Day-Neutral Strawberry Season Extension Using Low Tunnel Systems

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Availability of locally grown strawberries is extremely limited in the Upper Midwest due to the short growing season and cultivars with short harvest windows. While there is an expressed interest in having greater access to locally grown strawberries, lack of knowledge regarding innovative production systems and new cultivars has limited growers from being able to fulfill this need in our region. Our project continues to build on our last three years of research with organic production systems for day neutral strawberries to extend the season using plasticulture with and without low tunnels. Comparative field trials were established in 2015 on organic-certified land at the University of Minnesota West Central Research and Outreach Center (WCROC), Morris and the University of Minnesota St. Paul Campus. We examined nutrient requirements and pest management strategies for this system at these two sites. Low tunnel systems were also installed and planted at three grower cooperator sites in 2015. Our grower cooperators were: Mary Jo and Laverne Forbord, Owner/Operator Prairie Horizon Farm, Starbuck, MN, David Macgregor/Marsha Anklam, Owners/Operators Fairhaven Farm, South Haven, MN and Ron Branch, Owner/Operator Berry ridge Farm, Alexandrai, MN. They assisted with planting, cultural practices, harvest and have expressed keen interest in working with us to develop and refine the systems in this project, and to assist in educating other growers.

In year one of this two-year project we established day-neutral strawberry cultivar Albion on raised beds with plastic mulch in a low tunnel system compared to a non-low tunnel system. All treatments were managed under organic certification standards.

Objectives

1. To continue development of our innovative strawberry production systems, we are developing recommendations for
    - nitrogen and other nutrient requirements.
    - irrigation practices.
    - pest management strategies.
2. To increase supply of locally produced organic strawberries and encourage environmental stewardship, we are educating our stakeholders through:
    - frequent online research updates.
    - face-to-face educational events.

In order to determine optimal nitrogen rates for our annual, day-neutral strawberry production project, we tested five different nitrogen rates:

- 0 lb N/acre/week (0x)
- 2.5 lb N/acre/week (0.5x)

- 5 lb N/acre/week (1x)
- 7.5 lb N/acre/week (1.5x)
- 5 lb N/acre/week only until first harvest, then 0 lb N/acre/week for the rest of the season (1-0x).

This last treatment tested literature that implies nitrogen application *during harvest season* can actually reduce cumulative yields. We are hoping these treatments can help us answer these questions:

1. Which nitrogen rate is optimal for annual, day-neutral strawberry production in the Upper Midwest?
2. Are there noticeable effects of too much or too little nitrogen in the system?
3. Is there a point where additional nitrogen incorporation will not lead to higher yields?

A continuing objective from previous research was to determine if the use of a low tunnel system with day- neutral strawberries could provide adequate yields. Traditional June bearing strawberry varieties in Minnesota have a baseline yield of 5,500 pounds/A. As shown below in the summaries from both Morris and St. Paul trials, yield of Albion in the low tunnel and non-low tunnel surpassed this baseline.

Table 1. Summary of yield and berry weight of Albion at Morris, 2015. Letters indicate statistical differences by column groupings, i.e. values that share letters within groupings are NOT statistically different. If a grouping has no letters, there are no statistical differences between any of the values in that group. As mentioned above, the x in fertility rate is a multiplier that equals 5 lbs N/acre/week. 1-0x received 1x until first harvest, then 0x for the rest of the season.

Treatment	Fertility Rate	Avg. Yield/Plant (lb)	Average Yield/Acre (lb)	Avg. Berry Weight (g)
Low Tunnel	0x	1 ab	18450 ab	11.4 ab
	0.5x	0.75 c	13710 c	9.2 c
	1x	0.82 bc	14991 bc	9.8 bc
	1.5x	1.12 a	20446 a	11.9 a
	1-0x	0.94 abc	17228 abc	10.5 abc
No Low Tunnel	0x	0.95	17278	10.1
	0.5x	0.86	15687	10.1
	1x	1	18414	10.3
	1.5x	0.92	16828	9.7
	1-0x	0.9	16467	9.4

Table 2. Summary of yield and berry weight of Albion at St. Paul, 2015. Letters indicate statistical differences by column groupings, i.e. values that share letters within groupings are NOT statistically different. If a grouping has no letters, there are no statistical differences between any of the values in that group. As mentioned above, the x in fertility rate is a multiplier that equals 5 lbs N/acre/week. 1-0x received 1x until first harvest, then 0x for the rest of the season.

