indicating 2n = 54 and 108. I could locate no designated voucher specimens among those borrowed from TEX. Reeder (1968) published a meiotic count for *S. asper* as 2n = 54. The voucher specimen (Reeder 4558, Comal Co., Texas) is *S. asper* var. *drummondii*. Gould (1968) determined meiotic counts for three collections. Gould 11757a from Jack Co., Texas, is *S. asper* var. *asper*. The chromosome number was 2n = 54. Gould 11758 from Stephens Co., Texas, is *S. asper* var. *drummondii*.

The chromosome number was 2n = 54. Gould 8439 from San Saba Co., Texas, is *S. clandestinus.* The chromosome number was 2n = 88, which he regarded as an aneuploid in accordance with Brown's (1950) count of 2n = 108.

I was not able to determine chromosome numbers for all taxa. The 2n = 54 count for *S. asper* var. *asper* was verified. Counts of n = 18, 19, 20, 21, 23, and 24 were determined for *S. asper* var. *macer.* Counts of n = 23, 24, 26, 27, and 28 were determined for *S. clandestinus.* In both cases the material was from the same panicle. I never observed any definite meiotic irregularities that might account for the varying chromosome numbers.

Base chromosome numbers for *Sporobolus* are x = 6, 9, and 10. Most North American taxa have x = 9, but species with x = 6 and 10 have been reported (Pohl and Davidse, 1971; Reeder, 1968). Members of the *S. asper* complex may be hexaploid with 2n = 54.

Breeding System and Reproductive Biology

My observations on breeding system and reproductive biology were made in the field, greenhouse, garden, and growth chambers.

Depending upon the particular plant and growing conditions, the time from culm elongation to panicle formation may be from 5 to 14 days. Flowering within one panicle may proceed over a period of 5 days to 2 or 3 weeks. Three to 5 weeks may elapse between panicle formation and production of mature fruits.

Autogamy is virtually enforced and is certainly the usual means of sexual reproduction. The panicles may be completely enclosed in the sheath and cross-pollination prevented. Sometimes the panicles elongate and become exserted from the sheath after fruits are formed. In some plants 10-50% of the panicle may be exserted before anthesis, and cross-pollination is possible. However, cross-pollination can be prevented by certain variations in flowering behavior: (1) The florets may remain closed. As a result, the flowers are self-pollinated. (2) A differential elongation of the filaments of a single flower may occur, whereby one or two stamens are exserted and one or two are included in the floret. The filaments of the included stamens may elongate slightly but fail to become completely exserted from the floret before anther dehiscence. The flowers are self-pollinated in either instance. (3) All three filaments may become exserted and the filaments droop so that the anthers are below the stigmas of the same flower at dehiscence. This condition could result in either cross-pollination or geitonogamy, which would have the same genetic effect as self-pollination. All these variations have been observed on a single panicle.

Lodicule activity, floret opening, anther, and (or) stigma exsertion are observed more frequently in the upper panicle branches but are not associated with the exact position of the spikelets. There is no relationship between any of the variations in flowering behavior and time of day. In the field or greenhouse, more florets are open on hot, humid days than on cool days when the relative humidity is low.

My observations indicate that cross-pollination is possible but probably infrequent. I have rarely observed protandry and anther dehiscence followed by stigma exsertion and receptivity. Usually the stigmas are receptive when anthers of the same flower dehisce, but may or may not be exserted. Geitonogamy may also occur in those flowers that are protandrous.

Microspore mother cells are present synchronously with megaspore mother cells; the development of both mother cells proceeds synchronously until the formation of mature embryo sacs and microspores.

Within a panicle, the length of the anthers decreases from the apex downward and may vary from 3.0 to 0.3 mm. Larger anthers in the upper panicle branches have four microsporangia and produce many pollen grains. Smaller anthers from spikelets completely enclosed in the sheath may have two or three microsporangia and produce as few as 8 to 12 pollen grains. Mature anthers dehisce from the base upward.

Pollen from one or two anthers taken from a given plant was stained with cotton blue to estimate viability. Grains with densely staining cytoplasm were scored as normal; collapsed grains with unstaining cytoplasm were scored as abnormal. The results summarized in Table 2 indicate that pollen stainability is high.

Brown and Emery (1958) reported that embryo sac development in *S. asper* is normal and not apomictic. My observations confirmed theirs.

Table 2. Pollen stainability with cotton blue

POP.	TOTAL NUMBER OF GRAINS	% STAINABILITY
1001	2076	85.8
1013	2720	88.8
1015	615	83.0
1017	1754	75.4
1029	298	94.9
1031	829	68.9
1036	867	83.6
1039	250	99.2
1044	1601	89.6
1047	1420	91.5
1048	166	87.3
1058	1056	92.1
1062	825	91.1
1097	360	61.1
1100	617	88.9
1101	1051	89.0
1102	1873	82.4
1107	858	83.9
1109	1570	79.6
1111	1059	89.8
1113	755	76.5
1114	94	93.6
1115	1025	75.8
1118	1445	93.4

In *Sporobolus* the seed coat does not become fused to the pericarp except at the micropylar region; hence, the fruit has been considered an achene. Characteristic of *Sporobolus* is a loose or gelatinous pericarp. The mature fruit of *S. asper* has a gelatinous pericarp, which swells and slips from the seed when moist. The pericarp of *S. clandestinus* is loose and can be removed with a scalpel when moist. It never becomes gelatinous nor does it slip from the seed. Similar observations have been reported for *S. ozarkanus* and *S. vaginiflorus* (Riggins, 1969). Seed set is high except in transplants of *S. asper* var. *macer.*

Toole (1941) has described techniques for the germination of *S. asper.* Maximum germination occurred after prechill for 14 days and KNO_3 treatment. Prechill and KNO_3 treatment were not necessary after the seeds were 7 months old. Older seeds germinated readily in tap water at room temperatures.

Two methods of germination were tested in this study. Florets with recently formed fruits were collected, placed in petri plates lined with water-soaked blotters, and subjected to 5° C for 2 weeks. The florets were then sown on greenhouse soil and covered with paper toweling. Germination was high in all taxa.

Florets 6 months to 1 year old were allowed to stand in tap water at room temperature for 2 to 3 weeks. Germination was high for *S. asper* var. *asper, S. asper* var. *drummondii,* and *S. clandestinus* even when the florets were completely submerged. Germination of *S. asper* var. *macer* was low.

Asexual reproduction by vivipary was rarely observed in transplants of 1049, 1050, and 1056. Rhizomes are characteristic of *S. asper* var. *macer* and are occasionally present in *S. clandestinus.* In wild populations of *S. asper* var. *macer*, the rhizomes are slender and produce one or two culms. Transplants, however, produce many culms, but seed set is low. My samples and most herbarium specimens of *S. asper* var. *macer* were collected before seed was set. If seed set in wild populations is low, the selective advantage of rhizomes is obvious.

Morphological Variation and Numerical Analyses

Variation within individual populations was estimated from the computations of range, mean, variance, and standard deviation determined for the continuous and discrete variables and the ratios. For each of the variables extensive as well as restricted ranges of variability were evident. Plant height (variable 1) and floret length to width (variable 15) were highly variable for the 66 populations sampled. Little variability was recorded for floret width (variable 14) and fruit width (variable 15).

Within individual populations, extensive as well as restricted ranges of variability were also found. Certain samples exhibited substantial within-population variability for most characters, whereas other samples exhibited little within-population variability for the same characters.

When the mean values for variables 2, 3, 5, 8, 9, and 20 were ranked, a geographical trend in variation was evident. Larger values for variables 2, 3, 5, 8, and 9 were found in northern populations of *S. asper* var. *asper.* Larger values for variable 20 were shown for southern populations of *S. clandestinus.* The latter situation was also observed for variable 18.

Within any one population the presence or absence of lemma pubescence is usually constant. Plants with pubescent lemmas are immediately identified as *S. clandestinus.* Four population samples (1044, 1048. 1101, and 1110) contained plants with pubescent lemmas and plants with glabrous lemmas. The populations are from Texas, and the plants with glabrous lemmas are identified as *S. asper* var. *drummondii.* Plants of *S. clandestinus* also have pubescent paleas. All specimens of *S. asper* that I have examined have a slight pubescence between the palea nerves.

Blade pubescence is common, but its absence is recorded more frequently in populations of *S. asper* var. *drummondii.* Collar pubescence was recorded for the majority of plants; few plants were found to have pubescent sheaths, the majority of them belonging to populations of *S. clandestinus.* Populations 1062, 1069, 1072, 1089, and 1090 of *S. asper* var. *asper* contain some plants with pubescent heaths.

All plants of *S. asper* that I have examined have one lemma nerve. Lemmas of *S. clandestinus* may have one, two, or three lemma nerves, but the number is not constant within a population or one plant.

The presence or absence of rhizomes is constant within populations that I sampled. Rhizomes are characteristic of *S. asper* var. *macer* but are sometimes present in *S. clandestinus.* Populations 1029, 1117, and 1121 are the only samples with rhizomes included in the morphological studies.

The results of the ANOVA for each variable within and among populations are given in Table 3. For all variables, there is a greater variation among populations than within populations. All F values are significant at the 5% level. Because F values cannot be computed for attributes, variables 16, 17, 21-25 are excluded. Latitude (variable 26) and longitude (variable 27) are also excluded.

Although the variable x variable correlation matrix was a preliminary step for the factor analysis, it did provide some insight as to the degree to which the variables vary together (Table 4). Of the 402 possible correlation coefficients, 296 were significant (± 0.1 or above). Several coefficients were irrelevant, due to causal relationships of the variables (e.g., correlation between variables 5 and 28 or between variables 10 and 11).

Correlations between variable 26 (latitude) and other variables were of particular interest because they reflected geographical distribution. Positive correlation between variables 26 and 2, 5, 8, 9, and 14 indicated that higher values for the variables were characteristic of northern populations. Negative correlations of variables 26 and 29 indicated that lower values for the ratios were characteristic of southern populations. Negative correlation of variables 26 and 17 indicated that lemma pubescence occurs more frequently in southern populations. No significant correlation between variable 27 (longitude) and other variables was shown; thus, geographic variation in an east-west direction was not significant.

The -1.000 correlation coefficient between variables 16 and 25 expressed a consistent association of lemma pubescence and the absence of a gelatinous pericarp. It has been noted that these two characters are useful to identify *S. clandestinus.*

Table 3. ANOVA within and among populations for continuous and discrete variables

VARIABLE	df WITHIN	df BETWEEN	F
1	66	488	8.75
2	66	488	20.67
3	62	364	20.93
4	66	482	39.96
5	66	483	39.63
6	66	488	13.77
7	66	488	6.47
8	66	488	56.86
9	66	488	64.01
10	66	488	9.91
11	66	488	10.23
12	66	488	17.32
13	66	488	27.38
14	66	488	15.80
15	66	488	17.55
18	47	223	26.02
19	47	223	8.44
20	47	223	38.59
28	66	482	24.66
29	66	488	10.24

Factor analysis expresses covariation in terms of underlying factors that explain a large part of the variance and covariance of the original variables. With factor analysis, complex relationships are resolved into the interaction of fewer and simple factors, and causal factors behind correlations are isolated and identified (Sokal and Rohlf, 1969).

Seven factors, which accounted for 99.9% of the total variance, were extracted from the factor matrix. The results are presented in Table 5. Factor 1 contains characters that are valuable in separating the taxa and latitude, and the characters in factor 2 pertain to spikelet measurements. Functional character complexes cannot be described for the remaining factors.

The dendrograph of McCammon and Wenninger (1970) is a two-dimensional representation showing vertical and horizontal relationships of the clusters. The horizontal axis corresponds to correlation (r) values and reflects within-cluster similarity. The vertical axis reflects between-cluster similarity. The large distinct clusters, however, are more important in showing overall relationships of the OTU's.

In dendrograph 1 (Fig. 1), which is based upon all 29 variables, two large clusters are seen. Cluster 1 is composed of OTU's 1066-1013; all are samples of *S. asper* var. *asper*. The small clusters 1010-1089 and 1066-1081 are not highly distinct. Cluster 1100-1013 is identified as cluster 1B and is phenetically distinct from 1A.

Cluster 2 of dendrograph 1 is composed of OTU's 1047-1112, but is more loosely constructed than cluster 1. Smaller clusters can be identified. Cluster 2A1 is composed of 1047-1113 and is identified as Texas populations of *S. asper* var. *drummondii*; OTU 1011 is from a mixed population of *S. asper* var. *drummondii* and *S. clandestinus*. Cluster 2A1 is connected to cluster 1117-1029 (2A2) by 1095, a sample of *S. asper* var. *drummondii* from Marion Co., Kansas. There is certainly a phenetic relationship of 1095 and cluster 2A1, but they are not tightly clustered. OTU's 1029 and 1121 are samples of *S. asper* var. *macer* and are phenetically distinct from 1117, a sample of *S. clandestinus* with rhizomes.

In cluster 1017-1112, which is rather loosely constructed, clusters 2B and 2C can be identified, but they are not highly distinct. With the exception of three OTU's, clusters 2B and 2C are composed of samples of *S. clandestinus*. OTU's 1044, 1048, and 1110 are samples from mixed populations of *S. clandestinus* and *S. asper* var. *drummondii*.

Table 4. Correlation coefficients between individual variables of ± 0.600 and above

VARIABLE	.600 - .699	.700 - .799	.800 - .899	.900 - .999	1.000
1. Plant height					
2. Culm width	3, 9, 26	5, 8			
3. Terminal blade length	2, 5, 9, -16[a], 25				
4. Terminal sheath length	-16, -17	3, 8			
5. Terminal sheath width	3, 8, 15, -20, -28	2, 9, 26			
6. Panicle length					
7. Panicle width		3			
8. Number of primary		3			
panicle branches	5, -16, -17, -20, 26	2, 3, 4, 9, 25			
9. Number of spikelets/cm^2	2, 3, -16, -18, 25, 26	5, 8, -17, -20			
10. First glume length		11			
11. Second glume length	12	10			
12. Lemma length	11	13			
13. Palea length		12			
14. Floret width	5, -15, 19, 26				
15. Floret length/width	-14, 20				
16. Number of lemma nerves	-3, -4, -8, -9	18	17, 20	-25	
17. Lemma pubescence	-4, -8	-3, -9, 18	16, 20		-25
18. Fruit length	-9	16, 17, -25	20		
19. Fruit width	14				
20. Fruit length/width	-5, -8, 15	-9	16, 17, 18, -25		
25. Gelatinous pericarp	3, 5, 9	8, -18	-20	-16	-17
26. Latitude	2, 8, 9, 14	5			
27. Longitude					
28. Terminal sheath length/width	-5				
29. Panicle length/width					

[a]Negative coefficients are preceded by -.

Figure 2 is based on a reduced set of 17 variables. In dendrograph 2 the horizontal relationships of the OTU's are more defined than in dendrograph 1, and the vertical relationships are slightly more defined. Again two large clusters are seen. Clusters 1A and 1B are again distinct, but some shifts have occurred in 1A. Though OTU's 1010 and 1096 are grouped differently, the most striking shift is the addition of 1095 from cluster 2A. Cluster 1B is composed of the same OTU's in 1B of Figure 1. OTU's 1014 and 1013, 1016 and 1015 show a closer relationship.

Cluster 2A is now composed of OTU's 1107 - 1113; all except 1101 are *S. asper* var. *drummondii* from Texas.

Cluster 2B1 and 2C are still composed of the same OTU's, but they are rearranged. OTU's 1029 and 1121 (2B2) assume an intermediate position between clusters of *S. clandestinus* samples but are still connected by 1117. Closer relationships between 1112 and 1115, 1120 and 1118, 1088 and 1009, 1036 and 1031 are seen. The only major shift involves OTU's 1088 and 1009.

Figure 3 is based on 12 variables from factor 1 of the factor analysis. The vertical and horizontal relationships between the two large clusters are more defined than in dendrograph 2. Cluster 1 is composed of OTU's 1069-1013. With the exception of 1065, cluster 1A is composed of the same OTU's in cluster 1A of dendrographs 1 and 2.

Cluster 1B can be divided into two smaller clusters: 1B1, composed of OTU's 1039-1113, and 1B2, composed of OTU's 1100-1013. The three OTU's in cluster 1B1 were located in cluster 2 of dendrographs 1 and 2. OTU's 1039 and 1113 are samples of *S. asper* var. *drummondii;* OTU 1121 is *S. asper* var. *macer.* Cluster 1B2 is composed of the OTU's in 1B of dendrographs 1 and 2, with the addition of 1065. The rather distant relationships of 1065 and 1100 to cluster 1015-1013 is accentuated, and a higher correlation within and between OTU's 1015-1013 is shown.

The composition of cluster 2 is certainly different from Figures 1 and 2. Cluster 2A is composed of OTU's 1047-1095. OTU's 1039, 1101, and 1113, which appeared in cluster 2A of Figures 1 and 2, are rearranged. OTU 1095 is grouped as it was in dendrograph 1.

Clusters 2B and 2C are composed of the OTU's in those clusters of Figures 1 and 2, with the addition of 1101. OTU's 1009 and 1088 are grouped as they were in dendrograph 1. OTU 1117 is also rearranged.

When the clustering of OTU's is examined, characteristic patterns of similarities and dissimilarities of populations from particular geographical areas can be seen. Population samples of *S. asper* var. *asper* from Nebraska, Kansas, and Oklahoma (1089, 1090, 1091, 1092, 1093, 1094, 1097, 1098) for a smaller cluster within cluster 1A of each dendrograph. However, 1096 from the same geographical area does not cluster with the OTU's in dendrographs 1 and 2. Geographical locality cannot entirely account for the consistent clustering. The clustering of Texas populations of *S. asper* var. *drummondii* is consistent in each dendrograph and shows a distinct dissimilarity from Texas populations of *S. clandestinus.*

Within small geographical areas, the clustering of OTU's shows that local populations may exhibit either a distinct similarity or dissimilarity with each other. For example, 1064 and 1073, collected in Woodman Hollow State Preserve, Webster Co., Iowa, exhibit a distinct dissimilarity in each dendrograph. Sample 1073 was collected from a prairie remnant approximately 500 yards from the roadside habitat of 1064. On the other hand, 1118 and 1120 from habitats 60 miles apart in Mississippi show high similarity with each other.

The dendrographs clearly show that the OTU's are phenetically and to a certain degree geographically distinct. The phenetic relationships of *S. asper* var. *drummondii, S. asper* var. *macer,* and *S. clandestinus* are obvious. The overall relationships within and between the OTU's are highly consistent, but are more defined when based on the reduced sets of varibles. Certain OTU's, however, are inconsistently grouped.

A distinct cluster of OTU's 1013, 1014, 1015, 1016, 1062, and 1100 is seen in each dendrograph. Greatest values for variables 4 (sheath length) and 8 (number of primary panicle branches) were recorded for these samples of *S. asper* var. *asper* and may account for the grouping. Within *S. asper* var. *drummondii,* upper limits for variable 9 (number of spikelets/cm^2) were recorded for 1095. The inconsistent grouping of 1095 may be due to variable 9. The placement of 1039 with *S. asper* var. *asper* in dendrograph 3 is explained by variable 4. Within *S. asper* var. *drummondii,* upper limits for sheath length were recorded for 1039. Floret length to width values of 1113 are within the range of variation of *S. asper* var. *asper,* and may account for the similarity shown in dendrograph 3.

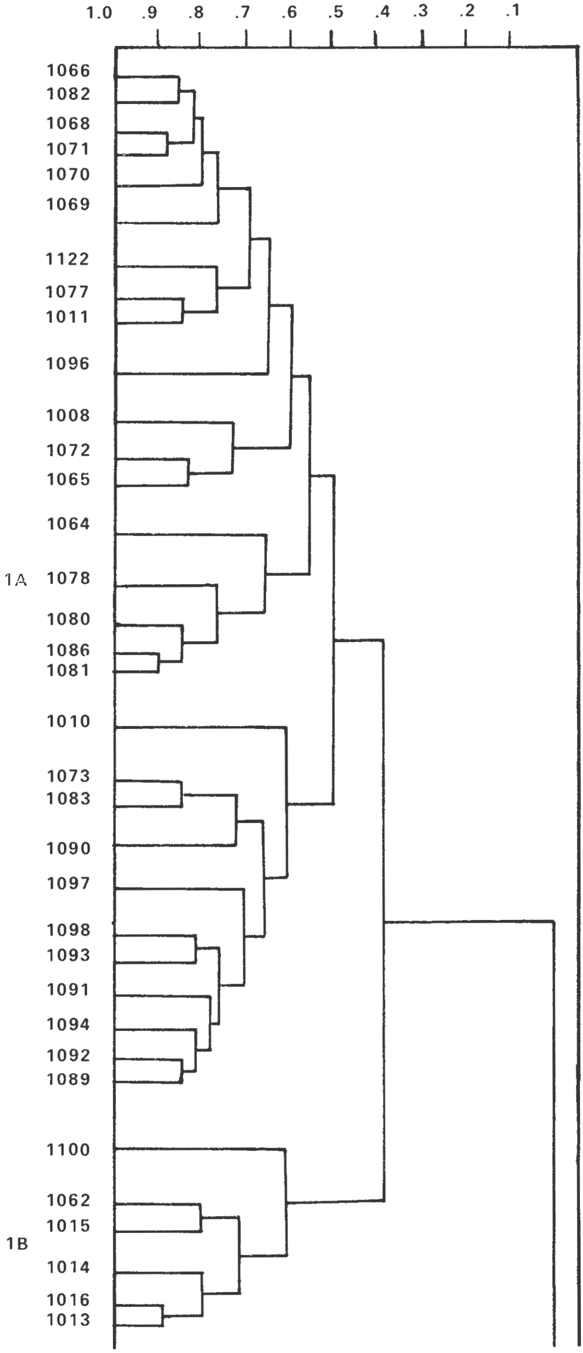


Figure 1. Dendrograph 1 based upon 29 variables.

