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# Using climatology to predict the first major summer corn earworm (*Lepidoptera: Noctuidae*) catch in north central Illinois

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**ABSTRACT:** One of the largest food production companies in the United States, with sales in the billions of dollars, must closely monitor anything that may affect their vegetable crops. This includes harmful insects, such as the corn earworm (CEW) (*Helicoverpa zea*), that can reduce sweet corn yields and cause losses of approximately 12 million dollars annually in the Midwest. For this study, a major sweet corn production area located in north central Illinois was used to evaluate CEW moth flight characteristics. The initial major CEW catch (i.e. when 10 or more CEWs were caught in a field trap within a 24 h period) occurs on average around 20 August. However, during the period from 1960 to 2005 the first major catch occurred between 1 August and 16 September. If climatological information can be used to anticipate the initial major CEW arrival, then pest management strategies can be better implemented and field losses reduced.

Seven of 13 years with an early first major CEW arrival (1 to 15 August) occurred when accumulated growing degree days (GDDs with a base of 10 °C) were >917 and the number of warm nights (minimum temperatures ≥18.3 °C) was above average (>21 days) from 1 May to 31 July, while 7 of 13 years with a late first major CEW arrival (24 August to 16 September) occurred when accumulated GDDs <853, the number of warm nights was <18 days, and the number of days with an average air flow from the south was <30 between 1 May and 31 July. Copyright © 2009 Royal Meteorological Society

KEY WORDS corn earworm moth; north central Illinois

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## 1. Introduction

An international food company that produces and distributes a variety of brands and has annual sales in the billions of dollars faces crop insect problems each year (Del Monte Foods, 2008). One of their production sites located in north central Illinois (Figure 1) produces a number of canned vegetables. Sweet corn is the predominate crop grown in this production area. Certain crops can only be grown in specific climate zones and the Midwest United States provides an excellent climate for sweet corn growth.

Growing season weather is a key ingredient to a healthy crop and high yields. To manage weather risks throughout the summer (e.g. periods of high heat or below average precipitation), sweet corn crops are planted weekly from late April to late June. In recent years, farm equipment and crop genetics have greatly improved and have reduced the harmful influence of weather on crop yields. Another annual growing season risk to sweet corn includes insects that can migrate from field to field or region to region and damage the kernels and reduce yields. Minor insect-related damage to a vegetable crop can cause extensive losses to yields and impact the economic bottom line for such a company. For example, untreated corn earworms (CEW) can damage 1280 kernels *per* 100 plants leading to a loss of US$ 140 *per* acre (Figure 2). For sweet corn grown in the Midwest United States the loss would total approximately US$ 12 million for a given year (Foster and Flood, 2005; Flood *et al.*, 2009).

Company entomologists are interested in finding predictive information on insects that could help them more fully understand when migratory insects, such as CEW moths (Figure 3), might arrive in sweet corn fields and impact yields. With useful predictive information they can plan spraying operations and reduce CEW-related losses.

Meteorology and climatology have been found to explain much of what is known about where CEWs overwinter in North America and how the CEW moth migrates long distances during the growing season to locations in the northern United States and Canada (Raulston *et al.*, 1986; Wolf *et al.*, 1986; Drake and Farrow, 1988; Johnson, 1995). Due to their inability to survive prolonged periods when surface minimum air temperature is ≤ −17.8 °C, CEW generally overwinter

