EFFECT OF ENVIRONMENT ON DRY MATTER OF POTATO TUBERS

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The dry matter content of potato tubers is of primary concern to potato processors because of its relationship to processability. Potatoes of high dry matter result in a higher quality processed product and greater recovery. The advantage of high dry matter potatoes has led to the incorporation of monetary incentives in grower-processor contracts. Because of the importance of this attribute of potatoes, we have been actively pursuing an understanding of factors which influence the accumulation of dry matter in potato tubers.

There are many factors which may influence the dry matter content of potato tubers. These may be separated into controllable and uncontrollable factors.

Controllable factors

1) Fertilization: overuse of nitrogen and/or potassium may reduce dry matter.
2) Irrigation: irregular irrigation may result in overall reduced dry matter or uneven distribution of dry matter (sugar end).
3) Planting date: late planting may not allow time for high/dry matter to be accumulated.
4) Variety: some varieties are naturally lower in dry matter content than others.

Uncontrollable factors

1) Air temperature
2) Soil temperature
3) Light; quantity and quality
4) Rainfall

The "uncontrollable factors" are all part of the potato crop environment and may be the major factors controlling production of potatoes at any location. For instance, potatoes are a successful crop in Washington, Oregon and Idaho because of climate. Within each of these states, areas differ in ability to produce high yields and/or a high dry matter crop. We also realize that production levels are not the same from year to year. Therefore, we need to gain an understanding of how these "uncontrollable factors" affect production and whether or not they are truly uncontrollable or if we can modify their effects on the crop.

One of the first prerequisites for obtaining high dry matter potatoes is to achieve early emergence of the crop. Sprout growth is greatly reduced at temperatures below 58°F and therefore, early establishment is hindered when soil temperatures are below this level (Table 1). Emergence and growth seems to be fastest at temperatures between 73° - 77°. When early emergence is achieved, the plant has a greater chance of survival and a greater opportunity to form tubers to which carbohydrates can be translocated for starch production in the tubers. This results in high dry matter potatoes.

The process by which carbohydrates are manufactured tn the plant is called photosynthesis. This process requires light and is sensitive to heat. Potato leaves show a broad optimum for photosynthesis between 60° and 77°F (Figure 1). At temperatures greater than 82°F significant reductions in photosynthesis occurs.

During the 1980 crop season we collected plant samples from three locations in the state in order to determine the effect of environment on; tuber set, vine growth, tuber growth, and tuber dry weight. These measurements are all related to the plants ability to photosynthesize. Samples were collected weekly at plots near Quincy (Hammond Farms), Ice Harbor Dam (Hanses Farm) and at the WSU research unit near Othello.

Growth of potato vines were most rapid from June 1 to August 1 at the Othello plot and from June 15 to July 15 at Quincy (Fig. 2). Tuber weight increased most rapidly from July 1 to August 1 at all locations. Although the average yield sampled from subsequent dates at Othello and Ice Harbor showed increases, they were not statistically different (Fig. 3). Tuber dry weight and specific gravity increased rapidly from June 15 to August 1 at all locations and then levelled off (Fig. 4). Acceptable specific gravities were obtained from potatoes harvested on August 1 at Othello and Pasco but not until about September 1 at the Quincy site.

Modeling growth

In order to establish a relationship between the growth of a potato crop and environmental changes we need to place numerical values on both sets of data. We can express the environment at any one time or over a period of time by numberical values which can be construed as good, bad or intermediate. Then we can compare the growth of the crop (rate of growth) over the same time period and assign it a ranking of good, bad or intermediate for comparison to the values for the environment. By making many of these comparisons and by supplementing with controlled climate experiments, we can construct a growth model. This model can then be used to approximate the growth of a potato crop in different environments.

We have used several environmental variables in developing a model which best predicts crop growth. It seems that, in the potato growing region of Washington, temperature is the major factor influencing growth of the crop. Because solar radiation is the source of heat and because light is necessary for growth it is obvious that solar radiation is the controlling factor for growth. However, solar radiation data is not as easily obtained as temperature records, and therefore temperature is used in this model.

