A Climatic Model for Pecan Production under Humid Conditions

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Abstract. A multiple regression model was developed from historical data, 1945–92, to predict pecan \textit{Carya illinoensis} (Wangen.) C. Koch production in a humid climate. Variables were production trend (year of production), previous year's production, and climatic indices for the previous and current year. Production trend was used to measure change in production with time. Previous year's production was the index of alternate bearing. Variables for previous year's climate were heating degree-days for April–October and cumulative rainfall during May–July and 1–15 Sept. Variables for current year's climate were cumulative rainfall during April–August and 1–15 Sept. The indicator used for scab \textit{Cladosporium caryigenum} (Ell. & Langl.) Gottwald infection was the highest cumulative sum of 2 or more days of consecutive rain occurring in May, June, or 1–15 July. The $R^2$ for the model was 0.908. Production trend was the most important factor influencing production during the 1945–92 study period. Importance of the other variables in decreasing order were previous year's rainfall in May–July, consecutive rainy days, previous year's production, current year's 1–15 Sept. rainfall, previous year's heating degree-days, previous year's rainfall for 1–15 Sept., and current year's rainfall during April–August. Previous year's conditions had a greater effect on production than current year's. The recent decline in pecan production in the southeastern United States is due to an unfavorable change in climate.

Humid climates are dynamic. Extreme deviations in climate greatly influence crop productivity. One extreme climatic event can affect pecan production for 2 or more years (Hunter, 1963). Long-term effects occur because fruiting in pecan, as in other tree crops, is a function of conditions existing the year before and during fruiting (Davis and Sparks, 1974; Lockwood and Sparks, 1978). Pecan pistillate flowers are produced from substrates accumulated during the previous year’s growing season (Lockwood and Sparks, 1978), with the number of pistillate flowers being fixed by the time of budbreak (Wetzstein and Sparks, 1986). Thus, maximum potential nut production (fruit numbers) for the season is determined at the time of budbreak and is a direct function of conditions in the previous growing season. The potential nut production realized is dictated by conditions affecting subsequent fruit development.

Irregular bearing, a major problem in pecan production (Sparks, 1983), was proposed by Hunter (1963) to be dominated by pronounced climatic deviations. Irregular bearing is minimal and production tends to increase with time when no extreme climatic deviations occur over consecutive years. However, various climatic extremes may induce irregular bearing. Prolonged cloudy conditions and excessive rainfall during a heavy crop year may induce irregular bearing the next year. Severe, season-long drought can likewise induce irregular bearing (Hunter, 1963). Even severe short-term droughts, common in late August and early September in the southeastern United States, can cause premature defoliation (Alben, 1958; Sparks, 1992a) that suppresses return bloom (Hinrichs, 1962; Moznette, 1934; Worley, 1979), especially on heavily fruiting trees (Sparks, 1983; Sparks and Brack, 1972).

The current year’s climatic conditions largely control attainment of the pecan production potential by influencing the development from flower to fruit (Alben, 1958; Sparks, 1989a, 1995a, 1995b; Stein et al., 1989). Nut quality is good with optimum rainfall throughout the growing season. Fruit elongation is maximized in May and June; fruit expansion from mid-July to mid-August (Sparks, 1995a); and kernel development in September (Andrews and Sherman, 1980; Sparks, 1992a). Inadequate rainfall during one or more of these stages will negatively impact fruit development. Dry conditions during May, June, or July produce small nuts (Sparks, 1989a) that become well filled if soil moisture is adequate during filling in September (Manness, 1955). The nut will be large but poorly filled under condition of adequate soil moisture during fruit elongation and expansion followed by inadequate moisture during kernel development (Andrews and Sherman, 1980; Magness, 1955; Sparks, 1992a). Kernel development and quality are suppressed by excessive rain during the growing season (Hunter, 1963; Schaller et al., 1968; Sparks et al., 1995). On the other hand, inadequate soil moisture causes fruit abortion (Gammon et al., 1955; Sparks, 1989a).

