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

Report, Research

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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^{-1} (120 lbs $acre^{-1}$) 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., l991).

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 is 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 be 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-spilt 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 (Altheimer 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.

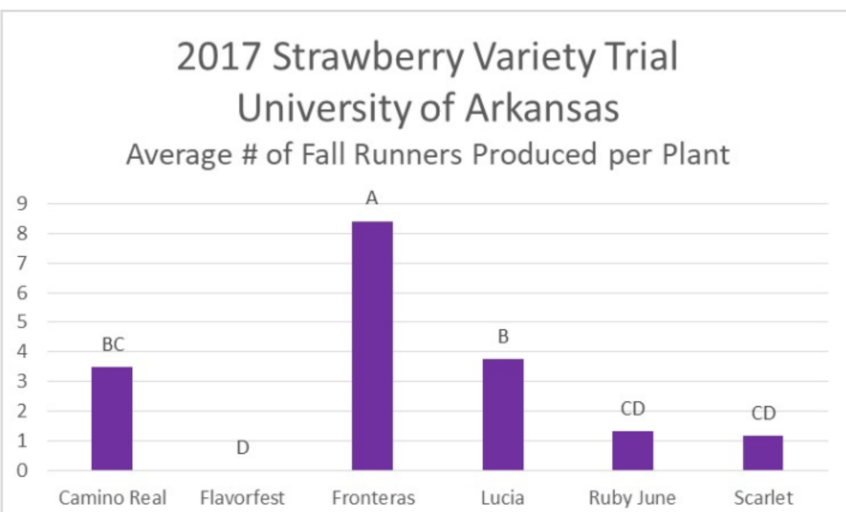
The Horticulture staff at the Southwest Research and Extension Center in Hope, Arkansas, and the PI's program technicians were in charge of much of the duties related to daily care, fertilizer application and will assist the PIs in data collection.

Results

Objective 1. 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.

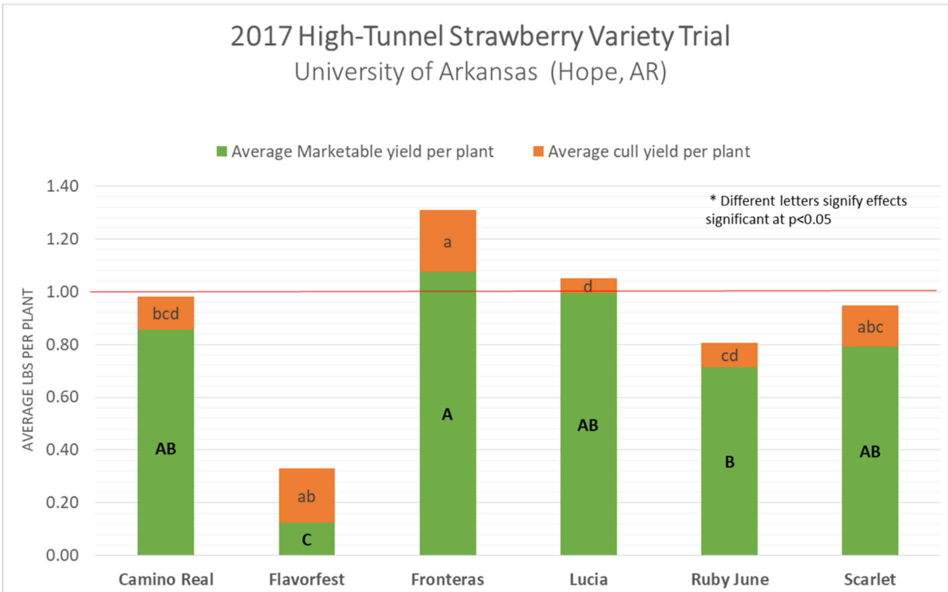
The number of runners produced in the fall was assessed for the different varieties on October 31st, 2016 (approximately 27 days after planting). 'Fronteras' had a significantly higher number of runners than all other varieties (Figure 1). Plant biomass as assessed by plant canopy diameter on February 22nd, 2017 was greatest in the high-tunnel and 'Fronteras', 'Ruby June' and 'Scarlet' had larger canopies than 'Flavorfest'.

Figure 1. Number of runners per plant for six different strawberry varieties as assessed on October 31st, 2016 at Hope, Arkansas.