The model is expressed by the following description:

Growth potential = g.p. + (TA - 43)
g.p. = addative growth potential units for each day previous
TA = average daily temperature $\frac{(\text{high + low})}{2}$
43 = 43°F, cardinal growth temperature for potato shoot growth

The temperature used for the daily high is further subjected to modification when it is below 69°F or above 77°F. This adjustment is made in order to match results found by measuring the changes in photosynthetic rate with temperature (Fig. 1).

If we plot growth potential units over the growing season we see that each season is different (Fig. 5). The 1977, 1978, 1979 seasons fall into one category or shape of curve and the 1976, 1980 seasons have different shaped curves.

The set of curves for the 1976 and 1980 seasons show uninterrupted growth potential and a high potential during the season. Comparing these curves to those of 1977-1979 we see that the growth potential levelled off for a 30 to 40 day period. Therefore, if our assumptions are correct, the 1976 and 1980 growing seasons should have been more productive than the others (on an average basis).

By comparing production records of approximately 75 growers for the years 1976-1980 we find differences in production levels between years.

	yield	specific gravity
1976	27	1.0815
1977	25	1.0753
1978	26	1.0787
1979	26	1.0797
1980	29	1.0840

The differences between the years 1977, 1978, 1979 and 1976, 1980 are seen in this data. It is evident from the comparison of the model predictions with actual field data that temperature is major contributor to yield and quality of potatoes in Washington. We can see from the growth potential curves that the most critical period for the crop is from about July 10 to August 20. During this period we may experience excessive temperatures which result in crop stress. This stress can be better understood if we look back fo figure 1. The rate of photosynthesis begins to fall off rapidly at temperatures above 80^{o}F. This results in less dry matter being accumulated in the tubers and therefore a lower specific gravity tuber is produced than if the temperature was more optimum. On the other hand, transpiration, water loss from the leaves increases from 60^{o}-75^{o}F and then levels off. At temperatures greater than 80^{o}F the ratio of transpiration to photosynthesis increases rapidly. This means that the plant is not being efficient and suggests that it is under a stressful environment. During this time the crop may undergo irreversible physiological changes which result in yield and quality being adversely affected.

There are two cultural variables which are being controlled at the time in which the environmental stress may occur. These are water and nitrogen application. If we expect the crop to be undergoing optimum growth more fertilizer and/or water may be necessary to satisfy the crops need. On the other hand, if the crop is under a water stress because of temperature it may need more water but less nitrogen. The adjustment of these inputs can be suggested, although at this time, no data is available for us to determine whether to increase or decrease water and/or nitrogen application during the stress period. It would seem reasonable that when the plant is growing under optimum conditions that more fertilizer (nitrogen) will be required. If the plant is under a moisture stress it obviously should require more water. Further data needs to be collected in regards to this subject.

Table 1.

THE RATE OF EMERGENCE OF POTATOES AT VARYING TEMPERATURES

TEMPERATURE °F	DAYS TO EMERGENCE
58	8
61	9
66	8
70	7
73	6
75	6
77	6

Figure 1.