Potential production is also influenced by scab \textit{Cladosporium caryigenum}, the major foliage and fruit disease in pecan. The development of scab is triggered by rains (Latham, 1982; Sparks, 1995b), and the disease can greatly suppress fruit growth and production of susceptible cultivars. Foliage is susceptible during leaf expansion in April and May, but not after leaves are fully expanded (Demaree, 1924; Gottwald, 1985; Valli, 1964). The fruit are susceptible from May to September (Gottwald and Bertrand, 1982). Scab infection on the foliage reduces photosynthesis efficiency (Gottwald and Wood, 1984), but the main effect of severe infection is suppression of leaf size and/or defoliation (Diner and Garrett, 1967). Damage from scab is most severe when the fruit are small in May and June. Damage decreases as fruit development progresses (Gottwald and Bertrand, 1982).

The apparent dominant relationship of nut production to previous and current climatic conditions suggests that pecan production might be predicted with acceptable precision from climatic factors. The objective of this study was to develop a model for predicting pecan nut production under humid conditions based on variation of climatic conditions. A model would be valuable to predict nut production.
Production and to assess the relative importance of individual factors on production.

Materials and Methods

Georgia’s nut production was selected for modeling because it accounts for about 50% of the total United States production (Wetzstein and Sparks, 1986) and the orchards consist almost entirely of pecan cultivars. Nuts from cultivars have a higher market value than nuts from native tree stands, therefore, orchards receive better management than native groves (Reid and Eikenbary, 1990; Sparks, 1980). Furthermore, estimates from states with a predominance of native stands (e.g., Arkansas, Louisiana, Mississippi, Oklahoma, and Texas) are not always reliable because the percentage of the crop harvested from one year to the next depends on prevailing market price of the nut. Crops may not be harvested in years of low market prices.

Production records (Fig. 1) used for modeling were reported by the Georgia Agricultural Statistics Service (Snipes, 1995) for the 48-year period 1945–92. Georgia records for 1943, 1944, and 1993 were used for model validation. Data before 1943 were excluded because of widespread zinc deficiency (Sparks, 1987). The year 1955 was not modeled, as most of the crop was destroyed by a late spring freeze (Hunter, 1963). The relationship of the Georgia estimates was compared with nut production from a single 383-ha spring freeze (Hunter, 1963). The production range (Gottwald, 1985; Valli, 1964). May, June, and early July were selected because leaf infection is usually highest in May (Latham, 1982), and scab infections on the fruit in May, June, and early July can result in total fruit loss or unmarketable kernels (Gottwald and Bertrand, 1982). The assumption was made that scab damage is proportional to the most intense rain period. Thus, highest cumulative sum by month and not the total for the 3 months was used.

Current rainfall for April–August and for 1–15 Sept. were included as variables. April–August encompasses leaf expansion (Davis and Sparks, 1974) and fruit enlargement (Sparks, 1986), which is governed by soil moisture (Finch and Van Horn, 1936; Sparks, 1995b), with maximum infection following 2 days of continuous leaf wetness over a wide temperature range (Gottwald, 1985; Valli, 1964). May, June, and early July were selected because leaf infection is usually highest in May (Latham, 1982), and scab infections on the fruit in May, June, and early July can result in total fruit loss or unmarketable kernels (Gottwald and Bertrand, 1982). The assumption was made that scab damage is proportional to the most intense rain period. Thus, highest cumulative sum by month and not the total for the 3 months was used.