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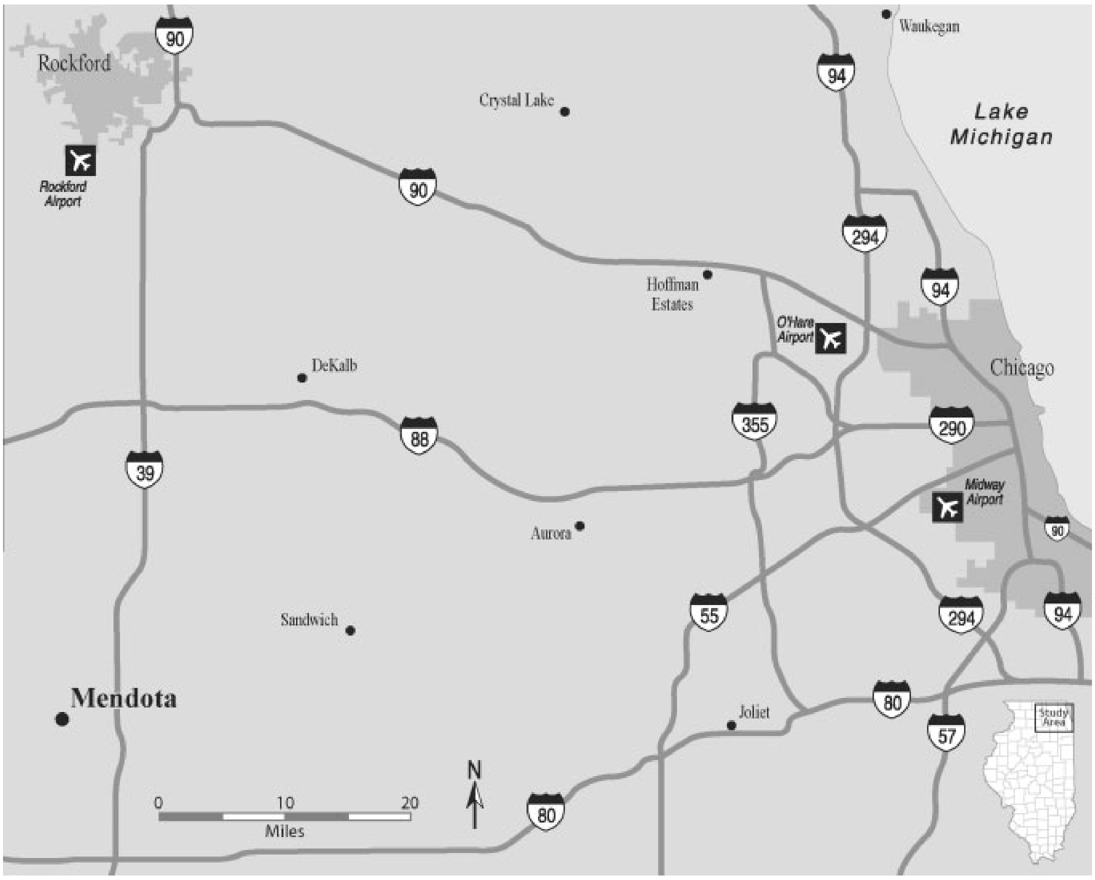


Figure 1. Study area in north central Illinois.

Figure 2. Corn earworm larva feeding on corn kernels.


Figure 3. Adult corn earworm moth.

in the southern United States, south of 35°N latitude and east of the Rocky Mountains (Foster and Flood, 2005; Sandstrom *et al*., 2007).

CEW moths fly at night, ascending from a source field about 30 min after sunset and flying until they terminate flight at sunrise (Drake and Farrow, 1988; Johnson, 1995). Sometimes, the CEW moths are forced back to the surface when they get caught in a precipitation event (Sandstrom *et al*., 2007).

Causes for CEW moths to leave a given region are not totally understood but are thought to be related to the need to locate to a better living environment (Johnson, 1995; Flood BR, 2008, personal communication). It has been shown that CEW moths are capable of long-distance flights that could approach 400 km or longer in one night (Wolf *et al*., 1990; Johnson, 1995; Westbrook *et al*., 1995). Once they lift off from the surface they generally fly in the planetary boundary layer between 200 and 700 m above the ground (Drake and Farrow, 1988; Johnson, 1995). On many nights the CEW moths are caught in the nocturnal low level jet (LLJ), an atmospheric wind maximum that develops in the planetary boundary layer, and are transferred northward. Using radar observations Drake and Farrow (1988) and Wolf *et al*. (1990) have been able to determine that the moths fly in wind speeds between 12 and 25 m $s^{-1}$, which are much greater than insect flight speeds, allowing them to cover much greater distances (Johnson, 1995). Climatological studies (Huff,

 

Figure 4. Corn earworm Hartstack trap.

1963; Muller and Tucker, 1986; Sandstrom *et al.*, 2007) have indicated that various weather variables and synoptic conditions cause moths to migrate northward in the lower troposphere (i.e. boundary layer) from their source regions *via* a southerly air flow. A study examining the seasonal migration of CEW moths for the years 1983–1985 (Goodenough *et al.*, 1988) identified that the first catch of moths at specific traps located between the Gulf of Mexico and Illinois varied from year to year and was dependent on latitude.