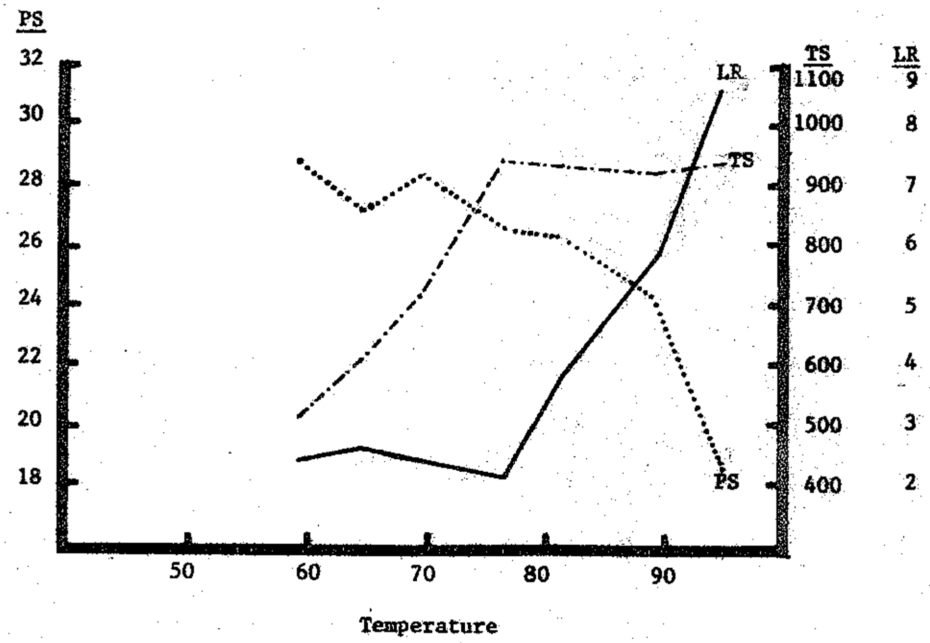


Figure 2.

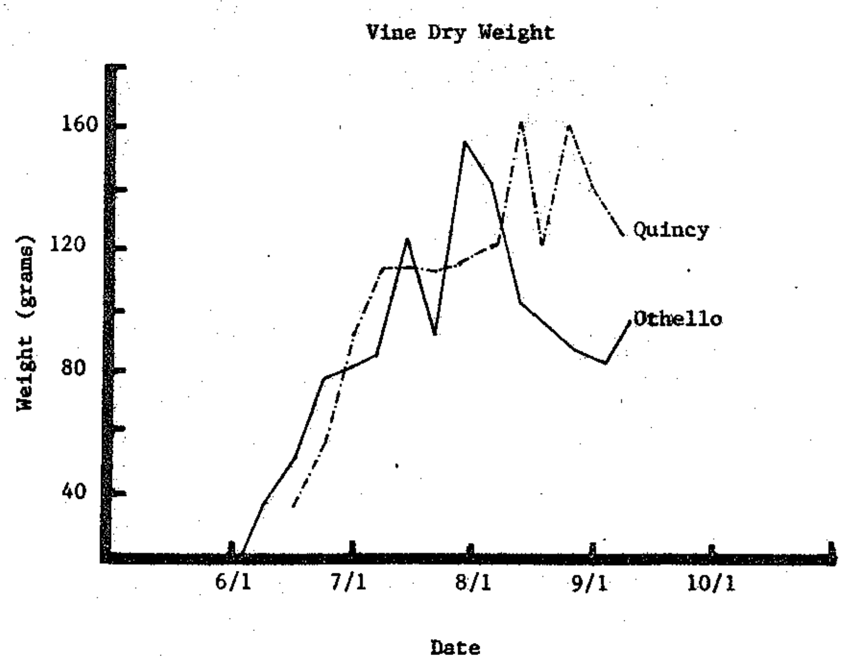


Figure 3.

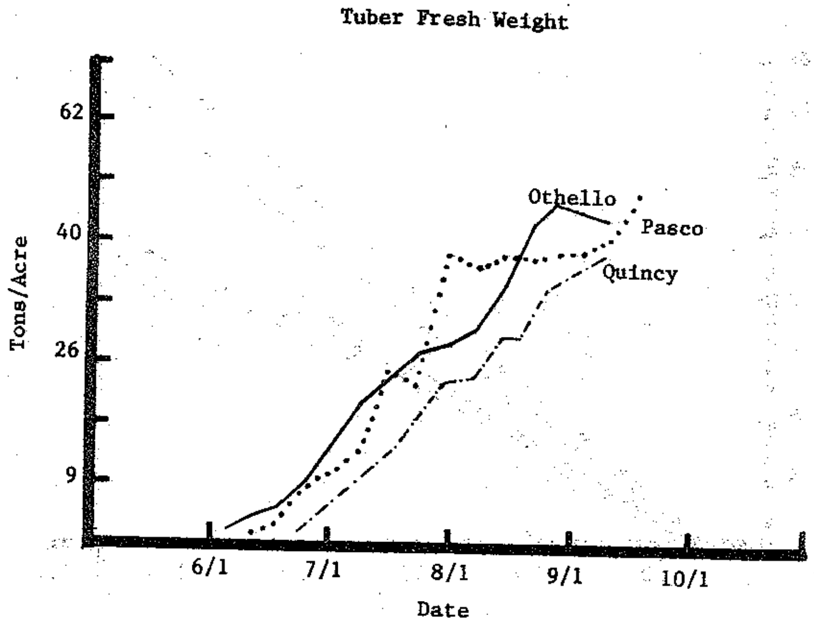


Figure 4.

