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Weather-Caused Unexpected Record High Corn Yields in Illinois

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ABSTRACT

Average corn yields in a four-county area of 6,422 km^2 in Illinois exceeded 11945 kg/ha in 2003, setting new statewide records and more than 945 kg/ha above previous high yields in this area. During the growing season, crop experts noted that the July weather was ideal but also predicted that the hot, dry August conditions would reduce average corn yields to 9431 kg/ha, which was 2514 kg/ha below the actual harvested yields. Examination of the weather conditions and plant stages during 2003 revealed that several factors led to the record yields. Factors that collectively caused rapid vegetative growth, maintained high plant density, and created extensive ear-filling were: rapid corn emergence after extensive early planting in April, deep rooting during a dry 3-week period in May, and frequent sunny skies in May-July coupled with timely rains, normal temperatures, few hot days, and adequate soil moisture. Moisture needs during the hot, dry August were met with high moisture levels in moderate to deep soils which eliminated potential crop stress. Comparison of the 2003 growing-season weather with that of 1994, when prior but lower yield records were set, revealed that the high frequency of clear skies and very few hot days were key to the higher yields in 2003. Sunny days from April through August 2003 were nearly double the monthly averages and greatly aided plant development, ear filling, and kernel weight. The number of days with maximum temperatures >32°C was only 56% of the average number, thereby minimizing heat stress. Because most crop experts did not detect the unusual combination of 2003 good weather factors, they predicted lower yields than occurred and were greatly surprised at the record yield outcome.

INTRODUCTION

For the past 100 years, scientists have been investigating the relationship between various weather conditions and corn yields. Regression models using monthly temperature and rainfall data were first developed by Henry Wallace (1920). In ensuing years, more sophisticated modeling included measures of agricultural technology and various weather measures, such as those for 1- and 2-week periods, during the growing season to try to identify the most important conditions and time of occurrence (Thompson, 1969). Most of these various quantitative analyses found that July temperatures and rainfall plus August temperatures were the most important weather factors related to Midwestern corn

yields. One result was a shift to earlier spring planting in an attempt to get critical corn development stages (tassel, pollination, and ear-filling) to occur before the often stressful hot, dry conditions of mid-July and August.

As agricultural technologies developed over time, particularly after the 1930s, the changes in planting management (dates, hybrid seeds, and methods), fertilizer and pesticide applications, and other advances affected the relative importance of various growing season weather conditions. Earlier planting produced corn more susceptible to late June-early July stressful weather (Changnon and Neill, 1968). Nevertheless, technology has increased corn yields since the 1940s. Another factor affecting ever-increasing yields is weather. A study of corn-weather conditions in Illinois during the 20th Century found that, on average, favorable growing-season conditions were much more prevalent during 1965-2000 than in earlier years (Changnon and Winstanley, 2000). Because of improving technologies and weather, corn yields have systematically increased over the past 70 years. However, occasional years of unusually high or low yields still occur due to extremely good or bad weather conditions (Changnon and Hollinger, 2003).

Given this background, the year 2003 resulted in record corn yields for Illinois and uniquely high yields in a four-county area comprising 6,422 km^2 in west-central Illinois (Fig. 1). As shown, corn yields in counties located south, west, and north of the four counties were notably less, although two nearby counties (Macon and Logan) also had high yields, but not at record levels.

These statewide and four-county record yields were partly a reflection of the upward time trends in yields (improved technology and weather), but the departures above prior records and averages were sufficiently sizable to indicate certain uniquely good weather conditions for corn in 2003. A study of the weather and corn yield relationships for each of the 102 counties in Illinois using 1930-1963 data found that the four counties were located in a region with the state's strongest weather-yield relationships (Changnon and Neill, 1967). Multiple correlation coefficients for growing-season weather conditions and yields in each of the four counties experiencing yield records in 2003 exceeded 0.94, indicating that weather explained more than 88 percent of all variability in yields. A subsequent analysis for this region–based on 1931-1982 data for weather, corn yields, and technology–found that July maximum temperatures were the most important weather factor, followed closely by July rainfall (Garcia et al., 1990). August temperatures and rainfall were found to have less importance. May rainfall was negatively related to yields because substantial May rain limits development of deep root systems needed to endure summer moisture stress.

