Sunlight, Yield, and Productivity of Apples

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The apple grower, at the most basic level, is a farmer of sunlight. The sun provides the energy that is converted from light to sugars and dry matter by photosynthesis of leaves. This dry matter is then distributed to grow the tree, grow the crop and burn by respiration to support all the growth.

Apple trees are also perennial plants that live many years and live through the dormant winter by storing away energy in the form of carbohydrate and nutrient reserves. These reserves, last year's sun, can then be used in the spring to support growth of the young shoots and roots when there are no or few leaves yet. Studies have shown that the reserves are critical before bloom, but they are used only until about bloom. After bloom, there are enough leaves that the reserves can be replenished.

Since the reserves are no longer used after bloom, this means that the development of the crop (1) is supported by the photosynthesis of the current season's leaves and (2) will be very dependent on the current weather. So we have studied over many years how the apple orchards capture sunlight, how the apple tree responds to weather, and what controls fruit growth and drop.

It is helpful to consider the steps of farming the sun and what factors affect them:

Sunlight Energy Availability and Utilization	**Affected by:**
Energy Available to Orchard	Region and climate
Energy Intercepted by Orchard	Planting Design, Spacing, Leaf Area
Energy Converted to Dry Matter for Growth	Health, Water & Nutrient Supply
Energy Distributed to Fruit vs Vegetative Growth	Rootstock, Pruning, Thinning

Clearly, for any given location the energy available to the orchard depends on the general latitude and the climate (sunny versus cloudy, and long versus short season). For NY growers this is a real limit as we have a relatively cloudy climate with fairly short season. So we have to make the most of the other things we can control.

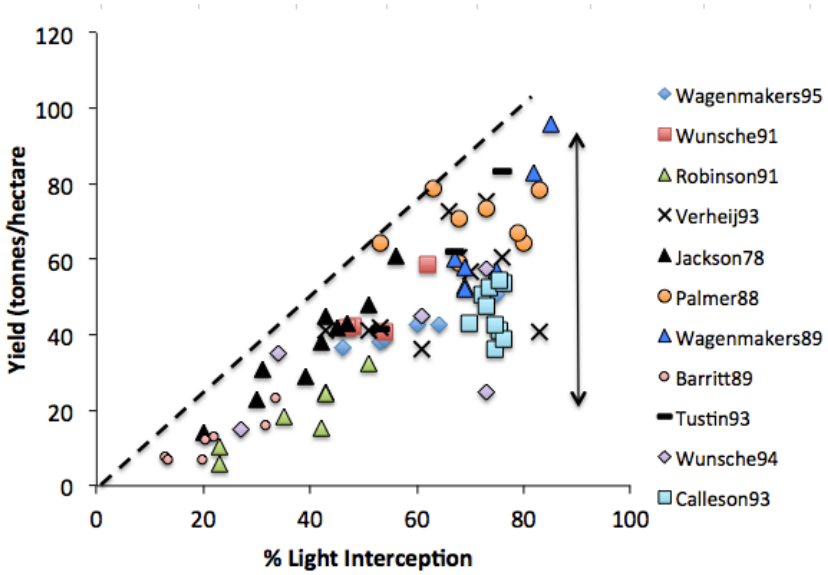
Consequently, we have focused a great deal on understanding how the grower can affect the sunlight intercepted by the orchard and how they can then distribute it optimally for balancing yield, fruit quality and return cropping.

Yield Potential is Limited by Sunlight Interception

Many studies have shown a clear positive relationship between light interception and apple orchard yield. A key point is that to have a high yield potential requires a high

percent of the available light to be intercepted by the orchard. Of course the conversion of sunlight energy into useable sugars depends on the health of the leaves and the supply of water and nutrients. So good pest, water and nutrient management is important to ensure that the sun that is intercepted is maximally converted to support growth.

The second key point is that even a high percent light interception is no guarantee of high yield; that depends on light distribution within the tree as will be discussed below.



The relationship of apple orchard yields to percent sunlight interception from many studies. The dashed line approximates the maximum yield possible for any orchard light interception while the vertical arrow indicates the reduced yields that result from poor light distribution *within* the trees.

The production of light crops even with high light interception is a long-standing problem that is based on poor pruning and training. Physiological studies have found that it is critical to have good sunlight exposure of apple spurs for (1) setting fruit after bloom, (2) producing good fruit size and quality, and (3) obtaining good return bloom. It turns out that except for fruit coloration, the critical time for spur exposure is the first 4-6 weeks after bloom. This is the time when fruit are being set, growing cell numbers for size potential, and developing flower buds for next year. So a particularly important time to check trees for good light penetration is around and just after thinning.

Factors Affecting Crop versus Vegetative Productivity

So why is it so important to get sunlight to the spurs and fruit? To answer that question, we and others have done several studies on how fruit is supported and found that:

- In the first weeks after bloom, fruit are supported by spur leaves, including non-fruiting spurs, but are not supported much by extension shoots

- Active extension shoots support their own growth first, and do not support fruit until they have at least 12 expanded leaves if in full sun. If shoots are shaded, they may require 20 leaves to support themselves before helping the fruit.
- The yield of an orchard is directly related to the total amount of sunlight intercepted by the spurs during the first 3 weeks or so after bloom. The more sunlight intercepted by shoots, the less by spurs and so the lower the yields.

So during the critical period of cell division and fruit drop, the spurs are the primary source of support for the fruit. This has several implications for growers. Trees will be more productive if:

- *they have a good balance of mostly spurs with some extension shoots to ensure high light interception by the spur canopy*. This is often attained by using thinning cuts instead of heavy heading cuts that reduce spur numbers and increase shade from more vigorous shoots on the outside of the tree.
- *the pruning and training of trees maintains excellent light exposure of the spurs at least until about a month after bloom*. So thinning time is a great time to examine the trees for good light penetration. In central leaders it may even require a few large thinning cuts at that time if the pruning did not open large enough windows. Alternatively, for older trees the Palmette Leader form may be worth using as the large gaps on the east and west sides guarantee good light penetration for several weeks after bloom.
- *have good but not excessive vigor due to good nutrition and water for spurs with large leaf area which supports good fruit development and return bloom*. Vigor is also needed to develop good branches for replacement pruning when other branches are thinned out.

Reaching the Crop Potential

Once the crop potential has been set early in the season with good light interception and good light distribution to the spurs, then it is important to reach and maintain the optimum crop. This requires thinning to a crop level balanced to the tree capacity to ripen it, and maintaining the tree health to fully support the crop.

This of course requires a healthy tree with good nutrition and adequate water supply. Also we have found that excessive summer pruning of dense canopies due to poor winter pruning can markedly reduce the tree's photosynthesis ability and limit final fruit sizing. This is due to a loss of function of the remaining leaves that were in the shade most of the season. So, better winter pruning to keep an open canopy will help early spur exposure to get better set and size potential, but will also help by requiring less summer pruning.

Finally, good pest management is important to reduce direct loss but also to maintain tree function for good ripening. In our study of European Red Mite effects, we found that the effects on the fruit were due to reducing the leaf photosynthesis ability, again reducing the ability to ripen the crop and reduce next year's crop potential.