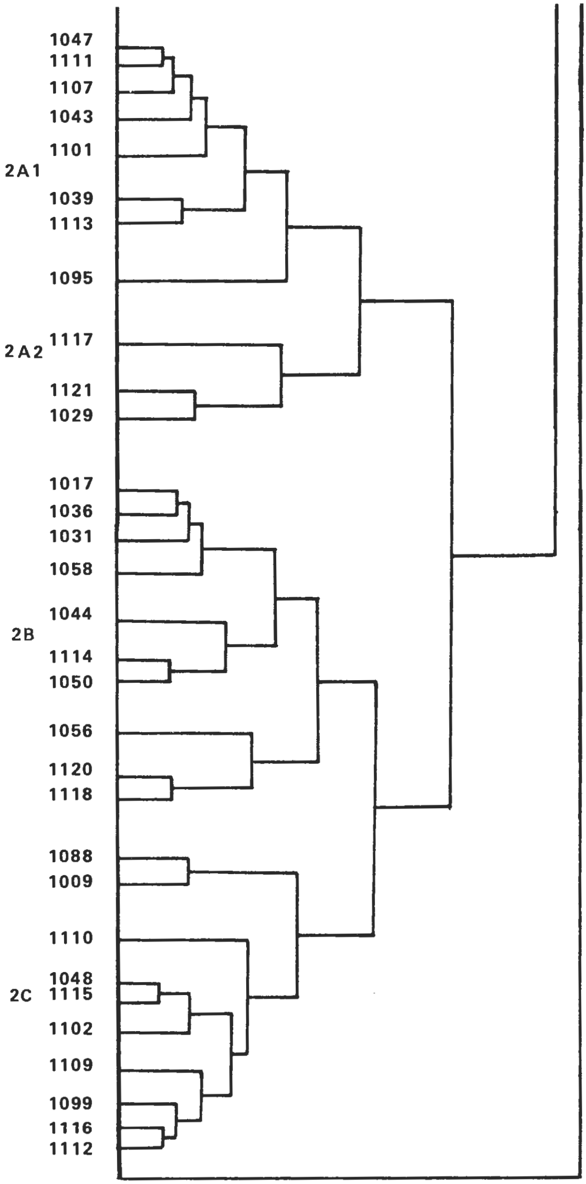


Figure 1 (continued). Dendrograph 1 based upon 29 variables.

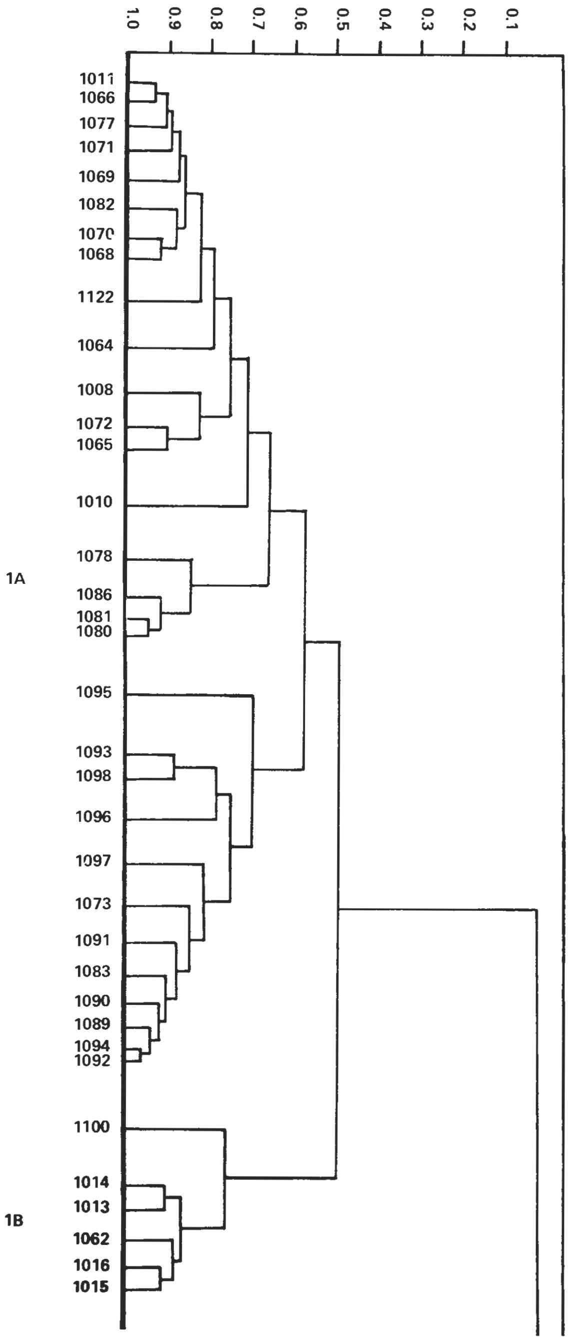


Figure 2. Dendrograph 2 based upon 17 variables.

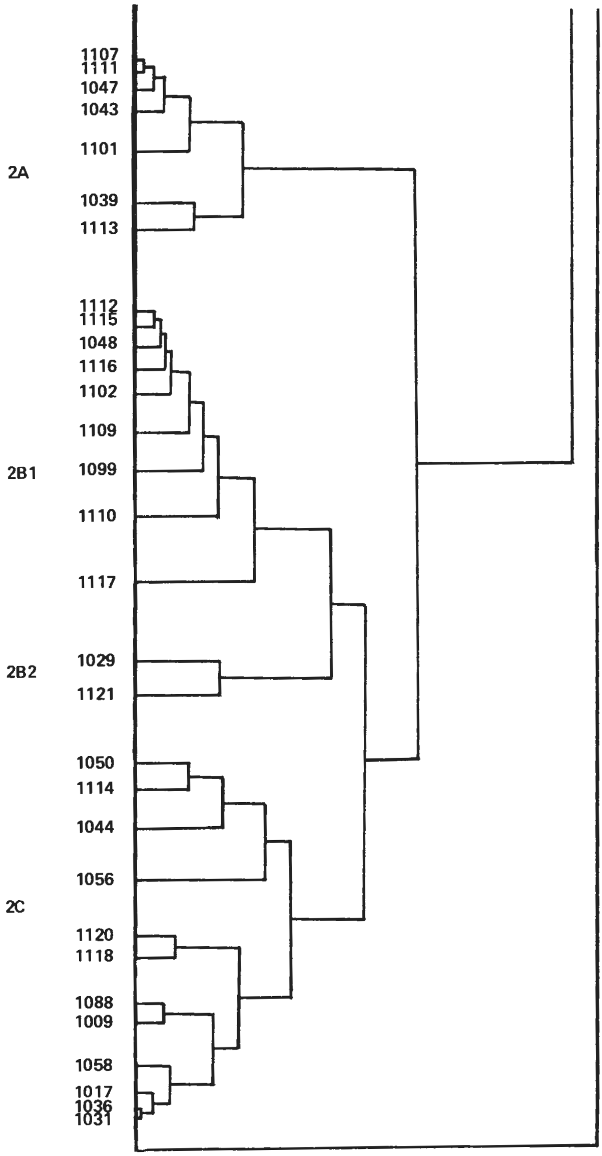


Figure 2 (continued) Dendrograph based upon 17 variables.

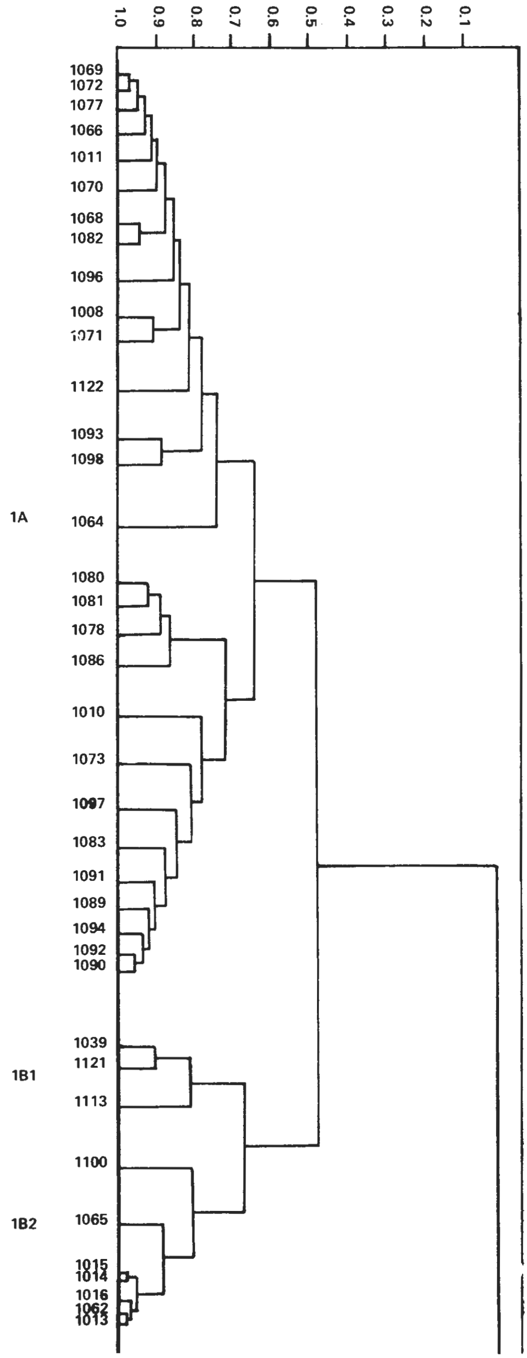


Figure 3. Dendrograph 3 based upon 12 variables.

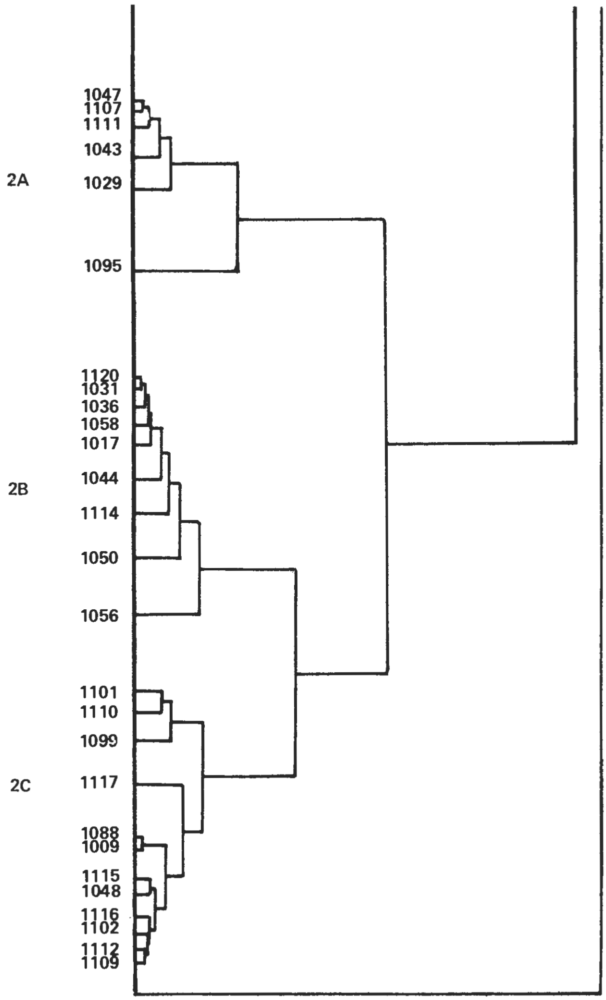


Figure 3 (continued). Dendrograph 3 based upon 12 variables.

The absence of a phenetic relationship of OTU's 1029, 1117, and 1121 in dendrograph 3 is explained by the exclusion of variable 24 (presence or absence of rhizomes). OTU 1121 *(S. asper* var. *macer)* is included in cluster 1B1 of dendrograph 3 and is grouped with OTU's 1113 and 1039. The high values for variable 9, which were recorded for 1121, may account for the rearrangement. Within *S. asper* var. *macer*, low values for variables 4 and 9 were recorded for 1029 and may be responsible for the grouping with *S. asper* var. *drummondii* in dendrograph 3.

To explain the consistent appearance of two clusters of *S. clandestinus*, the samples were divided into two groups corresponding to clusters 2B1 and 2C of dendrograph 2. Group 1 consisted of OTU's 1099, 1102, 1109, 1112, 1115, 1116, and 1117. Group 2 consisted of OTU's 1009, 1017, 1031, 1036, 1050, 1056, 1058, 1088, 1114, 1118, and 1120. F and t values between the groups were computed for variables 1-15, 28, and 29. Variables 18-20 were excluded because data were missing for group 1. Significant F values were obtained for variables 3-6, 9-14, and 12-15; significant t values were obtained for variables 3-7, 13-15, and 29. For all variables the ranges of variation overlapped. Greatest variation and significant differences in variables 3, 4, 6, 7, and 29 (Table 6) probably account for the groupings.

Table 5. Factor members exhibiting a correlation of ± 0.500 or above with other characters of the factor

FACTOR	FACTOR MEMBERS	% VARIANCE
1	2, 3, 4, 5, 8, 9, 16, 17, 18, 21, 25, 26	35.52
2	10, 11, 12, 13, 15	14.24
3	7, 24, 29	10.76
4	1, 4, 6, 7	10.83
5	13, 23, 27	9.03
6	14, 15, 19, 26	13.31
7	21, 22	6.30

Table 6. Variation in groups 1 and 2 of *S. clandestinus*

VARIABLE	GROUP 1 RANGE	$\overline{x}$	GROUP 2 RANGE	$\overline{x}$
3	0.3 - 12.0	3.8	0.2 - 7.0	2.2
4	4.9 - 21.0	13.0	5.0 - 20.0	9.9
6	8.0 - 50.0	28.0	5.0 - 42.0	15.8
7	2.0 - 11.0	5.5	1.0 - 10.0	4.2
29	20.0 - 100.0	55.0	16.0 - 130.0	44.0

Sporobolus clandestinus var. *clandestinus* and *S. clandestinus* var. *canovirens* were delimited by Steyermark (1963) on the basis of floret measurements. My collections, however, exhibited such extensive intergradation of floret characters that recognition of two varieties would not be practical. The differences between the two groups of my samples of *S. clandestinus* do not warrant taxonomic distinction.

The inconsistent groupings of OTU's 1009 and 1088 cannot be fully explained. I can only interpret them to be phenetically intermediate between the two groups.

Herbarium Studies

Distributional data from herbarium specimens are incorporated into Figures 9, 11, and 14.

Variables 1-5, 9-20, and 28 were scored from specimens selected to represent geographical areas where I had not collected. Because only a few specimens of *S. asper* var. *macer* had been collected, all available specimens were examined. The ranges of variation recorded from the population samples were expanded for a few variables and are included in the descriptions of the taxa. Larger values for sheath width were recorded for *S. asper* var. *drummondii* and *S. asper* var. *macer*. For *S. asper* var. *macer* the extreme ranges of variation for variable 9 represented by my collections were intergraded. Ranges of variation were established for variables 18, 19, and 20.

Table 7. Variation in palea length in *S. clandestinus*

REGION	RANGE	n	$\overline{x}$
Florida	7.0 - 10.5	11	8.3
Georgia, Alabama, Mississippi	4.6 - 8.4 (10.1)	33	6.7
Connecticut, New Jersey	5.5 - 7.0 (8.5)	7	6.3
Delaware, Maryland, Virginia	(4.2) 5.1 - 7.5 (7.9)	26	6.1
Indiana, Illinois, Wisconsin, Iowa	5.3 - 6.5 (7.0)	18	6.0
North and South Carolina	(4.6) 5.0 - 7.3 (8.4)	21	5.9
Tennessee, Missouri, Arkansas, Louisiana	4.1 - 6.7 (7.3)	93	5.3
Texas, Oklahoma	(3.2) 3.7 - 5.9 (6.6)	51	4.5

Examination of *S. clandestinus* indicated a clinal variation of palea length. Specimens from the southeastern and northeastern coastal plains states have longer paleas. Specimens from the central inland states have intermediate paleas. The shortest palea lengths were recorded from specimens from Texas and Oklahoma. The variation is summarized in Table 7 and shown in Figure 13.

Morphological Variation in Garden Plants

The ANOVA of garden-grown plants indicated that any significant variance among the plants was not due to location of the plants within the replicate, experimental error, or environmental differences between the replicates. Significant variance among garden-grown plants was attributable to differences within and among the populations from which they were collected. The objective of the garden experiment was to determine if the variation was genetically or environmentally controlled.

Within any single sample the presence or absence of lemma pubescence, gelatinous pericarp, and rhizomes remained unchanged. The number of lemma nerves in *S. asper* remained unchanged; the number in *S. clandestinus* was one, two, or three.

Variation in the presence or absence of leaf pubescence was considerable even among clones of the same specimen. The variation, however, did not occur in all taxa. There was no variation in blade pubescence among clones of *S. clandestinus*, or in collar pubescence among clones of *S. asper* var. *asper*. Sheath pubescence was not observed in any garden-grown plants of *S. asper* var. *asper*, *S. asper* var. *drummondii*, and *S. asper* var. *macer*.

Considerable variation within and among clones and populations was observed for the continuous and discrete variables and the ratios. F and t tests showed significant differences between wild and garden-grown plants. The majority of garden-grown plants had shorter and wider culms, terminal sheaths and panicles, shorter terminal blades, and smaller spikelets than wild population samples.

The ranges of variation for terminal sheath width, panicle length, terminal sheath length to width, and panicle length to width were extended for all taxa. For *S. asper* var. *asper* more variability was recorded for panicle width, floret width, fruit length, and fruit length to width. For *S. asper* var. *drummondii* more variability was recorded for panicle width, number of spikelets/cm^2, glume, lemma and fruit length, and fruit length to width. For *S. asper* var. *macer* more variability was recorded for panicle width, number of primary panicle branches, number of spikelets/cm^2, first glume and fruit length, floret and fruit width, and floret length to width. For *S. clandestinus* more variability was recorded for culm width, number of spikelets/cm^2, and glume lengths.

Figure 4. Wild and garden-grown plants of *S. asper* var. *asper*. A. Wild. B. Garden-grown. Line scale = 1 cm. From Riggins 1001.

Figure 5. Wild and garden-grown plants of *S. asper* var. *drummondii*. A. Wild. B. garden-grown. Line scale = 1 cm. From Riggins 1043.

Among the taxonomically useful variables (2, 3, 4, 5, 8, 9, 18, and 20), ranges of variation were not extended for terminal blade and sheath lengths. Although the ranges of variation for culm width, terminal sheath width, number of primary panicle branches, fruit length, and length to width were extended, the taxa could still be distinguished by these variables. The diagnostic value of variable 9 (number of spikelets/cm^2) was highly modified. Garden-grown plants of *S. asper* var. *drummondii* and *S. clandestinus* produced denser panicles than wild plants. For some clones of all samples, however, the number of spikelets/cm^2 remained within the limits of variation observed in wild populations. The clones that produced dense panicles flowered late in the season.

The results demonstrated that some differences among the taxa were genetically controlled. Other differences were slightly modified within the garden environment but remained diagnostic in separating the taxa. Fewer differences between wild and garden plants were recorded for *S. asper* var. *asper* and *S. clandestinus* than for *S. asper* var. *drummondii* and *S. asper* var. *macer*. Representative specimens from garden and wild populations are shown in Figures 4-7.

Variation Among Taxa

After taxa were delimited, population samples except 1044, 1048, 1101, and 1110 were grouped by taxa. The range, $\bar{x}$, s^2, and s were computed for variables 1-15, 18-20, 28, and 29; also, F and t values among taxa were computed. F and t values were not computed for variables 18-20 for *S. asper* var. *macer* because only one observation was recorded. The results are given in Tables 7 and 8.

Table 7. Significant F values among taxa

	S. asper var. *asper*	*S. asper* var. *drummondii*	*S. asper* var. *macer*
S. asper var. *drummondii*	all except 1, 11, 15, 20, 28		
S. asper var. *macer*	5, 6, 8, 10, 14 28, 29	4, 6, 9, 10, 12 13, 14, 28	
S. clandestinus	all except 1, 19	all except 4, 14, 28	all except 1, 2, 6, 8, 11, 12

Table 8. Significant t values among taxa

	S. asper var. *asper*	*S. asper* var. *drummondii*	*S. asper* var. *macer*
S. asper var. *drummondii*	all		
S. asper var. *macer*	all except 1, 11	all except 2, 3, 8, 10	
S. clandestinus	all except 6	all except 7	all

The results show clearly that variation among taxa is considerable. Although the F and t values are significant for the majority of variables, the ranges of variation are extensive enough to exclude variables 1, 6-7, 10-15, 19, 28, and 29 to separate the population samples by taxa.

Variables 2-5, 8-9, 18, and 20 are useful in separating the taxa. Data for these variables are summarized in Table 9. Although the range of variation for variable 4 is considerable in all

Figure 6. Wild and garden-grown plants of *S. asper* var. *macer*. A. Wild. B. Garden-grown. Line scale = 1 cm. From Riggins 1029.

Figure 7. Wild and garden-grown plants of *S. clandestinus*. A. Wild. B. Garden-grown. Line scale = 1 cm. From Riggins 1036.

taxa, it is included to show that *S. clandestinus* has a shorter sheath. Because several collections were made before fruit was set, data for variables 18 and 20 are based on fewer observations. The usefulness of these variables in separating the population samples can be questioned.

DISCUSSION

Taxonomic Treatment

Throughout this paper I have referred to the taxa as I recognize them and have presented evidence for their delimitation. My taxonomic treatment is based upon the simultaneous evaluation of the variation within and among local populations that share certain traits.

The presence or absence of rhizomes did not vary within populations. Within-population variability for presence or absence of lemma pubescence and gelatinous pericarp was recorded for four Texas populations. Considerable variation within and among populations was recorded for leaf pubescence.

Much variation was recorded for the continuous and discrete variables and discrete variables and the ratios. The variation, however, does not take the same form in all populations. Within any single population, some characters are highly variable, and other characters are slightly variable. For any single character, variation is greater among populations than within populations. The range of variation is not the same within all populations; extensive variability is observed in some populations, whereas restricted variability is observed in others. Variation in several characters is more or less normally distributed from one extreme to another with all degrees of intermediacy represented. A few characters are bimodally distributed and are diagnostic in separating taxa.