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Eight variables were used for modeling nut production (Table 1). Production year was used to measure change, i.e., trend, in production with time. The relationship of nut production with time was positive and linear (Fig. 1). Increased production with time is assumed to reflect increases in tree size and acres planted, improvements in tree nutrition; advances in pecan weevil [Curculio caryae (Horn)], hickory shuckworm [Laspeyresia caryana (Fitch)], black pecan aphid [Melanocallis caryae foliae (Davis)], and scab control; and some installation of solid-set sprinkler and drip-irrigation systems beginning in the late 1970s. Pecan production in a given year is influenced by the production level during the previous year (Sparks, 1983; Fig. 1). In the model, previous year’s production was used as the index of this alternate bearing influence.

Intermittent, variable cloud cover is a normal climatic condition in a humid climate that influences sunlight and temperature in the tree canopy. Heating degree-days were used to estimate the effect of sunlight and temperature and are assumed to be an overall indication of ambient photosynthetic conditions. One heating degree-day was accumulated for each degree that the daily mean ambient temperature was above base 18.3 °C. The mean temperature is the average of the maximum and minimum for the day. A 18.3 °C base was chosen as suitable for pecan growth and development (Sparks, 1989b). Previous year’s heating degree-days were accumulated daily from 1 Apr. to 31 Oct., and current year’s heating degree-days were accumulated daily from 1 June to 30 Sept. The interval from 1 Apr. to 31 Oct. is the period of photosynthetic activity for the pecan tree (Mielke, 1981), and from 1 June to 30 Sept. encompasses most of the fruit growth (Davis and Sparks, 1974).

The indicator used for scab severity during the current year was the highest cumulative sum of 2 or more days of consecutive rain occurring in either May, June, or in the first 15 days of July. For example, in a given year, if the sum was 10, 2, and 9 days for May, June, and 1–15 July, respectively, 10 days were used. Two or more days of consecutive rain is critical because scab infection follows rain (Latham, 1982; Sparks, 1995b), with maximum infection following 2 days of continuous leaf wetness over a wide temperature range (Gottwald, 1985; Valli, 1964). May, June, and early July were selected because leaf infection is usually highest in May (Latham, 1982), and scab infections on the fruit in May, June, and early July can result in total fruit loss or unmarketable kernels (Gottwald and Bertrand, 1982). The assumption was made that scab damage is proportional to the most intense rain period. Thus, highest cumulative sum by month and not the total for the 3 months was used.

Current rainfall for April–August and for 1–15 Sept. were included as variables. April–August encompasses leaf expansion (Davis and Sparks, 1974) and fruit enlargement (Sparks, 1986), which is governed by soil moisture (Finch and Van Horn, 1936; Sparks, 1980)

Table 1. Variables used for modeling pecan nut production.

| Variable | Mean  | SD (±) |
|----------|-------|--------|
| Y = Georgia’s nut production (metric tons) | 29,906 | 15,685 |
| X1 = Production trend 1945–92 or 45–92 (year) | 68.8 | 13.9 |
| X2 = Previous year’s nut production (metric tons) | 29,843 | 15,793 |
| X3 = Previous year’s heating, April–October (degree-days) | 1,275 | 96.4 |
| X4 = Current year, 2 or more consecutive rainy days, highest sum in May, June, or 1–15 July (days) | 8.9 | 2.6 |
| X5 = Current year’s cumulative rain, 1–15 Sept. (mm) | 43 | 13 |
| X6 = Current year’s cumulative rain, April–August (mm) | 554 | 115 |
| X7 = Previous year’s cumulative rain, May–July (mm) | 351 | 89 |
| X8 = Previous year’s cumulative rain, 1–15 Sept. (mm) | 43 | 13 |

Fig. 1. Pecan nut production in Georgia, 1945–92. The relationship of production to time (diagonal line) is Y = –22.17 + 0.76X, r² = 0.4474, P ≤ 0.05.
Current season’s rainfall in September influences production, as this month is the major period of kernel development (Davis and Sparks, 1974). Nut weight is about 50% kernel and kernel growth is water dependent (Alben, 1958; Andrew and Sherman, 1980; Stein et al., 1989). The 1–15 Sept. interval was used because of being critical to kernel development (Sparks, 1992a).

