A Mesoscale Study of Corn-Weather Response on Cash-Grain Farms

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(Manuscript received 10 April 1967, in revised form 8 August 1967)

ABSTRACT

Weather records for 49 locations and detailed agronomic data from 60 farms in a 400-mi^2 area in central Illinois were used to study corn-weather relations exhibited by actual farming operations in a typical agricultural area of the American Corn Belt. Weekly, monthly and seasonal rainfall and temperature values plus agronomic data were correlated with corn yields during 1955–1963. The results are of added importance because the data sample was from a period when new agronomic practices, which could alter corn-weather relationships established in previous studies, were being widely employed.

July and August mean temperatures and cumulative degrees above 90F during July and August had the strongest correlations with corn yield, −0.50, −0.69 and −0.51, respectively. July rainfall had a stronger association with yields than rainfall in any other month, but it was considerably less than the association for July temperature.

Weekly rainfalls and temperatures in early June and early August correlated moderately well with yields, a finding that does not agree with those from certain other corn-weather studies. Several weather variables were more highly correlated with corn yield than were any of the newer agronomic practices generally considered to be important factors relating to corn yields. A trend of increasing yields with time during the 9-yr period was related to steady improvement in technological practices and also to a trend for better (cooler) corn weather in July and August.

In general, the results indicate that corn-weather relations defined by data from cash-grain farms during a recent 9-yr period of technological change are somewhat different from those defined in earlier studies using either experimental farm data or regional average yield data.

1. Introduction

Many studies of weather influences on corn yields have been performed over the past 50 years. Wallace in 1920 and subsequently Davis and Palleson (1940), Ezekiel (1941), Houseman (1942), and Hendrichs and Scholl (1943) were among the first scientists to employ advanced statistical analyses in studies of corn-weather relationships. In more recent years, studies by Runge and Odell (1958) and Dale and Shaw (1965) have been made to determine the weather-yield relationships using phenological (stage of growth) data. These referenced corn-weather studies were based either on point data from university-operated experimental farms or on area-mean data from large (county or state) regions.

A major problem facing all corn-weather studies has been to ascertain accurately the roles of weather factors, treated individually or collectively, and those of man-made (technology) factors which interact to produce a corn yield. The adoption of hybrid corn in the 1935–1945 period altered the previously established interactions between technology factors and weather factors. Widespread employment of commercial fertilizers, particularly nitrogen, since 1950 and the adoption of higher planting rates since 1955 have further altered this interaction. This latest phase of technological change has been associated with a period of continuous and rapid increases in corn yields, and this has made delineation of corn-weather relations more difficult. However, assessment of the current role of weather in corn production is now essential because of the rapid increase in national and world food needs and the need to establish proper governmental controls on crop production. Recent studies relating to these needs have produced conflicting results concerning the role of weather and that of technology (Thompson, 1966; Shaw and Durost, 1965).

The availability of nine years of recent (1955–1963) data on weather conditions, corn yields, and associated agricultural practices on cash-grain farms in a small area of central Illinois offered a unique opportunity to make a mesoscale study of corn-weather relations during this latest technology phase. It also allowed an assessment of corn-weather relations derived from actual farming operations as opposed to those established using experimental farm data or that for large areas. The data for this study were obtained from 60 farms, 49 recording rain gages, and 7 temperature stations located in a 400-mi^2 area. Nine years of data at the 60 locations provided a sample size of 540 yield values for correlation with weather and agronomic observations. The study area is in a high-value, cash-grain farming region representative of large segments of the American Corn Belt. The value of the crops produced in this area in 1963 was

$16,500,000. Physiographically, the area is quite homogeneous. It is a flat, featureless plain (maximum relief of only 260 ft) having deep, moderately permeable prairie soils that are highly productive. Because the surface and soils are generally uniform, corn-weather responses are not strongly affected by variations of soil quality and drainage.

Analysis of the corn-weather data from this mesoscale area was limited in that detailed phenological records of the crops were not available, although the general times of corn planting periods were known. This lack of phenological data meant that the weather-yield analyses had to be based on weather data for fixed time periods rather than on non-calendar periods associated with times of emergence, silking, tasseling, or other growth stages. However, corn-weather relations determined for each of the three possible planting periods (early, middle and late) were quite similar, indicating that variations in stages of growth were not affecting the results based on arbitrary calendar periods.

Knowledge of the degree of correlation between weather conditions and yields from an actual group of farms has applications for 1) improving farm management practices (Runge, 1966), 2) ascertaining irrigation potential (Swanson and Jones, 1966), 3) determining the weather conditions that need to be modified to get increases in yields, and 4) estimating possible gains that could be derived from weather modification (Kirkbride and Trelogan, 1966). Corn has become the most important crop in the United States (Thompson, 1966), and the possible increase in production through weather modification is a matter of national concern.

2. Data

Precipitation and temperature. Most of the research was based on agricultural and weather data collected within a 400-mi^2 area in central Illinois (Fig. 1). The 49 recording rain gages in this area are about 3 mi apart in a grid pattern, forming a square network of 20 mi per side. Numerous measurements are needed to furnish an accurate picture of the rainfall variability in the area (Huff and Neill, 1957) which is typical of the rainfall regime of the Middle West. Rainfall values for each farm were those measured at the nearest rain gage, usually less than 1 mi from the farm.

