SPECIFIC GRAVITY OF POTATOES: OLD PROBLEM/NEW KNOWLEDGE

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The specific gravity of potatoes is used as a determinant of raw product quality by potato processors. This measurement is used because it is an easy method to approximate the starch content of the tubers which determines processing characteristics. Generally speaking, the higher the starch content, the higher the specific gravity of the tuber.

Washington, Oregon and Idaho are the major potato processing states for frozen French fries because the climate in this area is generally well suited for production of high quality, high starch, raw product. Although the climate is generally ideal, periodic weather phenomena can adversely affect the crop. Problems with the 1990 potato crop make a review of factors affecting specific gravity a timely topic.

Initial growth of the potato plant is a result of the starch and sugars in the seed piece being utilized for growth. The starch in the seed piece is first broken down to sugars which are then transported to the leaves and stems for growth. The foliage will normally cause the breakdown of essentially all the available starch in the seed piece.

After the foliage has become self sufficient for its supply of sugars through photosynthesis, tubers will begin to be formed. The allocation of sugars to various plant parts is referred to as partitioning. An efficient plant will partition just enough sugars to the foliage to maintain good leaf growth but not result in excessive top growth. Excessive nitrogen can cause excessive top growth at the expense of tuber growth. On the other hand, nitrogen deficiency can cause premature tuber growth which will ultimately lead to poor yields. Inadequate water availability can reduce yields in a similar fashion. It is the growers ability to manage nitrogen and water application that optimizes the crop's response to the climate which leads to high yield of potatoes with good quality.

The process of photosynthesis is affected by temperature. Maximum rates of net photosynthesis (photosynthesis-respiration) occur between 68°F and 78°F. Cooler temperatures slow photosynthesis slightly and higher temperatures cause a rapid decrease in net photosynthesis. The photosynthetic process may be completely inhibited above 95°F.

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If an equation is developed that adequately describes the response of photosynthesis to temperature, we should be able to calculate the total amount of photosynthesis that will occur under different growing conditions. This has been done, and one example of this type of calculation was reported by the senior author at the 1982 Potato Conference.

The specific gravity of potato tubers is determined by the favorable allocation (partitioning) of sugars into them and the subsequent formation of starch. The specific gravity is ultimately determined by 1) the amount of sugars produced in photosynthesis, 2) the amount of sugars respired, 3) the partitioning of sugars into foliage or tubers for growth and storage, 4) the repartitioning of starch through breakdown and movement back to the foliage. Each of these processes are affected by temperature and other stresses placed on the plant as a result of high temperatures. They may be modified by grower practices such as nitrogen and water application, but control measures to eliminate the problem of low specific gravity or high sugars are not yet available.

Several of the potato processors have provided us with average specific gravities or dry matter for potatoes produced by growers for their companies starting in about 1975. The historical records reveal the frequency of occurrence of low specific gravity of the potato crop in Washington (Fig. 1). The two years which had low specific gravity during this time were 1977 and 1990. Previous to 1975 the data is not readily available, but 1971 may also have been a poor specific gravity year. During the 1970's specific gravity trended downward, but the trend is upward during the 1980's and seems to have less fluctuation from year to year.

If we assess the weather during the years by using the equation to calculate the effect of temperature on photosynthesis, we can compare good specific gravity years with poor specific gravity years. For example, we may choose the two worst years, 1977 and 1990, to compare with two of the best years, 1980 and 1989. When the daily values are calculated, and added together (accumulated), a graph of the data can be made (Fig. 2). The units used here are arbitrarily called "Growth Potential Units" (GPU). The calculations show dramatic differences in growth pattern between good specific gravity years (1980 and 1989) and poor years (1977 and 1990). These differences result from long periods of high temperatures during July and August in the poor gravity years.

It is important to understand the changes in plant growth during these years with good and poor growth so that techniques to modify the effect of climate may be developed. We have measured the changes in foliage and tuber growth during 1980 and 1990 and a comparison may be made between some of the growth patterns during favorable and less favorable growing conditions.

Plants were sampled weekly in 1980 and twice per week in 1990 to develop growth curves for tuber yield and specific gravity. Detailed foliage growth measurements were also made to determine total plant growth.

The yield of tubers in 1980 increased at a rate of 0.7 tons per acre per day between July 15 and August 22 whereas in 1990 the tuber growth rate was 0.5 tons per acre per day (Fig. 3). The specific gravity of the tubers increased at a rate of 0.58 units per day in 1980 compared to only 0.16 units per day in 1990. Since the accumulation of dry matter measured as specific gravity is not linear as can be seen from the graph, we can not easily calculate a final predicted specific gravity.