The goal of this study was to identify key weather conditions that led to the record high corn yields in the four-county area. This would reveal the best possible weather conditions for today's ever-changing corn growth technology. Table 1 lists the four counties and their 2003 corn yields along with previous record high yields in 1994. These 2003 county values were also new records for any Illinois county. The prior highest single county yield attained in Illinois was 11568 kg/ha in two central Illinois counties in 1994. The 2003 statewide average corn yield of 10310 kg/ha was 502 kg/ha above the prior record of 9808 kg/ha set in 1994.

DATA AND ANALYSIS

Data were assessed for Springfield and five other National Weather Service weather stations evenly distributed across the four-county area (Fig. 1). Detailed daily and hourly data on temperature, rainfall, and sky cover were available for the Springfield station (NCDC, 2004). The Illinois State Water Survey (ISWS) measures soil moisture amounts in four soil levels throughout Illinois on the first of each month, and values were obtained for the four-county area from the ISWS's measurement site near Springfield (ISWS, 2003).

Assessments of crop conditions and yield expectations issued by state agricultural experts during the growing season were obtained from *Farm Week,* a weekly publication of the Illinois Farm Bureau. Important weekly measures of crop conditions, as reported by two crop watchers in Menard and Sangamon Counties and another located just 12 km east of Christian County, also were obtained from this publication. The Illinois Agricultural Statistical Service (2004) provided the state and county yield data for 2003.

WEATHER CONDITIONS DURING 2003

Table 2 presents monthly temperature and precipitation values for Springfield and the monthly averages for the four-county area. Because certain conclusions are derived from the Springfield daily data, a comparison of these values and area values reveals the representativeness of the Springfield data. Mean temperature departures at Springfield reveal that four of the six months during the growing season had below normal values. An interesting oddity was that the August mean temperature was higher than that for July, a reversal that occurs on average only once in ten years. June-August rainfall totals at Springfield and the four-county area were above normal, whereas the April-May values were below normal. The six-month Springfield total rainfall of 56.1 cm was slightly above normal and slightly less than the four-county average of 59.2 cm. Differences in the monthly totals were all slight, less than 2.5 cm, indicating that Springfield values were representative of the area conditions.

Table 3 presents the frequency of days with different sky cover during the sunrise-to-sunset period. Monthly totals of clear days exceeded historical averages (1971-2000) in all six months of the 2003 growing season. There were only 36 cloudy days during 2003, compared to an average of 70 such days for the growing season. There were 50 partly cloudy days in 2003, only slightly fewer than average (56 days for the six-month period). Thus, most of the shift to clear skies in 2003 was a reduction in cloudy days, which resulted in much more sunlight reaching the corn crop. Examination of clear day frequencies at the nearest surrounding stations with sunrise-sunset sky cover data revealed that stations 100-120 km to the west, south, and east had slightly above average frequencies, but that Peoria, located 95 km north of the four-county area, also had an abnormally high frequency (91 clear days).

The frequency of days with maximum temperatures of 32.2ºC or higher in 2003 was markedly less than average with 17 days compared to the 1971-2000 average of 30 days. Only in August, the summer's warmest month (table 2), did the number of 32.2ºC (or higher) days in 2003 exceed the average. Thus, the 2003 growing season had nearly twice

the normal number of sunny days and very few exceptionally hot days. Clear days in June-August totaled 54, nearly double the average, and more than occurred in any year since 1950. The frequency of hot days was much below average with only 4 years since 1950 having fewer such days. The record high number of clear days and near record low number of hot days was an unusual climatological outcome since all years since 1950 that had a much above average number of clear days (>38) also had an above average number of hot days.

