PHYSIOLOGY OF CRANBERRY YIELD

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Yield is the holy grail of cranberry producers. Pursuing higher yields requires knowing what is currently limiting yield. This article will outline our current understanding of yield limiting factors in cranberry production.

> *Practically everything we see about us involved photosynthesis at some stage or other. The gardener often talks about 'feeding' plants when he applies fertilizers and the notion that plants derive their nourishment from the soil is one that is commonly held. They do not. Plants take up minerals from the soil, they derive their nourishment from the air."*
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> *Edwards and Walker, 1983*

All yield and productivity in agriculture is based on photosynthesis. Photosynthesis is the process plants use to convert light energy from the sun and store it as chemical energy as lipids, proteins, and carbohydrates. Common external limitations to photosynthesis that may subsequently affect yield include light, CO_2 concentration, and temperature. Internal factors such as stomatal opening and the nutrient and water status of the vines may also affect photosynthesis.

Light. Cranberry growers really don't farm the soil, they farm sunlight. Fortunately, light is rarely limiting to cranberry photosynthesis. The maximum rate of photosynthesis occurs at about 1/3 of the light intensity of full sunlight. Light may be limiting on very heavily cloudy days and during the morning (sunrise) and evening (sunset). When vine canopies become too dense light may be limiting in lower portions of the canopy.

CO_2 Concentration. As a result of burning fossil fuels the CO_2 concentration in the atmosphere is increasing slowly over time. In theory as more carbon dioxide is available in the atmosphere the rate of photosynthesis should also increase. We tested on a small scale what happens to cranberry vines grown under elevated CO_2 levels. We found that growth and yield were not affected, but that starch accumulated in the leaves. In the real world CO_2 concentration is unlikely to limit crop yield.

Temperature. The optimum temperature for cranberry photosynthesis is about 70 to 75°F. When temperatures are lower or higher than the optimum the rate of photosynthesis declines. When correlations are made between yield and weather a frequent finding is that highest yields occur during years with moderate temperatures. Growers can affect temperature through timely irrigation during very hot weather.

Yield component analysis is a statistical procedure that assigns relative importance to various factors that determine yield of a given crop. Cranberry was subjected to yield component analysis and two factors were found to be the most

important determinants of yield: the proportion of fruiting uprights and fruit set. It seems prudent to focus our energy on the two factors that are most important in determining yield.

Fruiting uprights. Individual uprights tend to bear biennially. That is an upright that flowers and fruits one year is unlikely to flower and fruit the following year. Cultivars and location affect the extent to which biennial bearing occurs. Vigorous uprights are less likely to be biennial bearing than less vigorous uprights. Some newer cultivars show improvement in the inclination to rebud during the fruiting year. This should result in higher yields. This is an area where potential yield increases through breeding are possible.

Fruit Set. Fruit set is the culmination of several previous steps. Prior to fruit set we must have flowers, the flowers must be pollinated with compatible pollen, the pollen grain must germinate and the egg cell in the ovary must be fertilized by one of the sperm nuclei from the pollen. Once that happens, if there are sufficient resources, the fruit will begin to swell and grow. We know that fruit set can be improved slightly through better pollination. When insect pollination was supplemented with hand pollination fruit set increased by 8%. When vines are sprayed with the growth regulator Gibberellic acid fruit set increased to about 50%, but fruit size was about half the control group. Thus, fruit set increased, but yield did not.

Fruit development also requires resources, primarily carbohydrates. The time of fruit set is the most critical and anything that reduces availability of resources to fruit at the time of fruit set also reduced fruit set. Carbohydrates to support fruit growth can come from the new leaves above the fruit, from one-year-old leaves below the fruit, or from leaves on an adjacent upright along the same runner. Using leaf removal and radioactive labeling we determined that the primary source of carbohydrates for supporting fruit growth are the new leaves above the fruit. Thus getting sufficient vegetative growth before the time of fruit set and maintaining these leaves in good conditions appears prudent to maximize yields.

During the course of two seasons we measured the rate of photosynthesis and we followed the pattern of change in carbohydrate pools in cranberry vines. We found that carbohydrate pools were large in the spring, then dropped precipitously at the time of fruit set, suggesting that the developing fruit were a large draw on the carbohydrate resources of the vines. Thus anything that reduced the ability of vines to supply carbohydrates to developing fruit would be a potential cause of yield reduction. At the same time we measured photosynthesis in the field. We found that current season leaves had a rate of photosynthesis roughly double that of one-year-old leaves. When we totaled up the carbon cost of fruit and compared that to the carbon available via photosynthesis we calculated that, in general, an individual upright was capable of supporting the growth of two fruit per season. If you go out into a good bed of cranberries on your marsh I would be willing to bet that the average number of fruit per upright will be two.

Fertilizer. Having sufficient mineral nutrients in cranberry vines is essential to the process of photosynthesis. However, adding more fertilizer won't necessarily result in greater yields. Cranberry fruit are 85 to 90% water. About 94% of the remaining dry

weight is composed of carbon, hydrogen and oxygen: the products of photosynthesis. Thus, about 6% of the remaining dry weight is nitrogen, phosphorus, potassium, calcium, etc. Increasing the percentage of dry weight of these mineral nutrients won't necessarily result in higher cranberry yields.

In Oregon research was conducted on a nitrogen deficient cranberry bed. When nitrogen fertilizer was added upright density increased along with the number of flowering uprights. Fruit set increased as nitrogen fertilization rate went from 0 to 40 pounds per acre, but did not increase beyond 40 pounds of N per acre. The greatest increase in yield from providing sufficient nitrogen was from an increase in berry number. Only a marginal increase in yield was related to berry size.

Weather. Climate and weather have substantial effects on cranberry yield, yet we can do very little about the weather. Researchers in the 1940's correlated yield with weather patterns during bud development. Cranberry yield is not well correlated with growing degree days or light received by the canopy. It is, however, well correlated with the number of moderate temperature days (highs between 61 and 86°F). These results are interpretable because we know the optimum temperature for cranberry photosynthesis.

Climate and weather are important determinants of cranberry yield that we are unable to manage. While we should do our best to manage what we can, a substantial portion of what determines yield is outside of our control.

Summary. What is the 'take home message' from this article? Fertilizer is not the only determinant of yield. In fact, it is not a very important contributor to yield. Other factors such as weather and genetics are far more important contributors to yield than fertilizer is. With an understanding of the physiology of yield growers will be better able to make management decisions, including fertility. They'll be less prone to sales pitches that lack sufficient research base to support them.

Our goal with tissue testing and writing nutrient management plans is to apply sufficient fertilizer so that fertility is never the limiting factor for plant growth and yield. To say it another way, we want to obtain and then maintain tissue sufficiency. Adding fertilizer beyond that is wasteful and will not lead to higher yields.

Note: A longer version of this article was distributed at the 2007 Wisconsin Cranberry School. Rather than reprinting this publication in the proceedings the above summary was provided. The full text of the larger publication is available on the Internet at the following URL:

http://www.hort.wisc.edu/cran/mgt_articles/YieldPhysiology.pdf