The intervals for previous year’s rainfall were May–July and 1–15 Sept. Deficient (Stein et al., 1989) or excessive soil moisture (Hunter, 1963) in the previous year reduces production the following year. Observations indicate that a critical rainfall interval is May–July. The rationale for using 1–15 Sept. as a critical rainfall interval was that water stress during this time, simultaneously coupled with the stress of kernel development, would be expressed as reduced return bloom during the following year.

Heating degree-days and rainfall data were averages of conditions in Albany and Cordele, Ga. These two locations are in the major pecan production area of Georgia and their climates appear to be indicative of the pecan growing region (Sparks, 1989b).

The relationship of nut production to the variables was delineated by multiple regression analyses (Ezekiel and Fox, 1959). The equation producing the lowest standard error of the estimate (SEE) and with all partial regression coefficients statistically different (P ≤ 0.05) from 0 was used as the final model. During the development of the model, minimization of the SEE was also used to confirm the optimum intervals for heating degree-days, rainfall, and number of consecutive rainy days. For example, the previous year’s rain for 1–15 Sept. produced the lowest SEE compared with rain in either August, September, mid-August to mid-September, or August plus September, etc.

The graphical relationship of nut production to individual variables was calculated by holding the trend factor constant at 84 for 1984 and using the average values for all variables except the one being analyzed. Relative importance of the individual variables on nut production was evaluated by partial r². The graphical relationships illustrate the degree nut production can be affected by the variables in a given year, whereas, the partial r²s indicates the importance over years.

Nut production during the study period was standardized to examine variations in climate on relative production. Production was standardized by calculating the effect of previous and current climatic conditions on production with a fixed base for trend and previous year’s production of 45,359 metric tons.

Results and Discussion

The best equation for modeling nut production was Y = 14.6634 + 1.4273X1 – 0.4561X2 + 0.0611X3 – 1.9852X4 – 5.3302(1/X5) – 0.2010X6 + 9.9630√X6 – 7.9445√X7 – 1855.36(1/√X7) – 7.8672(1/X8), where X1

Table 2. Accuracy of pecan nut production predicted from the climatic model.

| Year   | Event/Note                  | Observed production | Predicted production | Observed – Predicted |
|--------|-----------------------------|---------------------|----------------------|----------------------|
| 1954   | Record dry 1–15 Sept.       | 9.1                 | 5.9                  | 3.2                   |
| 1956   | Recovery from 1955 freeze   | 27.2                | 34.7                 | -7.5                  |
| 1957   | Recovery from 1955 freeze   | 3.4                 | 11.9                 | -8.5                  |
| 1958   | Recovery from freeze completed | 20.4              | 23.7                 | -3.3                  |
| 1963   | Record production           | 51.7                | 45.7                 | 6.0                   |
| 1964   | Record rain, April–August   | 6.8                 | 6.9                  | -0.1                  |
| 1978   | Record production           | 61.2                | 56.3                 | 4.9                   |
| 1986   | Record drought, April–August| 54.4                | 49.9                 | 4.5                   |
| 1991   | Record dry, 1–15 Sept.: near record rain, April–August | 45.4                | 48.0                 | -2.6                  |
| 1992   | 28-year production low      | 13.6                | 13.4                 | 0.2                   |
| 1994   | Massive, extended flood in southwestern Georgia | 29.5                | 48.9                 | -19.4                 |
| 1943   | Model validation            | 13.8                | 6.5                  | 7.2                   |
| 1944   | Model validation            | 15.2                | 18.8                 | -3.6                  |
| 1993   | Model validation and record production | 68.0                | 67.1                 | 0.9                   |
\[ \text{production} = \text{production trend or year}, 45–92 \text{(year)}, \]
\[ X_2 = \text{previous year's nut production (metric tons)}, \]
\[ X_3 = \text{previous year's heating, April–October (degree days)}, \]
\[ X_4 = \text{current year's rain, 2 or more consecutive rainy days, highest cumulative sum occurring in May, June, or 1–15 July (days)}, \]
\[ X_5 = \text{current year's cumulative rain, 1–15 Sept. (mm)}, \]
\[ X_6 = \text{current year's cumulative rain, April–August (mm)}, \]
\[ X_7 = \text{previous year's cumulative rain, May–July (mm)}, \]
\[ X_8 = \text{previous year's cumulative rain, 1–15 Sept. (mm)} \]