Table 4 presents the 2003 soil moisture conditions for the Springfield field site. Examination of these values and monthly patterns based on the statewide network of soil moisture measurements (ISWS, 2003) revealed the Springfield values were regionally representative. The measurements also were in a prairie soil found throughout the four-county area. Moisture in the two shallow soil levels, 0-15 and 15-50 cm, was above normal in the spring (March-April), but decreased during May and June due to extensive evapotranspiration by the growing crops and below average May rainfall. Heavy rains in late June and in July brought the 0-15 cm level back to 100% of average, but the 15-50 cm level continued to decline as the plants used this soil moisture. The hot, dry August brought major decreases in all four levels. Moisture in the two deeper layers, 50-100 and 100-182 cm, increased during June and July as result of above normal rains, and then decreased as the crop relied on this moisture source during the hot, dry August. All four soil layers recovered in September when crops quit transpiring soil moisture.

Examination of the daily values of temperature departures from average, rainfall, and sky cover (sunrise-sunset) at Springfield for the growing season was quite revealing (Fig. 2). Above to near average temperatures with little rain and mostly sunny days April 9-24 (Fig. 2a) provided an excellent corn planting opportunity. May had a moderately rainy and cloudy period for the first ten days (Fig. 2b), followed by a 21-day period of little rain, near average temperatures, and above average sunny days which were excellent conditions for emergence, deep root development, and leaf development.

The dry and sunny period ended during the first 13 days of June (Fig. 2c), which had rain totaling 8.9 cm on six days, numerous cloudy to partly cloudy days, and below normal temperatures. However, the remaining 17 days in June were notable for clear skies (14 days), near average temperatures, and only two rain days, with one producing 7.14 cm.

July featured moderate to heavy rains every 6-8 days with clear skies in between, and near to slightly below average daily temperatures during the last 21 days (Fig. 2d). There was a long period of sunny days June 15-July 8. Mid-summer rains were evenly distributed with 1.8 cm on June 29, 4.3 cm eight days later on July 8-9, 2.3 cm eight days later on July 18, 1.2 cm two days later, and then 1.8 cm on July 28. July had clear skies on 19 days, almost double the normal number (Table 3).

Weather in August was a major shift from July. August daily temperatures were near average with mostly partly cloudy skies from August 1-12, and then temperatures became 1º to 2ºC above average with clear skies for the remainder of the month. Practically no rain occurred until August 31 when 8.3 cm fell, resulting in a hot and very dry 30-day period. The first day of September also had heavy rain, but little rain fell thereafter and many sunny days until September 22. This late summer heavy rainfall produced a late

season grain fill, creating large kernels. This too was an important factor in increasing the yields. October weather conditions were near average although an early freeze occurred on October 1, but this freeze did not affect yields since the corn was physiologically mature.

CORN PLANTING, GROWTH, AND HARVEST OF 2003

Corn planting in the four-county area began during the first week of April, accelerated during April 10-24, and was 90% complete by April 21, making 2003 an early planting year. All corn in the four-county area had been planted by April 30. This area, part of the west-southwest crop district of Illinois, led the state in planting rate (Farm Week, April 28, 2003). By May 5, more than 60 percent of all corn had emerged to the 3- to 4-leaf size. All corn plants had emerged by May 20, with most corn 25-30 cm tall. Crop observers reported good stands with high density. Density of corn plants can be modified somewhat by soil moisture and temperature conditions during germination and emergence (Hollinger and Changnon, 1993). The early April to early May period had above average soil moisture in the two upper soil layers (table 4) and normal temperatures, which were good conditions for ensuring high density. The lack of rain during the last 21 days of May depleted moisture in the upper soil layers, causing the corn plants to root deep in search of moisture.

By early June, crop observers reported the corn was growing well and looked like an above average crop (Farm Week, June 2, 2003). An increase in growing degree-days in June helped speed plant development with some corn in the area 3.3 m tall by mid-June. Studies of corn physiology have found that the first 55 days of corn growth (mid-April to mid-June 2003) is largely vegetative, but the ears are also forming. This development relies on adequate soil moisture and near average temperatures; thus, the 2003 weather of this period was nearly ideal for corn growth. The number of rows of corn per ear, one of the determinants of yield size, is determined 30-45 days after planting (Hollinger and Changnon, 1993). This occurred from mid-April to late May in 2003, a period with more than adequate soil moisture and no stress from high temperatures.

