Title: Shade Cloth For blackberry drupelet abortion and white drupelet problems in the southeastern USA

Sponsor: Sothern Agricultural Research and Education (SARE) farmer program grant and The Happy Berry (510 Gap Hill Rd., Six Mile, SC 29682)

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Introduction: High temperatures have been associated with white and aborted drupelets. Dr. Clark's (Prof. University of Arkansas) observations of beautiful fruit in the cooler Pacific Northwest discussed at several different meetings with pictures; the fact I could not find anyone who had looked at shading in blackberries; I was excited by the prospect of fall blackberries for direct marketing; and I already had two very small plantings in the ground of primo cane blackberries I decided to submit a producer grant to SARE.

Dr. Clark pointed out to me Dr. Stanton and others work demonstrated floral incompetence with 95 F degree days and 72 F night degree days in primocane blackberries. Stanton documented poor pollen viability and shorter times of stigma receptivity. I thought easy done. I justified it as an opportunity for piedmont area growers of the upper Southeast. I found there is a lot of literature all of which alluded to lower temperatures and even frost protection in shade events. In hind sight I had not done a thorough job in assessing the current state of information on shade cloth use some of which goes back to 1922, darn near 100 years ago.

The objectives of the project were: 1. Develop a reasonably cost shade structure for small growers that would work on uneven terrain that enable tractor management, use locally available supplies and was retractable/deployable and 2. Verify shade cloth anticipated impacts of lower high temperatures, improved quality of berries and reduced heat loss during frost events.

Results: In the test areas there were two varieties Black Magic and Prime Ark 45 about 500 feet of row each variety on 10 foot row centers. The shade trellis materials included treated four by fours, High tensile wire (12 gauge); Top rail used in chain link fence, hard ware, and 14 gauge electric fence wire and fence strainers. All together it cost about $1800 for the project or

$7850 per acre material cost plus labor for installation of support trellis for the shade cloth.

The shade cloth was purchased from Pak Unlimited. I was worried about insufficient sun shine but wanted to get the cooling effect. I selected Aluminet (50% shade) because of claims of greater reflectivity. Later I would learn more about what shade cloth actually does (see discussion below). The cost was $3046 for the project or $13,243 per acre bringing the total cost per acre to $21,100 per acre. A friend from Israel said White shade cloth was best in their trails but field life was much shorter. Black was guaranteed with 8 year life and Aluminet 5 year life by Pak.

NOAA weather boxes with max-min thermometer both inside and outside the box in the shade and in nearby Kiowa blackberries in the sun were used. The bottom line of the temperature data was that the air temperature was lower in the sun than in the shade! After the first year of collecting the data I was shocked if not dismayed. In fall frost events temperatures were higher in the shade in 9 out 9 events. We had a frost in the first year of the experiment before the trellis was up because of lack of confirmation of funding, so there were no observations on spring fruit. We used floral phenotypic competence indicators found by Stanton of primocane flowers in year one and both flora cane and primocane flowers in year two starting June 1, 2015. Availability of summer help determined starting date. Normal flowers got a rating of 1. Each additional petal, sepal or presence of sepal outgrowths got 1 count. For example a flower with 6 sepals, 7 petals and out growth(s) were present would get a rating of 5. Ten flowers would be rated each day in each variety. Black magic flower were closer to normal on 47 out 72 days than Prime Ark 45 in year one. In year two the observations were similar with regards to floral competence. In primocanes the frequency of floral incompetence was associated with warmer August and early September flowers. In flora canes flower incompetence increased in June. Flora cane fruit were beautiful with virtually no drupelet abortion in either Black Magic or Prime Ark and no white drupelets were observed. Unfortunately, there were no varietal controls. Kiowa berries adjacent to the shade cloth showed a normal amount of berry distortion and white drupelets as the summer progressed. In a project started about the same time as this one by Bobby Boozer in Alabama, now retired, and followed on by James D. Spiers using shade cloth and high tunnels, Spiers, in a personal communication, indicated reduced incidence of white drupelets and no apparent impact on growth or yield with a possible increase in yield under the shade cloth. Unfortunately the berry trellis was not same under the shade as out of the shade.

The results of the first year observations were presented at the North American Blackberry Association (NARBA) meeting. The discussion following the meeting indicated that Infrared thermometers should be used to follow plant temperatures. Discussions with Dr. Dale Linvill, Agricultural meteorologist that even in an open sided system the wind run is reduced and that elevated air temperatures are not unexpected because of reduced convection. Second year observation of max-min thermometers outside the NOAA box in sun verses shade were similar, with in-sun observations being cooler 60 or more percent of the time. Temperature observations inside the NOAA box were equal to or just 1 or so degree Fahrenheit cooler in the shade.