Temperature data for the 60 farm sites were obtained by regional interpolation of values recorded by seven U. S. Weather Bureau stations located in and around the network area (Fig. 1). Because weekly and monthly temperatures in this region have a uniform gradient across 10- and 20-mi distances, these temperature estimates were considered valid. The basic weather information used consisted of June through August data for weekly and monthly precipitation, weekly mean maximum temperatures, weekly and seasonal frequencies of days with 90F or higher temperatures, May–August data for monthly mean temperatures, pre-season precipitation (September through May), and cumulative degrees above 90F for the July–August period.

One limitation of this research and its results is the

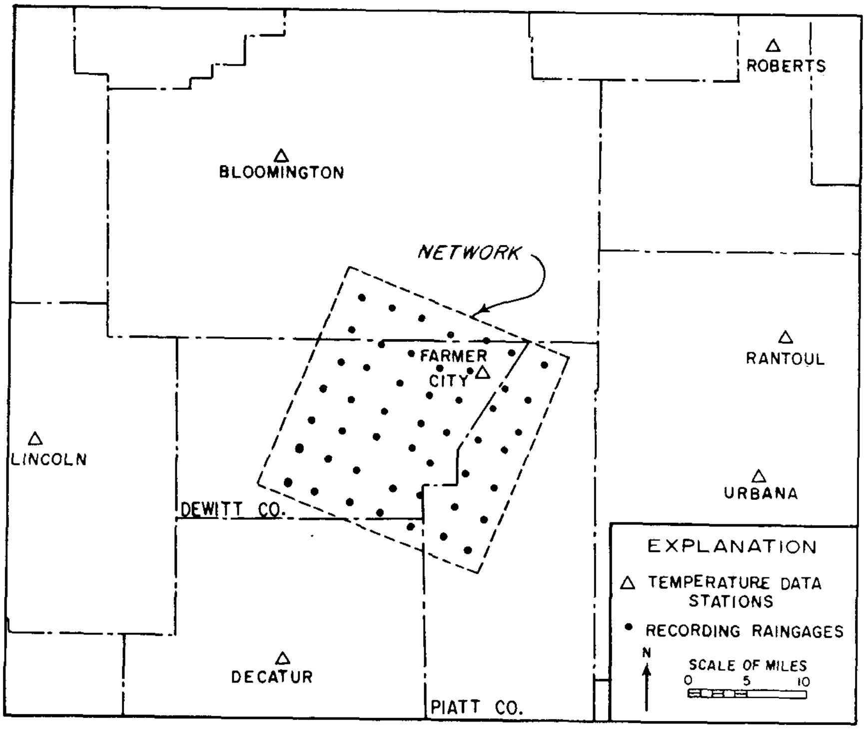


FIG. 1. Location of rain gage network in central Illinois.

9-yr sample of weather data which, unfortunately, measured only one moderate drought season, 1959. In the summer of 1955, the network area had between 39 and 43 days of 90F or higher temperatures, but near-normal rainfall somewhat alleviated the high temperature effect. In 1959 there were 36–40 days of 90F or higher temperatures, and the rainfall totals were only 50% of normal. The 1955–1963 period in Illinois has been classified as a uniquely good corn-weather period (Thompson, 1966). However, the ranges of the point (farm) weather values in the 9-yr sample are representative of the extremes recorded over a 60-yr period for 1) pre-season precipitation, 2) May temperature, 3) June precipitation, and 4) July precipitation. On the other hand, mean temperatures in June, July and August have been higher than the maximum sample values 10% of the time and August rainfall has been higher than the sample maximum (6.7 inches) 5% of the time, as measured over the 60-yr period. Normally, the area has 34 days per summer with 90F or higher temperatures, but in the 9-yr period only 1955 and 1959 had more than normal, and the 7 other years had values between 9 days (1958) and 28 days (1963).

Soil moisture calculations representative of the study area were made by Swanson and Jones (1966) for a period they considered critical for corn, 18 July–3 August, for 58 yr including 1955–1963. Their results showed that soil moisture available in the top 5 ft of soil was more than 70% of capacity in 8 of the 9 study years, and more than 80% in 5 yr (1957, 1958, 1960, 1962 and 1963). It was limiting only in 1959, when the amount in this 17-day period was 36% of capacity. For this 17-day period, the 58-yr average available soil moisture was 6.5 inches, but the average determined for 1955–1963 was 8.4 inches, further attesting to the generally good corn-weather conditions during most of the sample period. Since the soil moisture in this period was seldom limiting, it was expected that temperatures would show a stronger relation with yields than would rainfall.

Agricultural. Sixty farms (shown as shaded areas on Fig. 2) were chosen to furnish argicultural information on the basis of availability and completeness of data for the 9-yr period. Illinois Farm Bureau Farm Management Service records were available for most of the farms. Annual data for each farm included information on planting period, plant population, corn yield, soil productivity rating, and nitrogen application. Planting periods were recorded as occurring in one of three periods 1) early planting (prior to 1 May), 2) middle planting (1–15 May), and 3) late planting (after 15 May). Plant population was based on an estimate of the number of kernels planted per acre.

The 9-yr mean annual corn yield of the 60 farms was 96 bushels acre^{-1}, attesting to the high levels of productivity of these farms. Individual annual yields ranged from a low of 44 to a high of 145 bushels acre^{-1}. Farm size ranged from 60 to 760 acres with an average of 210 acres.

3. General correlations

First impressions of associations of corn yield with four agricultural variables and ten weather variables were obtained from simple linear correlations. Agricultural variables were planting period, plant population, soil productivity rating, and nitrogen applied in the year. Weather variables were pre-season precipitation; monthly mean temperature for May, June, July and August; number of days with 90F or higher for the June–August period; number of cumulative degrees above 90F in July and August; and monthly rainfall totals for June, July and August. The year of observation was also included as a variable to check for correlations which would suggest the presence of linear time trends among the variables.

