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A Model for Estimating the Probability of Crop Production for *Ginkgo Biloba* L.

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ABSTRACT

Mature female Maidenhair trees (**Ginkgo biloba** L.) have been observed to produce seed dispersal units in some years and none in other years. A temperature and/or photoperiod flowering threshold is suggested. Daily temperatures and daylengths at five **Ginkgo** sites in continental U.S. for January-April 1964-1974 were evaluated. A computer program was designed to estimate daily photothermal equivalent (PTE = temperature and photoperiod), and the magnitude and duration of the PTE in relation to a series of photothermal constants. Use of the data from production and nonproduction years provided a mathematical model for prediction of dispersal unit production. The model was tested with environmental data for additional sites recorded in the botanical literature.

INTRODUCTION

The prediction of plant responses to environmental factors long has been studied by investigators using many types of analytical procedures. As computers have become a common tool for research data analysis, more sophisticated biomathematical procedures have been devised. The objective, however, remains the same: a quantitative assessment of contributing factors and an equation considering such factors which will be reliable in predicting future plant responses.

Crop production model research for agricultural commodities such as grains and fruits has produced analytical procedures for determination of not only quantitative probabilities, but also qualitative predictions of crop production (Brown, 1953; Wielgolaski, 1973). It has been pointed out that greater emphasis should be placed on the relation of daily weather measurement to plant responses such as fruit production rather than average values over extended periods (Caprio, 1966). Because of the important role of climatological factors in the flower development period, equating daily spring weather measurements with fall crop production was chosen to be examined. The purpose of the investigation was (1) to determine which climatological factor or combination of factors best expresses variations associated with crop production in *Ginkgo biloba*; (2) to formulate an easily employed, reliable mathematical model for crop predictions in subsequent years.

MATERIALS AND METHODS

At four sites where mature female *Ginkgo* trees have been observed to produce seed dispersal units[1], available records of the occurrence of a fall crop were obtained. A fifth site was obtained from the botanical literature (West et al., 1970). The crop and weather data of these five widely dispersed sites were used in all computations for variable selection and model building (Table I).

A computer program was written to estimate the 1 January to 30 April daily photoperiod at each site for the years observed (U.S. Naval Observatory, 1971-74). Climatological data were compiled from the weather recording station nearest each site (U.S. Dept. Commerce, 1964-74). By use of the daily maximum and minimum temperatures, average temperature was calculated for 1 January to 30 April for each site. Maximum, minimum and mean temperature data for crop and non-crop production years at the St. Louis, Missouri, site were grouped into 10° intervals. Interval values from low to high temperatures for both groups were accumulated and the chi square of accumulated interval totals of both groups was calculated. The intervals then were accumulated from high to low temperatures and the chi square calculated in the same manner. Values above the 10.0% level of significance for 1° of freedom were noted. By this method, minimum temperature values of 25, 30 and 35F (-4, -1 and 2C) were selected as criteria for best temperature variations of crop and non-crop years. The importance of including a photoperiod threshold requirement in model building has been pointed out (Baier, 1973). Although a photoperiod requirement has not been established for *Ginkgo*, it has been observed that initial leaf formation of young greenhouse-grown trees is during early February in Fayetteville, Arkansas. If a photoperiod flowering requirement exists, it was assumed to be between 620 and 675 min to represent the daily photoperiods for 6 to 28 February at Fayetteville. A series of six photoperiod constants (620, 630, 640, 650, 660, 675 min were used in relation to the three temperature constants for determination of photothermal threshold values (PTT = photoperiod constant and temperature constant). A computer program was written to determine the photothermal equivalent (PTE = photoperiod and temperature) for each daily maximum, minimum and mean temperature for each site-year. The three PTE values were compared with each set of PTT values. Magnitude and duration of PTE-PTT data provided the values of the

Table I. Locations and Years of *Ginkgo* Seed Dispersal Unit Observation

Site	Crop Production Years	Non-Crop Years
Cambridge, MA	1973, 1974	—
Plainfield, NJ	1968	—
St. Louis, MO	1965, 1966, 1969, 1972	1964, 1970, 1974
Memphis, TN	1968, 1973	1974
Little Rock, AR	1973	1974

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[1] The writer favors the term "dispersal unit" (Evenari, 1965), because what constitutes the morphological seed of *Ginkgo* is ill-defined and because the physiological and anatomical maturity of the "seed" cannot be judged from outward appearance of the dispersal unit.

temperature-oriented variables to be analyzed by the logistic model of Walker and Duncan (1967).