There is a wide variation in capability of infrared thermometers with the major difference being field of view. The field of view determines the size of target from a millimeter to centimeters or more (from 1/16 to inches) depending on distance from the target. An inexpensive one from a Lowes was purchased for $20 and temperatures were determined of targets by holding it approximately 6 inches from the target. Our field of view was probably an inch or more. The targets were green, red and black fruit and we looked 5 fruits of each variety, Black magic, Prime Ark 45 and Kiowa. Kiowa was in the sun. Fruit were selected that were on the outside edge of the canopy and were not shade by objects such as trellis posts. Time of making reading was standardized at approximately 1 PM.

Variability of readings was high, usually about 3to 8 degrees at any given reading. The field of view was large and target often moved even with little wind and it is a cheap instrument. At the same time we gave each black berry a rating as to shape and presence of white drupelets. Inspection of the data, (no statistical analysis was done) revealed that there was no apparent difference in recorded temperatures between green, red or black fruit. I was expecting black to be warmer. The “heat capacity” of an object is determined by density and color has little influence. Since all plant tissues are approximately 95% water the densities are similar and the observations are as predicted. Similarly there was no apparent difference between Black Magic and Prime Ark 45 in the shade.

On June 14 through 16 of 2015 high temperatures were 100 plus degrees. Infrared temperatures of all fruit were generally 10 degrees or cooler than air temperatures. There was only slight difference, perhaps a trend, towards hotter temperatures in the sun with the infrared thermometer. I was expecting a larger difference. Perhaps quality of the instrument and the variability influence temperature observations and future work should be done with a better instrument with a smaller field of view.

Fruit quality ratings were definitely poorer in the Kiowa in the sun. Unfortunately, since quality parameters are influenced by variety there is not an appropriate control.

Figure 1. Black Magic (left) 7-24-15 and Prime Ark 45 (Right). Note the absence of white drupelets when temperature highs were between 98 the 102 degrees from 7/21 to 7/24.

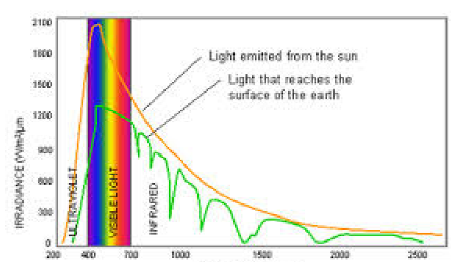
The fruit in figure were typical and suggest strongly that shade works for white drupelet problems but that fall yields were inadequate under the shade used.. Because of this I felt like I did not understand how shade cloth works I prepared the following discussion. I hope it is helpful to you if you consider using shade cloth.

I also noted that there was increase in Botrytis associated with increase relative humidity and slower drying times (see discussion below). As an aside that Botrytis was resistant a number of fungicides and resistance management program became necessary.

Discussion: How Does Shade Cloth Work?

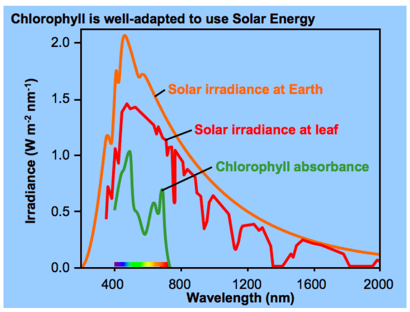
All energy used for plant growth originates in the sun. Solar energy arrives at earth's surface as electromagnetic energy. When solar energy strikes the earth's surface, it is either absorbed by or reflected from the surface. The absorbed solar energy, by a plant for example, transforms to thermal energy, heat (measured as temperature). Some heat energy (latent heat) is used to evaporate water while other heat energy is moved into the soil or air by conduction. Once air is heated, it moves taking heat away via convection.

Most of the solar energy is in wavelengths from about 200 to 2500 nanometers, nm. In the first chart (Length of a nanometer is 10^{-9} meters) colored sections of the chart show the visible energy that we see. About 2% of the sun's energy arrives in the short ultraviolet

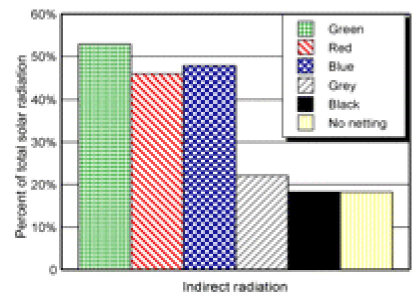


wavelengths and about 47% arrives in near infrared wavelengths too long for us to see. The bumps and valleys in these charts are caused by water vapor, ozone, carbon dioxide and methane molecules, etc., absorbing solar energy as it passes through the atmosphere.

Plants make use of solar energy in the 350 to 800 nm wavelengths for photosynthesis in the second chart. Plant scientists call energy in these wavelengths Photosynthetic Active Radiation (PAR). Photosynthetic tissues can become light saturated. For example an olive tree's leaves become light saturated at about 30% and a tomato pant's leaves at about 25% of full sunlight.