In order to minimize the influence of CEW on the corn crop, farmers closely monitor their movement and arrival. Many farmers set out traps to catch CEW moths that have emerged locally or moved into the region (Figure 4). Similar to other insect migration studies, scientists questioned whether the moths caught in a field trap on a given day are related to long distance moth migrations or to an increasing local population. Raulston *et al.* (1986) indicated that local population increases could not explain the extremely high densities found in traps on specific days and the presence of adults prior to the climatological emergence date. Such a finding provided further evidence that large moth counts were related to their long distance migration.

In the present study, if the number of CEW moths caught in a trap overnight is 10 or more, this suggests that crops may suffer enough of an economic impact that insecticides will need to be applied. Websites such as PestWatch (Pennsylvania State University, 2009) and Vegedge (Zea Map, 2009) provide information about where CEW are located in near real time. These tools provide evidence about the current CEW source region. However, in order to implement pest management strategies, entomologists need to have a better understanding of when these insects will arrive at locations away from the source region.

Many studies (Wolf *et al.*, 1986; Drake and Farrow, 1988; Goodenough *et al.*, 1988; Wolf *et al.*, 1990; Westbrook *et al.*, 1995; Westbrook *et al.*, 1997) have increased our understanding of CEW migratory flight characteristics and have identified atmospheric variables associated CEW flights. Although operational daily weather forecasts can highlight areas of greater risk for CEW immigrations, the use of these tools in daily pest management strategies has not been fully embraced by a major food processing firm at this point. However, leaders in the vegetable processing industry wanted to know whether early growing season climate conditions, prior to the period when the first major CEW catch (10 or more CEW caught overnight in a trap) occurs, could explain why the first major catch occurs earlier or later than average in a large sweet corn growing area in north central Illinois. If such a relationship existed, then certain spraying decisions could be planned in advance to minimize the impact from the infestation and save the company money. Thus, this study examines the use of climatological information as it relates to the northward migration of CEW moths through the growing season to north central Illinois.

## 2. Data and methods

The sweet corn production fields near Mendota, Illinois (north central Illinois), represent an excellent location to examine the relationship between early growing season weather and the occurrence of the first major CEW catch (i.e. flight) because records of daily CEW trap count date back to 1960. In the period from 1960 to 2005, 39 of the 46 years had continuous daily CEW trap count data during the entire growing season. These 39 years were used to develop a climate-CEW immigration forecast model with the goal to determine those weather variables (monitored during the early growing season) that can enhance predictions of the first major CEW flight date relative to its average occurrence.

The date of the first major CEW moth catch was identified for each of the 39 years and an average date determined. These dates were then ranked from earliest to latest in the calendar year. The ranked dates were then divided into three equally-sized groups: (1) those occurring early relative to the average date; (2) near the average date, and, (3) later than the average date.

Three weather factors: (1) accumulated growing degree days (GDD, base of 10 °C); (2) number of days with a minimum temperature $\geq$18.3 °C (i.e. warm nights), and, (3) number of days when the average wind direction based on averaging hourly values was southerly (135–225°), were found to be related to the development and migration of CEW prior to the time when the first major CEW catch occurred (Sandstrom *et al.*, 2007). The accumulated number of GDD was selected as a potential predictive variable because this number reflects the overall growing season and it was hypothesized that if the early growing season was warmer than average (i.e. higher number of GDD) then there was a greater chance for an earlier than average major CEW catch. Since the CEW moth flies at night and in warm conditions ($T > 15$ °C), an early season count of warm nights higher than average are hypothesized to cause an earlier than average migration to north central Illinois. Finally, days with southerly wind flow were evaluated

 