TABLE 1. Linear correlation coefficients.

Variables	Corn yield Individual observations	Corn yield Yearly-mean values	Year (trend)
Year	0.70	0.89	
August mean temperature	−0.69	−0.89	−0.69
Sum of degrees above 90F in July–August	−0.51	−0.66	−0.61
July mean temperature	−0.50	−0.64	−0.58
Nitrogen	0.41	0.91	0.87
Number of days above 90F, June–August	−0.37	−0.47	−0.31
Plant population	0.35	0.87	0.97
August rainfall	0.29	0.37	0.30
June mean temperature	0.29	0.37	0.33
July rainfall	0.24	0.34	0.15
June rainfall	−0.22	−0.29	−0.35
Pre-season precipitation	0.13	0.22	0.14
May mean temperature	−0.07	−0.09	−0.13
Soil productivity	0.05		
Planting period	−0.01	−0.25	−0.42

The sample from 60 farms over 9 yr provided a total of 540 individual observations for each variable, except soil productivity, for which one observation was available for each farm for the period. In addition, a mean value for each variable was determined for each year. Correlation coefficients were computed for the 540 individual observations and for the 9 yearly-mean values for each variable. These coefficients are shown in Table 1. Correlations based on the 540 individual observations denote the strength of associations for those interested in individual yield variation. Correlations based on yearly-means are appropriate when average production is considered. The latter correlations are also more appropriate for comparisons with the correlations in the year (trend) column which are also based on yearly-mean values. For a sample size of the order of 540 individual yields, correlations with yield on the order of ± 0.09 and ± 0.11 are sufficient for significance

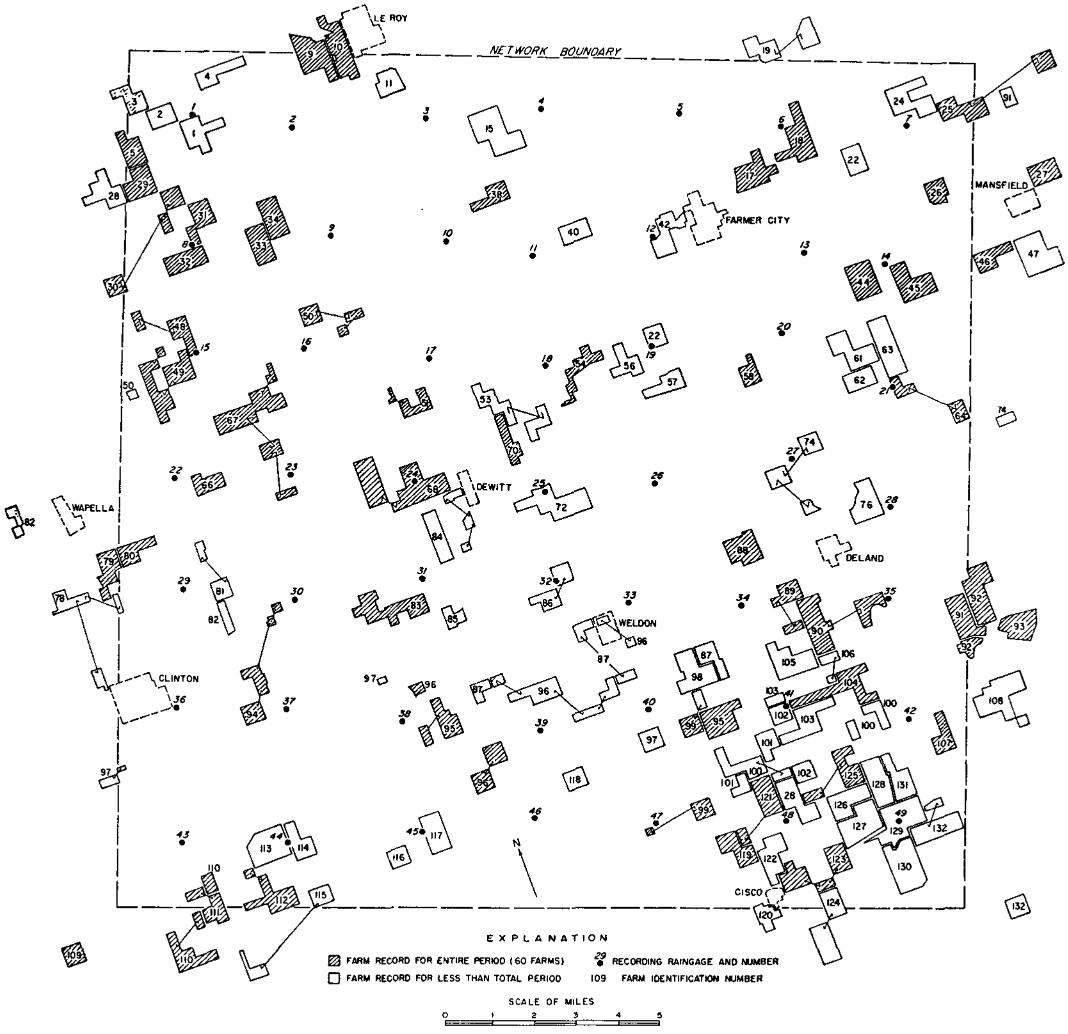
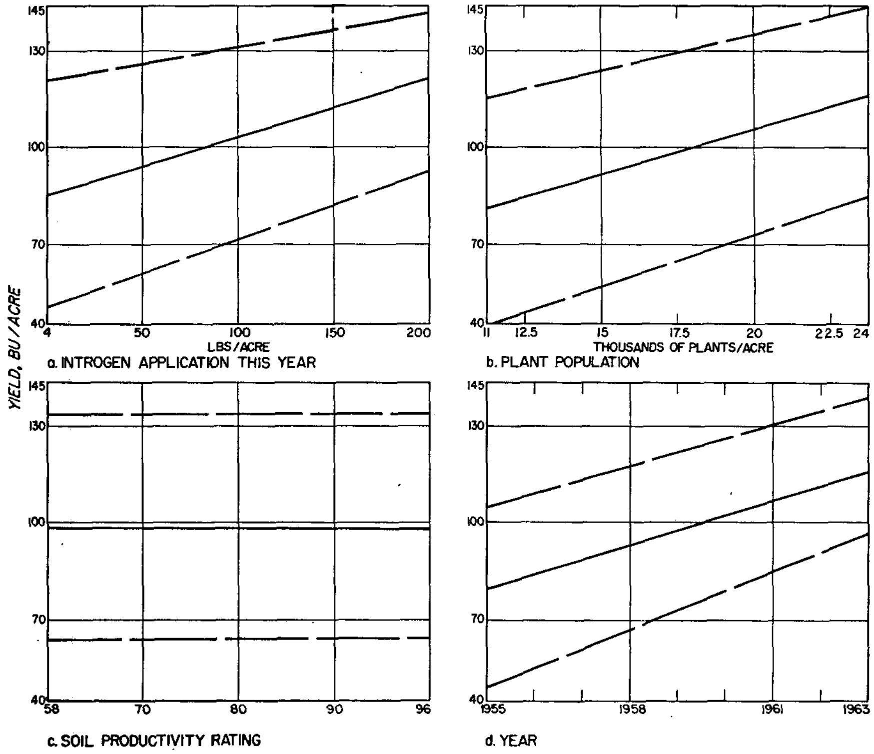