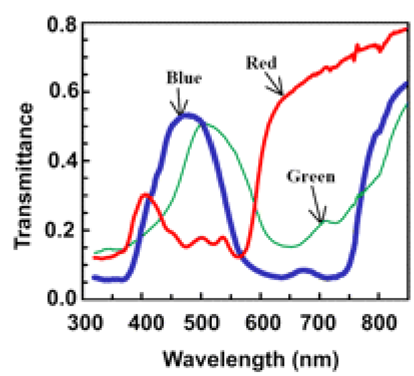


Solar radiation quality or amount of energy in each wavelength band affects photo-morphogenesis, e.g. direction of growth, length between internodes, degree of branching, quantities of chlorophyll, etc. These morphological responses are mediated by proteins such as phytocromes absorbing energy in the infrared wavelengths and cryptochromes absorbing in the blue wavelengths to trigger plant hormones.



Shade cloth materials are designed to reduce amount of solar radiation and/or quality of radiation passing through the netting. In addition to reducing the amount of radiation, multiple reflections as light passes through nettings creates diffuse light (indirect radiation-chart three). Aluminet netting in this demonstration increases light scattering but does not change the light spectrum. Diffuse light increases radiation use efficiency (more light is available lower in the canopy), yields and can affect plant branching, compactness, flower timing and numbers.

Reductions in radiation will affect temperatures (air, plant, soil) and relative humidity under the shade netting. Nettings also reduce wind speeds and wind run which can affect temperature, relative humidity, and gas concentrations resulting from reductions in air mixing. These changes can affect transpiration, photosynthesis, respiration, and other plant processes.



When compared to plants growing in full sunshine, shade will reduce the difference between air temperature (usually higher at mid day) and plant temperature (usually lower as measured by infrared thermometer). This in turn changes how the plant responds to its new microclimate. Since heat always flows from hotter to cooler, as the time progresses fruit temperatures would increase as long as air was warmer than the fruit. Air has a lower heat capacity than water, a plant is mostly water, and therefore it takes less energy to raise air temperature. It appears that our time of measurement was too late and that was the reason the difference between shade and sun was minimal. This further suggests there is need for information on how long at what temperature is required for white drupelet formation?

For example, a plant leaf under full sunshine loses water (transpires) at a much faster rate than a leaf in shade. The sunlight leaf will become much warmer than the shaded leaf. The added heat, if high enough, breaks molecular chemical bonds and/or unravels and denatures proteins which results in loss of function in plant cells. Shading will lower this temperature difference between air and leaf. The net effect is the shade cloth slows or delays the rate at which the plant warms over ambient air.

Our problem is blackberry viable flower, drupelet abortion and white drupelets. Stanton has identified temperature thresholds that initiate the problem of drupelet abortion. He associated abortion with reduced stigma receptivity and reduced viability of pollen. We are not aware if any temperature works with regards to white drupelets other than simple observations. There is a need to use more temperature points on the curve and use single continuous temperatures as opposed to different night and day temperatures used by Stanton. So that how long, at what temperature, does what damage, can be determined? This information could then be interpreted over daily diurnal cycles.

The cost of the trellis system still seems high for a small grower. An even less expensive system might be to use living pine trees. Pine trees are not epicormic, thus when a branch is removed it does not grow back. If pine trees, loblolly for example, were planted in north - south rows for maximum shade impact or east-west rows for minimal shade impact that were widely spaced, shade could be managed. The vision is that the trees would be totally limbed up till they were 4 -5 feet above the production canopy. For next 30 feet branches would be removed in the north - south direction to minimize shade (sun goes over east west) impact. Over 40 feet the canopy would be allowed to expand in all directions. The distance between the rows would be determined by number of hours of direct light required (e.g. photosynthetic saturation) and the threshold hours for flower and fruit damage. The advantages beside price are passive frost protection from east-west branches; diffuse or indirect light feeding the producing canopy; reduced damage from violent summer thunder storms; increased carbon sequestration; mulch production from needles on site for weed and water management. Disadvantages possibly would be increased disease and insect management, for example botrytis and blackberry psyllid and bird depredation. Instead of loblolly perhaps a nut bearing pine could be used like Italian stone pine.

Will covering the blackberry crop with shade netting eliminate the drupelet abortion and/or white drupelet problem? Our work moves Stanton's temperature research into a grower's field and raises questions with regards temperature thresholds in blackberries.

Conclusions: 1. An open sided trellis shade cloth support system was made that enabled normal field management with tractors, sprayers and mowers at less cost than what is commercially available. 2. Drupelet abortion and white drupelets were minimal under the shade cloth. 3. The apparent mechanism was to delay the rate of heat accumulation by plant parts, hence reducing the number hours at damaging threshold temperatures but not enough for a viable fall crop. 4. The physical mechanisms are discussed.

Background information:

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