Table 9. Ranges and means of taxonomically useful variables

VAR. NO.	*S. asper* var. *asper*	*S. asper* var. *drummondii*	*S. asper* var. *macer*	*S. clandestinus*
2	(1.4) 2.0 - 5.0 $\bar{x}$ = 2.8	1.0 - 2.0(2.5) $\bar{x}$ = 1.5	0.7 - 2.2 $\bar{x}$ = 1.5	0.8 - 3.0 $\bar{x}$ = 1.7
3	2.0 - 35.5 $\bar{x}$ = 16.0	2.0 - 14.0(17.0) $\bar{x}$ = 9.4	4.0 - 9.0(19.0) $\bar{x}$ = 8.6	0.2 - 11.0 $\bar{x}$ = 2.9
4	(9.5)11.0 - 34.0 $\bar{x}$ = 20.6	8.0 - 27.0 $\bar{x}$ =17.4	15.5 - 28.0(36.0) $\bar{x}$ = 17.4	4.0 - 21.2 $\bar{x}$ =11.3
5	(1.3) 1.5 - 6.0 $\bar{x}$ = 3.5	0.8 - 2.0 $\bar{x}$ = 1.2	0.8 - 1.7 $\bar{x}$ = 1.2	0.5 - 3.0 $\bar{x}$ = 1.5
8	12 - 35 $\bar{x}$ = 21.2	8 - 18 $\bar{x}$ =11.8	7 - 16 $\bar{x}$ = 12.1	(3) 5 - 18 $\bar{x}$ =10.0
9	30 - 75 $\bar{x}$ = 51.3	16 - 36 $\bar{x}$ =25.9	14 - 42 $\bar{x}$ = 27.5	9 - 38 $\bar{x}$ =19.7
18	1.0 - 1.8 $\bar{x}$ = 1.4	1.1 - 1.7 $\bar{x}$ = 1.4	1.5	1.5 - 3.5 $\bar{x}$ = 2.3
20	1.1 - 2.1 $\bar{x}$ = 1.5	1.3 - 2.5 $\bar{x}$ = 2.1	2.5	(1.5)2.0 - 4.8 $\bar{x}$ = 2.9
16	1	1	1	1, 2, 3
17	absent	absent	absent	present
24	absent	absent	present	present, absent
25	present	present	absent	absent

Morphological variation of some characters is geographic and is expressed as clinal and mosaic patterns. A north-to-south clinal variation was observed for culm width, sheath width, number of primary panicle branches, number of spikelets/cm^2, floret width, and fruit length to width. Clinal variation in palea length was recorded for *S. clandestinus*.

Cluster analyses of 66 population samples (OTU's) showed that the populations were phenetically distinct. A consistent phenetic relationship among OTU's of *S. asper* var. *drummondii*, *S. asper* var. *macer*, and *S. clandestinus* was seen. OTU's of *S. asper* var. *asper* showed little phenetic relationship to the OTU's of the other taxa. The overall relationships within and between the OTU's were more defined when the cluster analyses were based on fewer variables. Characteristic patterns of similarities and dissimilarities of the OTU's from particular geographical areas were observed. The patterns reflect similar or dissimilar population structures resulting from specialization and adaptation to the local environment.

Genetic control for the presence or absence of lemma pubescence, gelatinous pericarp, rhizomes, and to some extent the number of lemma nerves was demonstrated in plants grown under uniform conditions. The variation in certain continuous and discrete characters was slightly modified in the garden environment but remained diagnostic in separating the populations by taxa. Apparently the ranges of variation are under genetic control. Other characters were highly modified in the garden environment and are apparently environmentally controlled.

The amounts and kinds of variation in populations of the *S. asper* complex are undoubtedly affected by the breeding system. Members of the *S. asper* complex are autogamous, but outcrossing can occur within the populations. Outcrossing between populations is possible but probably occurs very rarely. Recent theoretical and experimental studies show that the population structure of inbreeding species is highly complicated, is genetically variable, and cannot be predicted by any single factor. Rather it is the "result of an integration of breeding into the totality of genetic and ecological factors affecting population structure" (Allard, Jain, and Workman, 1968). As a result, the variability in local populations reflects the adaptive qualities of the population to the local environment. The breeding system allows for the maintenance of highly adapted characters, but also allows for flexibility and survival in a changing environment. This characterization of population structure encompasses the concept of ecotypic variation but accounts for the role of the breeding system. It applies to the population structure exhibited by the *S. asper* complex.

Variation observed in the population samples was supplemented with data from herbarium specimens. The data are incorporated into descriptions given with each taxon. Herbarium studies also provided distribution data and further information of local population structure.

Sporobolus asper var. *pilosus* is known only by herbarium specimens from Ellis, Gove, and Hamilton Cos., Kansas. The specimens are easily recognized by the pilose blades. Otherwise they resemble specimens from New Mexico and Utah, and are regarded as representatives of locally adapted populations, being included in *S. asper* var. *asper.*

The characters that distinguished population samples of *S. asper* var. *asper* and *S. asper* var. *drummondii* showed overlapping ranges of variation. Intermediates between the varieties are shown by Tharp 511-523, Shinners 16733, Gould 7841, and Mahler 4117. The taxa cannot be distinguished by any single character; the association of the characters must be considered.

In addition to the presence of rhizomes in *S. asper* var. *macer,* they are also present in some populations of *S. clandestinus* from Jasper Co., Missouri; Osage Co., Oklahoma; and several locations in East Texas. Fernald and Long 11524 from Gates Co., North Carolina, also has rhizomes. The rhizomatous populations of *S. clandestinus* occur in sandy soil and often in pine woods. Several of the specimens have extremely short lemmas with three nerves and short appressed hairs at the base. The relationships of the taxa are not clarified on a cytological basis. Probably the taxa were derived from parental populations with $x = 9$ and are hexaploid.

Greatest diversity of the complex is in the southwestern areas of its geographical range, particularly in Texas, where all taxa are represented. *Sporobolus clandestinus* occurs primarily in the coastal plain province. *Sporobolus asper* var. *macer* has a restricted distribution in pine woods areas of Mississippi, Louisiana, Arkansas, and Texas. *Sporobolus asper* var. *drummondii* occurs from Alabama to Texas and Missouri, but is most abundant in Texas. *Sporobolus asper* var. *asper* is most abundant in northern areas that were glaciated.

McMillan (1959) has postulated three primary points for the postglacial distribution of grasslands vegetation. One was in southern Oklahoma and northern Texas, another was in the southeastern United States, the third was a western semimontane area such as Colorado Springs, Colorado.

The past history of the *S. asper* complex can be postulated assuming that parental populations were self-compatible, variable, and centered in Texas. Subsequent interbreeding, backcrossing, and migration would have resulted in the establishment of different populations. Within the populations variability could be retained by complex interactions of the breeding system, genetic, and ecological factors affecting the population structure. As a result of the selection and maintenance of the diverse variability, the *S. asper* complex became differentiated into local populations, which reflected the adaptive qualities to their local environment. Populations with pubescent lemmas may have migrated from Texas toward the east and differentiated into *S. clandestinus*. Populations with rhizomes may have become localized in pine woods areas, and those with glabrous lemmas differentiated into *S. asper* var. *macer*. Populations of *S. asper* var. *drummondii* probably differentiated near the parental populations but did not migrate into large geographical areas. Populations that could migrate into northern, previously glaciated areas differentiated into *S. asper* var. *asper*.

Key to Taxa

1. Lemma pubescent; pericarp loose when moist; Massachusetts to Florida and Texas to Kansas, Iowa, Wisconsin, and Indiana . . . . *S. clandestinus*
1. Lemma glabrous; pericarp gelatinous when moist 2
2. Rhizomes present; pine woods areas of Mississippi, Louisiana, Arkansas, and Texas . . . . *S. asper* var. *macer*
2. Rhizomes absent 3
3. Culms 1.0 - 2.0(2.5) mm thick; terminal sheath 0.8 - 2.0(2.5) mm wide; panicles with 8-18 primary branches, lax, spikelets 16-36/cm^2; Alabama to Texas, Oklahoma, Kansas, and Missouri . . . . *S. asper* var. *drummondii*
3. Culms (1.4) 2.0 - 5.0 mm thick; terminal sheath (1.3) 1.5- 6.0 mm wide; panicles with 12-35 primary branches, crowded, dense, spikelets 30-75(88)/cm^2; Vermont to North Carolina, Mississippi, Texas and North Dakota, New Mexico, Colorado, Utah, and Washington . . . . *S. asper* var. *asper*

Sporobolus asper (Michx.) Kunth var. *asper* (Figure 8)

Sporobolus asper (Michx.) Kunth, Rev. Gram. 1:68. 1829! *Agrostis asper* Michx. Fl. Bor. Amer. 1:52 1803! Type P. Fragment US! Photograph US! Isotype P! Michaux, Illinois. *Vilfa aspera* (Michx.) Beauv. Ess. Agrost. 16:147. 1812! *Muhlenbergia aspera* Trin. ex. Kunth, Enum, Pl. 1:210. 1833! pro syn.

Agrostis composita Poir. in Lam Encycl. Suppl. 1:254. 1810! Type not located. Bosc, Carolina. *Vilfa composita?* (Trin.) Beauv. Ess. Agrost. 16:147. 1812! *Muhlenbergia composita?* Trin. ex. Kunth, Enum. Pl. 1:229. 1833! pro syn. *Sporobolus compositus* (Poir.) Merr. U.S. Dept. Agr. Div. Agrost. Cir. 35: 6. 1901!

Agrostis involuta Muhl. Descr. Gram.:72. 1817! Type PH! Fragment US! Muhlenberg 114, Pennsylvania.

Vilfa hookeri Trin. Acad. St. Petersb. Mem. VI. Sci. Nat. 6:106. 1840! Type E! Fragment US! Isotypes PE, W. Fragments US! Isotypes GH! MO! Drummond 306, Texas. *Sporobolus asper* var. *hookeri* (Trin.) Vasey, Descr. Cat. Grasses U.S.: 43. 1885!

Sporobolus pilosus Vasey, Bot. Gaz. 16:26. 1891! Type US! Isotypes US! Smyth 217, Coolidge, Kansas, 1890. *Sporobolus asper pilosus* (Vasey) Hitchc. Biol. Soc. Wash. Proc. 41:161. 1938!

Although the type of *A. composita* has not been located, there is little doubt that Poiret's description pertains to *S. asper* var. *asper*.

The Drummond 306 collection apparently consisted of different plants that were subsequently designated 306 and 306 bis. The type of *V. hookeri* Trin. is Drummond 306, and the type of *V. drummondii* Trin. is Drummond 306 bis. Hitchcock (1951) considered the circumscriptions as synonymous and recognized the combination *S. asper* var. *hookeri* (Trin.) Vasey. Trinius' description of *V. hookeri* does not agree with Hitchcock's description of *S. asper* var.

Figure 8. *S. asper* var. *asper*. A. Habit. B. Inflorescence. C. Culm base. Line scale = 1 cm. D. Spikelet. E. Floret. Line scale = 1 mm. From Riggins 1001.

hookeri. Moreover, the type of *V. hookeri* is not *S. asper* var. *hookeri* sensu Hitchcock. Rather, the description and type of *Vilfa hookeri* agree with *S. asper* var. *asper*. The description and type of *V. drommondii* agree with Hitchcock's *S. asper* var. *hookeri*. In accordance with Articles 7 and 56 (Stafleu et al., 1972), *Vilfa hookeri* and its combinations are synonymous of *S. asper* var. *asper*.

Perennial, tufted; culms 40.0 - 150.0 cm tall, erect, (1.2) 2.0 - 4.0 (5.0) mm wide; lower sheaths glabrous, rarely ciliate along the midrib, collar pubescent to pilose, rarely glabrous, blades scabrous, frequently pubescent, rarely pilose; sheaths usually as long as or longer than the internodes, terminal sheath (9.5) 11.0 - 36.0 (46.0) cm long, (1.3) 1.5 - 6.0 mm wide when folded, length to width 15.0 - 175.0; terminal blade 2.0 - 35.0 cm long; panicles 2 - 6, 9.0 - 53.0 cm long, 1.5 - 10.0 mm wide, length to width 28.0 - 381.0, primary branches 12 - 35, contracted, frequently included in the sheath, dense, spikelets 30 - 75 (88)/cm^2; glumes shorter than to equal to the floret, first glume 1.7 - 4.7 mm long, second glume longer, 2.5 - 6.2 mm long; lemma (3.1) 3.6 - 6.5 (6.9) mm long, 1-nerved, glabrous, obtuse or acute, the keel scabrous; palea 2.9 - 6.3 mm long, minutely pubescent between the nerves; floret 0.8 - 1.2 mm wide, length to width 2.5 - 7.2; fruit 1.0 - 1.8 mm long, 0.6 - 1.2 mm wide, length to width 1.1 - 2.4, pericarp frequently striate, becoming gelatinous when moist.

Distribution of *S. asper* var. *asper* is shown in Figure 9. Hitchcock (1951) credits *S. asper* var. *pilosus* to Montana, but I have seen no specimens from that state. The variety occurs most frequently along roadsides, railroad rights of way, and similar disturbed areas. It also occurs along the beaches of the New England coast, in the cedar glades of Tennessee, the Ozark region of Missouri, and prairies and grasslands of the central United States.

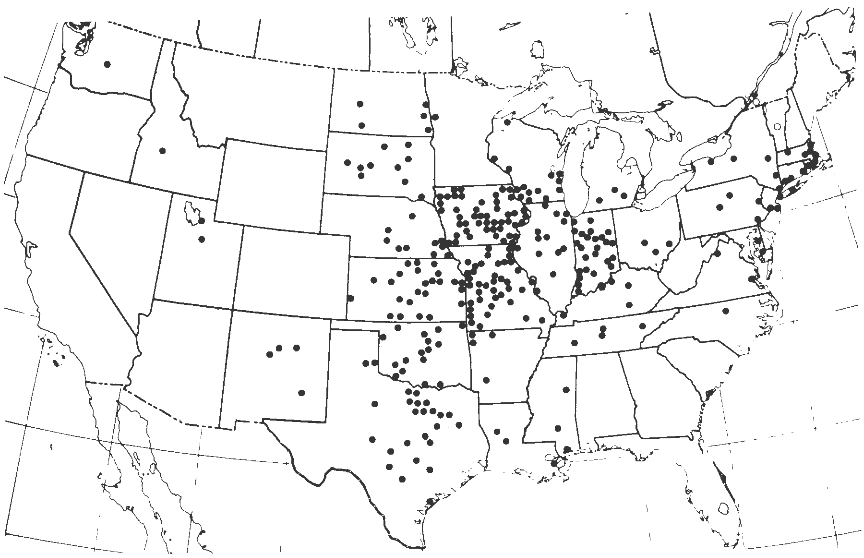


Figure 9. Distribution of *S. asper* var. *asper*.

Representative specimens: CANADA: Quebec: Ile St. Paul, Rouleau 5000 (GH). UNITED STATES: Without locality: Michaux *s.n.* (P, US). Arkansas: Boone Co., Meyers 4511 (US). Colorado: Boulder Co., Hitchcock 16243 (US); Los Animas Co., Rogers 5324 (TEX); Mesa Co., Hitchcock 2201 (US); Powers Co., Henderson 65-756 (FSU). Connecticut: New London Co., Rogers 5 (GH); New Haven Co., Harger *s.n.* (GH). Illinois: Cook Co., Bennett *s.n.* (NY); Monroe Co., Riggins 1010 (ISC); Stark Co., Chase 820 (MO, US). Indiana: Lawrence Co., Riggins 1013 (ISC); Marshall Co., Deam 66276 (IND); Vanderburgh Co., Riggins 1014 (ISC). Iowa: Black Hawk Co., Riggins 1082 (ISC); Boone Co., Riggins 1065 (ISC); Chickasaw Co., Riggins 1081 (ISC); Clayton Co., Riggins 1077 (ISC); Dickinson Co., Riggins 1083 (ISC); Henry Co., Riggins 1072 (ISC); Keokuk Co., Riggins 1071 (ISC); Marion Co., Riggins 1069 (ISC); Mahaska Co., Riggins 1070 (ISC); Story Co., Riggins 1001 (ISC); Webster Co., Riggins 1064 (ISC), Riggins 1073 (ISC); Winneshiek Co., Riggins 1080 (ISC); Wright Co., Riggins 1066 (ISC). Kansas: Barber Co., McGregor 15111 (SMU); Cowley Co., Riggins 1096 (ISC); Dickinson Co., Riggins 1093 (ISC); Ellis Co., Bibb *s.n.* (MO 1131664; WIS); Gove Co., Hitchcock 897 (GH, MO, US); Hamilton Co., Smyth 217 (US); Marion Co., Riggins 1094 (ISC); Riley Co., Riggins 1092 (ISC). Kentucky: Pulaski Co., Braun 2649 (US). Louisiana: Natchitoches P., Palmer 8855 (MO, US). Maryland: Queen Annes Co., Chase 12614 (SMU). Massachusetts: Essex Co., Morong *s.n.* (NY); Plymouth Co., Knowlton *s.n.* (US 1647189). Michigan: Kalamazoo Co., Hanes *s.n.* (US 1647189). Minnesota: Clay Co., Stevens *s.n.* (US 1723118). Mississippi: Oktibbeha Co., Chase 4443 (US). Missouri: Callaway Co., Riggins 1076 (ISC); Carter Co., Riggins 1016 (ISC); Cass Co., Riggins 1062 (ISC); Jasper Co., Riggins 1059 (ISC); Osage Co., Riggins 1074 (ISC); Pike Co., Riggins 1011 (ISC); Stoddard Co., Riggins 1015 (ISC); Vernon Co., Riggins 1061 (ISC). Nebraska: Dawson Co., Martin 518 (US); Gage Co., Riggins 1090 (ISC); Lancaster Co., Bates *s.n.* (GH), Riggins 1089 (ISC). New Jersey: Mercer Co., Benner 7519 (ISC); Monmouth Co., unknown *s.n.* (GH). New Mexico: Chaves Co., Goodding 3326 (US); San Miguel Co., Standley 5313 (GH, IND, MO, US); Santa Fe Co., Nelson Herbarium *s.n.* (WIS). New York: Onondaga Co., House 32170 (GA); Monroe Co., Baxter 5501 (GH); Suffolk Co., Farlow *s.n.* (GH); Westchester Co., Morichino 185 (ISC, SMU, TENN, WIS). North Carolina: Durham Co., Brown 51-1237 (TEX). North Dakota: Grant Co., Stevens *s.n.* (US 2078188). Ohio: Franklin Co., Gleason *s.n.* (GH); Noble Co., Brown 1301 (TAES). Oklahoma: Comanche Co., McMurry 561 (US); Love Co., Riggins 1100 (ISC); Lincoln Co., Riggins 1098 (ISC); Nobel Co., Riggins 1097 (ISC); Woods Co., Nighswonger 763 (TAES). Pennsylvania: Without locality, Muhlenberg 114 (PH, US); Centre Co., Wohl 1122 (GH, US); Lycoming Co., Wohl 15304 (SMU). Rhode Island: Kent Co., Congdon 9190 (GH, MO). South Dakota: County unknown, Griffiths 752 (US); Aurora Co., Wilcox *s.n.* (TAES 4925, US 746577); Jackson Co., Gillespee 1383 (ISC). Tennessee: Knox Co., Underwood *s.n.* (TENN); Rutherford Co., Riggins 1122 (ISC); Wilson Co., Riggins 1005 (ISC), Riggins 1008 (ISC). Texas: Without locality, Drummond 306 (E, US); Aransas Co., Tharp 7921 (TEX); Bexar Co., Silveus 2151 (TEX); Brazos Co., Gould 7298 (TAES); Dallas Co., Reverchon 2251A (TAES, US); Montague Co., Shinners 16388 (SMU); Stonewall Co., Cory 15749 (GH, TAES). Utah: Davis Co., Silveus 3307 (TEX); Utah Co., Mengies 8004 (MO, US). Vermont: Charlotte, Pringle 251 (US 825244). Virginia: New Kent Co., Fernald and Long 11525 (GH, US); Shenandoah Co., Hunndwell and Griscom 15109 (GH). Washington: Kittitas Co., Cotton 1797 (US). Wisconsin: Bayfield Co., Shinners and Catenhusen 2884 (WIS); Crawford Co., Riggins 1078 (ISC); Milwaukee Co., Shinners 3085 (GH, ISC, MIL); Pierce Co., Riggins 1086 (ISC).

Sporobolus asper var. *drummondii* (Trin.) Vasey (Figure 10)

Sporobolus asper var. *drummondii* (Trin.) Vasey, U.S. Natl. Herb. Contrib. 3:60. 1892! *Vilfa drummondii* Trin. Acad. St. Petersb. Mem. VI. Sci. Nat. 6:106. 1840! Type E! Fragment US! Isotype PE. Fragment US! Isotypes GH! MO! Drummond 306 bis, Texas 1835. *Sporobolus drummondii* (Trin.) Vasey, Descr. Cat. Grasses U.S.: 44. 1885!

Sporobolus attenuatus Nash in Small, Fl. Southeast. US.:123. 1903! Type US! Kearney 183, Starkville, Mississippi, 30 September 1886.

Figure 10. *S. asper* var. *drummondii*. A. Habit. B. Inflorescence. C. Clum base. Line scale = 1 cm. D. Spikelet. E. Floret. Line scale = 1 mm. From Riggins 1043.

Perennial, tufted; culms 55.0 - 170.0 cm tall, erect, 1.0 - 2.0 (2.5) mm wide; lower sheaths glabrous, collar pubescent, sometimes glabrous, blades usually glabrous, occasionally pubescent; sheaths shorter than the internodes; terminal sheath 8.0 - 18.5 cm long, 0.8 - 1.8 (2.5) mm wide when folded, length to width (45.0) 65.0 - 233.0; terminal blade (0.25) 2.0 - 14.0 (17.0) cm long; panicles 2 - 6, 8.5 - 53.0 cm long, 1.0 - 9.0 mm wide, length to width 28.7 - 381.8, primary branches 8 - 18, lax, usually exserted from the sheath, spikelets 16 - 36/cm^2; glumes shorter than to equal to the floret, first glume 1.7 - 3.7 mm long, second glume longer 2.4 - 4.2 mm long; lemma 2.7 - 4.2 mm long, glabrous, obtuse to acute, palea 2.0 - 4.1 mm long, minutely pubescent between the nerves; floret 0.5 - 1.2 mm wide, length to width 2.5 - 7.0; fruit 1.1 - 1.7 mm long, 0.5 - 0.9 mm wide, length to width 1.3 - 2.5, pericarp frequently striate, becoming gelatinous and slipping from the seed when moist.