Fig. 2. Location of farms in rain gage network.

at the commonly used 0.95 and 0.99 probability levels, respectively (Snedecor, 1946). Considering 9 yearly-means of each variable as a sample of size 9 correlations, of the order of 0.63 and 0.76 are required for significance at the 0.95 and 0.99 probability levels, respectively.

Agricultural variables. The correlations of individual and yearly-mean farm yields with nitrogen are substantial at 0.41 and 0.91, respectively. Doll *et al.* (1958) established that nitrogen was the single most important fertilizer relating to corn yields. The square of the correlation of individual yields with plant population suggests that this variable explained about 12% of the individual yield variation. The two remaining agricultural variables have correlations with yield which are less than those required for statistical significance. The association between farm yields and nitrogen applications, plant populations, and the soil productivity rating are shown also in Fig. 3. The smoothed dashed lines were drawn to incorporate 95% of the 540 data points, and their great separation on each graph illustrates the wide scatter of the data. These graphs emphasize the tremendous variation in farm yields about the best-fit curves (Figs. 3a and 3b) for two agricultural variables involving management (technological variables) considered by many to be very important in determining corn yields (Runge, 1966; Shaw and Durost, 1965).

A correlation of 0.70 was obtained between the individual farm yields and the year, which suggests a definite upward trend in yield over the 1955–1963 period of observation (Fig. 3d). In part, this is an expression of steady improvement in technology for increasing corn yield. Increase in average plant populations and nitrogen applications, the two most important technological factors analyzed in this study, have occurred during the sample period according to trend correlations of 0.97 and 0.87, respectively (Table 1). The yearly-mean values of these two variables are comparably well correlated with yield. Thus, there is evidence



a. NITROGEN APPLICATION THIS YEAR

b. PLANT POPULATION

c. SOIL PRODUCTIVITY RATING

d. YEAR

FIG. 3. Relation of corn yields with technological practices, soil and time.

that these two technological factors contributed to the increase in yield during the observation period.

Monthly and seasonal weather variables. The best correlations of yield with weather variables in Table 1 are with temperature factors. Correlations based on the 540 individual values of yield with July and August mean temperatures, with cumulative degrees above 90F during the July through August period, and with number of days of maximum temperature of 90F or above were −0.50, −0.69, −0.51, and −0.37, respectively. Thompson (1963) showed the importance of July and August mean temperatures; however, Thompson found that on a statewide basis July temperature is more hightly correlated with Illinois yields than is August temperature. The cumulative degrees above 90F in July–August, and the number of days with maximum temperature of 90F or higher for the period June through August were included to test for relations between corn yield and excessively high temperatures. Thompson (1966) has indicated that the best single measure of the effect of weather on corn yield was the cumulative degrees above 90F during July and August. These accumulations determined for the various farms were less than 55 in eight of the nine years. Only in 1955 were the accumulations relatively high, ranging from 124 to 150 for the 60-farm sample. Correlations for these two measures of high temperature might have been considerably higher if the sample period had included more years with greater numbers of high temperature days. For example, Dale and Shaw (1965) have shown that the relation of corn yields to frequency of moisture stress days in midsummer was poor until the number exceeded 30, above which a close relationship existed.

Since the relation of monthly rainfall to yield may be curvilinear rather than linear, correlation indices were also computed from quadratic regressions of individual yields and rainfall. These computations produced an index of 0.37 for July rainfall, a considerable improvement over the 0.24 linear correlation in Table 1. The quadratic relationship explained 14% of the yield variation, as compared to 6% for the linear, and produced an F-ratio test value which exceeded the 0.999 probability level. However, the curvilinear fit of yields with June, August, and pre-season rainfall totals resulted in correlation indices not appreciably greater than the linear coefficients.