All partial regression coefficients are significantly different from 0, \( < 0.05 \). The \( R^2 \) is 0.908 and the SEE is ±5424 metric tons. The nut production predicted from the model compared to recorded Georgia pecan production is acceptable (Fig. 2). Yield residuals were randomly distributed over years (Fig. 3) indicating the model was not appreciably biased with time.

The model adequately predicted production associated with extreme climatic events (record dry and wet periods) and years of extreme production (1963, 1978, and 1993) including the 28-year low of 1992 (Table 2). All were predicted with less error than the \( R^2 \) of the model, ±5424 metric tons, except the record production for 1963. Production for the years used for model validation—1943, 1944, and 1993—was also predicted with acceptable accuracy. The model failed to predict production for 1994, the year of massive and extended flooding in southwest Georgia. Also, the model predicted production during the 1956–57 recovery from the major freeze in 1955 (Hunter, 1963), although predictions were well within the error of the model. Nevertheless, the model should be used cautiously during recovery from a major freeze.

Extreme discrepancies between observed and predicted production of 8300 to 10,800 metric tons occurred for 1965, 1972, 1982, 1983, and 1990. Predicted production was less than observed for 1965, 1972, 1982, and 1983 and more than observed for 1990. In all these years except 1990, days of consecutive rain (the indicator for scab severity) were high at about 11. Data confirmed that scab was a major problem in these years (Bertrand and Gottwald, 1984; Diener and Garrett, 1967; Latham and Garrett, 1973). The possibility exists that the Georgia Agricultural Statistics Service failed to give sufficient weight to scab damage in these years. A reason for the discrepancy for 1990 is not apparent.

Relationship of nut production to production trend, previous year’s production, previous year’s heating degree days, and days of consecutive rain in May, June, or 1–15 July is linear as determined by the modeling equation and illustrated by Figs. 1 and 4–6. Relationship of nut production to previous and current season rainfall is curvilinear (Figs. 7 and 8). Extremes in previous year’s production (Fig. 4), previous year’s heating degree-days (Fig. 5), consecutive rainy days (Fig. 6), and rainfall during the previous and current year (Figs. 7 and 8) can have a pronounced influence on nut production in a given year.

The relative importance of the individual variables varied greatly (Table 3). By far, production trend had a greater effect on pecan production than any other factor. Production over the study period increased 4-fold at about 0.76 metric tons per year (Fig. 1). Previous year’s nut production, the alternate-bearing index, was

![Graphical relationship of pecan nut production to previous year’s heating degree-days.](image)

![Graphical relationship of pecan nut production to previous year’s cumulative rain, 1–15 Sept. and cumulative rain, April–August. Rainfall is cumulative in each interval.](image)
development. Shuck decline usually occurs late in fruit development (Sparks et al., 1995) and associated poor kernel effect of waterlogging during the current year is due to inducing dramatic suppression of following year production. The primary effect of waterlogging is to reduce flower formation in photosynthesis (Smith and Ager, 1988) and suppresses leaf Hunter (1963). Excessive soil moisture induces prolonged reduction in current season production because pecan production is dominated by nuts per tree and not by nut size (Sparks, 1992b). The curvilinear relationship of nut production to rain in the previous and current year (Fig. 7) shows that pecan nut production is sensitive to deficit and excessive soil moisture, as proposed by Hunter (1963). Excessive soil moisture induces prolonged reduction in photosynthesis (Smith and Ager, 1988) and suppresses leaf growth (Smith and Bourne, 1989), consequently suppressing flower formation by limited substrates (Lockwood and Sparks, 1978). Waterlogging has less effect on current year production than the dramatic suppression of following year production. The primary effect of waterlogging during the current year is due to inducing shuck decline (Sparks et al., 1995) and associated poor kernel development. Shuck decline usually occurs late in fruit development (Schaller et al., 1968), and production is reduced mainly because of suppressed kernel development. At the time shuck decline occurs, shell (which is about 50% of the nut weight) development is near completion. For this reason, suppressed kernel growth late in development does not result in a striking reduced production (Fig. 7). However, the effect on edible or marketable kernels can be pronounced (Sparks et al., 1995).

