Cotton and California temperatures

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Temperatures in some northern Central Valley areas might favor cotton production

The limit of cotton planting in the San Joaquin Valley has been pushed steadily northward in recent decades, and today the crop is successful as far north as Los Banos on the west side and Fresno to the east. The question is, has cotton reached some sort of temperature limit, or is production possible at a still higher latitude in the valley? A degree-day type of analysis has been used in the past to seek the answer, but a new methodology has been developed for measuring crop success against environmental temperatures most favorable to photosynthesis, the plant's food-making process. This methodology helps define areas of favorable temperatures during the vegetative growth period.

The calculation of equivalent hours of maximum net photosynthesis (EHMNP) provides a way to assess temperature favorability. Daytime temperatures are related to the "cardinal" temperatures of the photosynthetic process, which are (1) the most favorable or optimum temperature and (2) threshold temperatures above and below the optimum beyond which photosynthesis does not take place. Photosynthetic efficiency is considered to decline from the optimum to the thresholds, forming a broad bell-shaped curve. Air temperatures close to the optimum are most important agriculturally, because this is when most of the plant's food-making takes place.

One equivalent hour of maximum net photosynthesis is the food-making potential of a crop plant for one hour when the air and leaf temperatures are at the optimum and light is sufficiently strong. Partial responses for hours when light and temperature are less than ideal can add together to make full hours. Calculations for the accompanying map of California used an optimum temperature of 35°C (95°F) for cotton with thresholds at 17°C (62.6°F) and 47.5°C (117.5°F).

Two factors work against excessively hot sites. First, daytime temperatures may be so close to the upper threshold that little photosynthesis can take place during the hours when light is best. Second, nighttime temperatures may favor excessive nocturnal respiration, which consumes much of the food the plant has been able to make during a hot day, a phenomenon the EHMNP method also considers. During the summer peak in the Imperial Valley, afternoon temperatures may be sufficiently close to the upper threshold to "starve" the crop, a condition worsened by warm nighttime respiration losses.

Equivalent-hour units can be accumulated over monthly and seasonal periods to compare the food-making potentials of crop plants under specific thermal regimes to that which would exist under the best possible conditions of temperature and light. Except for cloudiness, light depends on time of day and year, and so the method (described in detail in the September 1984 issue of the journal *Agricultural and Forest Meteorology*) essentially relates a crop to temperature.

The comparison of a crop at a given site with its own potential under optimum conditions is a measure of climatic favorability rather than productivity. A high number of equivalent hours during a growing season of specified length is considered to indicate favorable climatic temperatures, whereas a low number would be unfavorable. The number of equivalent hours for a site where a crop is grown successfully is an indication of good climatic temperatures and helps in ascertaining what the optimum for the crop should be.

Photosynthetic efficiencies are based on simulated daylight hourly temperatures calculated from the climatic monthly mean maximums and minimums compiled and published by the National Weather Service. Since the maximum/minimum temperatures are measured in standard instrument shelters 5½ feet above the ground, they may differ from actual temperatures in a crop canopy. Where the shelters are in the fields, the difference is seldom as much as 2°C. Otherwise, shelter temperatures should be considered as describing the climatic environment in which the canopy temperature occurs. Data from poorly exposed shelters, such as those in urban heat islands, unfortunately can bias the agriculturally oriented EHMNP distributions.

The choice of a 35°C optimum for cotton is based in part on growing experience. A slightly lower temperature (93°F or close to 34°C) has been previously suggested, but a comparison of crop yields and calendars in the Imperial and San Joaquin valleys suggests that the slight increase is appropriate for the method.

A summer growing season of four months (120 days) has been used in the totals of equivalent hours listed on the accompanying map, a length of time that fits fairly well the vegetative period between emergence and opening of bolls. The season used begins on May 1, which appears close to a mean emergence date. The literature lists early to mid-April as the planting time to achieve best yields in both the Imperial and San Joaquin valleys, and by May 1 plants should be barely emerged. The season for equivalent-hour accumulation ends on August 31, or close to boll maturity. September, during which bolls open but remain on the plant until harvest, is not considered here to be a significant part of the vegetative period when the photosynthetic production of food is important.

In present cotton-producing areas of the state, the four-month season beginning May 1 has the greatest number of equivalent hours when compared with seasons of the same length beginning on the first days of other months. At Bakersfield, a season beginning May 1 has a total of 875 equivalent hours, compared with 756 for April 1, 866 for June 1, and 717 for July 1. Crop yields for plantings other than mid-April appear to roughly parallel these other EHMNP totals.

The shaded areas on the map show where cotton should be a successful and practical crop with regard to temperatures. The edges of the shaded areas are the 820 EHMNP isoline, the apparent lower limit of successful cotton culture based on present distribution of the crop. Where weather stations are few, the position of this line has been estimated by elevation and other climatic controls.

The movement of cotton northward to its present limit has been possible, because the equivalent-hour totals do not drop significantly from the southern end of the Central Valley to Fresno and Los Banos. North of this latitude, however, the totals drop off rapidly, becoming a marginal 813 by Modesto and a submarginal 782 at Sacramento.

Circa World War I, an attempt to raise cotton in the flood basins north of Sacramento failed, because the crop did not mature sufficiently before the first frosts of autumn. The inflow of marine air through the break in the Coast Ranges at San Francisco Bay, the so-called "delta breeze," sufficiently lowers summer temperatures to make the totals lower than those of the Central Valley on either side.

Shaded areas show where cotton could be grown successfully in California according to calculation of equivalent hours of maximum net photosynthesis (EHMNP) based on National Weather Service data.

A case in point is the 831 equivalent hours at Electra Power House east of Sacramento to which the marine ventilation does not penetrate because of its boxed-in location in the Sierra Nevada foothills.

EHMNP totals again pick up north of Sutter Buttes. Although not now a cotton-producing area, Orland would appear to have the most favorable cotton temperatures in the state. If a retarded rise in soil temperatures to the required 60°F delayed emergence here until after May 1, the strong temperature favorability of the area should still mature a crop before first frost, in contrast to the delta to the south. The 901 equivalent hours at Orland for the mapped season drops to 841 for the four-month season beginning June 1. The map also indicates that cotton planting may be possible in the Owens Valley around Bishop, although the site is close to the lower 820 EHMNP limit.

Even though important in cotton production, Blythe and the Palo Verde Valley appear close to the lower limit. This may reflect summer cloudiness from the so-called Arizona "monsoon." Reduced frost risk perhaps permits a longer growing season along the Colorado River and thus reduces the marginal nature of the equivalent-hour totals.

Each environmental factor other than temperature plays a part in determining whether a site is favorable for a crop. Suggestions that temperatures are favorable therefore should not be construed to mean that a site is wholly suitable. It is not suitable when any major environmental factor is negative, and temperature is one of these factors. Parts of the Sacramento Valley, for example, might appear to have suitable temperatures for cotton, but soil, water availability, and the date at which soil is sufficiently warm for germination could negate the choice.

An evaluation of EHMNP methodology as a measure of temperature favorability must consider the importance of photosynthesis to the overall success of a crop. Experience indicates that the relationship is strong and, although other phenomena such as changing length of daylight may set the date of maturity, good food-making capability on the part of the crop plant is necessary for productivity.

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