EFFECTS OF HEAT AND WATER STRESS ON THE PHYSIOLOGY OF POTATOES

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In terms of potato yield and quality for many growers, 2001 was not a particularly good year. It seems like every time we experience a season where potato yields and quality do not reach expectations, heat or water stress are blamed. Although this past season was characterized by long stretches of unusually warm weather, it's important to ask the question – was it hot enough to account for the reduced yields and quality? To answer this question it is important to understand what stress is and how it affects some of the basic physiological processes that determine potato yield and quality.

WHAT IS STRESS?

Stress can be defined as any condition that is above or below the optimum for plant growth and tuber production. Potatoes actually have a fairly low optimum growth temperature and it is likely that they experience some heat stress even during season when temperatures are more "normal." For vine growth, the optimum temperature is around 75^{o}F, while for tuber growth the optimum is closer to 65^{o}F (Figure 1). This disparity in conditions favoring vine versus tuber growth results in one of the common situations associated with heat stress, an imbalance between the above ground and below ground portions of the plant. Therefore, if heat stress is present for a long period around the time of tuber initiation, the result is a situation where the vines appear very big and healthy, but there are very few tubers underneath.

Not only is the average daily temperature important, but night time temperatures are especially critical in determining the timing of tuber initiation and the rate of tuber growth. The optimum day/night temperature for potato growth is generally considered to be 74/54^{o}F. However, at any given day time temperature there is a corresponding optimum night temperature. As the day temperature increases a larger difference between day and night temperatures is required for optimum growth.

So where does water stress come in? There is a very close association between heat and water stress, in fact it is very difficult to separate these two types of stress. Crop water use increases greatly with increasing temperature (Figure 2), resulting in rapid depletion of soil moisture. As the soil dries out a couple of things happen. First, the pores on the leaf responsible for evaporative cooling start to close resulting in an increase in leaf temperature. Evaporative cooling is also an important factor in soil temperature, so the drier the soil, the closer the soil temperature will be to the air temperature (Figure 3). Kleinkopf (1988) was able to show that increasing soil temperatures by as little as 6 to 9^{o}F during tuber initiation was enough to greatly reduce tuber yield and quality.

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HOW DOES STRESS AFFECT POTATO YIELD?

The potato plant is basically a starch factory. In fact, over 90 percent of the dry weight of a potato tuber is a direct result of a process called photosynthesis by which the plant uses sunlight, carbon dioxide and water to produce starch. Part of this starch gets broken down and used to keep the plant alive in a process called respiration. As temperature increases, the rate of respiration goes up dramatically, while at the same time photosynthesis declines (Figure 4). The net result is that at high temperatures there is less starch available to drive plant and tuber growth. Because high temperatures promote vine growth, there is also a tendency for more of the starch available for growth to go towards the vines at the expense of tuber growth.

HOW DOES STRESS AFFECT POTATO QUALITY?

Stressed potatoes often exhibit high levels of internal and external defects, as well as low specific gravity. High temperatures reduce specific gravity by reducing the total amount of starch available for transport from leaves to tubers, and by reducing the rate of incorporation of that starch into the tuber tissue. Low specific gravity in the stem-end of the tuber is often associated with high levels of reducing sugars. When processed, these potatoes make sugar-end fries that are very poor quality. Stress that occurs during the early part of tuber bulking causes the highest incidence of sugar ends (Figure 5). This early bulking period coincides with the uncharacteristically high temperatures in Idaho during the 2001 growing season, and probably accounts for some of the reports of lower tuber quality.

One of the most obvious signs that potatoes have been stressed is an increase in the proportion of misshapen tubers, such as pointed ends, knobs and dumb bells. During stress, the low availability of starch and/or nutrients may temporarily stop tuber growth. When growth resumes, it occurs at the site of most active cell growth. The end result is malformed tubers.

SUMMARY

- Heat and water stress alter plant growth and restrict the availability of the starch that drives tuber growth.
- Stress that occurs during the early tuber bulking period is most damaging, and results in lower yields, reduced tuber quality and lower specific gravity.
- Conditions that occurred during the 2001 growing season were favorable for stress, but management is also a big factor in determining yield and quality.

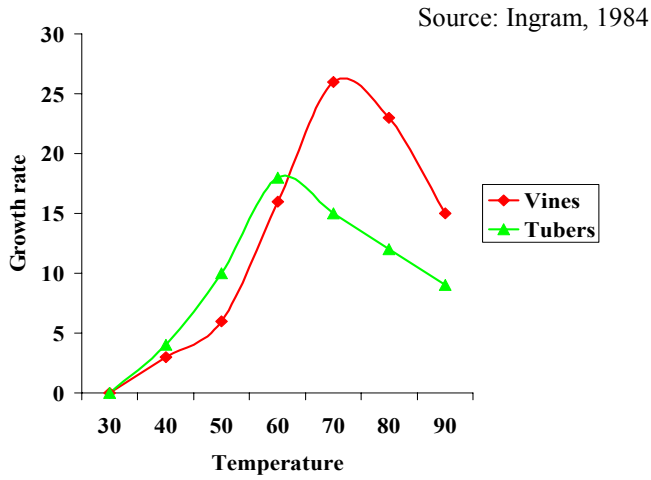

Figure 1. Effect of average daily temperature on growth rate of potato vines and tubers.