Consecutive rainy days in May, June, or 1–15 July, the index of scab infection, was the second most important climatic factor (Table 2). This is not surprising, as the recommended control program (Ellis et al., 1991) does not adequately control scab in seasons of high scab pressure (Latham and Campbell, 1991; Sparks, 1995b).

Rain during the first 15 days of September of the current year was the third most dominant climatic factor (Table 3). Current season’s rain had about twice the effect on nut production as the previous year’s rainfall for 1–15 Sept. Rainfall the first 2 weeks of September can have a dramatic effect of production (Fig. 8). The 2-week period is critical because it coincides with the beginning of rapid kernel development (Davis and Sparks, 1974) and because kernel development at this time is crucial dependent on soil water (Sparks, 1992a). The effect of soil moisture on kernel development is expected as September is historically the second driest month of the year and about one half of the total nut weight accumulates during this month. Effects of drought during 1–15 Sept. of the previous year are presumed due to suppressed substrate accumulation from reduced leaf efficiency (Loustalot, 1945; Mielke, 1981; Rieger and Daniell, 1988) or, in extreme cases, to drought-induced defoliation. Extreme drought during the previous year affects production more than does similar drought in the current year (Fig. 8).

Previous year’s degree-day accumulation was the fourth most important climatic factor (Table 3). Years with high production during the 1945–92 study period were associated with above-average heating degree-days. The relationship of production to heating degree-days supports the contention that low sunlight reduces next year’s nut production (Hunter, 1963). Current season’s heating degree-days were originally included in the model, but were not statistically significant. Because pistillate flower production is fixed at budbreak (Wetzstein and Sparks, 1986), any effect of current season heating would be on nut size and kernel development. As indicated earlier, nut size is a relatively minor component of total production (Sparks, 1992b). Nut size and kernel development are dominated by soil moisture (Finch and Van Horn, 1936; Sparks, 1989a), not heat variations.

The summation of the partial $r^2$ (Table 3) for previous year’s factors is 0.2821. The sum for the current year’s factors is 0.179. Previous year’s factors have about 1.6 times more influence on current season production than current season’s factors. If the

| Dependent variable | Partial $r^2$ |
|-------------------|-------------|
| Production trend  | 0.4474      |
| Previous year’s nut production | 0.0549 |
| Previous year’s heating degree-days | 0.0326 |
| Current year, days of consecutive rain in May, June, or 1–15 July | 0.1100 |
| Current year’s rain, 1–15 Sept. | 0.0526 |
| Current year’s rain, April–August | 0.0164 |
| Previous year’s rain, May–July | 0.1679 |
| Previous year’s rain, 1–15 Sept. | 0.0267 |
| Total | 0.9085 |
when production was at an all time high. Production is abnormally low. This was the situation during 1993 under less than optimum weather conditions if the previous year’s climates (Fig. 1 vs. 9). However, record production can occur in periods of 11 to 12 years. Division of periods are held constant (Fig. 9). Variation in relative production is about 11.5 times greater than the partial \( r^2 \) for previous year’s factors, \( 0.0549 \), indicating the predominant dependence of pecan production in a humid environment on variation of climatic factors. The climatic factors are mainly rainfall related. Sum of partial \( r^2 \) for rainfall factors, including the scab index, is about 11.5 times greater than the partial \( r^2 \) for heating degree-days.

