

**Title:** Nutrient Use Efficiency Assessments of Recently Released Strawberry Cultivars in Both Field and High-tunnel Production

## **Report, Research**

**Grant Code:** SRSFC Project #2018 R-03

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### **Objective**

1. Assess recently released strawberry cultivars for use in Southeastern field and high-tunnel production systems based on fruit yield, fruit flavor parameters, plant growth and susceptibility to pests.
2. Evaluate the effect of nitrogen and potassium fertigation rate on nutrient use efficiency (yield/ unit N or K) of newly released strawberry cultivars to gain preliminary data on optimal fertigation rates to maximize yield and fruit quality in both field and high-tunnel production systems.
3. Make preliminary assessments of if nutrient use efficiency varies between field and high-tunnel strawberry production systems.
4. Assess silicon fertilizer's effect on fruit yield, fruit flavor parameters, plant growth and disease and pest populations.

### **Justification and Description**

Standard recommended rates for fertilizing field grown strawberry to optimize fruit yields in the Southeastern US is 134.5 kg ha<sup>-1</sup> (120 lbs acre<sup>-1</sup>) of N during the cropping season, and P and K applied according to soil test results (Miner et al. 1997). These recommendations are based on work conducted nearly twenty years ago on Chandler variety plants. Subsequently, throughout the growing season plant tissue nutrient testing is used to ensure petiole nitrate-N is

maintained within recommended ranges (Campbell and Miner, 2000) which were also developed from studies conducted in the late 90s on Chandler variety plants.

These standard fertilization rates and practices continue to be recommended even as Southeastern strawberry growers increasingly seek out new varieties to diversify their field production systems or switch to high-tunnel production systems. Research based data on the nutrient needs of new varieties and nutrient needs of plants in high-tunnels relative to field produced plants is lacking. Better understanding of appropriate nitrogen and potassium rates is critical as over application can lead to soft fruit (Miner et al. 1997), malformed fruits (Albregts and Howard, 1982) or excessive foliage that favors disease development (Voth et al, 1967). Additionally high rates of K can reduce strawberry fruit size and yield (Albregts et al., 1991).

Previous work has shown that strawberry varieties do vary in their nutrient use efficiency (yield per unit of nitrogen input) and optimal rates of fertilization for the varieties ‘Camarosa’, ‘Ventana’, ‘Camino Real’, and ‘Candonga’ was determined to be 183, 196, 165, and 150 kg/ha respectively (Agüero and Kirschbaum 2013). A study in Florida found that an increasing rate of N was linearly related to yield in ‘Sweet Charlie’ but no relationship existed for ‘Oso Grande’ (Hochmuth et al, 1996). Currently no research based recommendations for fertilization rates on recently released varieties have been developed.

World-wide strawberry is the fruit crop most widely grown in high-tunnels (Wittwer and Castilla, 1995) but uncertainty remains regarding differences in fertility needs between field and high-tunnel systems. High-tunnel production systems may need lower nitrogen rates due to less loss from leaching rains, or higher rates of productivity and longer production seasons (Demchak, 2009) may necessitate higher rates of nitrogen. Previous work has shown that for the variety Festival lower than recommended rates of N fertility may benefit yield in high-tunnels where no statistically significant differences in yield were found between fertility treatments (Garcia et al. 2013).

Emerging research on the use of silicon fertilizers in strawberry also warrants further evaluation in SE production systems. Previously strawberry was thought to be a non-accumulator of Si but that the element could have important impacts on plant flowering (Miyake and Takahashi, 1986). Recently it was proven that strawberry does take up Si and may benefit from additional applications of Si to reduce the incidence of powdery mildew (Belanger, 2016). This is a newly emerging area of research that combines plant tissue nutrient management with integrated pest management which are the combined interdisciplinary focus areas of the PIs.

This preliminary research seeks to evaluate newly released strawberry varieties for Southeastern high-tunnel and field production, evaluate the addition of silicon fertilizers to standard production systems and to determine if standard rates of nitrogen fertilization should continue to be recommended for new strawberry varieties and in high-tunnel production systems.