Crop observers in the four-county area reported that the weather during the first two weeks of July was “ideal corn weather” (Farm Week, July 14, 2003). By July 5, 10 percent of fields were in tassel, and by July 10, 80 percent of the region’s corn crops had pollinated. Pollination was completed by July 16 and silks were drying. Physiological studies of corn development show that the number of kernels per ear is determined during a period beginning 30 days after planting (in mid-May 2003) and ending about two weeks after pollination (end of July 2003). Thus, kernel number was determined during a 2.5-month period with ideal weather for corn.

Studies have shown that weather stresses during pollination (early to late July 2003) decrease yields (Hollinger and Changnon, 1993). Adequate soil moisture, timely rains, numerous sunny days, few hot days, and near to below average temperatures in July did not stress the crop during pollination. Vegetative growth of corn ends after tassels have emerged (all leaves are developed and stalks stop elongating). Tasseling began in early July and ended by July 25, revealing that plant growth and kernel numbers had been decided by the end of July, and ears were partly filled by August 1.

The period of corn most sensitive to water stress begins with pollination and silking and lasts 22 days (Hollinger and Changnon, 1993). Silking occurred in early July 2003 when there was no water stress. All of this reveals why various crop observers throughout July issued statements like "ideal corn conditions' (Farm Week, July 21, 2003), the "crop looks good" (Farm Week, July 28, 2003), and that the week ending August 3 had been "another ideal week for corn" (Farm Week, August 4, 2003). A major rainstorm occurred in mid-July just north of the 4-county area, and damaging hailstorms in mid-May and early August also missed the area. Near perfect weather in July 2003, along with the early planting, provided excellent conditions for corn growth from planting through July.

Local crop observers reported in early August that the corn looked good and the ears were largely filled. Above average temperatures and lack of rain altered their attitudes as the month wore on (Farm Week, August 18a, 2003). Fifty percent of the corn had reached the dent stage by mid-August, and some leaf diseases were reported in the fields of late-planted corn. Yield predictions issued on August 16 called for 10688 kg/ha in the four-county area (Farm Week, August 18b, 2003). Hot and dry August conditions across Illinois produced anxiety among producers (Farm Week, August 25, 2003), and boosted corn prices in the grain market by late August. Shallow soil moisture decreased from 100% on August 1 to only 74% on September 1 (Table 4), and 47 percent of area farmers reported soil moisture as being short to very short (Farm Week, August 25, 2003). However, soil moisture in the deeper levels, 50-182 cm, remained near average (88% at the end of August) and supplied water needs of the corn crop for grain filling.

A field survey in late August to assess potential corn yields in Sangamon County (Fig. 1) led to predictions of final yields ranging from 5973 to 12637 kg/ha with a county average of 9682 kg/ha (Farm Week, August 25, 2003). One agricultural expert claimed the hot, dry August conditions had reduced corn yields by 629 kg/ha. The dry August was labeled the "pivotal weather event" of 2003 (Farm Week, September 1, 2003).

These various views of probable 2003 yields soon were altered as harvested yield values began to be reported. The corn harvest began on September 4, and by September 15 regional crop observers were noting that "the yields are better than expected" (Farm Week, September 15, 2003). Much of the corn was still at moisture levels greater than 24%. The excessive costs of drying corn (due to the high prices of natural gas) kept many farmers from harvesting early, choosing instead to let the crop stand and dry in the fields. Only 10 percent of the corn crop in the four-county area had been harvested by September 22, but agricultural experts were amazed that yields in many of the harvested fields exceeded 12574 kg/ha. An early frost on October 1 improved harvest conditions, and 95 percent of the area's 2003 corn crop had been harvested by October 27. Sangamon County yields averaged 12199 kg/ha, 27 percent above yields predicted in the late August field survey.