The best-fit curves determined for the six most relevant monthly weather variables are displayed in Fig. 4. The smoothed dashed lines incorporate 95% of the data points and outline the general configuration of the data scatter.

June mean temperatures fitted a quadratic regression curve significantly better than a linear regression line. However, the spread of the 95% bands (Figs. 4a and 4b) and the low correlation for June temperature and rainfall in Table 1 indicate that the corn yields in this area were poorly related to the range of monthly weather conditions for June.

July rainfall (Fig. 4c) exhibited a curvilinear fit with corn yields, indicating that the optimum July rainfall

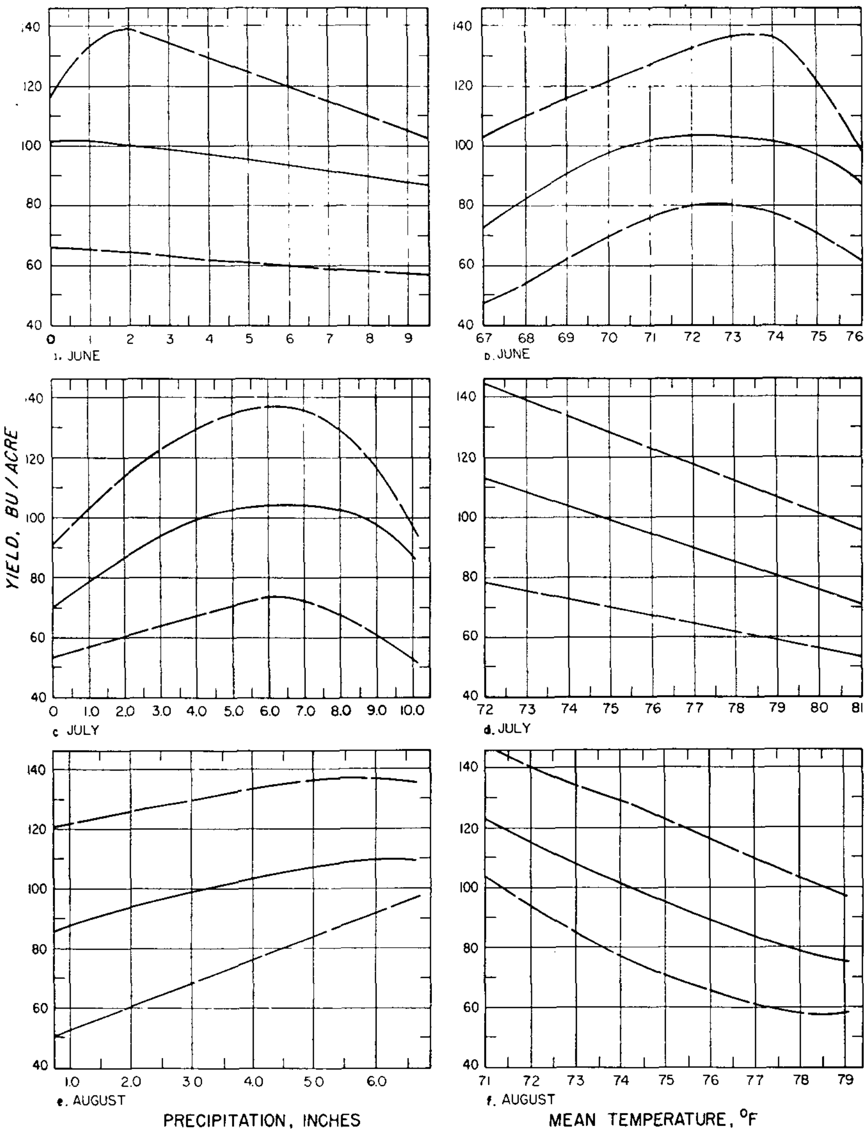


Fig. 4. Relation of corn yields with monthly weather conditions.

for maximum corn yields is between 6 and 7 inches. However, July rainfall explained only 14% of the corn yield variability. In a corn-weather study of all Illinois counties using 33-yr records of county yields and rainfall, Changnon and Neill (1967) showed relatively low correlations for July rainfall with corn yields in the counties encompassing their study area. In the present study, the relationship of corn yield with July mean temperature was linear (Fig. 4d), and the correlation coefficient of −0.50 (Table 1) indicates that 25% of the yield variations might be attributed to July temperature.

Fig. 4e indicates that corn yields were at a maximum when August rainfall totals were 6 inches or more and the quadratic regression line suggests that additional rain would not increase yields. Unfortunately, the 9-yr sampling period on the network did not include an extremely wet August at any farm. August temperatures (Fig. 4f) fit a quadratic distribution slightly better than a linear, but the correlation index of 0.70 was not significantly better than the linear coefficient of −0.69 in Table 1. The −0.69 was the highest correlation obtained for the monthly weather variables. It was also higher than those obtained for either of the excessive temperature factors and those for any of the weekly rainfall and temperature variables.

A weather-trend correlation (Table 1) for the sample period suggests that weather may have been partially responsible for the upward yield trend during 1955–1963. July and August temperature-trend correlations, significant at the 0.90 and 0.95 probability levels, respectively, are indicative of a cooling trend for these months. As noted previously, corn yield has a sub-

TABLE 2. Data and linear correlation coefficients for different planting periods.