## **Methodologies**

This trial was conducted at the Southwest Research and Extension Center in Hope, Arkansas and was carried out over the winter and spring of 2017. Strawberry plugs of five

short-day strawberry varieties released in the last 5 years (Flavorfest (2012), Fronteras (2014), Scarlet (2016), Lucia (2016) and Ruby June (2016)) and one "standard" variety (Camino Real, (2002)) were trans-planted in October of 2016 into high-tunnel and field plots. Plants will be grown under low (40% less than standard recommended), standard recommended (120lbs N per Acre over the season), recommended + micro-nutrients ((120lbs N per Acre, plus bi-weekly injections of Potassium Silicate), and high (40% more than standard) rates of nitrogen fertigation in both high-tunnel and field production systems to assess how nutrient use efficiency varies across new varieties and between production systems. Total season long nutrient budgets will be split evenly into weekly applications applied throughout the growing season (approximately 6 weeks in fall and 8 weeks in spring). This experiment is a completely randomized split-split plot design with the main split being the production system, the second split being sub-plots for each fertility treatment into which each variety is randomized into sub-sub-plots. Due to the preliminary nature of this study varieties (n=6; 12 plants per sub-sub-plot) were not replicated in each fertility treatment (n=4). This will limit our ability to statistically compare varietal response between fertility treatments to paired t-tests.

Nutrients for each fertility treatment will be applied via drip irrigation to feed the full amount of each fertility treatment cumulatively over the season directly to the roots of the plants. This will reduce nutrient loss compared to pre-plant broadcast applications of fertilizers. Potassium nitrate will be the source of nitrogen for all treatments in the fall and early spring, then the source will be switched to calcium nitrate at early fruiting. These are the standard fertility sources used in fertigation of strawberries and we hope to narrow in on the *optimized rates* of these fertilizers, and are not interested at this time in evaluating possible confounding or interactive effects of high rates of K, Ca and N. Future studies will be needed to determine more specific fertilizer recommendations.

The high tunnel production system was closed until late January to induce an early crop of berries in March. Due to this schedule drip irrigation and fertigation will continue for several weeks longer in the fall and early spring in the high-tunnel than the field and thus will get higher cumulative rates of fertilizer over the season.

Plant tissue nutrient analysis was also be used to see if plants are taking up the higher rates of fertilizer, and then compare differences in petiole nutrients to yield results to see if current recommended ranges of plant tissue nutrient standards correlate well with observed differences in yield for new varieties.

Non-destructive plant biomass, fruit number, fruit weight, fruit quality (brix, pH) and two-spotted spider mite populations were assessed across all treatments. In the spring, yield was measured on a bi-weekly basis and fruit flavor parameters (Brix) were measured at five points throughout the season. Plant tissue nutrient sampling will be conducted at five points early in the growing season and performed by University of Arkansas Agricultural Diagnostic Laboratory (Alzheimer Lab) Fayetteville AR. Current recommended ranges of sufficient plant tissue nutrient levels (Campbell and Miner, 2000), will be compared to plant tissue nutrient ranges of plants from the different fertilizer rate treatments and in-conjunction with yield data. Biomass will be assessed at dormancy to assess the number of crowns developed.

Pest populations will be assessed throughout the season including, monitoring disease incidence, percent number of cull fruits due to botrytis or anthracnose fruit rots, and populations of two-spotted spider mites. Emphasis on the interdisciplinary nature of our team will be important to assessing the viability of new cultivars for SE strawberry production in terms of their disease and insect resistance. Increases in plant tissue N and increases in two spotted spider mite populations (Rodriguez et al., 1970) have been observed previously. Thus it will be important to consider that when yield differences are negligible lower rates of N fertility may be preferable not only for reduced cost but also for reasons of lower pest pressure. Efficient nutrient management should be an important aspect of any integrated pest management plan.

The Horticulture staff at the Southwest Research and Extension Center in Hope, Arkansas, and the PI's program technicians were in charge of much of the duties related to daily care, fertilizer application and will assist the PIs in data collection.

## Results

### Objective 1

1. Evaluate the effect of nitrogen rate on nutrient use efficiency (yield/ unit N) of newly released strawberry cultivars to optimize fertigation rates to maximize yield and fruit quality in both field and high-tunnel production systems.

Marketable yields for the field and tunnels are reported separately due to a significant variety by production system interaction in both years (2017  $p= 0.0056$  and in 2018  $p= 0.0008$ )

	Average Marketable Yield per Plant By Variety and System							
	Field				Tunnel			
	2017		2018		2017		2018	
	g		g	g		g		
Fronteras	256.5	A	404.9	B	222.0	A	434.47	A
Chandler	.		617.9	A	.		.	
Camino	170.6	B	.		171.6	ABC	.	
Lucia	101.8	C	284.3	C	203.3	AB	247.7	B
Scarlet	109.2	C	.		162.5	BC	.	
Ruby June	120.5	BC	.		142.3	C	.	
Flavorfest	63.1	C	.		21.8	D	.	

