



Optimization of Growth-stage Specific Nitrogen Fertilization Improves Strawberry Growth and Yield

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The current commercial practice for nitrogen (N) fertilization by strawberry growers in Florida is to start with 1.75–2 lb/acre/day of N during transplant establishment and lower to 0.75–1.25 lb/acre/day of N for the rest of the season, whereas the university recommendation is to gradually increase from 0.3 to 0.75 lb/acre/day of N, based on crop requirements. The main objective of this study was to determine optimal N fertilization rates during the early season for two major strawberry cultivars, 'Florida Radiance' and 'Florida 127'. Five N rates of 0.2, 0.6, 1.0, 1.4, and 1.8 lb/acre/day of N were evaluated starting 22 Oct. and ending 14 Dec. 2014. Thereafter all treatments were fertilized at 1.0 lb/acre/day of N until the end of the season. The increase in N treatments during the early season resulted in increased leaf area and canopy size. This enhanced canopy growth increased marketable yield not only during early season (November and December) but also during the mid (January) and late (February) seasons. 'Florida Radiance' had the highest total marketable yield at 1.4 lb lb/acre/day of N, whereas the yield of 'Florida 127' peaked at 1.0 lb/acre/day of N. There was no effect of early season N rates on total non-marketable yield. In terms of fruit quality, there was no impact of increased rates on 'Florida 127', but it slightly decreased the °Brix value of 'Florida Radiance'. These results suggest that increasing the early season N rate up to 1.4 lb/acre/d is effective in maximizing strawberry yield during the entire season with minimal impact on fruit quality. Differential varietal responses should be taken into account to further improve the efficiency of N fertilization.

Higher strawberry yields are achieved as a result of continuous nutrient supply regardless of the source (Locascio and Martin, 1985). Insufficient nitrogen (N) supply leads to reduced strawberry total biomass, fruit size and yield (Deng and Woodward, 1998). Excessive N fertilization leads to overgrowth, increases susceptibility to disease and poor plant performance (Kirschbaum et al., 2010). Optimal N fertilization in strawberry ensures maximum yield and quality. The strawberry response to N rate is cultivar dependent (Simmone et al., 2001).

Several studies have focused on the individual effect of N, cultivar and their interactions. The supply of N by N phasing to meet the growing demands of plant growth stages improves the growth and yield of broccoli (Nkoa et al., 2000). There is no effect of pre-plant N fertilization on the total marketable yield of strawberry (Santos and Whidden, 2007).

Florida strawberry growers generally apply 150–200 lb per acre of N through drip irrigation during the growing season. They start with a high initial application of 1.75–2 lb/acre/d during the early season (Nov. and Dec.) and then gradually decrease to 0.75–1.25 lb/acre/d for the middle (Jan.) and late (Feb.) seasons depending on the cultivar. However, the current University recommendation is to start with a lower rate of 0.3 lb/acre/d during early season and then gradually increase to 0.75 lb/acre/d by the end of the season based on crop requirements.

The main objective of this study was to determine the optimal

early season N rate for two Florida strawberry cultivars, Florida Radiance and Florida 127. The study also aimed to determine if there were any cultivar and N rate interactions for the two cultivars that would lead us to develop growth-stage specific N recommendations for maximizing fruit yield and quality.

Materials and Methods

The field study was conducted at the University of Florida, IFAS Gulf Coast Research and Education Center in Balm, FL, during the 2014–15 season. Raised beds were 4 ft apart at the center, 10 inches high and 27 and 32 inches wide at top and base, respectively. The raised beds were fumigated with Pic-Clor 60 at 300 lb/acre and covered with black high density polyethylene mulch with one drip tape at the center of each bed and 12-inch emitter spacing. The sprinkler nozzles were placed 40 ft apart in the field plot with a flow rate of 5 gal/min.

Bare root strawberry transplants of 'Florida Radiance' and 'Florida 127' were planted on 9 Oct. 2014, with 15 inch plant spacing in double rows giving 24 plants per plot. Sprinkler irrigation was carried out for 2 weeks following planting for 8–10 h/d to ensure sufficient plant stand establishment.

There was no fertilizer applied during sprinkler irrigation period. The experiment involved testing five different N rates of 0.2, 0.6, 1.0, 1.4, and 1.8 lb/acre/d during the early season (22 Oct.–14 Dec.). For the rest of the season, all treatment plots were fertilized with the same rate of 1.0 lb/acre/d. The N fertilization was done using a Dosatron fertilizer injector. Urea ammonium nitrate (UAN) was used as the source of N, whereas phosphorous (P) and potassium (K) were supplied by the 0–2–8 (N–P₂O₅–K₂O) formulation.

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The harvesting was done twice a week from 24 Nov. to 26 Feb. Grading of fruit was done according to USDA grading standards. Harvested fruits were graded into marketable and non-marketable fruits. Fruit number and weight were recorded for each category. Leaf area measurements were carried out using a leaf area meter. The leaf area and shoot and root dry weight measurements were recorded at 5, 8, and 13 weeks after transplanting and also at the end of the season. The °Brix measurements were done using a refractometer twice, after the early season treatments and at the end of season.

The experiment was conducted using a split-plot design with N as the main plot and cultivar as the sub-plot. Each treatment was replicated four times. The data analysis was done using R software 3.2.2. The analysis of variance was used to determine the individual effect of cultivar, N rate, and their interactions. Comparison of means was done by Tukey's HSD test.