	Planting periods		
	Early, prior to 1 May	Middle, 1–15 May	Late, after 15 May
Number of samples	17	443	80
Average yield, bushels acre^{-1}	98.4	95.3	96.3
Variables			
Year	0.80	0.71	0.63
Plant population	0.65	0.34	0.22
Soil productivity	0.36	0.05	−0.02
Nitrogen	0.65	0.48	0.03
Pre-season precipitation	−0.15	0.13	0.25
May temperature	−0.11	−0.07	−0.04
June rainfall	−0.50	−0.22	−0.15
June temperature	0.58	0.29	0.19
July rainfall	0.02	0.25	0.24
July temperature	−0.61	−0.49	−0.54
August rainfall	0.45	0.26	0.38
August temperature	−0.74	−0.70	−0.68

stantial inverse correlation with these weather factors. Consequently, these downward temperature trends during the observation period should have favored an increase in corn yield. It is therefore likely that weather and technological trends interacted to favor corn production in this 9-yr sample, but the value of either influence on corn yield cannot be completely assessed in the available sample. Research on corn yields in Iowa (Bean, 1967) has shown that for the 1955–1963 period, weather effects caused an increase of 18 bushels acre^{-1}, whereas technological variables added 15 bushels, or less than the weather effects.

As shown in Table 2, 443 of the 540 corn-year values had planting periods during 1–15, May indicating that 82% of the crops sampled reached their various stages of growth at about the same time. The lack of phenological variability in the sample is further revealed by data for the crop-reporting district incorporating the study area. These data for the sampled 9 yr indicate that the dates when 50% tasseling occurred were between 18 July (1962) and 29 July (1960). The correlations presented in Table 2 allow inspection of the corn-weather relations for the different times of planting, and differences between them could be assessed as indicative of phenological variations. The general lack of major differences between the monthly weather correlations for the middle and late planting periods, which represent 97% of the data, indicates that the effect of phenological variations on the corn-weather relations established for the entire sample was negligible. Therefore, the use of weather conditions for fixed calendar periods should provide meaningful results. The results for the early planting cases have higher correlations with the early weather conditions, which suggests phenological associations, but the 17 samples are too few to derive reliable results. The major differences in the correlations of the 3 planting periods are those pertaining to the agricultural variables which show that technology-yield relations become poorer as planting time becomes later.

4. Weekly rainfall

Some crop-weather response studies have been done with monthly and seasonal weather data, primarily because these data are more rapidly available than short-term data. However, several investigators, including Runge and Odell (1958), have shown that corn yields are correlated with weather conditions during critical 7-, 10- and 14-day periods. Daily rainfall amounts for the rain gages nearest each farm were summed to obtain weekly rainfall amounts for correlation with the 540 farm yields. Running totals for 2-week, 3-week, and 4-week periods were then calculated and also correlated with the yields.

Correlations for both linear and curvilinear (quadratic) associations for rainfall and yields were determined. In every instance the curvilinear values, presented in Table 3, were higher than the linear values.

An examination of the correlations for 1-week rainfall totals with yield (Table 3) reveals several rather prominent features: 1) poor correlations in the first four weeks of June, 2) a change to a substantial indication of association during the weeks of 29 June–5 July and 6–12 July, 3) a return to poor associations for the weeks from 13 July through 2 August, 4) a relatively high correlation during the week of 3–9 August, and 5) poor correlations for the last three weeks of August. Fig. 5 depicts the best-fit curves for four selected weeks, and the 95% bands reflect the considerable data scatter found in these and all 1-week periods. By comparison with tabulated multiple correlations for 3 variables and a sample size of 540, correlations indices in Table 3 could be judged significant at the 0.95 and 0.99 probability levels if they exceed 0.11 and 0.14, respectively (Snedecor, 1946). However, a correlation of less than

TABLE 3. Corn yield versus rainfall for 1-, 2-, 3- and 4-week periods.

Beginning date of period	Quadratic indices of correlation for rainfall totals for given periods			
	1-week	2-week	3-week	4-week
6/1	0.08	0.46	0.30	0.26
6/8	0.27	0.24	0.24	0.28
6/15	0.04	0.13	0.43	0.46
6/22	0.20	0.26	0.35	0.31
6/29	0.47	0.39	0.34	0.32
7/6	0.48	0.36	0.25	0.22
7/13	0.05	0.15	0.19	0.09
7/20	0.16	0.31	0.12	0.04
7/27	0.13	0.29	0.26	0.21
8/3	0.54	0.35	0.37	0.31
8/10	0.17	0.11	0.07	—
8/17	0.27	0.17	—	—
8/24	0.26	—	—	—

±0.30 represents an association which explains a small percentage of the yield variation and is of questionable value in a practical sense.

The small correlations during the first four weeks of June agree with prior results (Runge, 1966) and reflect the common belief of farmers that below-normal rain in June favors corn production. The shift to relatively good correlation during 29 June–12 July (Figs. 5a and 5c) sug-