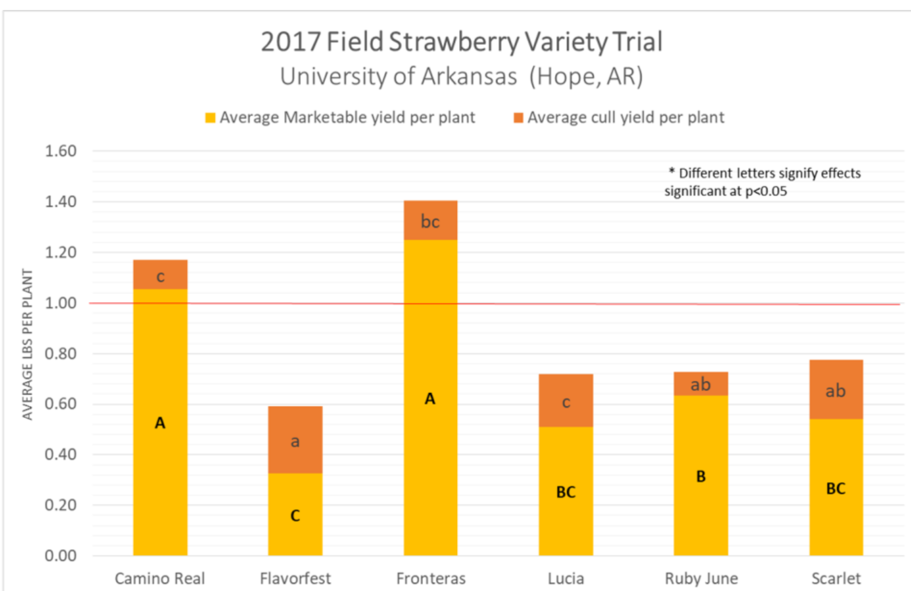


In both production systems 'Fronteras' was the highest yielding variety numerically (Figure 2 a,b), but was only statistically higher yielding than 'Flavorfest' and 'Ruby June' in both systems. In the field 'Fronteras' was also higher yielding than 'Lucia' and 'Scarlet' (Fig 2b), but was never higher yielding than ‘Camino Real’ the variety used as the “growers standard” for comparison in this study. ‘Lucia’ also yielded well in the high-tunnel system and was no different from ‘Camino Real’ but did reach beyond an average yield of 1lb per plant.

Figure 2. Average Yields of 6 varieties in High-Tunnel (a) and Field (b) production systems in the spring of 2017 at Hope, Arkansas.



a)



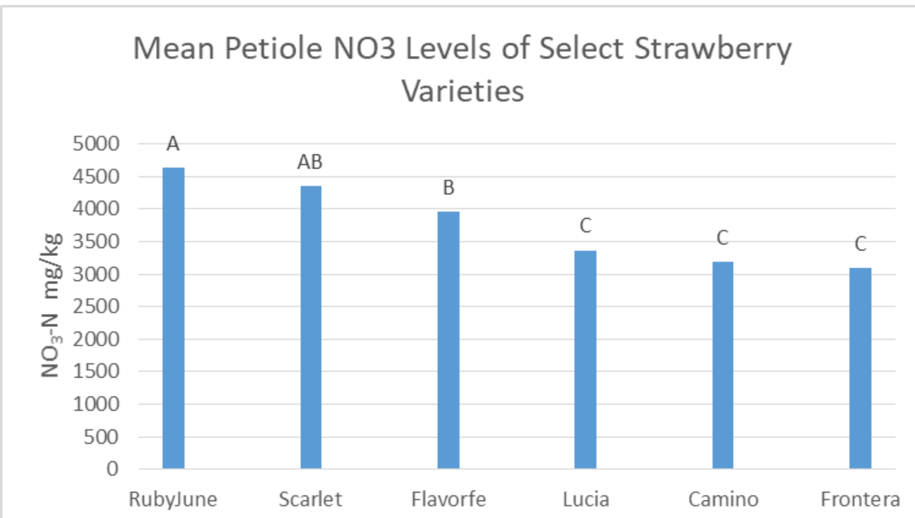
b)

Fruit berry size mimicked the observed differences among variety in fruit yields, with ‘Fronteras’ having the biggest berry weights and ‘Flavorfest’ being significantly lower ($p<0.05$). Fruit brix measurements were also influenced by variety, with ‘Ruby June’ averaging the highest brix (6.69) and being significantly higher than ‘Camino Real’, ‘Scarlet’ and

‘Flavorfest’. Additionally, ‘Fronteras’ was not significantly different from ‘Ruby June’ and averaged a brix of 5.88. Flavor in general was poor throughout the season, likely due to high rainfall. During a blind sensory taste test conducted in April 2017 ‘Fronteras’ and ‘Ruby June’ averaged the highest numerical rankings for measurements of “Overall impression” and “Overall strawberry flavor”, however this data has not been analyzed statistically due to low number of participants (n=30) and therefore is not presented here.