FACTORS LEADING TO THE RECORD YIELDS

Review of the 2003 corn growth cycle and the views of agricultural experts and crop observers reveal that no one predicted nor expected the high yield levels attained. Soon after the harvest began, experts reported that the unusually high yields were a major sur-

prise. What factors had been missed during the growing season? An agricultural expert in early October stated, "Amazing corn yields are being reported as producers approach the 50 percent mark" (Farm Week, October 6, 2003). All aspects of the harvested corn, including weight and grain quality, were found to be excellent. Crop experts at the U.S. Department of Agriculture reported in mid-October that Illinois was on the verge of a new corn yield record. One expert claimed that the unexpected jump in yields was due to much higher than expected grain test weight (Farm Week, October 13, 2003). "Corn kept filling even after moisture reserves became scarce" was another explanation (*Farm Week* October 13, 2003), revealing observers were unaware that the deep root systems (due to the dry April-May) had accessed high moisture levels in deeper soils during July and much of the dry August. Hence, corn filled better during the August dryness than experts expected. Warm, dry, and sunny days are good for corn if there is enough moisture to promote photosynthesis.

In retrospect, crop experts in the area recognized that the July weather conditions were excellent for corn. However, they apparently did not consider two other important weather conditions. Weather from early planting in April until July 1 also had been excellent for corn—creating early emergence, maintaining planting densities, encouraging deep rooting, and sustaining excellent vegetative growth and kernel development. These factors coupled with the July conditions had established a record crop.

What were the surprises? They included: 1) much higher yields than expected, 2) hot, dry August conditions did not hurt the corn, 3) failure to realize the crop was essentially made by the end of July, and 4) April-July conditions were essentially ideal for highly productive corn. Under prediction of yields had raised corn prices and incomes of area farmers.

The important weather factors on a month-to-month basis were:

- Corn was planted early in a dry period in April.
- Warm, sunny conditions in late April-May resulted in good emergence and high plant density.
- Dryness in May depleted near surface moisture and helped corn develop deep roots.
- June rains sustained soil moisture supply, and sunny days promoted rapid vegetative growth.
- July had several substantial and timely rains, few days with temperatures 32.2ºC or higher, and daily temperatures near or below average resulting in little crop stress. Many sunny days helped tasseling and pollination, and the corn crop was largely made as July ended.
- August was warm and dry, but the stress on corn was minimal because the crop was well advanced, deeper soil layers (50-182 cm) had above average soil moisture, and corn continued to fill, being enhanced by a heavy late August rainfall.
- Harvest began in early September but advanced slowly because corn moisture was high. The largely dry and sunny September and October resulted in the completion of harvest by the end of October.

Comparison with 1994 Corn Weather Conditions

Further assessment of the record 2003 yield outcome was done by examining the weather conditions in 1994, the year of the prior highest corn yields in the four-county area (Table 1). Yields in 1994 for each county were 10625 kg/ha (Menard County),11,128 kg/ha (Sangamon and Christian Counties), and 11128 (Morgan County). Growing-season weather conditions of 1994 and views of agricultural experts as the 1994 crop developed were assessed and compared with 2003 conditions and views.

Several weather similarities were found. April 1994 had dry, warm, and clear skies for 12 days. Considerable early corn planting was accomplished, but 40 percent of the corn was planted in May (Illinois Department of Agriculture, 1995). Hence, there was less early planting than in 2003. Both Mays had prolonged periods of dry, warm weather with clear skies; conditions that were conducive to deep rooting of the growing corn. Wet conditions in March, April, and June of both years resulted in above average deep soil moisture throughout the summer. Rainfall during both Julys was near average, timely, and well distributed throughout the month. Together, these conditions are conducive to high corn yields.