The nonlinear change in specific gravity is very evident from the 1990 data but is also evident late in the growth period with the 1980 data. We may also compare foliage growth with tuber growth measurements to obtain information about the partitioning phenomenon described earlier.

In 1990 we measured foliage growth by counting the number of nodes on each stem and totaling them. This provided us with a better estimate of growth changes than leaf weight or total weight because of older leaves dying and falling off the plant. The change in node number shows an inverse relationship with specific gravity during July (Fig. 4). When the foliage was not growing, July 11-19, the specific gravity of the tubers increased rapidly. When the foliage growth increased from July 23-July 27, the tuber specific gravity decreased. It was not until about the 12th of August after foliage growth began to slow down that the specific gravity of the tubers began to increase steadily. There is also a short time period between July 27 and August 8 when the foliage did not grow nor did the tubers change appreciably in specific gravity or yield.

The changes in plant growth in 1990 can be at least partially understood by relating them to specific weather during these time periods. The daily GPU for the 1990 growing season is superimposed over the growth data for the same time period to make this comparison (Fig. 5). The GPU are recorded as positive or negative numbers. The more positive the number is, the more favorable was the weather for growth. During the time when no foliage growth occurred in mid-July, the weather was not favorable for growth; however, the specific gravity of the tuber was still increasing. When the weather became favorable (shown as a peak on July 23) the foliage growth increased rapidly and the tuber specific gravity decreased. During the following unfavorable weather, (July 27 until August 15), little change in growth occurred. When favorable conditions resumed in the middle of August, all growth parameters measured showed an increase.

The decrease in specific gravity of tubers during the latter part of July when the foliage growth increased rapidly may be partially due to hydrolysis of starch in the tubers and remobilization of the sugars to the foliage (repartitioning). It may also be due to a "dilution" effect. Since the tubers were still growing at this time, there may not have been enough carbohydrate available to supply both the foliage and tuber adequately.

The data from this study show that temperatures above the threshold used in this model are a significant factor in controlling the production and allocation of dry matter to different plant tissues.

Figure 1. Specific gravity of potatoes reported by processors in Washington State from 1977-1990.

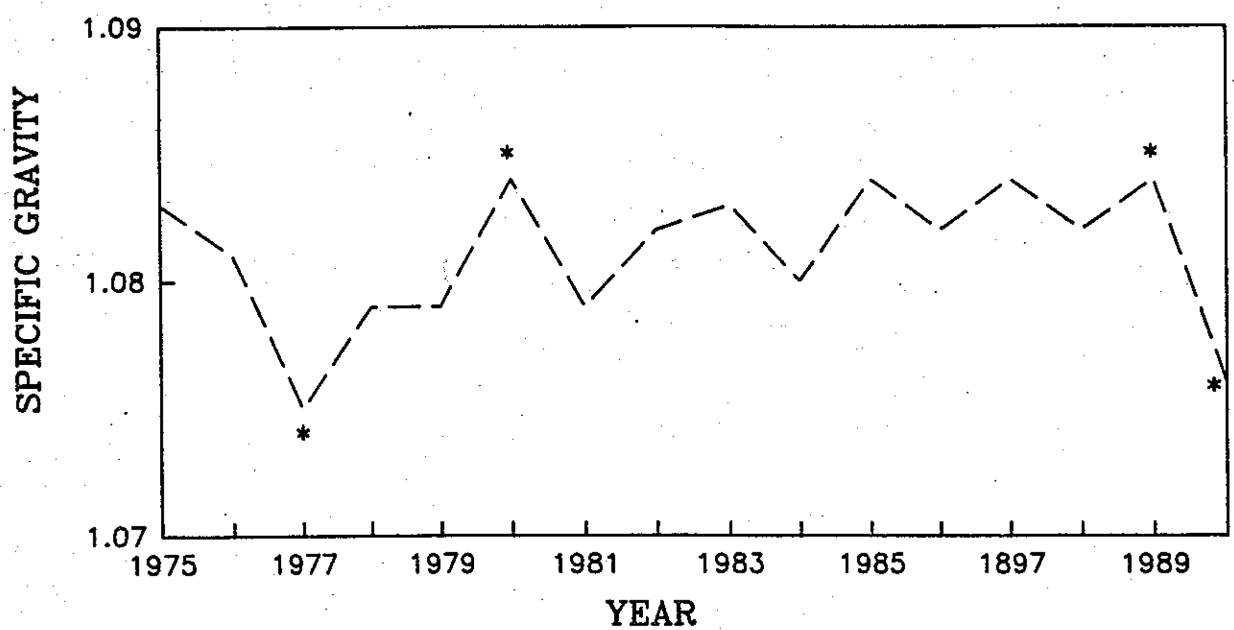

Figure 2. Accumulated Growth Potential Units (GPU) during 1977, 1980, 1989, and 1990.