Varieties were also found to naturally vary in their petiole NO3-N content, with ‘Ruby June’ being higher than ‘Flavorfest’, Lucia’, ‘Camino Real’ and ‘Fronteras’. For their NO3-N content ‘Scarlet’ and ‘Flavorfest’ were also higher than ‘Lucia’, ‘Camino Real’ and ‘Fronteras’. There appears to be a somewhat inverse relationship between average NO3-N content and yield capacity. However, this is not completely consistent as ‘Ruby June’ and ‘Scarlet’ both yielded higher than ‘Flavorfest’ and had higher NO3-N contents.

Figure 3. Mean petiole NO3-N content of the six evaluated strawberry varieties, at Hope, AR 2017. (Different letters indicate differences at $p<0.05$).



Objective 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.

Yield, and Cull Weights

Fertilizer treatment had no impact on yield (p= 0.3881). Due to our lack of replication of variety x fertilizer treatment we were not adequately able to investigate variety x fertilizer impacts on yield. Numerical differences in mean yields for ‘Fronteras’ and ‘Camino Real’ at different rates of fertilizer indicate that some differences between the standard fertilization rate and the low N fertilization rate may exist, and a fertilizer x variety interaction may be present. In both cases the standard rate had higher yields than the low rates, and the high rate was in-between the two. We plan to further investigate these differences in year 2 of the study.

Lower rates of culls were observed in the low N fertilizer (mean 35.2 g) rate as compared to the standard (mean 36.9g) and standard+silicon (mean 46.6 g) N fertilizer rates ($p<0.05$). No differences were observed between the high N fertility rate as compared to the standard and low rates for cull berry weights.

Petiole N content

Petiole NO3-N content was influenced by fertilizer treatment (Fig.4), but there was also a fertilizer x location interaction where in the field the standard N fertilizer rates had higher petiole NO3-N contents than the low and high N fertilizer rates. N Fertilizer rate did not impact petiole NO3-N in the high-tunnel. One hypothesis for why the high rate of N fertilizer did not result in increased petiole NO3-N content in the field is flushing of the N fertilizer beyond the root zone due to higher amounts of water being required to dissolve the higher amounts of fertilizer. In the second year of our study we will standardize and record how long irrigation cycles are run to ensure fertilizer is not being flushed beyond the rooting zone in the high N fertilizer rate.

There was no fertilizer x variety interaction observed for petiole N content, this result may be due to our limited ability to compare fertilizer effects within one variety.

Figure 4. LS Means for Fertilization Rates on Petiole NO3-N Content

T Grouping for fert Least Squares Means (Alpha=0.05) LS-means with the same letter are not significantly different.			
fert	**Estimat**		
Standard	4020.83		A
			A
Stndplu	3933.54		A
			A
High	3619.27	B	A
		B	
Low	3482.19	B	

Fruit Brix

Fruit brix was not effected by fertilizer treatment at $p<0.05$.

Spider Mite populations

Higher populations of two spotted spider mites were observed in the low N fertilization treatment as compared to the standard at $p=0.05$. The high N fertilization rate was no different than either the standard or low N fertilization treatments.

Objective 3. Make preliminary assessments of if nutrient use efficiency varies between field and high-tunnel strawberry production systems.

Petiole Nitrate-Nitrogen (NO3-N) contents were higher on average ($p<0.05$) in the tunnel as compared to the field. This in part may be due to higher cumulative rates of fertilizer applied in the tunnel. However, total marketable yields were not different between the tunnel (mean=98,445.0 g) as compared to the field (mean= 88,253.0 g). These differences may be *economically* significant however as this represents a difference of 22 lbs. per area or 0.08 lbs. per plant.

Objective 4. Assess silicon fertilizer's effect on fruit yield, fruit flavor parameters, plant growth and disease and pest populations.

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 spidermite populations or the incidence of disease.

Conclusions

Overall 'Fronteras' ranked high in measures of yield in both the field and high-tunnel system. It also had a high average brix and ranked well in the consumer taste panels. We will continue to evaluate this variety for its potential use in both field and high-tunnel systems, but recognize it may require extra work to manage due to high fall runner production.

Between the high-tunnel and field production systems Petiole NO3-N contents were higher in the tunnel likely due to higher cumulative rates of applied N, but we also observed higher yields in the tunnel as compared to the field. However, differences in N fertilizer rates did not result in differences in yield or in differences in petiole NO3-N within the tunnel. Differences in sampling dates between the field and high-tunnel for petiole NO3-N occurred due to differences in plant maturity and may explain in-part these results. However, the lack of a relationship between NO3-N and applied N in the tunnel may indicate a limited use of plant tissue nutrient sampling as a tool in these systems if this result is replicated in subsequent years.