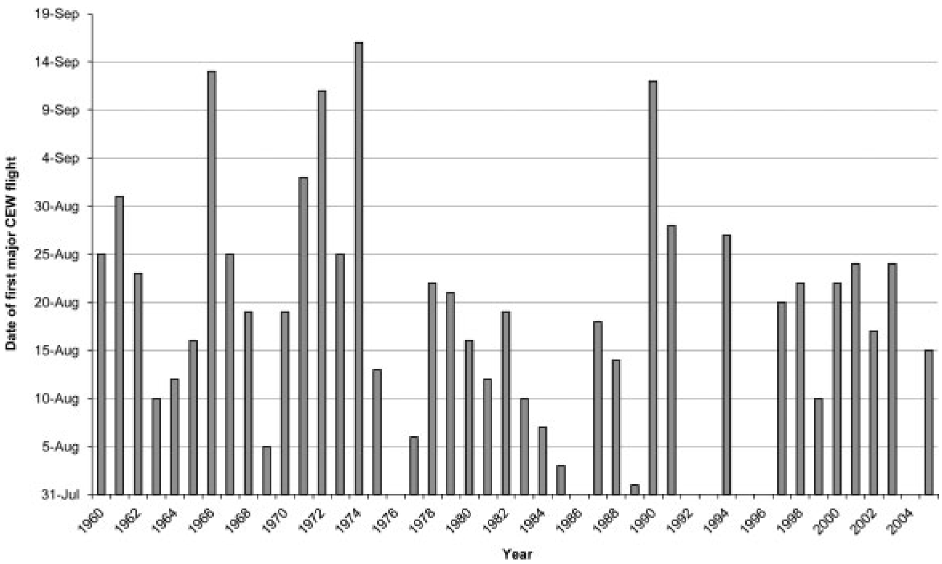


Figure 5. Date of first major CEW catch, 1960–2005. Years with missing and/or poor quality data do not have a date for the first major catch.

as a potential predictive variable because CEW moths generally arrive in north central Illinois from southern locales and in those years when there is a greater number of early season days with southerly flow it is hypothesized that CEW moths could arrive earlier than average. The source regions for these flights are generally located in central and southern Illinois, distances that range from 150 to 450 km from the study area. Although CEW moths fly at night, a calculated daily average wind direction was selected over a nocturnal average wind direction due to the availability of hourly data for this study and for potential use by agricultural decision makers in near real-time operational decisions (Midwestern Regional Climate Center, 2009). A day was counted as having a southerly flow if either the day prior to or after also had southerly flow, thus providing enough evidence that a homogeneous atmosphere was present and the wind direction at night remained southerly.

For the 39 years with continuous daily CEW trap count data, daily values for each weather factor were obtained, totalled over the growing season period prior to the first major CEW flight, ranked, and divided into three equally-sized groups of 13 (i.e. small, average, and large values). These three weather factors were measured at the long-term first-order National Weather Service station near Rockford, Illinois, approximately 72 km north of Mendota (Figure 1). This is the closest first-order weather station to the sweet corn production area. For each of the 39 years, the three weather factors were related to the date of the first major CEW catch using both a scatter plot (regression analysis) and 3-by-3 contingency tables. The $r$-values (correlation coefficients) were tested to determine if they were statistically different than zero using Student's $t$-test. Significance (i.e. $p < 0.05$) of the distribution within the 3-by-3 contingency tables was determined using a $\chi^2$ analysis. If the values in each box of the table were generally four or five there was no predictability. Finally, a climate profile was developed for each general arrival period, early, near average, and later than average. Means for the two periods, early and late, were compared for each weather variable to determine if there was a significant difference using the two-sided $t$-test statistic (Burt and Barber, 1996).

## 3. Results

Using the Mendota CEW trap data, dates of each year's first major catch (10 or more CEW caught in a trap during a 24-h period) were identified and plotted for the period 1960–2005 (Figure 5). Years when daily CEW count data were of limited quality (e.g. 1976, 1986, 1992–1993, 1995–1996, and 2004) were removed from the study and left blank in the figure. The average first major CEW catch, based on the 39 years of available records, was 20 August. The date of the first major CEW catch at the Mendota site ranged from 1 August (1989) to 16 September (1974). This large temporal variation in the occurrence of the first major CEW catch confirms findings described in a study by Goodenough et al. (1988). Once the 39 annual dates for the first major CEW flight were ranked, they were divided into three equally-sized groups (i.e. 13 years in each group), early, average, and late. Major catch dates were considered 'early' if they occurred between 1 and 15 August, 'average' if they occurred between 16 and 23 August, and 'late' if they occurred between 24 August and 16 September.

