CROP TEMPERATURE: INTERPRETATION AND PHYSIOLOGICAL IMPLICATIONS

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Crop temperature is an indication of physiological status of the plant. Plant temperatures vary with the external environment, often detrimentally, so that regulation of temperature is important to biochemical processes, overall productivity, and the ability of the plant to survive. A non-stressed plant regulates its temperature by evaporation of water through leaf stomates (transpirational cooling). Maximum rates of transpiration, and maximum cooling, are established by available moisture, atmospheric demand, the ability of the root system to extract water from the soil, the ability of the stomates to open in response to normal stimuli (light, moisture, air temperatures, humidity), and the ability of the vascular system to transmit water from the roots to the stems (the "plumbing" system). These complex interactions can be disrupted by disease, insects, great atmospheric demand for evaporation, or inadequate soil moisture. Most crops can maintain plant temperatures below air temperature in all but the most humid conditions (vapor pressure deficit < 1.5 kPa, comparable to 70%+ relative humidity at 85 F). Most species have optimal ranges of temperatures within which they are most actively manufacturing carbohydrates through photosynthesis.

Because crop temperature is so dependent on biological and physical variables, interpreting crop temperature involves removing, or accounting for, the effects of as many variables as possible. Effects of inadequate soil moisture are removed by adequate irrigation, while air temperature effects are removed by subtracting air temperature from crop temperature, and humidity is accounted for by recognizing that crop minus air temperature responds linearly to decreasing absolute humidity. Diseases and insects can be controlled, or damaged plants avoided, but the physiological and morphological variables are often intrinsic and not easily altered.

Crop temperature can be associated with yields, photosynthesis, evapotranspiration, soil moisture, and soil fertility. Generally, crop temperature decreases with respect to air temperature as absolute humidity decreases. For a well-watered crop, there is a baseline response of crop minus air temperature to absolute humidity. Elevations of crop minus air temperature above the base response are indications of water stress.

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Base responses can be used in irrigation scheduling and for assessment of crop physiological responses to treatments in research. Such a baseline was developed for Russet Burbank potato for use in commercial irrigation scheduling devices. However, no attempt was made to account for cultivar differences, or to test whether cultivar differences existed. The four baselines developed in my research indicated that some baseline responses differ among Russet Burbank, Century Russet, HiLite Russet, and Frontier Russet potato. (Among these cultivars, Russet Burbank and Century Russet were the indeterminate type, and HiLite Russet and Frontier Russet were the determinate type -- small canopies, soil always visible between the rows). This means that some cultivars transpire at different rates than others per unit leaf area. This is an intrinsic difference, The statistical analysis showed that the Frontier Russet baseline was different from the baselines of the other cultivars. While the HiLite Russet base response was similar to the Russet Burbank and Century Russet responses, there is another, more subtle point to consider: HiLite and Frontier Russet are partial canopy cultivars--they almost never achieve 100% row cover. Studies done on other crops showed that baseline response became steeper as the canopy grew from partial to complete cover. The reasons for this are complex, but are absolutely related to the fact that the heated soil under the partial canopy plays a profound role in altering the crop temperature response. The data from this experiment were collected while HiLite and Frontier Russet were at about 60 to 70% row cover, while Russet Burbank and Century Russet were at 100% row cover. Logically, if the crop temperature responses of Russet Burbank and Century Russet were measured at 70% row cover, their base responses would be less steep than the Frontier and HiLite responses. It follows that HiLite Russet and Frontier Russet should have steeper slopes at 100% cover than at 70% cover. Some evidence for this is given in Hattendorf et al. (1990) (Fig. 3). (Please note that in Fig. 3, Century and Frontier Russet are inadvertently exchanged. The Century response was similar to Russet Burbank.) In that experiment, HiLite, Norgold, and Frontier Russet did achieve 100% row cover. There is then evidence for different absolute transpirational responses of determinate, partial canopy potato and indeterminate, full canopy potato types.

Crop temperature was used in calculation of stress on potato and as a variable itself with regard to photosynthesis. In 1990, a hot growing season, photosynthesis was measured on extremely hot days. Frontier Russet and HiLite Russet had the capability of cooling their leaves enough to maintain photosynthesis rates well above zero. Russet Burbank and Century Russet, on the other hand, had higher leaf temperatures, with photosynthesis at or very near zero at the higher leaf temperatures. This is another indication that determinates vs. indeterminates have different transpirational abilities (transpiration is the main plant cooling mechanism). However, when water stress was imposed, photosynthesis decreased similarly with stress for all cultivars.

Photosynthetic measurements were obtained over a range of nitrogen levels under well-watered conditions. Photosynthetic rates increased slightly with fertigated N level with no cultivar differences, but HiLite Russet photosynthesis was greater than other cultivar rates on side-dress N plots.

For all cultivars, stress (i.e., crop temperature) increased as side-dress N level increased. This was not a 1:1 correlation with yield response, because best yields were obtained at 250 lb./A for HiLite and Frontier Russet, and at 350 lb./A for Russet Burbank and Century Russet. Applied N rates ranged from 100 lb/A to nearly 500 lb/A. One might expect no change in stress level (as calculated from crop temperature), or even a decrease as general crop condition improved, but excess nitrogen causes an imbalance between top and root growth. This may have occurred as N level increased and top growth exceeded the ability of the roots to supply water to the large tops, with resulting indications of water stress. It seems reasonable to assume that maximum yields and best quality occurred with the optimal balance of root and top growth.

The stress index used in this portion of the analysis was an average over time of the crop temperature data. It does not mean that nitrogen stress can be detected by crop temperature, but rather that some physiological changes induced by nitrogen can be discerned.

I conclude that differences for crop temperature (and therefore transpiration) responses exist among determinate and between determinate and indeterminate cultivars, and for photosynthesis under some conditions. Crop temperature was a valuable tool in interpreting photosynthetic data and physiological responses of potato.

REFERENCES:

Hattendorf, M.J., C.R. Brown, D.W. Evans, and J.E. Cochran. 1990. Potato foliage and tubers response to water stress. Proc. 29th Annual Wa. State Potato Conf. and Trade Fair, Jan. 30 - Feb. 1, 1990, Moses Lake.