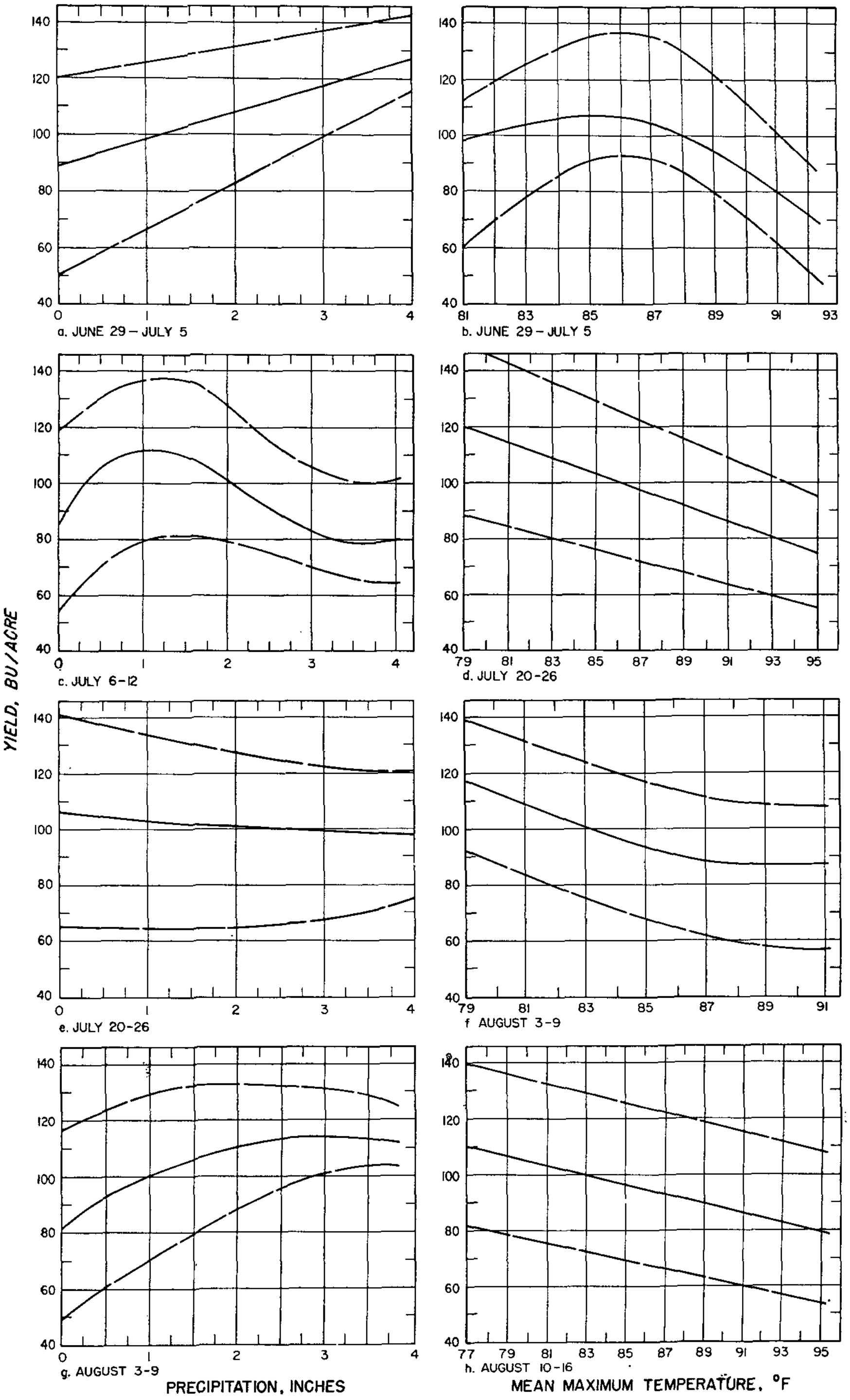


FIG. 5. Relation of corn yields with weekly weather conditions.

gests the corn plant had reached a stage of growth when it would show a greater response to rainfall. However, this rain-yield response is a week or more earlier than that found by Runge and Odell (1958) from analyses of 1903–1956 crop-weather data from an experimental farm near the study area. At this experimental farm, the greatest response of corn to rainfall was during 7 July–24 July. As illustrated by Fig. 5e, the 60-farm data did not show any appreciable response to rainfall during this middle to late July period, but this may have resulted because the soil moisture values for this period were generally not limiting. The correlation indices for 2-, 3- and 4-week rainfall values (Table 3) support the weekly findings, particularly showing the importance of rainfall in the late June-early July period. Also, the relatively strong rain-yield response of 3–9 August (Fig. 5g) for the 60-farm sample does not appear in the experimental farm data.

These dissimilar results may be due to the short duration of the network sample, or they may reflect differences in the operations of the experimental farm and those generally practiced by the cash-grain farmer. Improvements in technology for corn production such as earlier planting, increased use of a commercial fertilizers, and other factors may have helped the crop reach a rain-responsive stage of growth earlier in the season during this 9-yr period. It is reasonable to expect that a longer, more representative period of record for the 60 farms could account for some of the difference.

These findings for weekly rainfall also may partially result from using a period as short as one week. For example, Fig. 5e illustrates that many of the higher yields tend to occur with very low weekly rainfall and lower yields tend to occur with much higher rainfall during the week of 20–26 July. This is evidence that a single week of dry weather at this time was not critical and may have been beneficial when preceded by a wet week. Many of the good yields associated with very low rain were cases in which rain occurred either before or after a dry week. Thus, the interaction of rainfall for adjacent periods as short as one week may have helped to effect an optimum rain of near zero. Fig. 5a may be showing a linear trend because 1) corn plants may have generally reached a stage of growth by 29 June to 5 July when they could respond strongly and positively to rainfall, 2) the maximum amount of rain received was not enough to determine the optimum, or 3) portions of the rain in this period provided much of the soil moisture required and used to sustain the crop through July. The values in Table 3 for 2-, 3- and 4-week periods indicate that the two most important 2-week rainfall periods were 1–14 June and 29 June–12 July. The 15 June–5 July period was the most critical 3 weeks for corn, and 15 June–12 July was the most critical 4-week period.