Climate data were then examined for each of the 39 years during that part of the growing season (i.e. 1 May to 31 July) prior to the time when first major flights begin to occur (i.e. 1 August). Scatter plots were developed to show the relationship between each weather variable (e.g. accumulated GDD, number of warm nights, and number of days with southerly flow) and the first major CEW catch. Figure 6 shows a weak negative relationship between the date of the first major CEW catch and accumulated GDDs. This weak ($r$-value

 

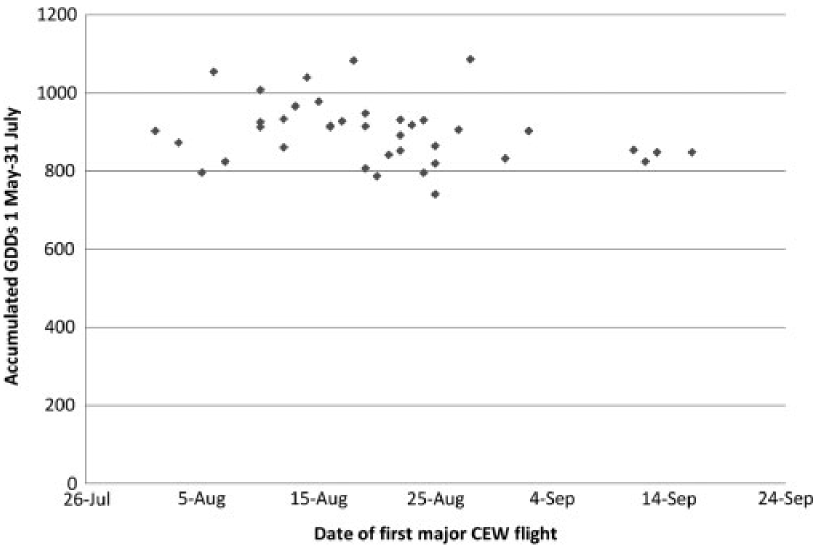


Figure 6. First major CEW catch *versus* 1 May to 31 July accumulated GDDs, 1960–2005.

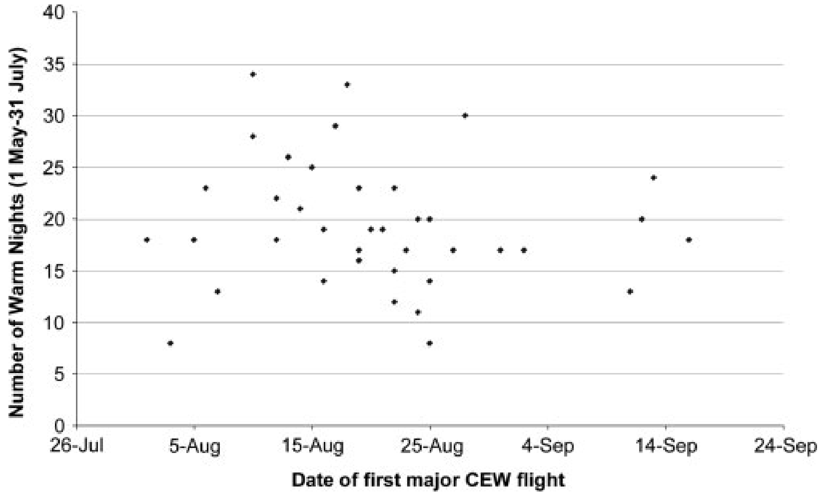


Figure 7. First major CEW catch *versus* number of 1 May to 31 July 'warm nights', 1960–2005.

$= -0.29$, significant at the $p < 0.05$ level) decreasing trend indicated that as the number of 1 May to 31 July accumulated growing degree days (base of 10 °C) decreased, the date of the first major CEW catch generally occurred later in the growing season. There was much more scatter ($r$-value $= -0.13$) when examining the relationship between the number of warm nights (i.e. minimum temperature $\geq$18.3 °C) from 1 May to 31 July and the occurrence of the first major CEW catch (Figure 7). As the number of days with an average flow from the south (135–225°) decreases, the date of the first major CEW catch appears later (Figure 8, $r$-value $= -0.27$, significant at the $p < 0.05$ level). Each of these scatter graphs are associated with fairly weak negative relationships (explaining less than 9% of the variance) suggesting that predicting the exact date of the first major CEW catch is not likely. These results indicate that there may be more important variables, some not related to weather, that explain why the first major CEW catch occurs on specific dates.