However, two key weather conditions in 2003 differed from those in 1994, and these differences help explain the higher yields obtained in 2003. Sky conditions in 2003 had much above average numbers of clear days (97), whereas 1994 had near average numbers of clear days (61). Hence, much more photosynthesis occurred in the crop-critical months of 2003. The method of making sky cover measurements (sunrise-sunset) shifted in 1996 from human observations to the use of data from a celiometer that measures clouds from the surface up to 4000 m and data from satellites that measure clouds above 4000 m. Assessment of the new measurement form revealed no discontinuity. The 54 days with clear skies during June-August 2003 were a record high for the 1951-2003 period. Maximum temperatures were at or above 32.2ºC for 27 days in 1994, which is near the normal number (30), but only 17 such hot days occurred in 2003. The state's highest yields in 2003 occurred in west-central Illinois, which had a high frequency of clear days and few hot days. For example, counties around Peoria (located 80 km north of Springfield) had yields of 11750- 11825 kg/ha, similar to those in the four-county area. Sky conditions and hot-day frequencies at Peoria were similar to those in Springfield but the late August rains were much less, leading to less grain filling.

Views of local and regional crop experts during the 1994 crop season were similar to those issued during 2003. Most comments from mid-June onward in 1994 noted that the corn crop looked very good to excellent, and everyone reported that July 1994 had excellent corn weather (Farm Week, July 18, 1994). A sizable corn yield was forecast during August, with expected yields set at 10059 kg/ha. However, as data on actual harvested yields became available after mid-September, all experts expressed surprise, noting the 1994 yields were well above expectations (Bridson, 1994). One agricultural expert noted that continued genetic improvement in corn yields was the "hidden engine" that had pushed yields to better than expected levels even with the less-than-perfect growing- season weather that occurred in 1994.

Technological improvements during the latter part of the 20th Century have been reported to create a one percent per year growth in yields (Troyer, 2004). If one assumes a one

percent growth in yields in each year due to improvements in technology, then the four-county yields would have increased since 1994. For example, the 1994 record of 10625 kg/ha in Menard County would have produced 11631 kg/ha in 2003 with similar weather to that in 1994, as opposed to the 12197 kg/ha yield obtained in 2003. Thus, the major factors behind the differences in the high yields of 1994 and those of 2003 are improved farming practices, better hybrids, and better weather conditions in 2003.

CONCLUSIONS

By mid-May 2003, corn plant density was optimal; by mid-June, vegetative growth was rapid and completed by mid-July; by the end of July, a large number of kernels had been formed, tasseling was finished, and plants were set for high yields. The key weather factors behind the record 2003 high yields in the four-county area included the following conditions:

1. Necessary soil moisture was available throughout the growing season.
2. A record number of clear skies and few cloudy days led to fast growth and good pollination.
3. Only about half the average number of high daily temperatures occurred, and June and July had below average temperatures, collectively minimizing temperature-related stresses.
4. There was no crop damage due to hail, heavy rains, or storms with high winds.
5. Timely and sizable rains throughout July aided kernel frequency and helped sustain the deep soil moisture, and heavy rains at the end of August helped enhance kernel size.

It should be noted that factors 1 and 4 were also present in 1994. The difference between the record yields of 1994 and even higher yields in 2003 was a result of improved agricultural technologies over time, and more sunny days and few hot days in 2003. The many sunny days without many hot days in 2003 is a climatological oddity since past Illinois summers since 1900 with an above average number of sunny days experienced an above average number of hot days (Changnon et al., 2004).

Interestingly, local farmers, crop observers, and agricultural experts did not expect the high record-setting magnitude of the 2003 (or 1994) yields. Experts in 2003 appeared to have not fully recognized the significance of the weather conditions from early planting through July, and that deeper soils contained sufficient moisture into August to sustain the crop during the only stressful (hot and dry) month of 2003. Such underestimates of yields can affect corn prices and how farmers market their corn. The influence of the record number of clear skies is also a yield enhancing factor that few realized.

Farm income did increase for farmers in the four-county area in 2003. The record four-county average yield of more than 12000-kg/ha helped establish a new state yield record for Illinois and the for the nation. An impact of the 2003 conditions has been closer monitoring of growth-affecting weather and soil moisture conditions during 2004 and future growing seasons. It was reported that farmers would shift from soybean planting to increased corn planting in 2004, particularly because soybean yields in 2003 were depressed. Ironically, this shift did not occur.