*\*Letters indicate a significant difference at  $p<0.05$  within the same column*

### Nitrogen Rate Effect on Yield

No yield responses to varying N fertilization rates were observed in year one (2017) of this study. Variety interactions with N fertilizer rates seemed probable but due to the preliminary nature of our study this will be further investigated in the present year's study with full replication of treatment combinations.

In 2018 a significant effect for fertilizer rate on marketable yield was observed ( $p=0.0358$ ), however the interaction effect of fertilizer rate x variety within system was also significant. This effect will be discussed under Objective 2 results. In 2018, injector issues lead to questions about the accuracy of application of fertilizer rates to the fertilizer treatments within the tunnel. For this reason correlation and regression analysis of petiole  $\text{NO}_3$  rates with yield are used to assess if higher or lower nitrogen uptake by the plants resulted in a subsequent response in marketable yield. Using untransformed data no correlation or linear association was found between marketable yield and petiole  $\text{NO}_3\text{-N}$  or leaf tissue N was found. This mimics similar results from 2017 where no strong effect of fertilizer rate on yield were observed.

**Effect of Fertilizer Treatment on Average Marketable Yield Per Plant**

	2017		2018
	g		g
High	146.7	High	435.8
Low	134.2	Low	413.6
Standard	160.6	Standard	345.9
Stndplu	159.8	VeryLow	389.5
<i>p</i>	<i>0.3881</i>	<i>p</i>	<i>0.0358</i>

### Varietal Differences in Petiole $\text{NO}_3$ Content

*Varieties were also found to naturally vary in their petiole  $\text{NO}_3\text{-N}$  content, with 'Ruby June' being higher than 'Flavorfest', Lucia', 'Camino Real' and 'Fronteras'. For their  $\text{NO}_3\text{-N}$  content 'Scarlet' and 'Flavorfest' were also higher than 'Lucia', 'Camino Real' and 'Fronteras'. There appears to be a somewhat inverse relationship between average  $\text{NO}_3\text{-N}$  content and yield capacity. However, this is not completely consistent as 'Ruby June' and 'Scarlet' both yielded higher than 'Flavorfest' and had higher  $\text{NO}_3\text{-N}$  contents. In year 2 'Lucia' was significantly different from 'Chandler' with a higher average petiole  $\text{NO}_3\text{-N}$ .*

<u>2017 Average Petiole NO<sub>3</sub>-N Content</u>			<u>2018 Average Petiole NO<sub>3</sub>-N Content</u>		
Variety	Estimate		Variety	Estimate	
Ruby June	4,636.56	A	Lucia	3,382.88	A
Scarlet	4,351.72	AB	Fronteras	3,005.87	AB
Flavorfest	3,950.78	B	Chandler	2,901.55	B
Lucia	3,366.25	C			
Camino Real	3,188.91	C			
Fronteras	3,089.53	C			

#### Effect of Nitrogen Rate on Petiole NO<sub>3</sub>

In both years there were significant effects at  $p < 0.05$  of fertilizer rate on petiole NO<sub>3</sub>-N rates, but a significant interaction effect of fertilizer by location (growing system) on petiole NO<sub>3</sub>-N was also present so the interaction effect is presented. Concerns over accuracy of the injection system in the tunnel in 2018 were present, and are partially confirmed by the lack of a difference between any fertilizer treatment for petiole NO<sub>3</sub>-N in the tunnel. However, no effect in the field in 2017 was also observed and an effect inconsistent with fertilizer rate was observed in the tunnel during that year possibly due to fertilizer flushing with increased water application under the high rate.