Treatment	Fertility Rate	Avg. Yield/Plant (lb)	Average Yield/Acre (lb)	Avg. Berry Weight (g)
Low Tunnel	0x	0.78	13263	10.1
	0.5x	0.76	13933	10.9
	1x	0.71	12991	8.8
	1.5x	0.79	14393	10.7
	1-0x	0.91	15493	9.6
No Low Tunnel	0x	0.55 b	9933 b	10.3
	0.5x	0.79 ab	14330 ab	10.4
	1x	0.61 ab	11081 ab	9.7
	1.5x	0.61 ab	11164 ab	9.6
	1-0x	0.85 a	15493 a	9.8

Similar to our previous findings, day neutral production resulted in higher yields than the 5,500 lb/acre/year average observed with June bearing production, regardless of fertility practice or low tunnel use. Since the day neutrals in this production system are treated as annuals, growers can enjoy the added economic benefit of yield in the first year, rather than the typical no yield 'establishment year' common to June bearing systems. Similarly, labor and other management costs are saved by eliminating the need to overwinter the plants. Day neutrals managed this way can be incorporated into annual crop rotations, reducing the potential buildup of soil pathogens.

Interestingly, fertility rate did not always significantly affect total yields, and when it did the differences were not consistent between sites or tunnel practices. At the St. Paul site, 1-0x resulted in the highest yields in both tunnel treatments and had the same approximate average yield per acre (15,493 lbs/acre). However this figure was only significantly higher than one other treatment/practice combination, 0x without tunnel protection.

There was no significant difference in average berry weight at the St. Paul site, regardless of fertility rate or tunnel presence. This implies that if Albion is grown in environmental conditions similar to what was experienced at the St. Paul site in 2015, concentration of fertilizer may not have an effect on yields. In addition if the plants are managed under low tunnels, they may need no fertility management.

At Morris there were no significant differences in cumulative yield or average berry weight of fruit managed without low tunnels. When fruit was managed under low tunnels, 1.5x resulted in the heaviest fruit and the highest cumulative yields, while 0.5x resulted in the lowest cumulative yields and average berry weight.

Taken together it seems that the effect of fertility practice on yields is dependent on site and possibly tunnel presence. At St. Paul total average yields were 14,014 lbs/acre under low tunnels and 12,400 lbs/acre without low tunnels. At Morris these averages were 16,965 lbs/acre under low tunnels and 16,934 lbs/acre without low tunnels. Thus our first year of data implies that in environments without rich prairie soils (St. Paul site) low tunnels appear to offer some yield advantage. If low tunnels aren’t used in these environments some form of fertility should be applied, though the rate does not appear

to be important if the crops are managed annually. In rich prairie soils (Morris site) tunnel presence does not seem to have an effect on cumulative yields unless low tunnels are combined with a high fertility rate. In this case the highest average yields may be obtained.

Hourly temperature and relative humidity were recorded at the Morris site in 2015 using WatchDog A-Series data loggers in the low tunnel and non-low tunnel beds. The data loggers were suspended 12 inches above both beds. Observations from data loggers showed average temperatures in the low tunnel were normally higher than non-low tunnel temperatures. Previously recorded 2013 and 2014 temperatures in the low tunnel averaged 3.1 F and 1.0 F above the non-low tunnel bed, respectively. 2015 data shows average temperatures to be very similar in both low tunnel and non-low tunnel treatments, with only a 0.9 F average increase under tunnels. The benefit of higher average temperatures is that it increases plant respiration, which typically results in more photosynthesis and potentially higher yields. Also, while average humidity is higher underneath the tunnels, the tunnel provides a physical barrier that keeps standing water from accumulating on the leaves during rainfall events. This in turn reduces fungal pressure, as fungal spores often need standing water in order to germinate.