The dominating influence of climate is also evident when the effects of production trend and previous year’s production are held constant (Fig. 9). Variation in relative production is proposed to occur in periods of 11 to 12 years. Division of periods was based on variation among years and on magnitude of relative production. The first period was very favorable for nut production, the second and third periods were less favorable, and the fourth period was favorable. Beginning in 1989, a major reversal occurred and relative pecan production reached an all time high in 1992, after which production improved but remained below normal. Real production (Fig. 1) followed a similar trend, and, in 1992, nut production reached a 28-year low. Pecan production in the southeastern United States has followed a similar trend (Pena, 1995). The correlation of real production with relative production during 1989–95 indicates that decline in regional production was due to an unfavorable climate.

Usually, years of high or record pecan production, e.g., 1963 and 1978, have been associated with optimum or near optimum climates (Fig. 1 vs. 9). However, record production can occur under less than optimum weather conditions if the previous year’s production is abnormally low. This was the situation during 1993 when production was at an all time high.

Once the current growing season is completed, the model can be used to predict production for the following year under assumed conditions. Such a prediction would be valuable in making marketing decisions. For example, if the prospects are poor for a good return bloom, nuts from the current year can be placed in storage for next year’s market. If prospects are high for a good return bloom, storing nuts would likely be an unprofitable decision. For instance, the prospects for an excellent return bloom in 1996 are very good because of the favorable climate existing in 1995. If the climatic factors for 1996 are average (1945 to 1992), production in 1996 is predicted to be 77,233 metric tons, which would be a record production. Thus, storing part of the 1995 crop would be a risky decision.

The model can be used to predict production assuming adverse climatic conditions. If September is dry in 1996, predicted production is reduced from 76,765 to 55,905 metric tons. If the dry September is preceded by high scab pressure as occurred in 1991, predicted production is further reduced to 46,698 t.

Climatic factors influencing nut production manageable by the grower are scab from frequent rains, drought, and, indirectly, sunlight. The current scab control program (Ellis et al., 1991) gives poor control during seasons of high scab pressure (Latham and Campbell, 1991; Sparks, 1995b). A new approach to scab control has been proposed (Sparks, 1995b) and is currently being evaluated. Whatever the preventive program used, scab control can be greatly improved by minimizing mutual shading among trees.

Disastrous droughts occur mainly in late August through September. The 148 mm of rain per hectare needed during 1–15 Sept. for maximum kernel development (Sparks, 1992a) is often deficit. During the 1945–92 study period, <148 mm of precipitation occurred during the critical period in about 60% of the years. Since the importance of water in September was reported (Sparks, 1992a), many growers have been irrigating during early September with improved kernel quality and return bloom. The detrimental effect of excessive moisture from prolonged rains can be minimized by selecting pecan sites with adequate surface drainage. In this regard, return bloom following the excessive rains in 1994 was much better in orchards situated on slopes or ridges than in orchards on flat sites (Sparks, 1995c). Many pecan orchards are overcrowded, with a major reduction in photosynthesis from overproduction (Hinrichs, 1961). The use of available sunlight and tree productivity can be improved by thinning crowded trees (Alben, 1958; Alben and Sitton, 1950; Crane et al., 1934; Romberg et al., 1959).

The climatic model predicts pecan nut production with acceptable precision. The major limitation of the model is that production is assumed to be linear with time. If production deviates from linearity, the model must be adjusted accordingly. Furthermore, but of lesser importance, the model will not adequately predict production following either a major freeze or a major flood. The model clearly defines factors influencing pecan production in a humid climate and indicates areas for improved management. Additionally, the model can be used as a tool for planning marketing strategies.

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