A second approach to examine the relationship between these three weather variables and the first major CEW catch involved the use of 3-by-3 contingency tables. For each year, values for each of the weather variables and timing of the first major CEW catch were examined and used to place counts in the various contingency table boxes. Given the negative correlations described earlier, one might expect the higher co-located counts to be present in the upper right hand and lower left hand boxes of each 3-by-3 contingency table. Analysis of the three 3-by-3 contingency tables identified that the strongest relationships existed for accumulated GDDs (Table I) and number of warm nights (Table II) where 7 of the 13 years with an early first major CEW catch occurred when the early growing season (1 May to 31 July) was warmer than average and had more warm nights. For all three 3-by-3 matrices (Tables I–III) 7 of the 13 years with a late first major CEW catch occurred when the early growing season was cooler than average, experienced fewer warm nights, and had fewer days with an average wind

 

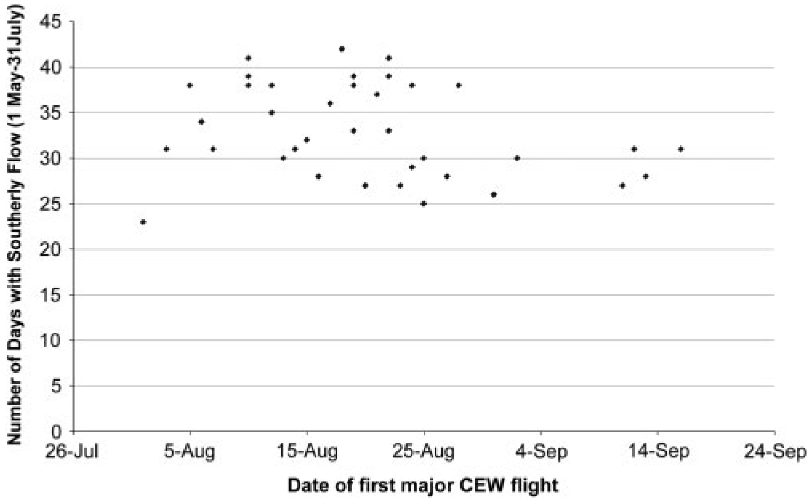


Figure 8. First major CEW catch *versus* number of 1 May to 31 July days with southerly flow, 1960–2005.

Table I. Three by three matrix of early growing season (1 May to 31 July) accumulated GDDs (small, average, large) *versus* first major CEW catch (early, average, later) based on 39 years.

| | Small number of accumulated GDDs (<853) | Average number of accumulated GDDs (853–917) | Large number of accumulated GDDs (>917) |
|---|---|---|---|
| Early first major CEW catch (1 August to 15 August) | 2 | 4 | 7 |
| Average first major CEW catch (16 August to 23 August) | 4 | 5 | 4 |
| Late first major CEW catch (24 August to 16 September) | 7 | 4 | 2 |

Table II. Three by three matrix of early growing season (1 May to 31 July) number of warm nights (small, average, large) *versus* first major CEW catch (early, average, later) based on 39 years.

| | Small number of warm nights (<18) | Average number of warm nights (18–21) | Large number of warm nights (>21) |
|---|---|---|---|
| Early first major CEW catch (1 August to 15 August) | 2 | 4 | 7 |
| Average first major CEW catch (16 August to 23 August) | 4 | 5 | 4 |
| Late first major CEW catch (24 August to 16 September) | 7 | 4 | 2 |

Table III. Three by three matrix of early growing season (1 May to 31 July) number of days with average winds from the south (small, average, large) *versus* first major CEW catch (early, average, later) based on 39 years.

| | Small number of days with south winds (<31) | Average number of days with south winds (31 to 36) | Large number of days with south winds (>36) |
|---|---|---|---|
| Early first major CEW catch (1 August to 15 August) | 2 | 5 | 6 |
| Average first major CEW catch (16 August to 23 August) | 4 | 4 | 5 |
| Late first major CEW catch (24 August to 16 September) | 7 | 4 | 2 |

from the south. Overall, the 3-by-3 contingency tables, similar to the scatter plots, indicate a generally weak and negative relationship (i.e. using $\chi^2$ on these contingency tables, no $p$ values were significant at the 0.05 level); however, the 3-by-3 matrices do indicate a subtle pattern exists between variables when trying to predict either an earlier or later than average first major CEW catch.