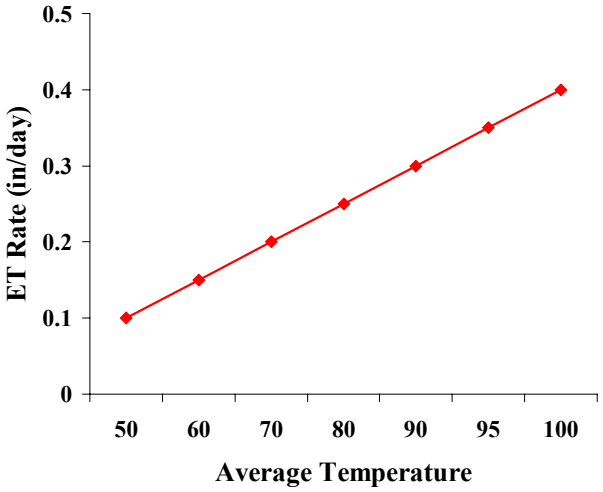

Figure 2. Effect of daytime temperature on rate of crop water use

Source: Kohl, 1973

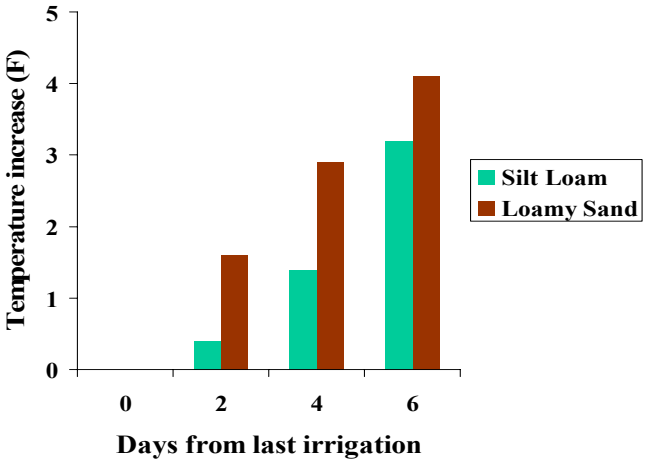

Figure 3. Effect of irrigation frequency on soil temperature

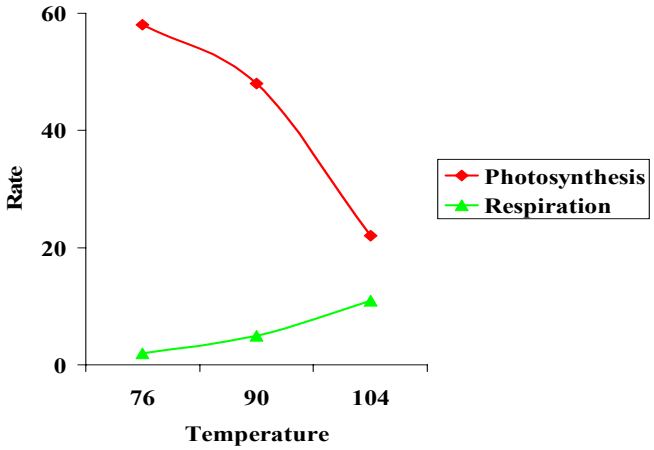

Figure 4. Effect of temperature on photosynthesis and respiration rate of potato leaves

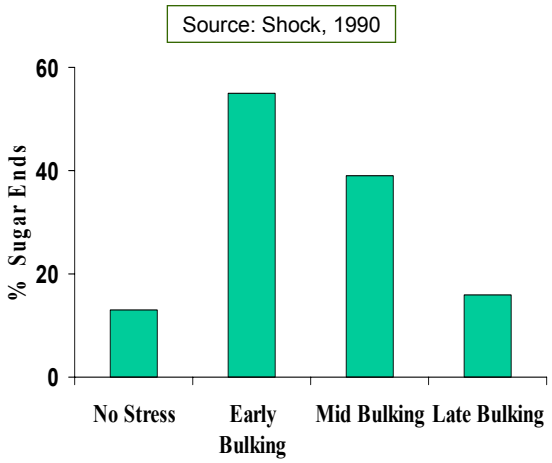

Figure 5. Effect of timing of stress on incidence of sugar ends.