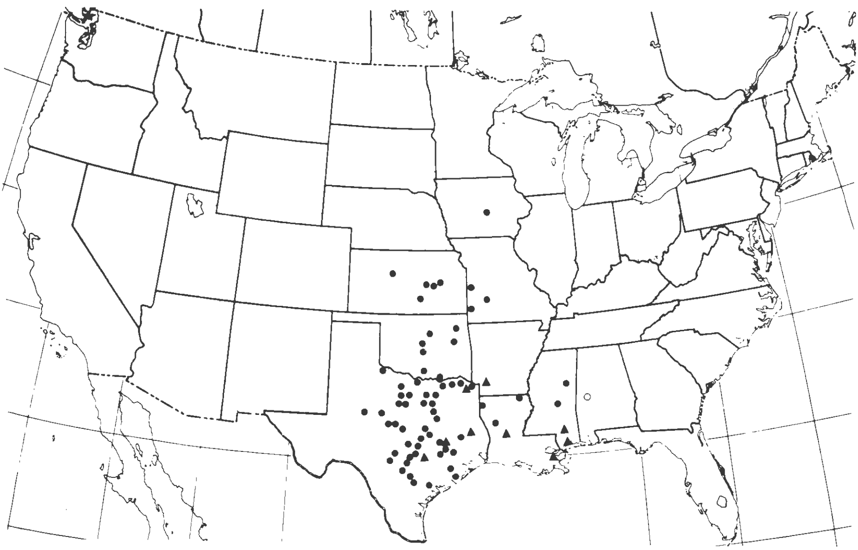


Figure 11. Distribution of *S. asper* var. *drummondii* and *S. asper* var. *macer.* ● is *S. asper* var. *drummondii.* ○ is *S. asper* var. *drummondii* with locality. ▲ is *S. asper* var. *macer.*

As shown in Figure 11, *Sporobolus asper* var. *drummondii* is most abundant in Texas and occurs only occasionally in Alabama, Mississippi, Louisiana, and Missouri. Steyermark (1963) recognized the variety as widespread in Missouri, and Pohl (1966) noted that the variety was occasionally found on dry morainic hills in Iowa. The one specimen from Iowa bears the note "This low slender growth is probably due to mowing in previous seasons and to late mowing." I have observed that plants of *S. asper* var. *asper* that have been mowed or burned have stunted, narrow culms. The Pammel specimen, however, is indistinguishable from other specimens of *S. asper* var. *drummondii.*

The variety occurs along roadsides and railroad rights of way in Kansas, Oklahoma, and Texas. It is particularly abundant in the Hill Country and Edwards Plateau regions of Texas where it is usually associated with live oak. Habitat data from other areas is scanty.

Representative specimens: UNITED STATES: Alabama: Without locality, Buckley *s.n.* (MO 2000978). Iowa: Story Co., Pammel 1462 (ISC). Kansas: Ellis Co., U.S.D.A. 652 (US), Bibb *s.n.* (GH, MO 1132286, TAES, TENN, WIS); Marion Co., Riggins 1095 (ISC); Sedgwick Co., Bartley 1222 (US). Louisiana: Caddo P., Thieret 21143 (US); Natchitoches

P., Palmer 8739 (MO). Mississippi: Oktibbeha Co., Kearney 83 (US); Scott Co., Swallen 2331 (US). Missouri: Rock Creek, Bush 5301 (GH, MO, US); Jasper Co., Palmer 3479 (MO), Palmer 3485 (GH, MO). Oklahoma: Mayes Co., Bibb 5936 (US); Muskogee Co., Wallis 5506 (SMU): Oklahoma Co., Smith 215 (GA). Texas: Without locality, Drummond 306 bis (E,US 997649); Brazoria Co., Rogers 6570 (ISC, TEX); Brazos Co., Gould 7814 (TAES); Brown Co., Riggins 1110 (ISC); Comal Co., Reeder 4558 (US); Dallas Co., Lundell 11978 (ISC); Jack Co., Riggins 1101 (ISC); Kimble Co., Riggins 1113 (ISC); Mills Co., Riggins 1111 (ISC); Mitchell Co., Pohl 4640 (ISC, SMU); Montgomery Co., Gould 5388 (SMU, TAES); Stephens Co., Riggins 1107 (ISC), Gould and Roy 11758 (TAES, US); Tarrant Co., Shinners 16733 (SMU); Taylor Co., Mahler 4117 (TAES); Travis Co., Tharp 51-523 (TEX).

Sporobolus asper var. *macer* (Trin.) Shinners (Figure 12)

Sporobolus asper var. *macer* (Trin.) Shinners, Rhodora 56:30. 1954! *Vilfa macra* Trin. Acad. St. Petersb. Mem. VI. Sci. Nat. 6:79. 1940! Type LE. Fragment US! Louisiana. *Sporobolus macrus* (Trin.) Hitchc., Am. Journ. Bot. 2:203. 1915!

Perennial, rhizomatous; culms (40.0, 50.0) 70.0 - 125.0 cm tall, erect, 0.7 - 2.2 mm wide; lower sheaths glabrous, collar pubescent rarely pilose, blades softly pubescent; sheaths usually shorter than the internodes, terminal sheath 11.8 - 36.0 cm long, 0.7 - 2.5 mm wide, length to width (86.0) 115.0 - 360.0; terminal blade 2.0 - 9.0 cm long; panicles 2 - 4, 16.5 - 25.0 (56.0) cm long, 1.0 - 5.5 mm wide, length to width 73.0 - 225.0, primary branches 7 - 16, lax, usually exserted from the sheath; spikelets not crowded, 14 - 42/cm^2; glumes shorter than to equal to the floret, first glume 2.2 - 3.0 mm long, second glume longer 3.0 - 4.9 mm long; lemma 2.7 - 5.4 mm long, 1-nerved, glabrous, obtuse to acute; palea 2.7 - 5.0 mm long, minutely pubescent between the nerves; floret 0.6 - 0.9 mm wide, length to width 3.0 - 7.0; fruit 1.3 - 1.6 mm long; 0.6 - 0.9 mm wide, length to width 1.5 - 2.5, pericarp becoming gelatinous and slipping from the seed when moist.

Sporobolus asper var. *macer* is rare and has a restricted distribution (Figure 11). I have collected *S. asper* var. *macer* in Hempstead Co., Arkansas; Rapides P., Louisiana; Forrest Co., Mississippi; and Angelina Co., Texas. The collections are from shaded, relatively undisturbed pine woods with little undergrowth. The Rogers 4147, Chase 4341, and Silveus 2397 collections are from similar areas. Habitat description of the Reeves 1220 Collection is "vacant lot in sandy soil." The Letterman labels cite locality as "R. R. line in Texarkana."

Representative specimens: UNITED STATES: Arkansas: Hempstead Co., Riggins 1057 (ISC). Louisiana: Without locality (US 556863); Rapides P., Riggins 1049 (ISC); St. Bernard P., Drummond *s. n.* (GH, MO 2001002). Mississippi: Forrest Co., Riggins 1121 (ISC), Rogers 4147 (ISC); Harrison Co., Chase 4341 (ISC, US). Texas: Angelina Co., Riggins 1037 (ISC); Bastrop Co., Silveus 2397 (TEX, US); Bowie Co., Letterman *s. n.* (MO 768615); Brazos Co., Reeves 1220 (TAES, US).

Sporobolus clandestinus (Biehler) Hitchc. (Figure 13)

Sporobolus clandestinus (Biehler) Hitchc. Man. Grasses U.S. ed 2:418. 1951! *Sporobolus clandestinus* (Spreng.) Hitchc. U.S. Natl. Herb. Contrib. 12:150. 1908! *Agrostis clandestina* Biehler, Pl. Nov. Herb. Spreng. Cent.:68. 1807! Type PH! Fragment US! Muhlenberg 115, Pennsylvania. *Muhlenbergia clandestina* (Spreng.) Trin. Gram. Unifl.:190. 1824! *Vilfa clandestina* (Spreng.) Nees ex. Steud. Nom. Bot. ed. 2, 2:767. 1841! *Sporobolus asper* var. *clandestinus* (Biehler) Shinners, Rhodora 56: 31. 1954!

Agrostis longifolia Torr. Fl. North. and Mid. U.S. 1:52. 1826! Type NY. Photograph ISC! *Vilfa longifolia* Torr. in A. Gray, N. Am. Gram. and Cyp. 1:4. 1834! *Sporobolus longifolius* (Torr.) Wood, Classbook ed. 1861:775. 1861!

Sporobolus canovirens Nash in Britton, Man.:1042. 1901! Type NY! Photograph US! Kellerman, St. George, Kansas, 3 September 1890.
Sporobolus asper var. *canovirens* (Nash) Shinners, Rhodora 56:30. 1954!

Sporobolus clandestinus var. *canovirens* (Nash) Steyerm. & Kucera, Rhodora 63:24. 1961!

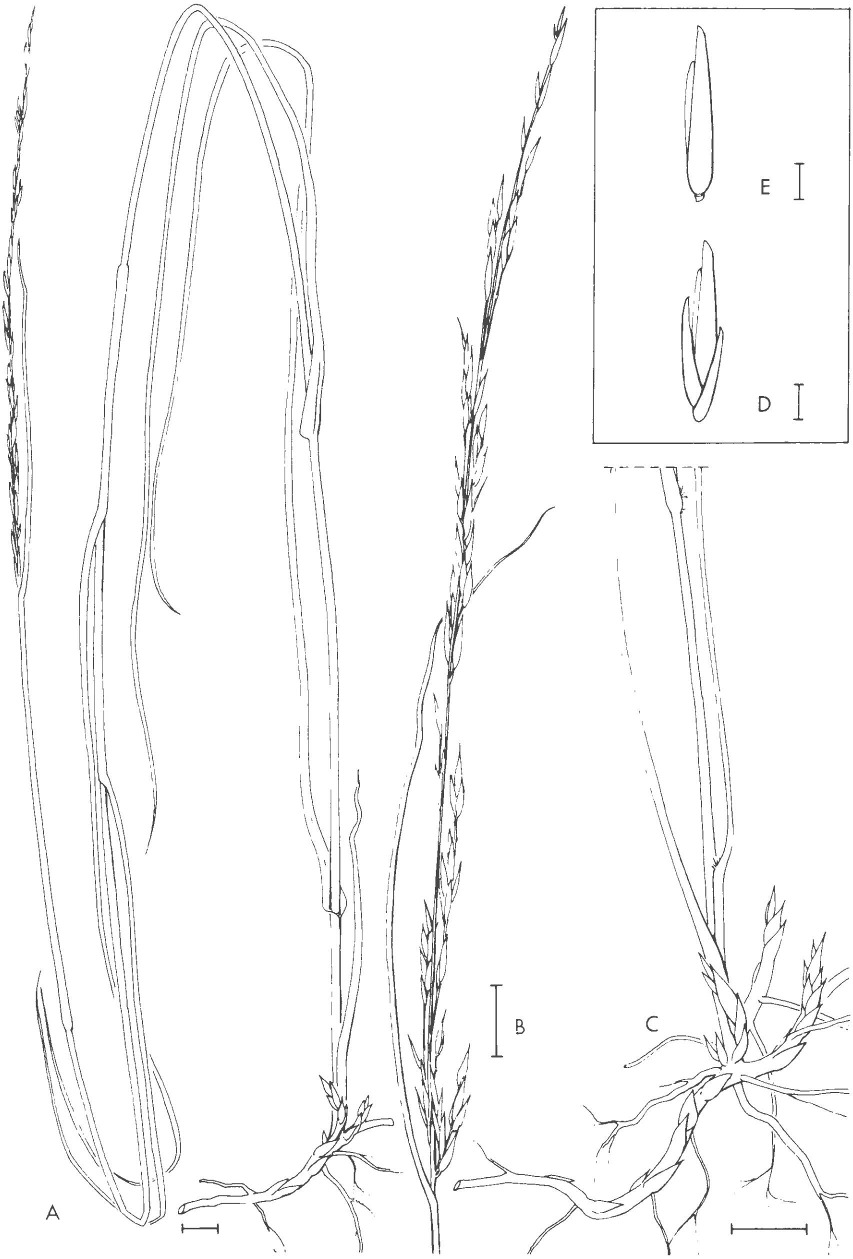


Figure 12. *S. asper* var. *macer.* A. Habit. B. Inflorescence. C. Culm base with rhizomes. Line scale = 1 cm. D. Spikelet. E. Floret. Line scales = 1 mm. From Riggins 1029.

Biehler's work, issued 30 May 1807, contained new names and descriptions for seven grasses. Among the seven was *Agrostis clandestina*, the basionym of *S. clandestinus*. Sprengel included the work unaltered and without reference to his student in "Novarum Plantarum ex Herbario Meo Centuria," which was issued later in 1807 (Fernald, 1945). Hitchcock was unaware of Biehler's work until Fernald discovered it.

Agrostis longifolia and its combinations have been cited by Hitchcock (1951) as synonyms of *S. asper* var. *asper*. Torrey's (1826) description clearly refers to *S. asper* var. *asper*. Rickett and Gilly (1942) designated as the type the specimen in the bound volume of North American Gramineae and Cyperaceae (Gray, 1834) in the Herbarium of the New York Botanical Garden. The type specimen is *S. clandestinus*[4].

Glyceria stricta Buckl. was cited as a synonym of *S. asper* by Hitchcock (1951). Buckley's (1863) description was based upon a panicle of *S. clandestinus* with proliferating spikelets. Because the name was based upon a monstrosity, it is rejected in accordance with Article 71 (Stafleu et al., 1972).

Perennial, occasionally rhizomatous; culms solitary or tufted, frequently glaucous, erect, 40.0 - 170.0 cm tall, 0.7 - 3.0 (3.8) mm wide; lower sheaths frequently pubescent, collar usually pubescent, rarely pilose, blades frequently pubescent, rarely pilose; terminal sheath 4.0 - 19.0 (23.0) cm long, 0.5 - 3.0 cm wide, length to width 29.0 - 170.0 (230.0); terminal blade 0.2 - 11.0 cm long; panicles 2 - 5, the lower included in the sheaths, terminal usually exserted, rarely included, 5.0 - 50.5 cm long; 1.0 - 11.0 mm wide, length to width 16.1 - 130.0, primary branches (3) 5 - 15 (18), compressed to lax, spikelets 9 - 38/cm^2; glumes shorter rarely equal to the floret, first glume 1.5 - 6.2 mm long, second glume longer 2.5 - 6.5 mm long; lemma (2.2) 3.0 - 7.0 (7.4) mm long, 1-, 2- or 3-nerved, pubescent, frequently mottled; palea (2.2) 3.0 - 9.3 (11.0) mm long, pubescent, equal to or 0.1 to 11.0 mm longer than the lemma; floret 0.7 - 1.6 mm wide, length to width 2.8 - 10.0 (14.2); caryopsis 1.5 - 3.5 mm long 0.5 - 1.1 mm wide, length to width (1.5) 2.0 - 4.8 (6.0), pericarp smooth, rarely striate, becoming loose when moist, but not slipping from the seed.

Sporobolus clandestinus occurs along the eastern coastal plain and in the southeastern United States to Texas, Oklahoma, Kansas, and Missouri. The species is rare in the glaciated areas of Massachusetts, Connecticut, Indiana, Illinois, Wisconsin, and Iowa. Except for one collection from Cocke Co., Tennessee, it is absent in the Southern Appalachian Mountains (Figure 14).

The species occurs primarily in sandy soils along the coast and along roadsides in the interior United States. It is found in pine woods in the southeastern states, in live oak-pin oak woods in Texas and Oklahoma, and in cedar glades in Tennessee and Missouri. The Iowa, Wisconsin, and northern Illinois collections are from sand prairies.

Representative specimens: UNITED STATES: Without locality, (GH, MO 2000970, NY). Alabama: Franklin Co., Isely 4595 (ISC); Marengo Co., Kral 29618 (SMU); Mobile Co., Kral 29729 (TENN). Arkansas: Benton Co., Plank *s. n.* (MO 1719379); Pike Co., Riggins 1058 (ISC); Sharp Co., Riggins 1017 (ISC); Union Co., Hoiberg 376 (SMU). Connecticut: New Haven Co., Woodward *s. n.* (US 1038367). Delaware: New Castle Co., Canby 297(TAES). Florida: Alachua Co., Swallen 5625 (US); Dade Co., Eaton 225 (GH); Franklin Co., Chapman Herbarium *s. n.* (MO 985579); Jackson Co., Kral and Godfrey 5949 (FSU); Manatee Co., Combs 1328 (US, GH). Georgia: Clarke Co., Duncan 23535 (ISC); DeKalb Co., Hitchcock 1296 (GH, WIS); McIntosh Co., Duncan 20640 (GH, ISC, SMU, TEX, WIS); Stewart Co., Latimer *s. n.* (NY). Illinois: Madison Co., Buckley *s. n.* (MO 2000977, NY); Winnebago Co., Fell and Duller 55662 (WIS). Indiana: Elkhart Co., Deam 26362 (GH, IND). Knox Co., Potzger 4674 (IND, TEX). Iowa: Henry Co., McDonald 2963 (ISC); Jefferson Co., McDonald 3027 (ISC). Louisiana: Calcasieu P., Chase 4431 (ISC); Lincoln P., Moore 6514 (GH, US); Natchitoches P., Riggins 1031 (ISC); Sabine P., Riggins 1033 (ISC). Maryland: Montgomery Co., Herman 9873 (MO). Massachusetts: Essex Co., Oakes *s. n.* (NY). Mississippi: Forrest Co., Riggins 1120 (ISC); Marion Co., Riggins 1118 (ISC); Oktibbeha Co., Tracy *s. n.* (NY, TAES 4835). Missouri: Dunklin Co., Bush 117 (GH, MO); Jasper Co., Palmer 3216 (MO); McDonald Co., Palmer 60937 (ISC, SMU, WIS); Montgomery Co., Riggins 1088 (ISC); Shannon Co., Bush 1741 (MO); Stoddard Co., Steyermark 80348 (SMU). New Jersey: Cape May Co., Stone *s. n.* (GH). North Carolina: Brunswick Co., McCarthy *s. n.* (NY); Cleveland

[4]Holmgren, O., New York, New York. Private communication. Type specimen of *Agrostis longifolia*. 1972.

Figure 13. *S. clandestinus.* A. Habit. B. Inflorescence. C. Culm base. Line scale = 1 cm. From Riggins 1036. D-H. Florets illustrating variation in palea length. D. From Swallen 5625, Alachua Co., Florida. E. From Riggins 1120, Forrest Co., Mississippi. F. From Riggins 1009, Wilson Co., Tennessee. G. From Riggins 1050, Hamilton Co., Texas. H. From Shinners 16810, Brown Co., Texas. Line scale = 1 cm.

Co., Ahles and Leisner 19118 (SMU); Durham Co., Brown 51-1239 (TEX); Gates Co., Fernald and Long 11525 (GH, US). Oklahoma: Major Co., Engleman 579 (SMU, TEX, US); Murray Co., Riggins 1099 (ISC); Stephens Co., Shinners 30782(ISC, SMU).South Carolina: Charleston Co., Chase 4535 (ISC); Orangeburg Co., Ravenal *s. n.* (GH); Pickens Co., Swallen 6713 (GH). Tennessee: Cocke Co., Kearney 951 (NO, NY, US); Humphreys Co., Rogers 42727 (TENN); Meigs Co., Sharp 27742 (TENN); Wilson Co., Riggins 1009 (ISC). Texas: Bastrop Co., Silveus 2397 (TAES), C. C. C. Boy *s. n.* (TEX 10939); Bell Co., Coleman *s. n.* (TAES); Blanco Co., Riggins 1116 (ISC); Brazos Co., Reardon 59 (TAES), Willman 65-30 (TAES); Camp Co., Turner 22-F (TAES); Comal Co., Riggins 1115 (ISC); Coryell Co., Riggins 1045 (ISC); Fannin Co., Riggins 1056 (ISC); Hamilton Co., Riggins 1049 (ISC); Riggins 1050 (ISC); Gregg Co., Shinners 16234 (ISC); Gonzales Co., Plant 56 (US); Jack Co., Riggins 1101A (ISC); Kendall Co., Riggins 1114 (ISC); Leon Co., Riggins 1117 (ISC); Menard Co., Riggins 1112 (ISC); Mills Co., Riggins 1110A (ISC); Nacogdoches Co., Riggins 1036 (ISC); Red River Co., York *s. n.* (SMU, TEX 11169); Robertson Co., Duncan *s. n.* (TAES); San Saba Co., Gould 8439 (TAES, TEX); Young Co., Riggins 1102 (ISC). Virginia: Sussex Co., Fernald and Long 11233 (GH, ISC, MO); Stafford Co., Iltis 3683 (TENN). Wisconsin: Crawford Co., Fassett 20693 (ISC, MIL, SMU, US).

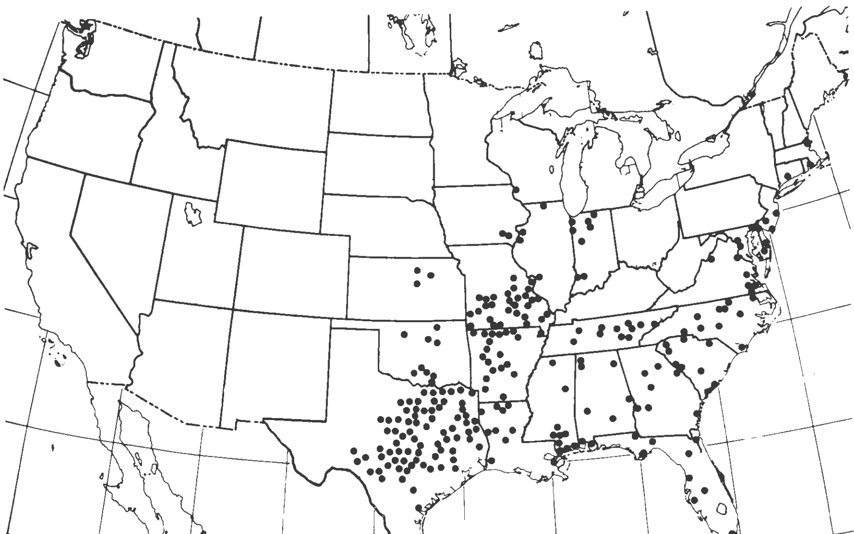


Figure 14. Distribution of *S. clandestinus*.