TABLE 4. Corn yield vs. weekly mean maximum temperature

Week	Correlation Linear	Correlation Quadratic
6/1–6/7	0.15	0.20
6/8–6/14	−0.07	0.08
6/15–6/21	0.14	0.21
6/22–6/28	0.05	0.06
6/29–7/5	−0.40	0.51
7/6–7/12	−0.18	0.53
7/13–7/19	−0.01	0.23
7/20–7/26	−0.56	0.56
7/27–8/2	−0.12	0.21
8/3–8/9	−0.56	0.61
8/10–8/16	−0.44	0.44
8/18–8/23	−0.43	0.47
8/24–8/30	−0.06	0.23

5. Weekly temperature

The importance of temperature as a weather index of corn yield in the sample under study was established by the correlations shown in Table 1. Short-period comparisons were made to examine further the effect of temperature during the corn growth period.

Linear and quadratic curve fitting were carried out and scatter diagrams prepared for each of the 13 weeks beginning 1 June. Correlations (Table 4) and graphs (Fig. 5) document the seasonal variation of yield association with maximum weekly temperature for the 9-yr sample of 540 yields. The relationship between the frequency of days per week with high temperatures, above 85 and 90F, was also investigated, but these produced lower correlations than were obtained for the weekly mean maximum temperature.

Associations between weekly mean maximum temperature and yield were weak for the first four weeks of June. High temperature had a pronounced negative effect for the week of 29 June–5 July (Fig. 5b), which corresponds with a pronounced yield response to rainfall (Table 3 and Fig. 5a). Negative correlation between corn yield and the weekly mean maximum temperature was substantial for most of the weeks during late July and August (Figs. 5d, 5f, 5h). Significant negative correlations in the two weeks of mid-July may be lacking because the highest maximum temperatures sampled were 3–5F lower than those sampled in preceding and succeeding weeks. Comparison of the weekly temperature correlations (Table 4) with those for weekly rainfall (Table 3) reveals that the temperature correlations are higher for most of the weeks.

6. Conclusions

The primary purpose of this study was to investigate the degree of response of corn yields to various weather variables using non-experimental farm data collected during a period of new and expanding agricultural practices. The results have several practical applications, since the research was based on extensive rainfall and current agronomic data from a cash-grain farming area of high management and productivity and of homogeneous climate, and similar topography and soils.

The correlation between August mean temperatures and yields was −0.69, which was higher than that for any other weather condition. The next best weather correlation, −0.51, was for the cumulative number of degrees above 90F during July and August. July mean temperature ranked as the second best monthly variable, and July rainfall ranked third. Most previous studies have shown that July rainfall is the most important monthly variable, July temperature second, and the August temperature third. This disagreement partially results from the weather conditions sampled in the 9-yr period. Many previous studies also have shown that the most critical weather period for corn is in late July, but this study showed that temperature and rainfall in late June and early July were the most critical short-term weather conditions for corn. Such disagreement reflects differences between farming practices at experimental farm sites and those currently employed by cash-grain farmers, and it partially results from the inadequacies of the 9-yr sample.

During the 9-yr period a temporal increase in yield was evident. Upward temporal trends were found in the employment of major technologic practices, and a trend for better corn-weather conditions (cooler July and August temperatures) also occurred during the 1955–1963 period. Analysis of the corn-weather relations determined for each of the three planting-period groups indicated that phenological variations in corn did not materially affect the final corn-weather results that were based on the entire data sample and on weather data for fixed calendar periods.

The results also indicate that added water from irrigation or man-made rainfall would be beneficial only in late June and July, but that added water would not produce significant increases in yields because of the relatively poor correlation between rainfall and corn yields in this area. The results suggest that lowering of high temperatures in July and August would be of considerably greater value in increasing corn yields.

Although certain weather conditions and technological practices could be identified as having some association with yields, no single variable explained more than 50% of the variability in the 540 yields. Of importance was the finding that in this apparently homogeneous sample, the yields varied considerably for any specific weather factor or level of technological practice. Such great variability of yields about a given rainfall amount, temperature level, or amount of nitrogen indicates the lack of major dependence of corn yields on any one weather condition or single agronomic activity in the sample area and sample period. Knowledge of this is especially important in making individual farm management decisions concerning the use and amount of fertilizer, the planting rate (population) or date of planting. The generally poor correlations between individual yields and these three technological practices indicate that weather conditions and other unmeasured technological practices are of considerable importance on an individual basis.

The correlations based on the individual observations indicated that several weekly, monthly, and seasonal weather variables had closer relations with yield than did nitrogen application, which had the strongest association with yield of the agronomic practices investigated. However, the correlations based on yearly-mean values indicated that nitrogen application was more closely associated with the area-mean yields than were any of the weather variables. This reversal in correlations indicates how different treatments of data for corn-weather studies can produce quite different conclusions. These reversals may also indicate why there has been disagreement between the results of some corn-weather studies using experimental farm data and those based on large-scale regional mean data.

Acknowledgments. This work was done under the general supervision of William C. Ackermann, Chief of the Illinois State Water Survey. Direction was given by Glenn E. Stout, Head of the Atmospheric Sciences Section of the Survey. The authors are indebted to Prof. Allan G. Mueller of the University of Illinois, who graciously supplied agricultural data and advice on its interpretation. Dr. Louis M. Thompson of Iowa State University furnished pertinent suggestions. Mrs. J. Loreena Ivens, Survey Editor, is acknowledged for her careful review of the manuscript, and Carl Lonnquist of the Survey staff materially assisted in the statistical and computer analysis.

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