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Table 1. Corn yields for the four counties with Illinois' highest yields in 2003 and 1994.

County	2003 Yield (kg/ha)	Prior record yield (year) (kg/ha)	Difference (kg/ha)
Sangamon	12199	10939 (1994)	1257
Menard	12199	10625 (1994)	1572
Christian	12071	10939 (1994)	1132
Morgan	12008	11128 (1994)	880

Table 2. Monthly weather conditions in 2003 for Springfield, Illinois, and area average values based on all weather stations in the four-county area.

	Mean temperature (ºC)		Rainfall (cm)		
Month	Springfield	Area	Springfield	Area	difference
April	12.3 (+0.8)[1]	12.3	7.1 (-1.2)[1]	8.1	1.0
May	16.3 (-1.3)	16.2	8.1 (-2.3)	8.4	0.3
June	20.3 (-2.3)	20.2	17.2 (+7.6)	15.5	1.7
July	23.9 (-0.7)	24.0	9.9 (+1.0)	10.8	0.9
August	24.1 (+0.6)	24.1	9.7 (+1.0)	10.2	0.5
September	17.2 (-2.3)	17.4	4.1 (-3.3)	6.0	1.9
		Totals	56.1 (+2.8)	59.2	3.1

Note: Values in parentheses are departures from 1971-2000 normal values.

Table 3. Frequency of days with different sky cover (sunrise-sunset) and high temperatures at Springfield, Illinois.

	Clear sky days			Cloudy sky days		Days with max temperatures 32.2ºC or higher values		
Month	2003	Average	Difference	2003	Average	2003	Average	Difference
April	16	7	+9	10	15	0	0	0
May	11	8	+3	8	13	0	2	-2
June	17	9	+8	7	12	2	7	-5
July	19	10	+9	3	10	7	11	-4
August	18	11	+7	2	10	8	7	+1
September	16	12	+4	6	10	0	3	-3
Totals	97	57	+40	36	70	17	30	-13

Table 4. Soil moisture conditions during 2003 growing season, as measured in four soil levels near Springfield, Illinois, with values expressed in percent of average.

Soil depth (cm)	April 1	May 1	June 1	July 1	Aug. 1	Sept. 1	Oct. 1
0-15	103	114	90	91	100	74	118
15-50	101	103	95	101	83	77	105
50-100	98	95	101	99	93	88	101
100-182	92	95	104	105	100	90	100

Figure 1. County yields in the 4-county area with record high yields and in surrounding counties in 2003, and local weather stations are indicated.