ACKNOWLEDGEMENTS

I thank Dr. Richard W. Pohl for his assistance and advice during the study. Thanks are also due to the members of my graduate committee: Drs. Duane Isely, Roger Landers, K. Sadanaga, and the late Jean Laffoon. The curators of the herbaria from which specimens were borrowed are acknowledged, particularly Dr. W. H. Duncan of the University of Georgia, who kindly provided transplants. I also thank Dr. William Warde for his assistance in the computer studies and statistical analyses, Diane Peake for typing the manuscript, and Marguarite Costigan for preparing the illustrations. Part of the research was financed by a grant from The Society of the Sigma Xi.

LITERATURE CITED

Allard, R. W., S. K. Jain, and P. L. Workman. 1968. The population genetics of inbreeding species. Advances in Genetics 14: 55-131.

Bowen, C. C. 1956. Freezing by liquid carbon dioxide in making slides permanent. Stain Technology 31: 87-90.

Brown, W. V. 1950. A cytological study of some Texas Gramineae. Torrey Botanical Club Bulletin 77: 63-76.

Brown, W. V. 1958. Leaf anatomy in grass systematics. Botanical Gazette 119: 170-178.

Brown, W. V., and W. H. P. Emery. 1958. Apomixis in the Gramineae: Panicoideae. American Journal of Botany 45: 253-263.

Buckley, S. B. 1863. Descriptions of plants-No. 3. Academy of Natural Sciences, Philadelphia, Proceedings (1862): 88-100.

Fernald, M. L. 1945. Some inconvenient upheavals of familiar names and author citations. Rhodora 47: 197-204.

Gerlack, A. C., editor. 1970. United States Geological Survey. The National Atlas of the United States of America. Washington, D. C.

Gould, F. W. 1968. Chromosome numbers of Texas grasses. Canadian Journal of Botany 46: 1315-1325.

Gray, A. 1834. North American Gramineae and Cyperaceae. Part 1. J. Post, New York.

Hitchcock, A. S. 1951. Manual of the grasses of the United States. 2nd edition revised by Agnes Chase. United States Department of Agriculture Miscellaneous Publication 200.

Jensen, W. A. 1962. Botanical histochemistry. W. H. Freeman and Company, San Francisco.

Metcalfe, C. R. 1960. Anatomy of the monocotyledons. I. Gramineae. Clarendon Press, Oxford.

McGammon, R. B., and G. Wenninger. 1970. The dendrograph. Kansas State Geological Survey Computer Contributions 48: 1-28.

McMillan, D. 1959. The role of ecotypic variation in the distribution of the central grassland of North America. Ecological Monographs 29: 285-308.

Newcomer, E. N. 1953. A new cytological and histological fixing fluid. Science 118: 161.

Pohl, R. W. 1965. Dissecting equipment and materials for the study of minute plant structures. Rhodora 67: 95-96.

Pohl, R. W. 1966. The grasses of Iowa. Iowa State Journal of Science 40: 341-566.

Pohl, R. W., and G. Davidse. 1971. Chromosome numbers of Costa Rican grasses. Brittonia 23: 293-324.

Prat, H. 1932. L'épiderme des graminées. Étude anatomique et systématique. Annales des Sciences Naturelles Botanique Série 10, 14: 119-324.

Prat, H. 1934. Contribution a l'étude systématique et histologique des Chloridées. Société Botanique de France Bulletin 81: 475-491.

Reeder, J. R. 1968. Notes on Mexican grasses VIII. Miscellaneous chromosome numbers 2. Torrey Botanical Club Bulletin 95: 69-86.

Rickett, H. W., and C. L. Gilly. 1942. Asa Gray's earliest botanical publications. Torrey Botanical Club Bulletin 69: 461-470.

Riggins, R. L. 1969. The annual cleistogamous species of *Sporobolus*. Unpublished M.S. thesis. Iowa State University Library. Ames.

Riggins, R. L. 1973. A biosystematic study of the *Sporobolus asper* complex (Gramineae). Ph.D. dissertation, Iowa State University, Ames.

Sass, J. E. 1958. Botanical microtechnique. Third edition. Iowa State University Press, Ames, Iowa.

Shinners, L. H. 1954. Notes on North Texas grasses. Rhodora 56: 25-38.

Shobe, W. R., and N. R. Lersten. 1967. A technique for clearing and staining gymnosperm leaves. Botanical Gazette 128: 150-152.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Company. San Francisco, California.

Stafleu, F. A., editor. 1972. International code of botanical nomenclature. Regnum Vegetabile 82. A. Oosthoek for I.A.P.T., Utrecht.

Steyermark, J. A. 1963. Flora of Missouri. Iowa State University Press, Ames, Iowa.

Steyermark, J. A., and C. L. Kucera. 1961. New combinations in grasses. Rhodora 61: 24-26.

Toole, V. K. 1941. Factors affecting the germination of various drop-seed grasses (*Sporobolus* spp.) United States Department of Agriculture Journal of Agricultural Research 62: 691-715.

Torrey, J. 1826. A compendium of the flora of the northern and middle states. Stacy B. Collins, New York.

IOWA STATE JOURNAL OF RESEARCH / FEBRUARY, 1977
Vol. 51, No. 3 323-325

Eragrostis contrerasii, A NEW GRASS SPECIES FROM CENTRAL AMERICA (GRAMINEAE: CHLORIDOIDEAE)[1]

Richard W. Pohl[2]

ABSTRACT. A new species of grass, *Eragrostis contrerasii*, is described from Central America. Morphology of the plant and detail of the inflorescence are illustrated.

* * *

Eragrostis contrerasii Pohl, sp. nov.

Gramen reptans annuum subsect. *Reptantibus* pertinens, ab *E. hypnoide* (Lam.) B.S.P. florum masculinum antheris tribus 1.3-1.5 mm longis, pistillo abortivo, et ab *E. reptante* (Michx.) Nees panicula patenti pedicellisque 2-6 mm longis abhorrens.

Duration indefinite, probably annual; plants spreading and forming mats or patches from decumbent, rooting stolons; internodes up to 6 cm long, ca. 1 mm thick, hollow; glabrous; nodes glabrous or minutely bearded; sheaths mostly much shorter than the internodes, keeled, striate, the margins softly short-ciliate; ligule a rather sparse ring of hairs, 0.5-0.8 mm long; leaf blades linear, 2-5 cm long, 1.5-3.0 mm wide, flat, glabrous beneath, papillose-puberulent on the nerves above; inflorescences terminal on apparently ascending portions of the culms; panicle open, narrowly ovoid, up to 8 cm long and 3 cm wide, the branches few flowered; lateral pedicels 2-6 mm long, shorter than the spikelets, the terminal ones up to 9 mm long; rachis, branches, and pedicels angular, puberulent on the angles. Spikelets laterally compressed, up to 10.5 mm long, 1.5-2.0 mm wide, linear, with 9-15 florets; lemmas disarticulating from the persistent rachilla; first glume 0.6-1.1 mm long, 1-nerved, acute, ovate 4:1 as folded; second glume 1.8-2.1 mm long, 1-3-nerved (the lateral nerves short), acute, ovate 5:1 as folded; lemmas strongly keeled, 2.0-2.4 mm long, ovate 3:1 as folded, acute, the keel scabrous near the tip; palea in staminate spikelets nearly as long as its lemma, the keels scabrous; in pistillate spikelets the palea only half as long as the lemma; lodicules truncate; staminate spikelets sometimes with abortive ovaries; anthers 3, 1.3-1.5 mm long, yellow-orange. Pistillate inflorescences and spikelets similar to the staminate ones, but the flowers having exserted plumose stigmas and lacking stamens.

Eragrostis contrerasii differs from the two other members of the subsection Reptantes in the following features. It is larger in all of its parts than either *E. reptans* or *E. hypnoides*, with longer and wider leaf blades, longer pedicels, glumes and lemmas. It differs from *E. hypnoides* in having three very long anthers in contrast to the two minute ones of the latter and in the unisexual flowers. It differs from *E. reptans* in the open inflorescence with much longer pedicels. Its somewhat intermediate position between these two species suggests that the recent acceptance of the genus *Neeragrostis* by Nicora (1962)and others for the dioecious *E. reptans* may not be tenable. The type specimen of *E. contrerasii* has only staminate spikelets, but another specimen from the Petén (Steyermark 45965) has both sexes. These

[1]The facilities of the Iowa State University Herbarium, supported by the Sciences and Humanities Research Institute, were used in the preparation of this paper. Support is acknowledged from N.S.F. Project GB 32085. Journal Paper No. J-8650 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa 50011. Project 1833. The author thanks Mr. Rupert Barneby of the New York Botanical Garden for revising the Latin diagnosis. The illustration was done by Judy Appenzeller LaMotte.
[2]Professor, Department of Botany and Plant Pathology, Iowa State University, Ames, Iowa.

collections were obtained from an area south of the known limits of the range of *E. reptans*. *Eragrostis hypnoides*, which does occur in Central America, has two minute anthers, 0.2-0.3 mm long, and possesses perfect flowers.

HOLOTYPE: Guatemala:Dept. Petén: in clearing, bordering Rio Usumacinta, about 9 km west of Lacondon, 8 March, 1962. Elias Contreras 3484. Holotype in F; isotypes in TEX; LL.

OTHER SPECIMEN: Guatemala:Dept. Petén: along Rio Machaquila, north of El Cambio, alt. 75-100 m, 25 April, 1942, J. A. Steyermark 45965. F.

LITERATURE CITED

Nicora, E. G. 1962. Revalidación del Genero de Gramineas "*Neeragrostis*" de la Flora Norteamericana. Revista Argentina de Agronomia 29(1-2): 1-11.

Figure 1. *Eragrostis contrerasii* Pohl. Drawing based on the holotype, Contreras 3484. Scale line is 1 mm long.

IOWA STATE JOURNAL OF RESEARCH / FEBRUARY, 1977
Vol. 51, No. 3 327-361

TORNADOES, FUNNEL CLOUDS, AND THUNDERSTORM DAMAGE IN IOWA DURING 1974[1]

Steve Eshelman[2] and John L. Stanford[3]

ABSTRACT. Results are reported from an exhaustive survey of severe storm events in Iowa in 1974. Much greater storm damage is revealed than might be expected from limited news media coverage or from the best other source, the Department of Commerce National Oceanic and Atmospheric Administration (NOAA) publication *Storm Data.* The latter reported 27 tornadoes in Iowa in 1974. In contrast, the present work indicates 81 separate tornado touchdowns, a three to one ratio. Long tornadoes are well reported, but brief touchdowns are evidently not as accurately documented in the usual data sources. This seems to be especially true during an outbreak when many tornadoes occur in mutual close proximity.

Although 1974 does not appear to have been an unusually bad year for tornadoes in Iowa, the total reported here is the largest number for any year since records have been kept. This record number is attributable to the systematic and careful search carried out to uncover all such reports.

A map of tornado occurrences is presented, along with a complete listing of events. Detailed descriptions of selected instances are also given.

INTRODUCTION

To aid in the interpretation of radio-noise measurements of Iowa thunderstorms, it was necessary to obtain a listing of the location and time of occurrence of severe thunderstorm events in the state. Unfortunately, our experience indicates that no one of the several usually available sources of severe weather reports is adequate by itself.

Thus, we undertook the job of preparing our own severe weather log for Iowa in 1974, when we had experimental recording stations at several locations in the state. The compilation of an accurate record of all severe weather events in Iowa proved to be a formidable task; and the compiled records themselves reveal much greater storm damage over the state as a whole than one might suspect from limited news media accounts.

Aside from the data presented here, the only other listing of tornadoes in Iowa in 1974 is given in *Storm Data,* a publication of the Department of Commerce's National Oceanic and Atmospheric Administration. For Iowa in 1974, *Storm Data* lists 27 tornadoes, approximately the average number in the past quarter century. Thus 1974 could be considered a rather average year for Iowa tornadoes.

In contrast, careful examination of the data presented here reveals 81 separate tornado touchdowns in Iowa in 1974, three times that given in *Storm Data.* An additional seven events are classed as possible tornadoes. This is the largest number of Iowa tornadoes reported in one year since records have been kept. Most of these tornadoes were of short duration; only two had path lengths exceeding 10 miles, the Grant tornado (15 mi) of May 13 and the Ankeny tornado (22 mi) of June 18.

The detailed record of severe weather events reveals a vast and largely unsuspected amount of damage in the state overall. Much of this is due to the scattered nature of the

---

[1] Supported in part by the National Science Foundation under Grant GA-31776.

[2] Research Helper, Department of Physics, Iowa State University, Ames, Iowa 50011.

[3] Professor, Department of Physics, Iowa State University, Ames, Iowa.

damage: winds blowing down a barn here and there, or the brief touchdown of a tornado damaging a farmstead somewhere else, or hail damage to crops in another county. Brief touchdowns of tornadoes seem to be observed fairly well by the public in Iowa, but do not usually rate much attention in the news media. This is especially true during a tornado outbreak: when a number of tornadoes occur in close proximity to each other, either in time or location or both, it is difficult to disentangle the various reports and some tornadic events may be overlooked.

Some subjectivity and error always occur in evaluation of tornado reports. Certainly we do not claim that our listing is free from such. However, the three-to-one difference in the two listings is too great to be dismissed lightly: the much larger number of tornado reports in our listing results from the exhaustive search carried out to uncover all such storm reports for the period. Probably 1974 was not an unusually prolific year for tornadoes in Iowa; the record number reported here is the result of many hundreds of man-hours spent in collecting, following up, and evaluating the great quantities of initial reports of tornadic storms. It thus seems worthwhile to present the results of this one-year careful survey of storm reports to give a better understanding of the magnitude of tornado and severe thunderstorm occurrences during an "average" Iowa storm season.

FORMAT AND SOURCES

Time

Times are given in 24-hour notation in Central Daylight Time. For example, "2110" would be 9:10 pm CDT.

Event

Damage reports list the type of storm event in the following five categories:
T = tornado; F = funnel cloud (not touching down); H(1") = hail, 1 inch in diameter; W = wind damage; LTNG = lightning damage

Direction

When specified, this shows the direction of movement of the event.

Location

"3W Hampton, Franklin Co." means the event was reported at three miles west of Hampton in Franklin County.

Source

Sources from which the information was obtained are specified as follows:

1 = newspaper clippings (obtained from a clipping service that covers all newspapers in the state)
2 = SELS log (severe local storm log of the National Severe Storm Forecast Center, Kansas City, supplied by courtesy of Mr. Allen Pearson, Director)
3 = Storm Data (published by the National Oceanic and Atmospheric Administration)
4 = Telephone calls or personal interviews
5 = Weather Service teletype reports

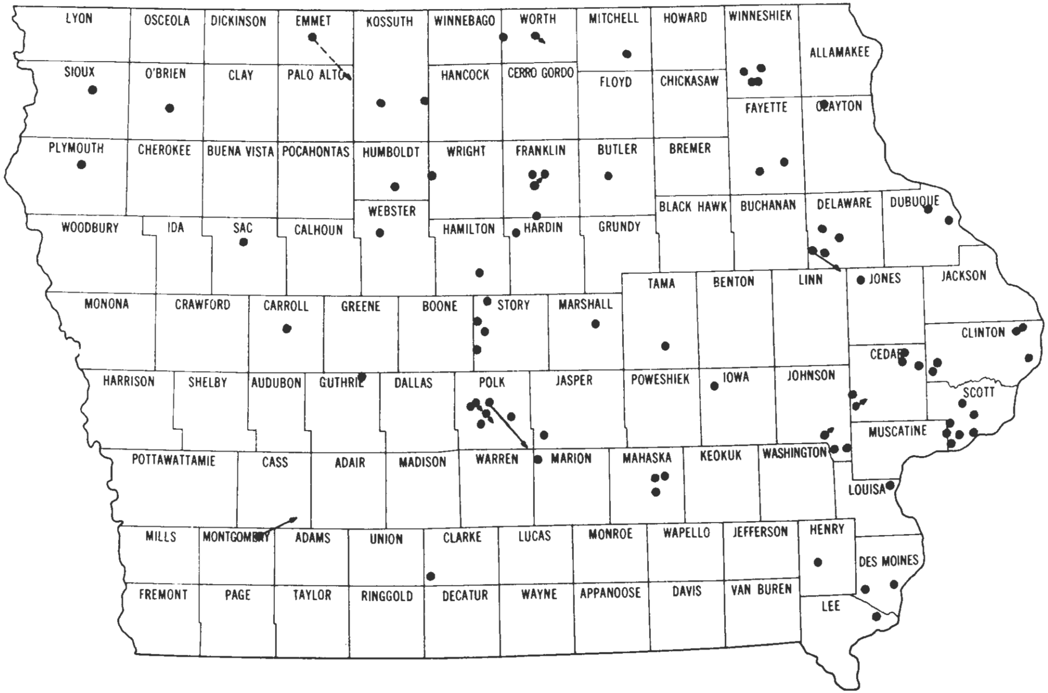


Fig. 1. Map of Iowa Tornadoes in 1974

SEVERE WEATHER EVENTS IN IOWA DURING 1974

DATE: 28 April 1974 Iowa

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1400	T		Altoona, Polk Co.	3

A tornado was reported to have touched down near Altoona.

~1800	W,T?		6S Montezuma, Poweshiek Co.	1

Strong winds in extreme southern Poweshiek County very damaging, cutting path 2 mi wide. Some damage indicated a tornado as top 40 ft were taken off a silo, remaining 30 ft left standing, 16 in. east of original position. Seemed to have been lifted, then set back down. On one farm, cherry blossoms were stripped from one tree but completely unharmed on another tree next to it.

1820	T		2S Hills, Johnson Co.	3

Small tornado with path 2 mi long and 50 yd wide reported. Newspapers reported that high winds destroyed mobile homes.

1840	F		2S West Branch, Cedar Co.	3

Funnel sighted.

1845	T	moved NE	West Branch, Cedar Co.	1, 2, 3

A tornado touched down for about 4 mi with a 100-yd-wide path. Destroyed 15 mobile homes and injured 16 people at one trailer court. Much damage to trees and roofs. Damages estimated at $225,000 to $300,000 at West Branch and environs.

1855	F		West Branch, Cedar Co.	2

Funnel reported in the West Branch area.

1915	F		Bennett, Cedar Co.	1, 2, 3

Funnel cloud reported by the public.

1924	F		Durant Cedar Co.	1,2,3

Funnel cloud reported by the public.

	W		Knoxville, Marion Co.	1,3

Strong winds reported in Knoxville, damaging trees and roofs. Two persons injured when struck by flying debris.

1930	LTNG		Bloomfield, Davis Co.	3

One person injured when struck by lightning.

DATE: 7 May 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1400	W		Marshalltown, Marshall Co.	1

Winds knocked down a tree and some branches in Marshalltown.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2029	H		Red Oak, Montgomery Co.	2, 5

Golf-ball-size hail covered ground at Red Oak; 2-in hail in Clarinda (Page Co.) and New Market (Taylor Co.) areas, ~25 mi SE of Red Oak.

DATE: 12 May 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0416	H		Sioux City, Woodbury Co.	2

¾" hail was observed.

DATE: 13 May 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0630	T		Early, Sac Co.	1

Tornado touched down briefly, destroying a barn and throwing debris into the air on the L. F. Dahm farm.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0700	H		Sioux City, Woodbury Co.	3

Much wind-driven hail, not too large.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0700	F		Panora, Guthrie Co.	3
0700	H (¾")		Des Moines, Polk Co.	2
0725	W,H	moved E at 40 mph	Johnston, Polk Co.	1, 3, 5

55-mph winds in Johnston knocked down chimney on the Jr.-Sr. High School building and it broke through the roof. Windows were broken, damage estimated at $250,000. Hail up to 2 in. in diameter fell elsewhere in Polk and Iowa Counties.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0800	F,T		Saylorville, Polk Co.	2, 3, 5,

Unconfirmed funnel cloud reported to have touched down, but no damage.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1630	T,H	moved ENE at 40 mph	1½ NE Grant Montgomery Co.	1, 2, 3, 5,

Tornado damaged three farms. It knocked down a grain elevator on one; destroyed a cattle shed on another; and destroyed a barn, took off a porch from a home, and destroyed the garage on still another. Report: "There were five or six tornadoes flapping together. They would hit each other, dissipate, then come right back." Storm width was 100 yd; length, 15 mi. Damage estimated at $350,000. Touch-down and damage reported 1 mi west and two miles south of Cumberland in Cass Co., width about 100 yd. Heavy rain and 1½" hail accompanied the tornado. Three barns and many outbuildings

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
destroyed, two homes damaged, a mobile home destroyed. Tractor had a board driven through engine. Mud and debris blown into and onto all buildings in the area.				
1740	H	moved ENE at 35-40 mph	Des Moines, Polk Co.	1, 2, 5
1-½" hail and damaging winds reported over Des Moines.				
1750	H		Polk City, Polk Co.	2
1- ½" hail reported.				
1810	H		Williamsburg, Iowa Co.	2
1900-2000	F (2)		4N Diagonal, Ringgold Co.	1
Unconfirmed.				
1900-2000	T(?)		Urbana, Benton Co.	1
Unconfirmed report of tornado near the junction of Highways 101 and 150. Some damage reported, possibly straight wind damage.				
1910	H(2")	moved ENE at 40 mph	Williamsburg, Iowa Co.	1, 2, 5
1912	H		Victor, Iowa Co.	2
2000	F	moved ENE at 40 mph	5-10 NE Osceola, Clarke Co.	2, 5
Funnel cloud spotted. No touch-down, no report of damage.				
2000	T		3S Liberty,(Hopeville) Clarke Co.	1
Tornado touch-down. No damage.				
2000	F	moved ENE at 40 mph	6S New London, Henry Co.	2, 3, 5
Funnel cloud reported, but no damage.				
2048	H		Walford, Benton Co.	2
1¾" hail reported.				
2100	H	moved ENE at 40 mph	Victor & Belle Plaine, Iowa Co.	1, 5
1-1¾" hail reported.				
2225	F	moved ENE at 40 mph	20W Burlington, Des Moines Co.	2, 5
Funnel cloud reported by the public but no damage.				
2230	T,W		Danville, Des Moines Co.	1
Tornado reported by the public. It scattered and destroyed corn bins and downed utility lines. Also strong winds present.				