Silicon fertilizer was not readily observed to have an impact on increased strawberry yields, or decreased pest pressures and in fact had a higher cull rate than the low N fertilizer treatment. Spider mite populations tended to increase with decreasing petiole NO3-N contents. Coordination between petiole NO3-N sampling and mite sampling will be conducted in year 2 to further investigate this observation.

No yield variations in responses to varying N fertilization rates were observed in year one of this study. Variety interactions with N fertilizer rates seem probable but will be further investigated in year 2 with full replication of treatment combinations. Additionally, because petiole NO3-N rates did not increase with higher rates of Nitrogen fertilizer we plan to control possible N fertilizer loss from the rooting zone in year two. However, the lack of statistical differences in yield between the standard rate of N fertilizer and the low rate despite that there were differences in petiole NO3-N contents, indicates a non-linear increase of yield with increasing petiole NO3-N. At what point optimum yield returns per unit N occurs is yet to be determined by this study.

Most significantly, varieties were found to vary in their natural levels of petiole NO3-N, which may complicate the use of current petiole NO3-N standards developed for other varieties.

Impact Statement

Varieties naturally vary in their petiole NO3-N content and current established ranges for spring plant tissue nitrogen and nutrient testing may be un-reliable for use with newly released varieties.

References

Albregts, E.E. and C.M. Howard. 1982. Effect of fertilizer rate on number of malformed strawberry fruit. Proc. Fla. State Hort. Soc. 95:323–324.

Albregts, E.E., C.M. Howard, and C.K. Chandler. 1991. Effect of high N rates on fruiting strawberry. Soil Crop Sci. Soc. Fla. Proc. 50:134– 136.

Agüero Juan J. & Daniel S. Kirschbaum. 2013. Approaches to Nutrient Use Efficiency of Different Strawberry Genotypes, International Journal of Fruit Science, 13:1-2, 139-148, DOI: 10.1080/15538362.2012.697047

Belanger, R. 2016. Understanding the potential benefits of silicon fertilization in strawberry. 8th International strawberry Symposium. Quebec, Canada. August 13th-17th.

Campbell CR, Miner GS. 2000. Strawberry, annual hill culture. In: Campbell CR, editor. Reference sufficiency ranges for plant analysis in the southern region of the United States. Raleigh (NC): NC Dept of Agriculture & Consumer Services. Southern Cooperative Series Bulletin 394

Demchak, K., & Hanson, E. J. 2013. Small fruit production in high tunnels in the US. *Acta Horticulturae*, *987*(March), 41–44.

Garcia, M.E, Johnson, D., and Kirkpatrick, T. 2013. Determining Optimum Nitrogen Nutrition Management for Offseason High Tunnel Plasticulture Strawberry Production for Arkansas and the Southeast. Final Report; SRSFC Project # 2013-06.

Hockmuth G, Albregts E. 1994. Fertilization of strawberries in Florida. Gainesville (FL): University of Florida Cooperative Extension Service. Circular 1141. 4 p.

Hochmuth, G. J., Albregts, E. E., Chandler, C. C., Cornell, J., & Harrison, J. 1996. Nitrogen Fertigation Requirements of Drip-irrigated Strawberries. Journal American Society of Horticultural Science, 121(4), 660–665.

Miyake, Y. and E. Takahashi, 1986. Effect of Silicon on the Growth and Fruit Production of Strawberry Plants in a Solution Culture. Soil Sci. Plant Nutr., 32 (2), 321-326

Miner GS, Poling EB, Carroll DE, Nelson LA, Campbell CR. 1997. Influence of fall nitrogen and spring nitrogen-potassium applications on yield and fruit quality of ‘Chandler’ strawberry. J Am Soc Hort Sci 122(2):290–5.

Rodriguez, J. G., Chaplin, C. E., Stolz, L. P., and A. M. Lasheen 1970. Studies on resistance of strawberries to mites . I. Effects of plant nitrogen. J. of Econ. Ento. 63(6): 1855–1858.

Voth, V., K. Uriu, and R.S. Bringhurst. 1967. Effect of high nitrogen applications on yield, earliness, fruit quality, and leaf composition of California strawberries. Proc. Amer. Soc. Hort. Sci. 91:249–256.

Wittwer, S.H. and N. Castilla. 1995. Protected cultivation of horticultural crops worldwide. Hort Technology 5:6– 23.