Table 3. Temperature and relative humidity at WCROC, Morris

	Low tunnel	Non-low tunnel
Average temperature	67.3 F	66.2 F
Average relative humidity	81.7%	56.1%
Average due point	60.3	54.0

Insect pest and disease pressures posed significant challenges in 2015, at both the Morris and St. Paul sites. One of the first insects we encountered was the spider mite. While unsightly, spider mites don't cause much damage to the fruit themselves and can be controlled easily, even with organic measures. Another insect at both sites proved to be a much bigger problem – *Lygus lineolaris*, commonly known as the tarnished plant bug (TPB). TPB damage occurs when the insects use their sucking mouth parts to "drink" the sugars out of developing fruit. This results in distorted, cat-faced berries at maturity. TPB pressure was noticeably higher in 2015 than our 2013 or 2014 projects. Starting in late July we noticed minimal-to-severe TPB damage on our fruit leading a reduction in total and marketable yields. TPB was present in both the low tunnel and non-low tunnel treatments, however the damage was markedly more severe in the non-low tunnel plants at the beginning of the season. At both sites a variety of organic insecticide sprays were applied on a weekly basis to both low tunnel and non-low tunnel day-neutral strawberry plants.

The St. Paul site experienced minimal pressure from the fungus *Phytophthora cactorum*, commonly known as leather rot. This was likely due to increased precipitation along with a silty clay soil. Once the soil dried, the disease pressure diminished. The St. Paul site also experienced the arrival of the spotted wing drosophila (SWD). SWD damage is obvious – sunken, soft flesh. While yield loss was minimal, the presence of SWD required constant monitoring.

At the Morris site, Spotted Wing Drosophila was not detected in trap cups or in ripe fruit. The trap cups are clear plastic quart-size cups, with lids. Small 3/16" holes are drilled all the way around the cup. A wire handle inserted into the sides of the cup allows hanging the cup. A mixture of water, sugar, dry

yeast, apple cider vinegar and whole wheat flour is used as bait in the cups, and yellow sticky traps are placed inside the lid using twist ties. The yellow sticky traps were removed each week and observed for SWD using a 10x magnifying glass. More detailed information about these trap cups can be found on our website http://fruit.cfans.umn.edu/spotted-wing-drosophila/.

At the Morris site we experienced leaf spot disease on the plants. Leaf spot disease was more prevalent on the non low-tunnel plant leaves versus the low tunnel. We also saw rhizoctonia, or black root rot. We first noticed some strawberry plants wilting, then the underside of the leaves turned purplish and curled up. Eventually, the crown of the plants died. In order to properly diagnose, we collected plant and soil samples and sent into the U of MN Plant Disease Clinic. The results showed the disease rhizoctonia in both the plant roots and crown tissue. This disease significantly stunted fruit production in certain areas of our strawberry planting. Further investigation into the cause of rhizoctonia continues and will be evaluated through the UM Plant Disease Clinic report.

One of the major challenges confronting us in the past was wind damage to the tunnels. Our original low tunnel system was very labor intensive to construct, and highly prone to wind damage. In 2015 we purchased a retractable tunnel system, called the Tunnel Flex Retractable Low Tunnel System, from Dubois Agrinovation (www.duboisag.com) of Quebec, Canada. This system offered a simpler, labor-efficient solution to our original system. This new system withstood any major damage from higher than normal winds, however we did observe a difference when the temperatures dropped near freezing. With our old system, the 4 mm thick plastic sheeting provided enough heat retention that our harvest season was extended by three weeks in 2014. In 2015, however, the 1 mm plastic sheeting provided with the Tunnel Flex system provided little if any heat retention. The low tunnel plants froze the first night of freezing temperatures.

Previously, at one of our grower sites we observed iron chlorosis in the day neutral cultivars due to high soil pH. Iron chlorosis is a yellowing of foliage when high soil pH prevents plants from the uptake of iron present in the soil. Yellow foliage indicates a lack of chlorophyll, the green pigment responsible for photosynthesis (sugar production) in plants. Any reduction in chlorophyll during the growing season can reduce plant growth and vigor. Chlorotic plants often produce smaller fruits of poor quality with bitter flavor. In order to avoid this issue again we took soil tests from three different planting locations at this grower site. The planting sites that had previous iron chlorosis on strawberries measured 7.5 soil pH. The site we selected for planting in 2015 had a soil pH of 7.3. This 7.3 pH site had no symptoms of iron chlorosis on the strawberry plants in 2015. Consequently, we suggest a grower should select sites that have a pH level of 7.3 or lower to successfully grow these newer day- neutral strawberry cultivars.

The innovative strawberry production system that we are developing couples day neutral strawberry cultivars with organic-certified plasticulture, with and without low tunnels. By continuing our research and education, we can provide specialty crop growers with the knowledge they require to confidently establish extended season day neutral strawberry plantings on their farms. Consequently, the number of growers producing strawberries outside the traditional harvest season will hopefully increase, translating to a greater supply of locally grown organic strawberries.