In 2018 a fertilizer rate x variety within system effect was significant for petiole NO<sub>3</sub>-N. This is not surprising given that we know varieties vary in their baseline petiole NO<sub>3</sub>-N concentrations. However each variety followed nearly exactly the system x fertilizer rate effect presented below. One distinct trend across years was observed with regards to how fertilizer rates impact petiole NO<sub>3</sub>-N concentrations between systems: where on average the tunnel had lower petiole NO<sub>3</sub>-N compared to the field. The exact cause behind this result is unknown, but could in theory be related to various differences in growing conditions in the tunnel including: warmer temperatures, a difference in plant growth or a lack of true plant dormancy. *This result should be taken into account when standard petiole NO<sub>3</sub>-N ranges are applied to tunnel grown berries.*

<b>Petiole NO3-N 2017</b>				<b>Petiole NO3-N 2018</b>			
System	Fertilizer tmt.	Estimate		System	Fertilizer tmt.	Estimate	
Field	Standard	4643.8	A	Field	Standard	4085.9	A
Field	High	4623.8	A	Field	High	3846.1	AB
Field	Low	4541.0	A	Field	Low	3416.2	BC
Field	Stndplu	4465.0	A	Tunnel	VeryLow	2996.3	DC
Tunnel	Stndplu	3402.1	B	Tunnel	Standard	2969.8	DC
Tunnel	Standard	3397.9	B	Tunnel	Low	2647.7	DE
Tunnel	High	2614.8	C	Tunnel	High	2577.2	DE
Tunnel	Low	2423.3	C	Field	VeryLow	2234.9	E

## Objective 2

2. Assess if nutrient use efficiency varies between field and high-tunnel strawberry production systems.

### Effect of Nitrogen Rate on Yield in Tunnel vs. Field Production Systems

In 2017 no interaction effect of fertilizer rate and production system on marketable yield was observed. In 2018 the three way interaction of fertilizer rate by variety in production system on marketable yield was significant at  $p < 0.05$ . These complex three-way interactions are still being investigated but appear to be due to base differences in plant performance between the field and high-tunnel. After the tunnel is dropped and the field from 2018 is analyzed alone a trend toward higher yields with the “High Rate” even as compared to the “Standard” rate where evident for ‘Chandler’ and ‘Fronteras’ but not for ‘Lucia’. However this only takes into account marketable yields, as cull yields and berry size have not yet been analyzed. Additional analysis of the economic returns related to the additional costs of fertilizer units per increase in yield are needed.

An additional complicating factor seems to be that in 2018 while yields in the field were higher with the “High” fertilizer rate, petiole NO<sub>3</sub>-N concentrations did not follow the same trend and often were no different from either the standard or low fertilizer rates.

## Objective 3

3. Measure silicon fertilizer’s effect on fruit yield, fruit flavor parameters, plant growth and disease and pest populations.

### Silicon fertilizer’s effect on Yield

In 2017 no statistical differences were found between the standard fertilizer rate and the standard fertilizer rate+ silicon for yield, berry size or fruit Brix. However in paired t-tests the standard + silicon rate had a higher average cull weight ( $p < 0.05$ ) as compared to the low fertilizer rate. The low rate was not different from the standard or high fertilizer rates. The addition of silicon did not appear to have any effect on the observance of two spotted spider mite populations or the incidence of disease. For this reason the silicon treatment was not continued in year 2.

## Conclusions

Direct linear relationships between increasing fertilizer rate and increasing yield were not observed in this study. Instead complex interactions between variety and growing system were observed. In many cases changing the standard fertilizer rate by half or doubling it resulted in statistically non-significant changes in yield and/or in changes to petiole  $\text{NO}_3\text{-N}$  that were not indicative of the change in nitrogen fertilizer rate. Further the average petiole  $\text{NO}_3\text{-N}$  rate for 'Fronteras' and 'Lucia' was relatively consistent between years on average, despite that yields varied by more than 100g per plant between the two seasons. In general however the standard  $134.5 \text{ kg ha}^{-1}$  ( $120 \text{ lbs. acre}^{-1}$ ) of nitrogen (N) during the cropping season or a slightly higher rate resulted in good crop production for most varieties. However, further work should be conducted in larger trials to pin-point the exact breakeven point for each increase in N unit per increase in yield. Our preliminary trial found that varieties naturally vary in their petiole  $\text{NO}_3\text{-N}$  content, and that tunnel produced berries tended to have lower petiole  $\text{NO}_3\text{-N}$  concentrations even when sampled at the same phenological stages as field grown plants. This may make the use of current established ranges for spring plant tissue nitrogen and nutrient testing may be unreliable for use with 'Fronteras' and 'Lucia' varieties which have higher concentrations than 'Chandler'. Further the use of the petiole sampling standards for many varieties grown in tunnels may result in over fertilization.

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