13 May 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2230	T,F	moved ENE at 40 mph	Davenport, Scott Co.	1,5

Funnel cloud reported over Davenport. Touch-down reported on a farm near Mt. Joy (northern edge of Davenport), destroying a barn and some outbuildings. Touch-down also reported at intersection of Locust St. and Interstate 80, damaging farm buildings.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2240	T	moved ENE at 45 mph	West Davenport, Scott Co.	1, 3

DATE: 16 May 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0540	H (1")		Tipton, Cedar Co.	3
0643	H (1")		West Liberty, Muscatine Co.	3
0700	W, H (2")	moved ENE at 45 mph	Blue Grass, Scott Co.	3, 5

Damaging winds and 2-in hail indicated by radar and storm spotters.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1425	F		Barnes City, Mahaska Co.	2
1550	H (1")		Cedar Valley, Cedar Co.	3
1732	F		Grand View, Louisa Co.	2
1732	H (3")		Maysville, Scott Co.	2, 3
	H (2")		Donahue, Scott Co.	3
1810	H (1¾")		Eldridge, Scott Co.	2, 3
1815	H (1¾')		Wapello, Louisa Co.	2
1831	F		Grand View, Louisa Co.	2
1835	F	moved E at 40 mph	Wapello, Louisa Co.	2, 5

Funnel cloud reported.

16 May 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1910	T		9S Muscatine, Louisa Co.	2, 3, 5
Tornado reported to have touched down briefly. No damage reported.				
2030	F		Davenport, Scott Co.	3
2030	F		Grandview, Muscatine Co.	3
2048	T		Davenport, Scott Co.	3
Tornado reported to have touched down briefly at SW edge of Davenport.				
2050	T		Davenport, Scott Co.	2, 5
Tornado reported to have touched down in NW Davenport.				
2108	F		Bettendorf, Scott Co.	3
2110	T		Donahue, Scott Co.	2, 3, 5
Tornado reported to have touched down briefly. No damage reported.				
2130	F	moved E	DeWitt, Clinton Co.	2, 3, 5
Funnel reported by Scott County sheriff just west of DeWitt, moving toward DeWitt.				
2300	F		Tiffin, Johnson Co.	3

DATE: 17 May 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1500	H (1¾")		Harrison Co.	2
1732	H (1¾")		Neola, Pottawattamie Co.	2
1809	H (1¾")		Harlan, Shelby Co.	2

DATE: 21 May 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1430	W		Menlo, Guthrie Co.	3
Strong winds caused injury to one person.				
1430	W		Algona, Kossuth Co.	1, 2, 5
Winds at 60 mph reported.				

21 May 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1500	T		1W Alden, Hardin Co.	1

Tornado reported shortly after 3:00 PM. No damage reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1500	T		4N Iowa Falls, Hardin Co.	1

(Likely the same reported 1W Alden.) Tornado reported shortly after 3:00 PM. No damage reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1510	T, F(3)	moved NE at 35 mph	4SW Hampton, Franklin Co.	1, 2, 3, 4, 5

Tornado reported on ground 4 mi SW of Hampton in field. Tornado spotted from SE because of large cloud of dust caused by 60 to 70 mph winds in its vanguard. Parent cloud reddish; just SW of the tornado, and following it, very heavy rain. Tornado, or high winds preceding it, destroyed trailer home on west side of Hampton. Many trees damaged or destroyed at north edge of town. Funnel reported to move over Hampton without touch-down. Three other funnels also sighted in area.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1515	T (same tornado or parent cell as above)		3W Hampton,	1, 4

Truck driver on highway 65 reported tornado. No damage reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1525	F		Sheffield, Franklin Co.	4

School children saw funnel while riding bus home. Likely same as 1510 Hampton tornado because cloud appeared similar. Loud road reported in Sheffield; some trees topped, some power lines downed in town.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1600	T, F	moved NE at 35 mph	Allison, Butler Co.	1, 3, 5

Tornado and funnel cloud reported by the public in Butler Co. Tornado reported near Allison.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2010	F(2)		Southern Taylor Co.	5
2115	F(?)	moved NE at 30 mph	Melbourne, Marshall Co.	1,3,4,5

Funnel reported over Melbourne. No damage reported. (This report believed to be false, by unreliable witness.)

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2130	F		Alden and Iowa Falls, Hardin Co.	3
2130	W (70 mph)		Eldora, Hardin Co.	3
2202	F	moved NE at 30 mph	7SE Waverly, Bremer Co.	1,2,3,5

Funnel reported by the public. No damage reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2210	F	moved NE at 30 mph	Dysart, Tama Co.	1,2,3,5

Funnel cloud was reported by the public, also "indicated by radar."

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2210	T		Algona, Kossuth Co.	1

DATE: 28 May 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0205	H		Wiley and Dedham Carroll Co.	2, 3

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1830	H (2")		1 W Estherville, Emmet Co.	2

Extensive damage from 2-in hail.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2010	H,W	moved SE at 30 mph	Estherville, Emmet Co.	1,5

Golf-ball- to tennis-ball-size hail hit Estherville and surrounding areas. Two people injured and hospitalized. Over $100,000 damage to car dealers's lots. Greenhouse almost ruined. Winds reported at 75 mph. Many windows broken, cars damaged. Ringsted, Emmet Co., (20ESE) also reported golf-ball-size hail, with much damage to cars and larger windows.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2047	H	moved SE at 30 mph	Interstate 35 & Minn. border, Worth Co.	1.2.5

Golf-ball-size hail reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2025-2110	T,F,H	moved SE at 30 mph	Palo Alto & Kossuth Cos.	2,3,4,5

Tornado moved from NW to SE from central Emmet Co., through northeastern Palo Alto Co., into west central Kossuth Co. At Depew (Palo Alto Co.) it took out a 100-ft-wide path through a grove, destroyed an outbuilding, and downed two utility poles. It picked up a man seeking cover in a ditch, threw him into the ditch on the other side of the road, removing most of his clothes, leaving him with severe gravel burns. The funnel then lifted, followed by observers to near Whittemore (Kossuth Co.) where it was still visible hanging from its parent cloud at 2110 CDT. Hail 3" in diameter fell between Depew (Palo Alto Co.) and Fenton (Kossuth Co. and 7 mi NE of Depew).

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2100	T,H,W	moved SE	Kensett, Worth Co.	1,2,3,5

Several touch-downs reported along 5-mi path NE of Kensett. First touch-down reported 1½ W and ¾ N of Kensett, destroying a barn and several outbuildings and damaging or destroying trees and crops. Strong wind and loud noise were also reported. 1 SE on a farm, trees uprooted, windows broken. Touch-down also reported 1¼ SE of Kensett, with wind damage and golf-ball-size (1½") hail. Woman injured by flying glass and hospitalized; two others injured. Some livestock killed, trees downed, many windows broken. Roof damage reported on many buildings.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2110	T		8S Northwood, Worth Co.	2

Perhaps same as tornado reported above.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2115	W		Algona, Kossuth Co.	2

Wind gusted to 70 mph.

28 May 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2300	H		Mt. Auburn-Vinton Area, Benton Co.	3
Much small-to-medium-size hail, wind driven, drifted 1 ft deep in some places.				
2300	H		Greene, Butler Co.	3
Much hail, drifted to 1 ft deep.				
2345	H		Waterloo, Black Hawk Co.	2,3
¾" hail reported at Waterloo; up to 2" reported between Waterloo and Washburn. Extensive property damage; drifts of hail still unmelted next morning.				

DATE: 29 May 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0100	W		Onawa, Monona Co.	3
Damaging winds reported.				
0330	W		Des Moines, Polk Co.	3
Damaging winds reported.				
0430	T		6NE Oskaloosa, Mahaska Co.	1
Tornado apparently touched down and destroyed barn, corncrib, and trees. Occupants said storm made "awful noise." *Storm Data* reported it as a windstorm.				
0610	W		Burlington, Des Moines Co.	3
Strong winds did much tree damage.				
1520	T		13NE Oskaloosa, Mahaska Co.	2,3,5
Tornado reported by the public. Some farm buildings destroyed, some trees uprooted on two farms. Tornado lifted and soon dissipated.				
1530	F(2)		Lacey, Mahaska Co.	1,3
Twin funnel clouds reported in Lacey-Union Mills area; one black, the other white. Raining very hard when funnels were spotted. No touch-down reported.				
1530-1600	F		Rose Hill, Mahaska Co.	1,3
Funnel cloud reported; no touch-down or damage reported.				
1905	F	moved SE at 35 mph	10E Lowden, Cedar Co.	2,3

DATE: 30 May 1974

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1346	W		Ottumwa, Wapello Co.	2

Damaging winds up to 55 mph reported.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1400	W		Keokuk, Lee Co.	1

Winds to 55 mph reported.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1443	H (1")		Bedford, Taylor Co.	2
1700	H,W		Monona to Shelby to Cass Cos.	2

Two-in hail and strong winds reported, which overturned a semitrailer and truck.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1745	H (1¾")		20 NNW Atlantic, Cass Co.	2
~1800	H (1¼")		Elk Horn, Shelby Co.	1

The 1¼" hail driven by strong winds caused much damage. Many windows broken, cars damaged by hail.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1820	T	moved SE at 4 mph	3W Goldfield, Wright Co.	3,4

(thunderstorm - moved SE at 30 mph)

Palo Alto Co. civil defense director, driving home from Des Moines, spotted what he thought was a column of smoke. Then he realized that the "smoke" was ascending to clouds overhead. Since the wind was blowing, "smoke" should not be rising straight up. The tornado was kicking up dust in a plowed field (ground was wet from rain earlier); dust made the funnel black. While he was watching, the tornado seemed to lose strength and lift a little, but then strengthened forming a clear gap in its funnel. After strengthening, the tornado continued on the ground for several minutes. Width estimated as 100 ft.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1830	H,F	moved SE	Ringgold and Taylor Cos.	1,2,3

Hail up to 1¾" did extensive crop damage 5 mi NW of Benton in Ringgold Co. Reports said up to half a foot of hail reported in some places. "Huge" funnel sighted just NW of Clearfield in Taylor Co. No touch-down reported, but noise heard in Diagonal, Ringgold Co. Some wind and hail damage between 5 mi NW of Benton and 2 mi SE of Diagonal; three barns and two outbuildings destroyed, some windows broken.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1840	H (1")		Mt. Ayr, Ringgold Co.	2
afternoon	W		southeast section of state	1

Strong winds caused some tree damage.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
afternoon	W		North English, Iowa Co.	1

Winds between 60 and 70 mph knocked down trees.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
afternoon	W		Ainsworth, Washington Co.	1

Winds felled a few trees.

30 May 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
afternoon	W		Fairfield, Jefferson Co.	1

Winds at 55 mph knocked down trees and power lines.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
late afternoon	W		Wilton, Muscatine Co.	1

Winds felled some trees.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1920-1930	F	moved SE at 35 mph	1½ SW Dows, Wright Co.	4

A deputy, following the storm in his car, spotted funnel when the rain let up for 2 or 3 minutes. "The funnel tail started down, made this kind of whip, and started up into the cloud cover." Lowest point of the funnel was 800-1000 ft; cloud base, 1500-2000 ft. The main cell changed colors, as he followed the storm, from deep black to black with white stripes to ash brown.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2030	F	moved SE	between Eldora and Iowa Falls, Hardin Co.	4

Funnel cloud, reported by police, was heading SE over open field.

DATE: 2 June 1974

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1745	F		7SSW Iowa City, Johnson Co.	3

DATE: 3 June 1974

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1621	H (¾"-1")	moved NE at 20-25 mph	Charles City, Floyd Co.	1,2,3,5
1749	H (1")	moved ENE at 20-25 mph	Garner, Hancock Co.	3,5
1830	F		6NW Fort Dodge, Webster Co.	3
1835	F,T	moved ENE at 20-25 mph	4E Osage, Mitchell Co.	2,3,5

Funnel cloud reported by the public, touched down a few minutes later. The small tornado damaged at least three farms. On one, large cattle shed destroyed and treetops removed. On another farm, roofs of two outbuildings removed. On third farm, about 1 mi away, side of barn and a machine shed were demolished.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1850	F		St. Ansgar, Mitchell Co.	3
1900	H (1")		Hampton, Franklin Co.	3
1915	F	moved NE at 15 mph	Sheffield, Franklin Co.	1,3

Funnel sighted; no touch-down.

3 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1954	T	moved ENE	Hampton, Franklin Co.	3,4,5

Small tornado, 50-60 ft wide, touched down in a field on W edge of Hampton. Lasted 3 to 4 min, only knocking down two telephone poles and lifting before reaching Hampton. Much cloud turbulence during and after tornado, with much lightning and thunder all the time.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2000	W		1S Alexander, Franklin Co.	3

Damaging wind reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2030	F		Aredale, Butler Co.	3
2100	F		Dougherty, Cerro Gordo Co.	3

DATE: 7 June 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1045	F		Estherville, Emmet Co.	3
1240	F (2)		Ayrshire, Palo Alto Co.	3

DATE: 9 June 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0330	W		Jones, Delaware, Buchanan and Benton Cos.	3

Wind damage in many places in these counties.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0352	T		5W Monticello, Jones Co.	1

Damage and duration of storm on a farm indicate probability of tornado, "lasting 30 sec or less." House roof taken off, some trees and outbuildings destroyed.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0353	T		Delhi, Delaware Co.	1

Many trees damaged or uprooted along a path about two city blocks long and half a block wide. A "roar-like-a-train" reported. A concession stand from a baseball diamond was set on a house roof. No severe damage, no funnel sighted.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0440	T		5W Ryan, Delaware Co.	1

A 30-sec storm, believed a tornado, damaged buildings and uprooted 16 trees. Storm described as resembling a loud crash. Knocked out most of the windows in a house.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1140	F		Storm Lake, Buena Vista Co.	3

9 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1230	T	moved NE	4½E Humboldt, Humboldt Co.	1,3

Farm residents saw a funnel dip from approaching cloud. They took shelter in their basement on hearing a roaring and whistling. Some outbuildings and a grove of trees destroyed on this farm; trees and garage on a farm farther NE also destroyed. Path about 2 mi long, 200 yd wide.

1330	T	moved NE	½SW Wesley, Kossuth Co.	1,3

Tornado first touched down on extreme SW edge of Wesley, destroying a barn and damaging several other buildings and many trees, then damaging house on next farm. After damaging trees and small buildings in Wesley, tornado continued NE, scattering debris for about ½ mi, then lifted but did touch down briefly twice more, farther to NE.

1415	F		Northwood, Worth Co.	3
1530	F		3NW Storm Lake, Buena Vista Co.	3
1530	W		Lake Rathbun, Appanoose Co.	3
1906	F	moved E	Creston, Union Co.	1

Funnel moving east sighted by the public. Much cloud turbulence.

DATE: 14 June 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1535	H (¾")		Blue Grass, Scott Co.	3
1600	W (50 mph), H (¾")		Des Moines, Polk Co.	5
~1600	H,W,T		Bryant-Andover area, Clinton Co.	1,3

Small tornado touch-down near Andover; silo on one farm destroyed, barn on another. Some wind damage reported in Andover. Much hail between Bryant and Andover, damaging crops.

~1600	W (55 mph)		Clinton, Clinton Co.	1
1650	H (2")		Hartford, Warren Co.	3
1650	H (2")		2N Ackworth, Warren Co.	3
1725	T (2), F(2), H (2¾")	moved SE	Polk City to Ankeny, Polk Co.	1,3,4,5

Twin funnels spotted by patrolman about 1½ mi NE of Polk City. Funnels touched

14 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE

down briefly; path estimated as 200 yd long, 100 yd wide. At least one funnel traveled over Polk City; winds associated with it blew dust into many buildings. About 10 min later two funnels observed from southern Ankeny. Funnels dissipated but considerable cloud turbulence remained. Baseball-size hail fell in Ankeny for about 5 min.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1730	W,T(?)		Along Interstate 80, Western Jasper Co.	5

Strong winds and possible tornado caused people to leave cars and lie in ditch.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1730	H		Black Hawk, southern Grundy, and northern Tama Cos.	3,5

Hail and winds caused heavy crop damage.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1800	W,H (2")		Hartford, Warren Co.	3,5
1815	H (2")		Promise City, Wayne Co. to Centerville, Appanoose Co.	3,5
1835	H (2")		Milo, Warren Co.	5
2000	H,W		Centerville, Appanoose Co.	3,5

Damaging 2" hail, driven by 45 mph winds.

DATE: 18 June 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~0300	T		Sioux Center, Sioux Co.	1

Tornado, preceded by short heavy rain, touched down near Middleburg (6ENE Sioux Center) destroying three barns and blowing down trees. Tornado traveled about 2 mi on the ground, with over ¼ mi width.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1800	H		Palo Alto, Humboldt, and Pocahontas Cos.	3

Extensive crop damage.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1838	H(1")		Fort Dodge, Webster Co.	3
1838	H(2")		Jewell, Hamilton Co.	3
1917	H(1¾")		Mason City, Cerro Gordo Co.	3
1922	H		Charles City, Floyd Co.	3

18 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1930	H(3")		Mason City, Cerro Gordo Co.	2,3
1946	F		6NW Boone, Boone Co.	1,2,3
Funnel reported by the public; no damage reported.				
1946	F	moved SE	5 NE Boone, Boone Co.	3,4
Funnel reported by the public; no damage reported.				
1955	T	moved SE	1E Story City, Story Co.	2,3,5
Funnel reported by the public. Brief touch-down destroyed a barn. Strong winds reported; flying glass injured one person.				
2005	H(1")		Cresco, Howard Co.	2,3
2005	F(2)		14E Jackson Junction, Winneshiek Co.	2,3
Shortly after 2000	W	moved E at 25 mph	Dayton, Webster Co.	1
Strong winds and wind damage reported. Barn flattened, full grain bin blown away, building lost roof. Elevator, trees, telephone poles, and windmill badly damaged.				
2020	F		near Havelock, Pocahontas Co.	2, 3
2025	F,T	moved SE at 30 mph	Gilbert, Story Co.	1,2,4,5
Funnel sighted by the public. May have touched down because some damage reported.				
2030	T	moved SE	3NE Ames, Story Co.	5
2040	F		3E Pocahontas, Pocahontas Co.	2,3
2040	F		Bouton, Dallas Co.	3
2045	W		Gilbert, Story Co.	3
2050	T,H		5W Fort Dodge, Webster Co.	1,3
Tornado touched down briefly, destroyed barn and shed. Residents, putting horses in barn when tornado struck, were buried with horses underneath hay and straw in the barn. Neighbors reported seeing "a huge black twister dip down over the farm." At farm 1 mi S barn destroyed and flying debris for about 15 min. Hail damage to crops on this farm; wind and hail damage throughout area.				

18 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2052	H,F		Clare, Webster Co.	1,2,3,

Two-in hail reported. Funnel cloud reported near Clare by newspaper. Wind damage reported in the area.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~2100	W		New Hampton, Chickasaw Co.	1

Many trees downed and some roof damage from high winds.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2101	F,T	moved SE	Marshalltown, Marshall Co.	1,2,3,5

Des Moines weather service reported funnel cloud NNE of Marshalltown. Newspaper reported touch-down 3N at airport; no damage reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2105	W (56 mph)		Ames, Story Co.	1,2
2110	H(2¾")		Ames, Story Co.	1,2,3,4

Much large hail fell for about 10 min; extensive damage to roofs, siding, windows.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2115	T	moved SE	Kelly, Story Co.	1,2,3,5

Tornado reported to have destroyed a barn. Path width estimated at 200 yd; length, 2 mi.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2115	F	moved SE	Huxley, Story Co.	3,5

Funnel reported NE of Huxley.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2120-2210	F(7)		~2NE Ankeny, Polk Co.	1,4,5

Patrolmen from Polk Co. reported 7 funnels just NE of Ankeny.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2130	F		Altoona, Polk Co.	3,5,
2132	F	moved SE	3NE Ankeny, Polk Co.	1,2,3,4,5
2200	F(2)	moved SE	N Altoona, Polk Co.	2,3,5

Two funnel clouds reported just north of Altoona.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2203	F		3NW Ames, Story Co.	4

Well-defined and slightly hook-shaped funnel sighted.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2207	F	moved SE	8SE Altoona, Polk Co.	2,3,5

Funnel reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2210	H(1")		Nevada, Story Co.	2,3

18 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2215	F		1SE Ames, Story Co.	4
Funnel reported.				
2220	F		3½E Ames, Story Co.	2,3
Funnel reported.				
2220	H		Iowa Falls, Hardin Co.	3
2220	T	moved SE	2NW Ankeny, Polk Co.	4
Patrolman spotted tornado on ground kicking up dust.				
2229	T		Ankeny, Polk Co.	4
Patrol car with patrolman picked up off the ground. No lightning observed while he was off the ground; darkness seemed to come with the tornado.				
2230	T(2)	moved SE path length ~22 mi	Ankeny, Polk Co.	1,3,4,5
Tornado with path width of about ¼ mi hit north Ankeny first, continued SE through the SE part of town (2235). Some observers saw two tornadoes just before electricity went off. Watching the storm, they headed for the basement and just got there when it hit. Two people killed in bed when the tornado hit. Path was traced across Highway I-35, through NE Des Moines, through Pleasant Hill, and lifted 2 mi NE of Runnells where there was wind damage. Storm variously described as sounding like a steady roar, a swoosh, and a load roar.				
2245	W,F,T		Des Moines, Polk Co.	2,4,5
Some wind damage reported near Des Moines, probably from the tornado (Ankeny) that skipped through NE Des Moines. At 2315 the weather service reported a funnel and possible tornado with damage; probably a late report. Wind at 70 mph reported.				
2245	T		Prairie City, Jasper Co.	1
Small tornado damaged house and buildings on three or four farms in the area. Approximately two barns and six or seven outbuildings damaged.				
~2300	W		10E Des Moines Polk Co.	1,2
Some wind damage reported in SE Polk Co. and at Pleasantville, Marion Co.				
~2300	W		Carlisle, Warren Co.	1
Strong winds downed trees and damaged buildings.				
~2300	F		3W Oskaloosa, Mahaska Co.	1
Funnel spotted but no touch-down reported.				