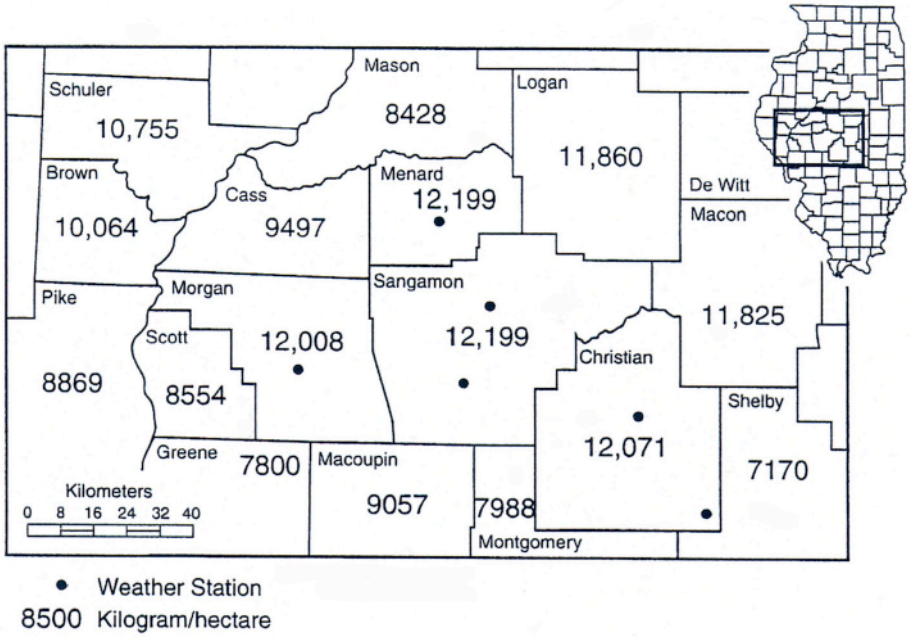

Figure 2. Graphs depicting the daily values of temperature departures, amount of rain, and sky conditions (sunrise-sunset) at Springfield, Illinois, April-July 2003.

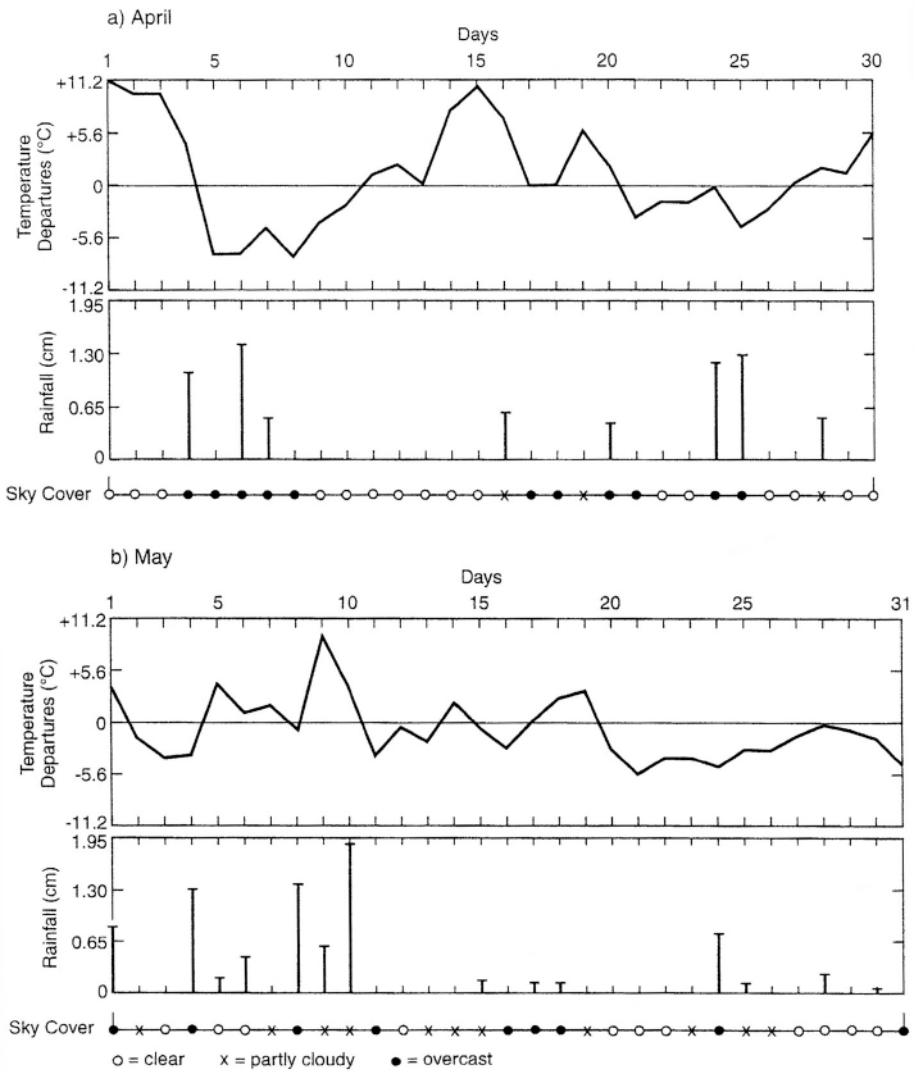

Figure 2. continued