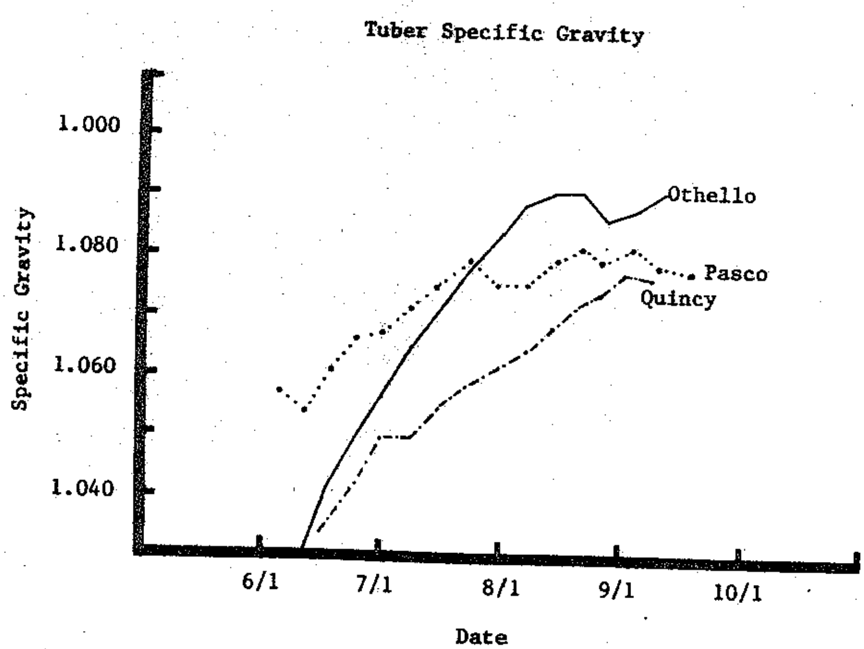
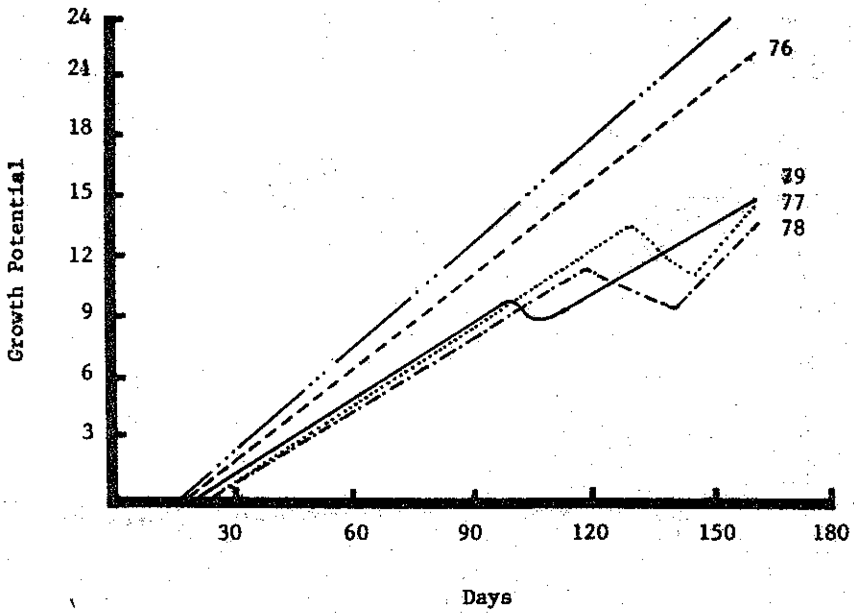


Figure 5.


24
21
18
15
12
9
6
3
Growth Potential
30
60
90
120
150
180
Days
76
79
77
78