RESULTS

The greatest separation of crop and non-crop production probabilities for the site-years investigated occurred when a combination of 10 predictor variables were correlated. The predictor variables were the actual number of days during February and March that various relationships occurred between (1) the PTT constant for 640 min and 25F and (2) the daily minimum PTE (Table II). A PTE> PTT day is defined as one in which both daily photoperiod and daily minimum temperature were equal to or greater than the constant values of 640 min photoperiod and 25F temperature.

The probability of crop production and individual variable regression coefficients were determind by the following multivariate logistic model:

$$P = \frac{1}{1 + e^{-(B_o + B_1 x_1 \ldots B_p x_p)}}$$

where P is the probability of seed dispersal units being produced, B_o is a calculated constant, x_i is the actual number of days derived for the ith predictor variable, B_i is its associated regression coefficient and e is the base of the natural logarithm.

All site-years in which a crop was observed had calculated crop production probability greater than 0.9826. Those site-years when no crop was observed had calculated crop production probability less than 0.0156 (Table III). The model was tested with the climatological data for three additional site-years not used in developing the prediction equation. By use of the model, all three sites had calculated probability that a crop would be produced (Table IV). A fall *Ginkgo* crop at all three sites was reported (Lee, 1955; Pollock, 1957; pers. comm.). A prediction of 1975 crop production for the five test sites was determined (Table IV). However, verification of fall crop production could not be made at the time the paper was submitted for publication.

As additional *Ginkgo* sites and years of observation are recorded, the requirements which determine whether or not a crop will be produced should become more clearly defined. Continual updating of the equation will give greater reliability to each regression coefficient, and thus greater reliability of predictions for yearly crop production.

Note Added in Proof:

A fall observation for 1975 crop production was made at each test site listed in Table IV. All sites produced a crop contrary to the model predictions based on previous years' information.

Table II. Predictor Variables and Their Regression Coefficients Determined by PTE Using February-March Minimum Temperatures and PTT of 640 Min and 25 F

Predictor Variable (X)	Regression Coefficients	
Constant	32.494406	(B_0)
Total number of days PTE> PTT in February	3.959442	(B_1)
Total number of sign changes for daily PTE-PTT values in February	-3.075101	(B_2)
Greatest number consecutive days PTE> PTT in February	-4.652010	(B_3)
Least number consecutive days PTE> PTT in February	-1.162381	(B_4)
Greatest number consecutive days PTE <PTT in February	0.792214	(B_5)
Total number of days PTE> PTT in March	-1.072725	(B_6)
Total number of sign changes for daily PTE-PTT values in March	-0.532523	(B)
Greatest number consecutive days PTE> PTT in March	-0.179378	(B_8)
Least number consecutive days PTE> PTT in March	0.327010	(B_9)
Greatest number consecutive days PTE <PTT in March	-1.424315	(B_{10})

Table III. Estimation of Probability of *Ginkgo* Seed Dispersal Units as a Function of Selected Predictor Variables.

Site/Year Status*			Crop Production Probability
Memphis, TN	1974	0	0.0033
St. Louis, MO	1974	0	0.0055
St. Louis, MO	1970	0	0.0094
St. Louis, MO	1964	0	0.0156**
Little Rock, AR	1974	0	0.0061
Memphis, TN	1968	1	0.9972
Memphis, TN	1973	1	0.9926
Little Rock, AR	1973	1	0.9990
Cambridge, MA	1973	1	0.9916
Cambridge, MA	1974	1	0.9996
St. Louis, MO	1972	1	0.9920
St. Louis, MO	1969	1	0.9876
St. Louis, MO	1966	1	0.9835
St. Louis, MO	1965	1	0.9826**
Plainfield, NJ	1968	1	0.9968

*Fruit not produced = 0. Fruit produced = 1.
**Limit values.

This outcome does not invalidate the model, but indicates the need for additional data which will define more precisely the limits for crop production. The 1975 data will be used in updating the equation for future predictions of crop production.

Table IV. Location and Prediction of *Ginkgo* Crop Production

Site	Year	Crop Production Probability
Charlottesville, VA	1957	0.9728
Urbana, IL*	1950	0.8527
Philadelphia, PA*	1973	0.6090
Cambridge, MA**	1975	0.0000
Plainfield, NJ**	1975	0.0000
St. Louis, MO**	1975	0.0090
Memphis, TN**	1975	0.0000
Little Rock, AR**	1975	0.0000

*Site of recorded crop production to test model.

**Calculated probability for fall crop production.

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