A climate profile (Table IV) was developed and used to determine whether any of the three climate variables had means that were statistically different when comparing the early major CEW catches to the late major CEW catches. The climate profile provides descriptive statistics to potential decision makers that explain how each of the three climate variables differ based on the timing of the first major CEW catch. The difference between

 

Table IV. Climate profile for the early, average and late first major CEW catch sub groups.

| 1 May to 31 July Weather variable | Early Catch | Average Catch | Late Catch |
|---|---|---|---|
| Accumulated GDD | 928 (79) | 902 (74) | 865 (83) |
| Number of warm nights | 21.7 (5.9) | 19.7 (6.0) | 17.5 (5.5) |
| Number of days with southerly flow | 33.9 (4.9) | 34.5 (5.5) | 29.6 (4.2) |

The average and standard deviation values based on the 13 years in each sub group are provided with the standard deviation in parentheses.

the mean number of 1 May to 31 July GDDs when comparing the early to the late was not significant. However, when comparing the number of 1 May to 31 July warm nights experienced before an early major catch *versus* a late major catch, the difference between means was significant at the $p < 0.10$ level. The differences in number of days with southerly flow when comparing those years with an early major catch to those with a late major catch was significant at the $p < 0.05$ level.

Three years (2006–2008) were then used to test the predictive model. The 1 May to 31 July values for each weather variable and their anomaly (small, average or large) were determined and used to predict the first major CEW catch relative to average (Table V). The predicted catch was based on that anomaly most frequent among the three variables. The climate data pointed toward an early date of the first major CEW catch in 2006, while the 2007 and 2008 data suggested an average date of the first major catch. The trap data indicated that predictions based on using climate data were correct in 2006 and 2007. This limited test of the relationship between climate variables and the first major CEW catch indicated that no one weather indicator is adequate to predict the first major CEW flight and more research is necessary.

## 4. Conclusions

Major U.S. food processors are faced with a complex set of issues as they estimate yields each season. In the Midwest United States, sweet corn is susceptible to *Helicoverpa zea* or corn earworms (CEW) that attack the ears of corn, thus reducing the quality and quantity of the yield.

The average first major CEW moth catch was found to occur on 20 August, with the first major CEW catches ranging from 1 August (1989) to 16 September (1974), based on 39 years with continuous daily trap data (1960–2005) obtained at a north central Illinois site. Three weather variables, growing degree days (base of 10 °C), warm nights (daily minimum temperature $\geq$18.3 °C) and days with southerly flow (135–225°), were examined during the early growing season (1 May to 31 July) and related to the date of the first major CEW catch each year. In each case a weak negative relationship (*r*-values ranging from −0.13 to −0.29) was found. As the number of GDDs, number of warm nights, or the number of days with southerly flow, decreased, the date of the first major CEW flight generally occurred later in the growing season. This result indicated that the northward migration of CEW moths was related to summer climate conditions (i.e. warmer *versus* colder than average summer), a finding that parallels the dependence of latitude (i.e. extent of northward CEW progression) on the first CEW catch found by Goodenough *et al*. (1988). The ability to determine whether first major CEW flights occurred earlier or later than average was enhanced using 3-by-3 contingency tables. Relationships identified using the 1960–2005 data in the 3-by-3 contingency tables successfully predicted the general timing of the first major CEW flight (i.e. early, average, or late) in 2 of 3 years (2006–2008). Although results suggest that the specific date of the first major CEW flight cannot be identified, early growing season weather variables can be used to identify the general timing of the average first major CEW catch. This information can be used by entomologists as they plan spraying activities to reduce losses related to CEW.

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Table V. Early growing season (1 May to 31 July) accumulated GDDs, number of warm nights, days with a southerly wind direction, predicted first major CEW catch (relative to average using three by three contingency tables) and actual first major CEW catch based on trap data.

| Year | Accumulated GDDs | Number of warm nights | Number of days with southerly flow | Predicted flight | Actual flight |
|---|---|---|---|---|---|
| 2006 | 914 (average) | 25 (large) | 37 (large) | Early | Early |
| 2007 | 1019 (large) | 18 (average) | 34 (average) | Average | Average |
| 2008 | 877 (average) | 19 (average) | 30 (small) | Average | Early |

 

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