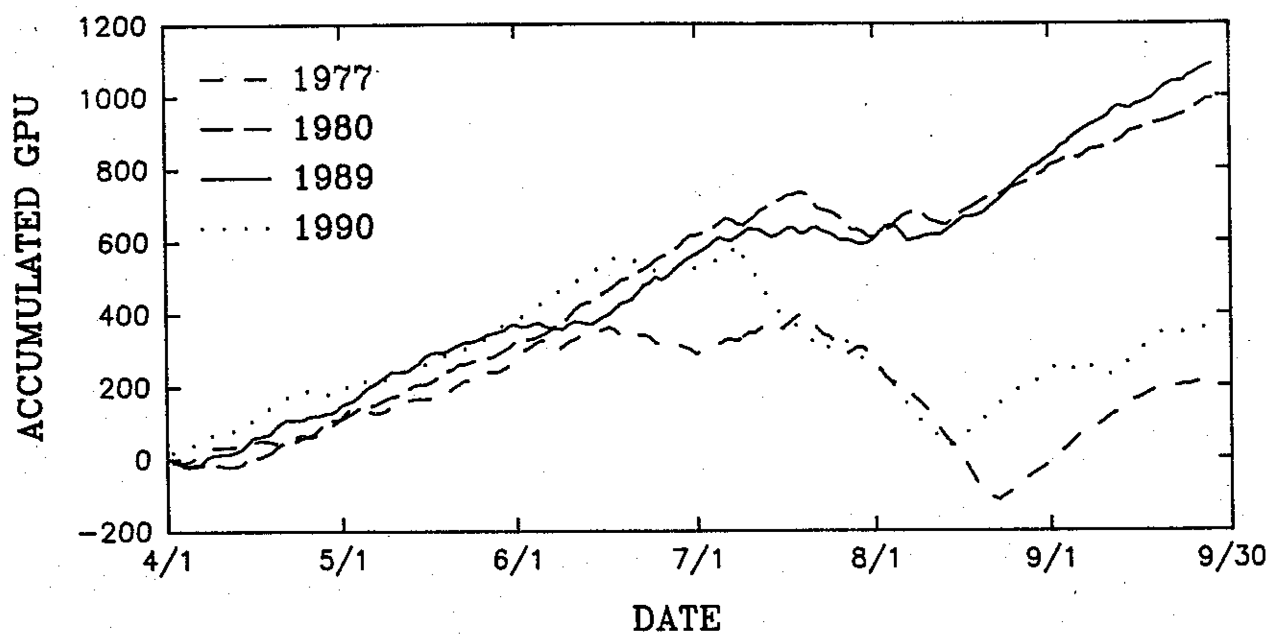

Figure 3. Yield and specific gravity of potatoes from research plots grown in 1980 and 1990.