18 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~2300	W	moved NNW at 35 mph	Carlisle, Warren Co.	1

Strong winds reported in Carlisle. Winds knocked down or damaged trees, damaged roofs, and blew out windows in two stores. SE of Carlisle 2 mi, barn blown down and across Highway 5. Roof torn off a home in Carlisle; two mobile homes destroyed. Two barns, many outbuildings blown down.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2310	F,W		Hartford, Warren Co.	2,3,5

Funnel sighted and wind damage reported in the area.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2310	W		Des Moines, Polk Co.	1

Some wind damage reported in NE Des Moines.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2315	W		Swan, Marion Co.	2

Strong winds and some damage reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2315	T,W		Runnells, Warren Co.	1,2,4,5

Tornado 4 mi NE of Runnells reported to the Des Moines weather service. Believed to be same tornado that went through Ankeny, NE Des Moines, and Pleasant Hill. Wind damage reported in Runnells at 2315; house, barn, outbuildings, many trees destroyed. This was the same cell that produced the Ankeny tornado. According to the weather service, the tornado was thought to have lifted just NW of Runnells but may have caused spotty damage here and also further SE. Touch-down with some damage.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~2325	F(2), T		Swan, Marion Co.	1

Two funnel clouds sighted. One touched down SW of Swan, destroying a double mobile home and a new mobile home just to the east. It also took the roof off a barn, destroying the hay inside. In Swan a family fled to the basement and said they heard what sounded like a train going through their house. Afterward, they discovered one end of their house was missing and the garage was destroyed.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2345	T		10ENE Oskaloosa, Mahaska Co.	1

A barn and outbuildings were damaged. Two miles west on another farm the tornado twisted trees and also twisted some sheet metal from a corn crib roof around the trees. One of the neighbors said, "It made a lot of noise and I could see it through the lightning flashes. I didn't see a funnel—only a long gray cloud that seemed to touch down behind the grove."

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2345	T		Rickardsville, Dubuque Co.	2,3

Tornado touched down briefly near Rickardsville. No damage reported.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0003 6/19/74	W,T?		Sigourney, Keokuk Co.	1

On a farm SW of Sigourney, barn destroyed, garage flattened, and house suffered roof damage. The family heard an extremely loud noise on their way to the basement. Trees were damaged or blown down in the area.

19 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0003	W		Keota, Keokuk Co.	1
High winds damaged trees and roofs, also farther west.				
0045	W		Pleasant Hill, Polk Co.	1
Wind damage reported.				

DATE: 20 June 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0035	H(1¾")		Marshalltown, Marshall Co.	2
0050	H(1")		Ames, Story Co.	2
1325	F		Ottumwa, Wapello Co.	2
afternoon	W(80 mph)		Aredale, Butler Co.	2
1400	W,F	moved S	Nashua, Chickasaw Co.	1
Public reported strong winds and funnel cloud approaching from the north.				
—	F		New Hampton, Chickasaw Co.	1
—	F		Fredericksburg, Chickasaw Co.	1
—	T		5S Sumner, Bremer Co.	1
Small tornado, with a path width of about 10 yd destroyed 11 small buildings and drove 2 x 4's into the ground.				
—	F		Randalia, Fayette Co.	1
—	F		Arlington, Fayette Co.	1
~1500	T		4E Lake Mills, Winnebago Co.	1
Small tornado reported to have touched down; destroyed trees and a garage.				
—	F(2)		Elkader, Clayton Co.	1
1515	F		5NE Estherville, Emmet Co.	3
Funnel reported.				

20 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1535	F		Kensett, Worth Co.	5
~1615	T	moved SE	Luana, Clayton Co.	1,2,5
—	W		Aredale, Butler Co.	1
Winds estimated up to 80 mph destroyed grain bin and trees on farm near Aredale.				
~1630	W		Elkader, Clayton Co.	1
~1630	T		6½SW Arlington, Fayette Co.	1
Tornado touched down briefly, destroying a barn and a few outbuildings and damaging a farmhouse. Other wind damage reported in the area.				
1630	F	moved SE	Dubuque, Dubuque Co.	1,2,5
Residents sighted a funnel cloud near fairgrounds. No touch down.				
1650	W(60 mph)		Jesup, Buchanan Co.	1
~1655	W(64 mph), F		Waterloo, Black Hawk Co.	1,2
Funnel reported near Waterloo.				
~1700	T		Oelwein, Fayette Co.	1
Farm residents saw an "awfully black cloud" with funnel. Tornado destroyed their barn, scattered the remains, drove boards into the sides of the house, and damaged other small buildings.				
~1700	W(85 mph)		Dubuque, Dubuque Co.	1
1700	T,F,W		Manchester, Delaware Co.	1,2,5
Funnel cloud reported near Manchester. Tornado reported to have touched down on a farm near Manchester, which received severe wind damage. More than 50 trees uprooted, some buildings damaged.				
1710	W(70 mph)		Dyersville, Dubuque Co.	1
~1715	F		Dubuque, Dubuque Co.	1,5
—	W(80 mph)		Clinton, Clinton Co.	
—	F		Rowley, Buchanan Co.	1

20 June 1974, Continued

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1730	F,W		Marion, Linn Co.	1

Funnel reported on east edge of Marion. Winds of 65 mph reported in Cedar Rapids and uprooted about 50 trees.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1730	F		Wyoming, Jones Co.	1
1732	W,T.F	moved SE	Dubuque, Dubuque Co.	1,2,5

Winds of 85 mph blew a large part of roof from Wahlert High School. Water damage reported throughout the building. Many trees and large branches downed. Several funnel sightings in the area; tornado reported by the public 4 mi west of Dubuque, causing some damage to buildings on one farm. Tornado described as a black cloud with a tail.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
—	W(60 to 80 mph)		Jackson Co.	1
~1740	T(2)	moved S	Wheatland, Clinton Co.	1

A civilian reported twin funnels passing over his car, moving farther south, touching down, and destroying several barns and buildings, which "blew apart."

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1740	W		Olin, Jones Co.	2
1740	W		Lisbon, Linn Co.	2
1740	W,F,T		Lowden, Cedar Co.	1,2

Seventeen cars of a C & NW freight train derailed by 90 mph wind; about 30 people injured. Tornado touch down reported near Lowden; two funnel clouds sighted in the area. Two barns destroyed, damage to other buildings.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1740	W		Stanwood, Cedar Co.	2
~1740	T		Clarence, Cedar Co.	1

Tornado touch-down reported.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1745	W		Mount Vernon, Linn Co.	1

Winds estimated at 60 mph destroyed many trees, damaged buildings.

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1745	T	moved SSE	Andover, Clinton Co.	1,2,3

Fire station roof taken off, small buildings destroyed, mobile homes damaged, many trees downed, at least three barns destroyed. SE of Andover a church was damaged extensively and 90% of the roof taken off. A barn was also destroyed.

20 June 1974, Continued

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1745	T,W		Clinton, Clinton Co.	1,2
Winds up to 80 mph caused severe damage. One man killed when some boards from ball park bleachers were blown through windshield of his car. Many trees uprooted. Church roof taken off. Damage path about 2 mi wide. Clouds described as going along the ground, just blowing things apart. About 25 people injured.				
1750	T,W		West Branch, Cedar Co.	2
—	W(60 to 70 mph)		Muscatine, Muscatine Co.	1
Some wind damage reported.				
~1800	W		Preston, Jackson Co.	1
Strong winds destroyed many trees, damaged buildings.				
~1800	T		Clarence, Cedar Co.	1
Tornado with a short path damaged many buildings.				
1800	W(90 mph)		Lowden, Cedar Co.	1
~1800	F(2)		Lowden, Cedar Co.	1
1816	W(67 mph)		Davenport, Scott Co.	1
1900	H(2")		Marengo, Iowa Co.	1
~1900	H(1½")		Williamsburg, Iowa Co.	1
2040	T,F,H	moved SE at 40 mph	Oakland Mills, Henry Co.	1,2,5
Tornado knocked trees down and damaged buildings. Hail (2") reported just south of Mount Pleasant. Funnel cloud sighted between Oakland Mills and Mount Pleasant.				
2050	T,W		Burlington, Des Moines Co.	1
Small tornado touched down, damaged some buildings and took a screen off a drive-in theater in Burlington. A loud roar was heard along with the tornado. Winds were measured at 80 mph in Burlington; at 2058 they broke many windows, four persons injured by flying glass at a supermarket.				
2110	T		Wever, Lee Co.	1
Some damage reported on a farm near Wever.				
2115	F		5WSW Fort Madison, Lee Co.	1

20 June 1974, Continued

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2120	F		2SE Donahue, Scott Co.	2
2120	F		2SE De Witt, Clinton Co.	2
2315	W,T(3)		Calmar, Winneshiek Co.	2
Two tornadoes sighted on the ground in the Calmar area and a third sighted at Ridgeway, about 8 miles NW. Wind damage reported in these areas.				
2315	W		Allamakee Co.	2
2322	T	moved SE at 45 mph	Spillville, Winneshiek Co.	3

DATE: 22 June 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~0010	W		Holstein, Ida Co.	1
Strong winds estimated at 75 mph damaged trees and buildings.				
~0010	W		Pomeroy, Calhoun Co.	1
Strong winds and hail reported.				
0030	W(52 mph)		Sioux City, Woodbury Co.	1
Strong winds and small hail reported.				
0050	H(2¾")		Clarion, Wright Co.	2,3,5
0100	W,H		6N Rockwell City, Calhoun Co.	1
Small hail and strong winds reported.				
just after 0100	T		5SSE Primghar, O'Brien Co.	1
Tornado touched down briefly and destroyed barn and small buildings.				
~0130	W		Denison, Crawford Co.	1
Winds of 55 to 60 mph knocked down trees and damaged buildings.				
~0130	W,T?		Farnhamville, Calhoun Co.	1
Strong winds blew down a barn near Farnhamville. They could have been associated with a tornado; whistling sound was heard in the wind.				
~0135	W,H		Rockwell City, Calhoun Co.	1
Strong winds and small hail reported.				

22 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0144	W		Kingsley, Plymouth Co.	1,2,5
Damaging winds of 75 mph.				
~0145	W		Lawton, Woodbury Co.	5
Strong winds reported.				
—	W(75 mph)		Kingsley, Plymouth Co.	1
0200	H(1")		Webster City, Hamilton Co.	1,2,3
0200	H(2 to 2¾")		8NE Webster City, Hamilton Co.	1,2
Hail reported.				
~0200	W,H	moved SE	Hamilton, North Story, South Hardin, and Boone Cos.	1
Near McCallsburg and Zearing in Story Co. many trees, barns, and small buildings destroyed. In Stratford (Hamilton Co.) barns and outbuildings destroyed. Roland (Story Co.) also had severe wind damage. Hail (up to 2¾") started near Webster City; left a path through Kamrar, Jewell, and Randall; ended near Story City. At Ogden (Boone Co.) winds estimated at 45 to 65 mph damaged trees and buildings. Winds around McCallsburg (Story Co.) estimated up to 70 mph and damaged or destroyed barns and small buildings. Small hail fell in the area.				
0215	F		Alden, Hardin Co.	3
0225	T	moved SE	Jewell, Hamilton Co.	1,2,5
Brief tornado touch down, completely destroying two homes and damaging trees. Violent wind, hail, and rain accompanied the tornado, causing damage to trees. Three mi east, many barns and small buildings destroyed.				
~0300	W		Union Co. and Whitten, Hardin Co.	1
Strong winds damaged the area.				
0325	W		Denison, Crawford Co.	1,3
0335	W(53 mph), H (2")		Des Moines, Polk Co.	1
~0400	H,T?		6N Dysart, Tama Co.	1
Barn destroyed by what was thought to be a tornado. "It was too dark to see anything, but it sounded like a tornado (roar)." Extensive tree damage, some hail reported in Dysart and surrounding areas.				

22 June 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~0430	T		3SE Lone Tree, Johnson Co.	1

Tornado touch down briefly, destroying two barns and all buildings except two silos and the house. Residents heard a "buzzing" sound.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0530	W(50 to 55 mph)		Carroll, Carroll Co.	1
~0530	H,W		Grundy and Tama Cos.	1

Hail and damaging winds damaged crops extensively in southern Grundy and NW Tama counties.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
—	T		Seney, Plymouth Co.	1

Small tornado reported to have destroyed a garage and moved a house off its foundation.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
—	T		Bagley, Guthrie Co.	1

Small tornado reported to have destroyed two grain storage bins.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
—	W		Conrad, Grundy Co.	1

Wind damage to trees was observed in the area.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
—	W(65 to 70 mph)		Eldora, Hardin Co.	1
—	W(70 mph)		Iowa Falls, Hardin Co.	1

DATE: 3 July 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1500	W		NE Mahaska Co.	3
1535	T		3NNE Carroll, Carroll Co.	2,3

Tornado touched down briefly.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1945	T(?), F(?)		Mt. Ayr, Ringgold Co.	2,3

Storm Data reported a funnel; SELS log reported a tornado.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2215	F		5E Fort Dodge, Webster Co.	2

DATE: 10 July 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1645	W		Tipton, Cedar Co.	2
Gusts to 70 mph reported.				
1650	H(1¾")		Eldridge, Scott Co.	2
1655	W		Davenport, Scott Co.	2
Gusts to 75 mph reported.				
1830	H(1½")		Washburn, Scott Co.	2

DATE: 21 July 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1930	W		Des Moines, Polk Co.	1,3
Strong winds broke windows, damaged roofs downtown.				
2030-2125	W,LTNG		Waterloo, Cedar Falls, Black Hawk Co.	3
Strong winds downed trees and damaged buildings. Lightning damaged two houses and some trees.				
2110	F	moved E at 25 mph	1SW Marshalltown, Marshall Co.	1,2,3,5
2200	LTNG		Quasqueton, Buchanan Co.	3
2215	LTNG		Blairstown, Benton Co.	3
2223	W		Ottumwa, Wapello Co.	2
Winds gusting to 70 mph reported.				
2225	T		12E Tama, Tama Co.	1,2,3,5
Tornado reported to have touched down. No damage reported.				

DATE: 22 July 1974

TIME(CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0200	T		1W Lone Tree, Johnson Co.	1,2,3
Small tornado touched down briefly, destroying a barn and many trees and breaking windows in the area. *Storm Data* estimated the path length as 1 mi and width as 150 yd. Wind damage also reported.				

DATE: 25 July 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0048	W		Mason City, Cerro Gordo Co.	2
Gusts to 60 mph reported.				
0123	H(¾")		5SE Fort Dodge, Webster Co.	2
1735	H(1¾")		Manly, Worth Co.	2,5
1835	W,H	moved SE at 15 mph	Clear Lake, Cerro Gordo Co.	1,3,5
Some damage by hail, driven by winds up to 75 mph.				
1810	H(1" to 2")		Fort Dodge, Webster Co.	1,3,5
Some crop damage resulted from wind-driven hail in Fort Dodge and in southern Webster County.				

DATE: 26 July 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1000	LTNG		Cleghorn, Cherokee Co.	3
One man killed by lightning.				
1050	H		SW Lake Mills, Winnebago Co.	3
Much marble to pea-size hail, causing crop damage.				
2215	H(2")		Winfield, Henry Co.	2,3
0400	LTNG		Rembrant, Buena Vista Co.	3
Lightning struck rural home, started a fire, house was burnt to the ground.				
2131	T?		4N Boone, Boone Co.	1
Tornado reportedly sighted by the public; unconfirmed, no damage reported.				
night	H		Kamrar to Ellsworth, Hamilton Co.	3
Hail destroyed 8,000 acres of crops.				

DATE: 28 July 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0014	W		Ottumwa, Wapello Co.	2
Winds gusting to 60 mph reported.				

DATE: 8 August 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2245	H(¾")		Walnut, Pottawattamie Co.	2

DATE: 10 August 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1207	F	moved NNE	1W Webster City, Hamilton Co.	1

Funnel cloud, sighted by the public, confirmed later by police, moved NNE.

DATE: 12 August 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0400	LTNG		Clutier, Tama Co.	3

Lightning fired a barn.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1620	T,F,H	moved SE at 10 mph	Ryan, Delaware Co.	1,2,3

Tornado destroyed about 20 homes and one church and damaged about 15 other homes. Eleven persons injured. Tornado touched down about 2 mi WNW of Ryan, moved through southern Ryan, moved east, then headed SE. On a farm 3 mi SE of Ryan, the whole house disappeared as residents took refuge in the basement. At another farm 4 mi SE of Ryan, a barn was destroyed, the farm house was extensively damaged, and hay and straw from the barn were scattered. On the two farms almost nothing was left. On yet another farm 2 mi N of Prairieburg (7 SE Ryan), many buildings destroyed. Many persons who saw the tornado were amazed by the amount of debris in the funnel. Tornado path ranged from about 50 to 150 yd wide and between 8 to 9 mi long. An invoice from a doctor's house destroyed in Ryan was found at about 1820 CDT in a resident's yard in Galena, Ill. (about 55 mi E). Wind damage reported on a farm 6 mi SE of Ryan. Damage estimates in Ryan ranged from 1 to 1.5 million dollars. One church destroyed, as was the elementary school. The Ryan Cooperative was badly damaged, and the Great Plains Supply Co. (SE corner of town) was completely destroyed. Hail was also reported. About 1720, a tornado was reported in northern Linn Co. probably the same tornado or thunderstorm cell. At 1740 a funnel was reported at Prairieburg, probably the tornado as a funnel aloft.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1600-1800	F(3)		Coggon, Linn Co.	1
1600-1800	F		Delaware, Linn Co.	1
1600-1800	F		Earlville, Delaware Co.	1
1845	H		Cedar Rapids, Linn Co.	2

1" hail reported.

Figure 2. The tornado shown here was about 10 mi away. The photograph was taken from the Williamsburg High School while the twister was ripping up four farms between Ladora and Marengo, Iowa, August 12, 1974. The tornado came out of the NW at about 7:15 p.m. A second funnel, also in the area, failed to touch down. The damage path was ½ mi wide and 2 mi long. Note the precipitation shaft just visible on the far right of the photograph. The storm is moving left to right. This is a typical tornadic storm structure: the tornado track is often found parallel to and to the right of the movement of the main precipitation area. Photograph by *Journal Tribune*, Williamsburg, Iowa.

12 August 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1915	T,F	moved SE at 5 mph	1¾ NE Ladora, Iowa Co.	1,2,3

Tornado touch down for about 3 miles, damaging four farms. On two farms the houses were destroyed—nothing left on the ground except scattered debris. The two other farms had slight building damage, most damage being to trees. The tornado was visible for miles around and was photographed from several locations up to 10 to 12 mi away. A second funnel appeared after the tornado lifted and dissipated, but did not touch down. Three persons injured by flying debris. Tornado moved very slowly, between 3 and 5 mph.

1950	T		Davenport, Scott Co.	1,2

Brief tornado touch down reported NE of Davenport.

1950	T		Le Claire, Scott Co.	2

Brief tornado touch down reported SE of Le Claire.

12 August 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2030	H		Kalona, Washington Co.	1

½" hail covered the ground.

DATE: 13 August 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1005	H(1¾")		Avoca, Pottawattamie Co.	2,3
1200	W,H		Atlantic, Cass Co.	2,3

Wind caused most of the reported damage, some small hail observed.

morning	H		Henry Co.	3

Hail caused severe crop damage in northern Henry County.

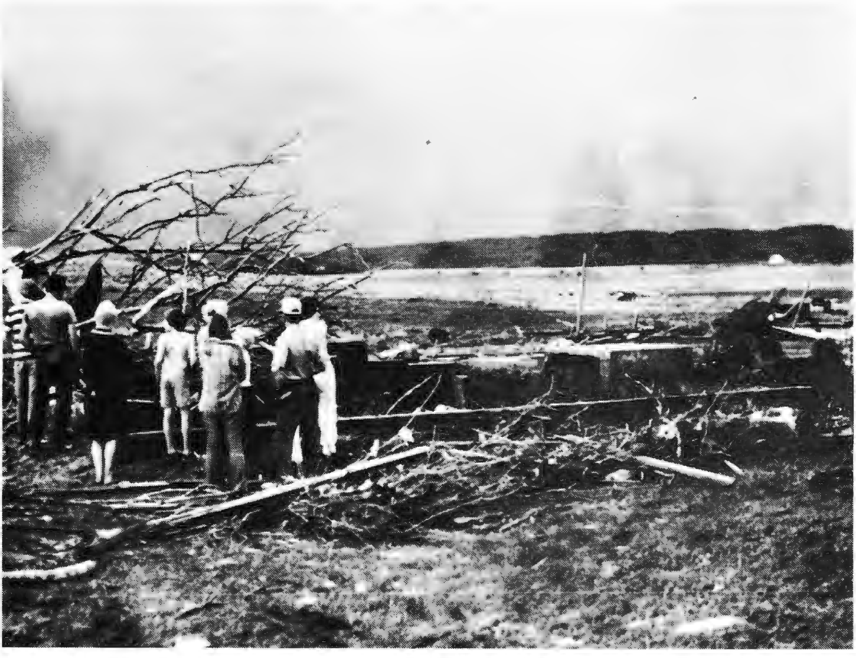


Figure 3. After the tornado shown in Figure 2, only the foundation was left at this farm home near Ladora, Iowa. The family survived by taking cover in the basement. Four sows and a pig were blown into the basement with the family when the home was swept away. A sturdy item such as a work bench or pool table generally offers good protection during a tornado. Photograph by *Journal Tribune*, Williamsburg, Iowa.

DATE: 17 August 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0730	H,W,F(2)		Fonda, Pocahontas Co.	1,3

Wind-driven hail damaged crops NE of Fonda. Two funnels sighted just S of Fonda; but no touch down.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
0905	W	moved SE at 35 mph	Le Mars, Plymouth Co.	2,5

Winds up to 60 mph were accompanied by very heavy rains.