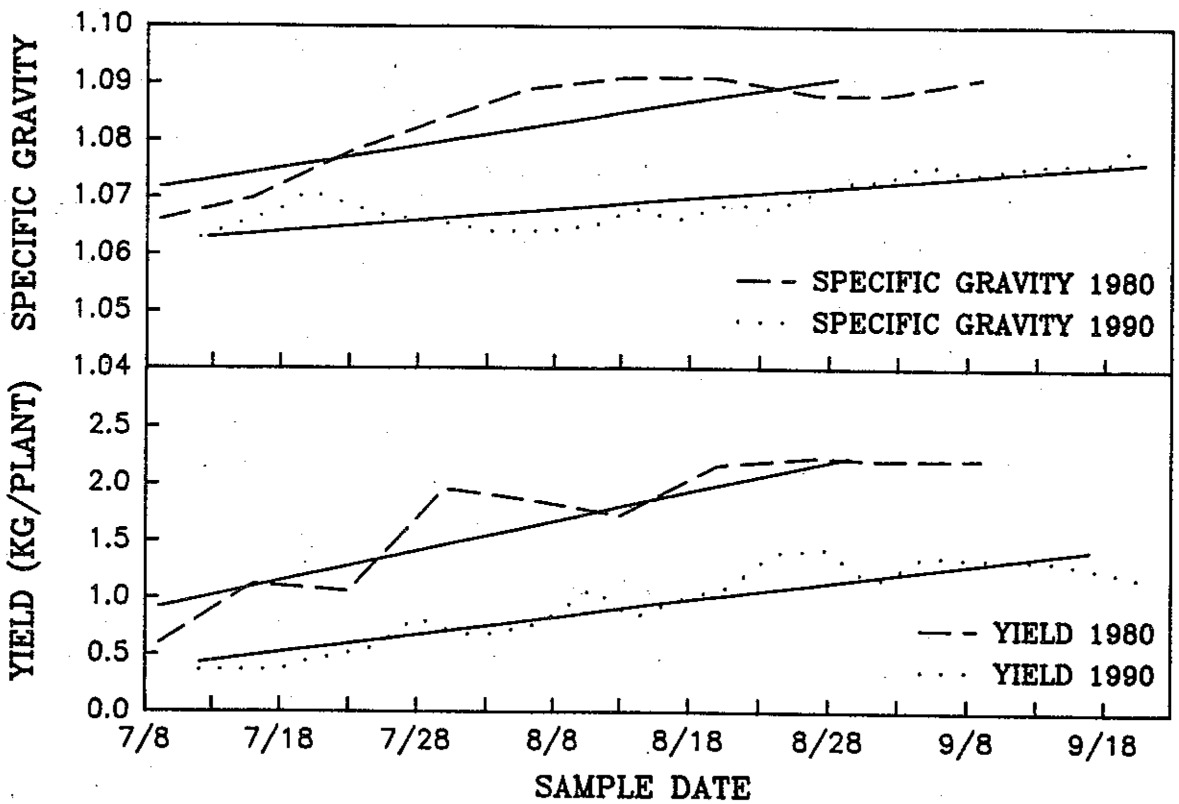

Figure 4. Foliage growth measured as number of nodes and specific gravity of tubers from samples collected twice per week in 1990.

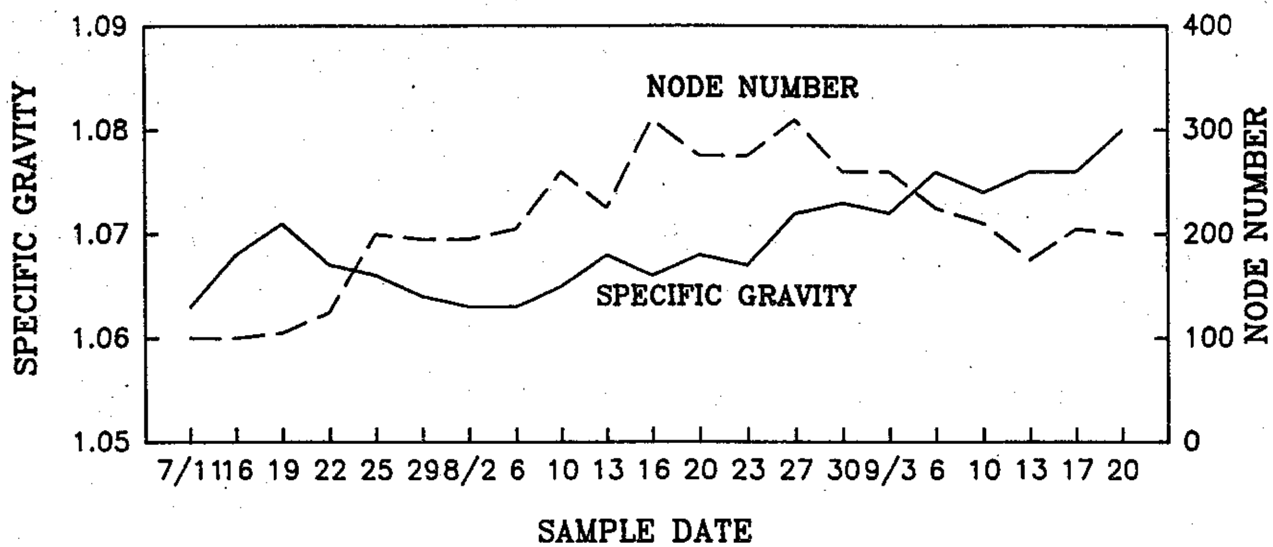

Figure 5. Comparison of crop growth and daily Growth Potential Units during 1990.