DATE: 18 August 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1630	H		Little Rock, Lyon Co.	3
1650	H		Sibley, Osceola Co.	1,2,3,5

Hail up to 2¼" in diameter reported. Accumulations up to 5" reported S of Sibley.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1700	H		Ocheyedan, Osceola Co.	1

Hail up to 2" in diameter damaged crops extensively.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1700	W		3½ SE Melvin, Osceola Co.	1

Strong winds damaged buildings on farm 3½ miles SE of Melvin.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1715	H(1½")		May City, Osceola Co.	5
1800	W		Primghar, O'Brien Co.	1,2,3

Damage in the Primghar area from winds estimated at 70 mph.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1800	H(1")		Gaza, O'Brien Co.	2
1800	F,Rain		Paullina, O'Brien Co.	2,3,5

Funnel cloud reported. Five to six in. of rain reported just north of Paullina.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1800	W,H		Sanborn, O'Brien Co.	1,2

1¾" hail driven by strong winds.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1845	H(1")		Peterson, Clay Co.	2,3,5
~1850	H		Linn Grove, Buena Vista Co.	3
~1900	H		Sioux Rapids, Buena Vista Co.	3

18 August 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1920	H(½")		Cherokee, Cherokee Co.	3
~1945	H		Aurelia, Cherokee Co.	3
~2000	H		Alta, Buena Vista Co.	3
2030	H(1")		Holstein, Ida Co.	3,5

DATE: 20 August 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
evening	W		Rock Rapids, Lyon Co.	3
Winds up to 70 mph reported.				
~2200	F(2), H		Sanborn, O'Brien Co.	1,3
Two funnels sighted SW of Sanborn. Light hail damage in and around Sanborn.				
night	W		Nashua, Chickasaw Co.	1,3
Winds destroyed a barn NE of Nashua.				

DATE: 21 August 1974

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
1630	W		Cambria, Wayne Co.	3
Winds damaged buildings and crops.				
1730	W		4E Belle Plaine, Benton Co.	1
Winds destroyed a barn and several farm outbuildings.				
~1750	W		Albia, Monroe Co.	1,3
Winds accompanied by heavy rains destroyed a mobile home and damaged several buildings.				
~1845	W		Wapello Co.	3
1900	LTNG		7N Decorah, Winneshiek Co.	1,3
Lightning struck a barn, which burnt to the ground.				
1900	LTNG		Iowa City, Johnson Co.	3

21 August 1974, Continued

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
~1940	W		Fairfield, Jefferson Co.	1,3

Winds removed a house roof and damaged trees in the area.

TIME (CDT)	EVENT	DIRECTION	LOCATION	SOURCE
2020	W		Mount Pleasant, Henry Co.	1,3

Strong winds destroyed two trailers and moved several others off their blocks in a trailer court in Mount Pleasant.

A SELECTED LIST OF ANNOTATED REFERENCES

Notis, Charles and John L. Stanford. 1973. The Contrasting Synoptic and Physical Character of Northeast and Southeast Advancing Tornadoes in Iowa. *Journal of Applied Meteorology* 12: 1163-1173. This gives the results of a systematic study of the character of Iowa tornadoes over the 13-year period, 1959-1971.

Spohn, H. R., and P. J. Waite. 1962. "Iowa Tornadoes," *Monthly Weather Review* **90**: 398-406. This gives an account of the characteristics of Iowa tornadoes for the years 1916-1960.

Stanford, John. 1977. TORNADO - *Accounts of Tornadoes in Iowa*. Iowa State University Press. This book is written for the non-specialist and gives an account of all important Iowa tornadoes from 1803 through 1976. A large number of photographs, detailed descriptions of the more famous storms, and a special section on tornado safety are included.

IOWA STATE JOURNAL OF RESEARCH / FEBRUARY, 1977
Vol. 51, No. 3 363-368

FORECASTING GREEN CLOVERWORM[1] LARVAL POPULATION PEAKS[2]

Thomas V. Myers[3] and Larry P. Pedigo[4]

ABSTRACT. A green-cloverworm population study was established in three central Iowa soybean fields. Numbers of adult and larval populations were recorded in each of the fields to determine the possibility of using the number of adults to forecast larval population peaks.

The first larval peak was noted in early July. A first peak in adult collection occurring on July 26 was followed by a major peak in larval numbers during the first part of August. The second larval peak occurred 11 to 13 days after the adult peak. Blacklight monitoring of the adult, green-cloverworm population offers potential in giving a warning of an approaching peak in larval numbers.

INTRODUCTION

The green cloverworm, *Plathypena scabra* (F.), is the major insect pest on Iowa soybeans. This insect causes reduction in crop yield through defoliation, and, during outbreak years, is often sustained by the crop before control measures can be implemented. Delays caused by weather or the shortage of insecticides in a local area add to the loss.

An early warning of the approaching peak larval numbers would allow more flexibility and greater efficiency in control programs. During the spring and summer of 1975, a study was initiated in central Iowa to assess the possibility of using the numbers of adult green cloverworms collected in blacklight traps to forecast larval population peaks.

Few published references can be found in which light-trap collections of noctuids are used to predict damaging larval populations. Pfrimmer (1961) stated that there was a need for more investigations on the relationship between light-trap catches and field populations.

During studies with cabbage looper and bollworm, Falcon et al. (1967) found good correlation between the field counts of eggs and larvae and the mean number of adults collected in light traps. Other researchers have observed that peaks in the numbers of adults collected in light traps are followed by peaks in larval numbers (Beckman, 1970; Hartstack et al., 1973; Hofmaster, 1961; Stanley and Bennett, 1965).

According to Miller et al. (1963), the number of southern armyworm adults collected in light traps in Tasmania were a reliable guide to the likelihood of outbreaks. Mangat and Apple (1964) stated that relating light-trap catches to temperature accumulations should provide a means of timing insecticide treatments against the corn earworm. Parencia et al. (1962) stated that information obtained with light traps, in combination with the knowledge of experienced workers, may be useful in giving cotton growers a few days advance warning of potentially injurious infestations of lepidopteran larvae.

---

[1] Lepidoptera:Noctuidae

[2] Journal Paper No. J-8582 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa 50011. Project 1956.

[3] Formerly Research Assistant. Present address: Department of Entomology, University of Kentucky, Lexington, Kentucky 40506.

[4] Professor, Department of Entomology, Iowa State University, Ames, Iowa 50011.

METHODS AND MATERIALS

During the spring of 1975 a green-cloverworm population study was established in three central Iowa soybean fields. Green-cloverworm adult and larval populations were recorded in each of the fields to determine the possibility of using numbers of adults to forecast larval population peaks.

Green-cloverworm adults were collected by using 15-watt blacklight survey traps, constructed to the standard specifications as outlined by Harding et al. (1966). The killing agent used was one dichlorvos strip (Shell No Pest® Strip) per trap, with the strip being replaced every 21 days. Trap tending was conducted every third day, with the number of adults collected in each trap recorded.

Larval populations were sampled with a 15-in sweep net. Four random sweep samples were taken weekly in each field, with 48 sweeps in one sample.

RESULTS AND DISCUSSION

Figures 1 to 3 represent the three fields in which data were gathered on both green-cloverworm—larval and adult populations.

Larval-population data from all three fields indicated two distinct peaks, with the larger peak occurring in early August. Other researchers also have noted the occurrence of a major larval peak (of endemic populations) in August (Blickenstaff and Huggans, 1962; Burbutis and Kelsey, 1970; Carner et al., 1974; Pedigo et al., 1972; Shepard et al., 1974), but previous research in Iowa reported only one larval peak in soybeans (Pedigo et al., 1972; Pedigo et al., 1973).

The inability to detect an early, green-cloverworm peak in Iowa soybeans in 1968 and 1969 (Pedigo et al., 1972) probably was because of the long time period between sample dates (two weeks).

Sweep sampling during the spring and summer of 1971 revealed three cloverworm larval peaks in alfalfa, but only one in soybeans (Pedigo et al., 1973). The lack of a first larval peak on soybeans, or of one of a size sufficient to sample, possibly was caused by the cool, dry, spring weather, which slowed germination of the 1971 crop (Iowa Department of Agriculture, 1971). Scattered frost or light freeze was reported as late as May 27, with spring precipitation deficiencies in March, April, May, and the first 2 weeks in June (U.S. Department of Commerce, 1971).

Numbers of adults collected in the three fields varied considerably. This was because of the variation in population density in the three fields, and also because uneven terrain caused the amount of area sampled by each trap to differ.

Similar trends of adult populations were noted in Fields 1 and 3, as were trends of larval populations in all fields. The availability of electrical power in Field 2 necessitated locating the trap close to occupied buildings. Unfortunately, the infrequent competition from nearby light sources affected the collection stability of the light trap. This sporadic competition resulted in erratic, and consequently unusable, adult-collection data in Field 2. Therefore, comparisons between adult and larval populations are discussed for Fields 1 and 3 only.

In Fields 1 and 3 the first larval peak was noted in early July. A first peak in adult collection occurred later in July, followed by a major peak in larval numbers during the first part of August. The largest number of adults was collected during mid-August, peaking August 16 in Field 1 and August 19 in Field 3.

The shape of the second larval peak suggests that the population in each of the two fields peaked between the sample dates of August 4 and August 12. The peak seems to have occurred in Field 1 approximately August 6 and in Field 3, August 8.

Because the second larval peak is the largest and most damaging on soybeans, the ability to forecast the time of its occurrence would be of great benefit. Considering the first substantial peak in numbers of adults on July 26 in both fields, the second larval peak occurred 11 days later in Field 1 and 13 days later in Field 3. Thus, the monitoring of the adult, green-cloverworm population through the use of blacklight traps offers potential in predicting an approaching peak in numbers of larvae.

The warning period would be about 5 to 7 days. This estimate is based on the requirement of two additional light-trap sampling periods (6 days if sampling at 3-day intervals) to

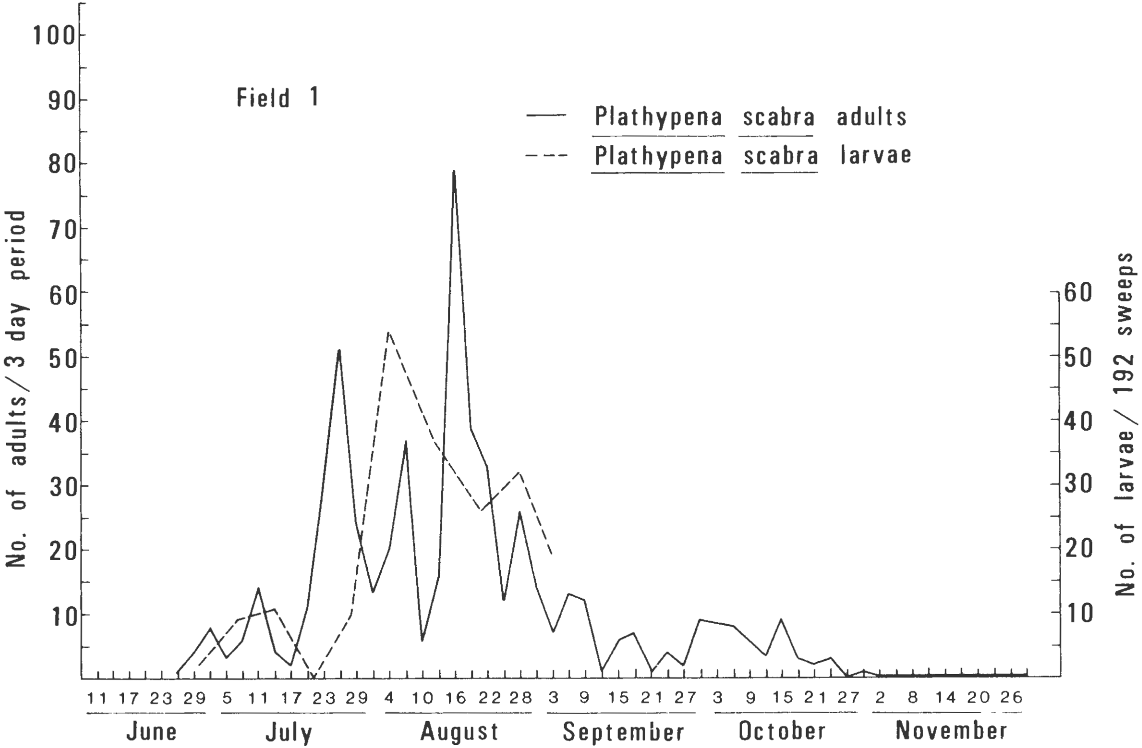


Figure 1. Number of green-cloverworm adults and larvae collected in Field 1.

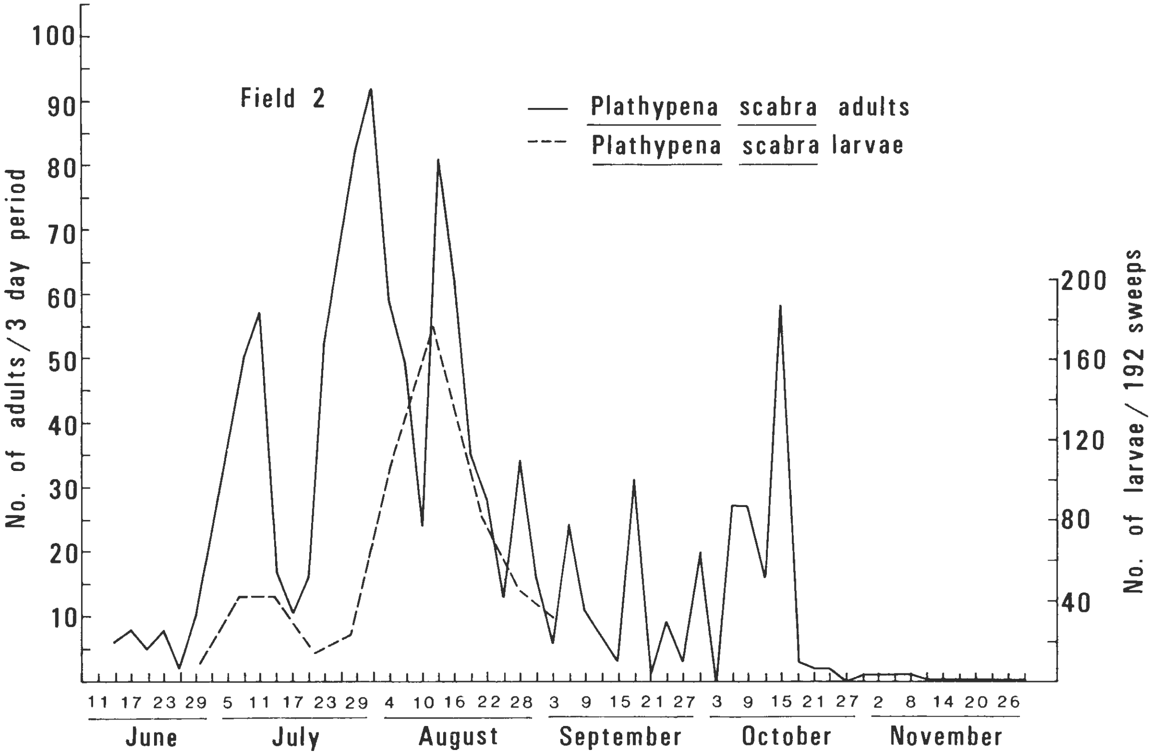


Figure 2. Number of green-cloverworm adults and larvae collected in Field 2.

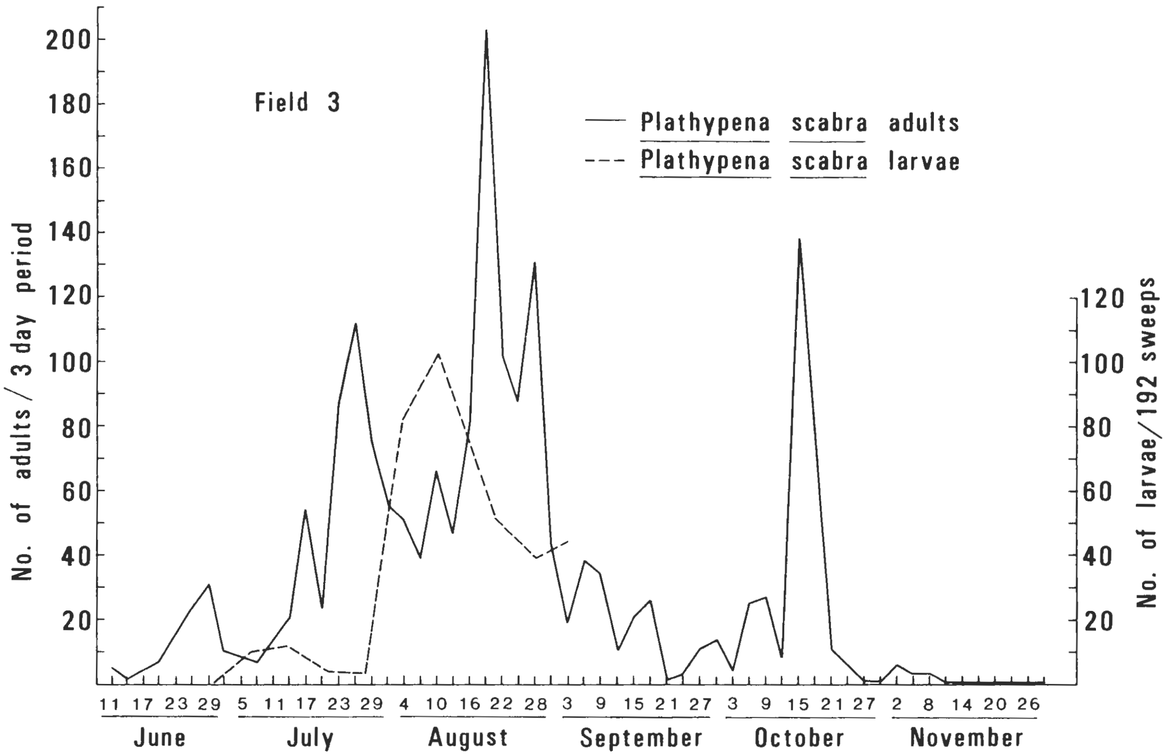


Figure 3. Number of green-cloverworm adults and larvae collected in Field 3.

determine the actual peak in numbers of adults. Such a warning could alert crop protection scouts and soybean growers of a need to check fields for the presence of large numbers of larvae.

Because about 90% of feeding by the green cloverworm is done by the last two larval instars (Stone and Pedigo, 1972), the major damage to the crop takes place in about 6 days. This advance warning would allow time to sample larval populations, make management decisions, and, if necessary, to complete control operations before the crop has been damaged extensively.

REFERENCES CITED

Beckham, C. M. 1970. Seasonal abundance of *Heliothis* spp. in the Georgia piedmont. Journal of the Georgia Entomological Society 5: 138-42.

Blickenstaff, C. C., and J. L. Huggans. 1962. Soybean insects and related arthropods in Missouri. Missouri Agricultural Experiment Station Research Bulletin 803: 51 pp.

Burbutis, P. P., and L. P. Kelsey. 1970. Pest status of the green cloverworm on lima beans in Delaware. Journal of Economic Entomology 63: 1956-8.

Carner, G. R., M. Shepard, and S. G. Turnipseed. 1974. Seasonal abundance of insect pests of soybeans. *Ibid.* 67: 487-93.

Falcon, L. A., R. van den Bosch, L. K. Etzel, C. A. Ferris, and L. K. Stromberg. 1967. Light traps as detection devices for moths of cabbage looper and bollworm. California Agriculture 21(7): 12-4.

Harding, W. C., Jr., J. G. Hartsock, and G. G. Rohwer. 1966. Blacklight trap standards for general insect surveys. Bulletin of the Entomological Society of America 12: 31-2.

Hartstack, A. W., Jr., J. P. Hollingsworth, R. L. Ridgway, and J. R. Coppedge. 1973. A population dynamics study of the bollworm and the tobacco budworm with light traps. Environmental Entomology 2: 244-52.

Hofmaster, R. N. 1961. Seasonal abundance of the cabbage looper as related to light trap collections, precipitation, temperature and the incidence of a nuclear polyhedrosis virus. Journal of Economic Entomology 54: 796-8.

Iowa Department of Agriculture, Division of Agricultural Statistics. 1971. Iowa annual farm census 1971. Iowa Department of Agriculture Bulletin 92-AG. 31 pp.

Mangat, B. S., and J. W. Apple. 1964. Heat units and light trap collections as methods for timing corn earworm insecticidal treatments. Proceedings of the North Central Branch of the Entomological Society of America 19: 108-9.

Miller, L. W., E. J. Martyn, and N. M. Hudson. 1963. The prediction of outbreaks of the southern armyworm, *Persectania ewingii* (Westw) in Tasmania. Tasmanian Journal of Agriculture 34: 92-4.

Parencia, C. R., Jr., L. B. Cowan, Jr., and J. W. Davis. 1962. Relationship of Lepidoptera light-trap collections to cotton field infestations. Journal of Economic Entomology 55: 692-5.

Pedigo, L. P., G. L. Lentz, J. D. Stone, and D. F. Cox. 1972. Green cloverworm populations in Iowa soybeans with special reference to sampling procedure. *Ibid.* 65: 414-21.

Pedigo, L. P., J. D. Stone, and G. L. Lentz. 1973. Biological synopsis of the green cloverworm in central Iowa. *Ibid.* 66: 665-73.

Pfrimmer, T. R. 1961. Light traps to predict need for control. Pages 48-50 *in* Response of insects to induced light. United States Department of Agriculture, Agricultural Research Service 20-10. 66 pp.

Shepard, M., G. R. Garner, and S. G. Turnipseed. 1974. A comparison of three sampling methods for arthropods in soybeans. Environmental Entomology 3: 227-32.

Stanley, W. W., and S. E. Bennett. 1965. Seasonal abundance of 13 species of moths caught in light traps in Tennessee. Journal of the Tennessee Academy of Science 40: 118-31.

Stone, J. D., and L. P. Pedigo. 1972. Development and economic-injury level of the green cloverworm on soybean in Iowa. Journal of Economic Entomology 65: 197-201.

U.S. Department of Commerce. 1971. Climatological data, Iowa. United States Department of Commerce Publication 82. 81 pp.