Results and Discussion

The individual effects of cultivar and N rate and their interactions were assessed for monthly and total marketable yield (Table 1). The interactions were significant for marketable yield in December and February. The individual effect of cultivar was only significant for marketable yield in December, when 'Florida 127' yielded more than 'Florida Radiance'. Cultivar effects were not significant for marketable yield of other months and total marketable yield.

There was almost a linear increase in total marketable yield of 'Florida Radiance' with increasing N rate from 0.2–1.4 lb/acre/d (Fig. 1). There was no significant difference in total marketable yield between 1.4–1.8 lb/acre/d for 'Florida Radiance'.

Table 1. Significance of main and interaction effects according to analysis of variance.

Factor	Marketable yield (t/ha)			
	Dec.	Jan.	Feb.	Total
Cultivar	*** _z	NS _w	NS	NS
N rate	***	***	**	***
N rate*Cultivar	** _y	NS	* _x	NS

_z*** = significant effect at 0.1 % level

_y** = significant effect at 1% level

_x* = significant effect at 5% level

_wNS = nonsignificant

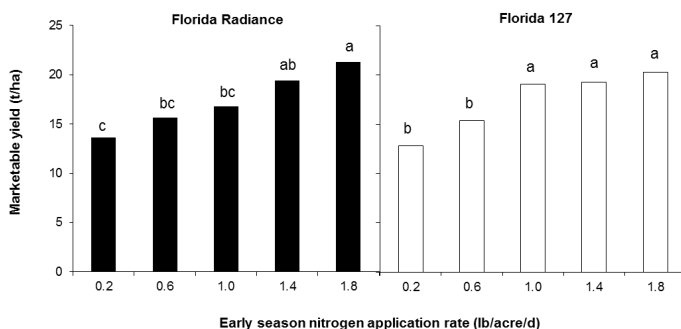


Fig. 1. Total marketable yield of 'Florida Radiance' and 'Florida 127' as affected by early season N rates. For each cultivar, values of means sharing a common letter do not differ on the basis of Tukey's HSD test.

However, total marketable yield at 1.8 lb/acre/d was significantly different from all other N treatments from 0.2–1.0 lb/acre/d. For 'Florida 127', the maximum total marketable yield was recorded at 1.0 lb/acre/d with no significant effect of subsequent increase in N treatments.

Strawberry prices are typically higher in November and December than for rest of the season. For 'Florida Radiance', the highest December marketable yield was recorded at 1.0 lb/acre/d whereas for 'Florida 127' yield peaked at 1.4 lb/acre/d with no significant effect of subsequent increase in N treatments (Fig. 2). The cultivar and N rate interactions for total marketable yield were nonsignificant.

Both monthly and total non-marketable yields were unaffected by early season N treatments for both cultivars. In general, 'Florida 127' had a significantly higher total non-marketable yield than 'Florida Radiance' (Fig. 3).

Leaf area recorded almost one month after the end of early season treatments had a strong correlation with N rate for both cultivars. Leaf area values also had a high correlation with total marketable yield for both cultivars (Data not shown).

The increase in N rate resulted in increased yields for both the cultivars. However, the effects on fruit quality were minimal for both the cultivars. The increase in N rate from 0.2 to 1.8 lb/acre/d resulted in one degree decrease in °Brix value for Florida Radiance whereas there was no effect of increased rates on °Brix values for Florida 127 (Fig. 4).

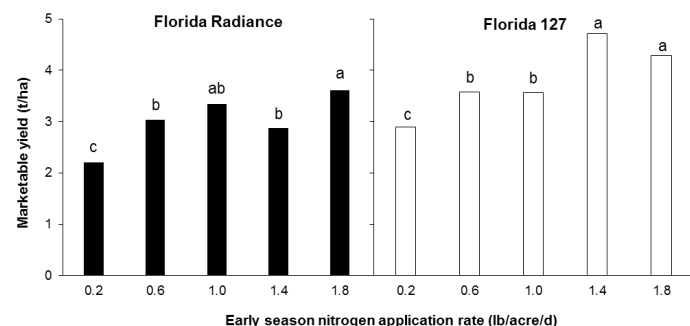


Fig. 2. Marketable yield of 'Florida Radiance' and 'Florida 127' in November and December as affected by early season N rates. For each cultivar, values of means sharing a common letter do not differ on the basis of Tukey's HSD test

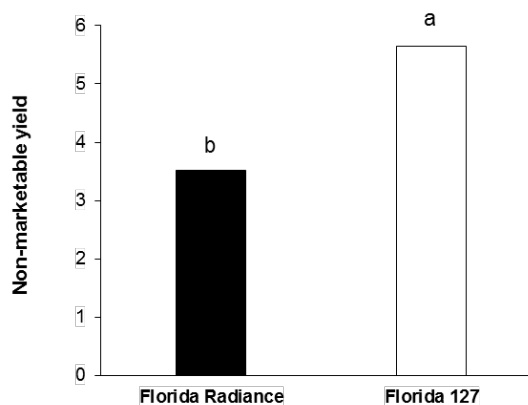


Fig. 3. Total non-marketable yield for 'Florida Radiance' and 'Florida 127'. Values of means sharing a common letter do not differ on the basis of Tukey's HSD test.

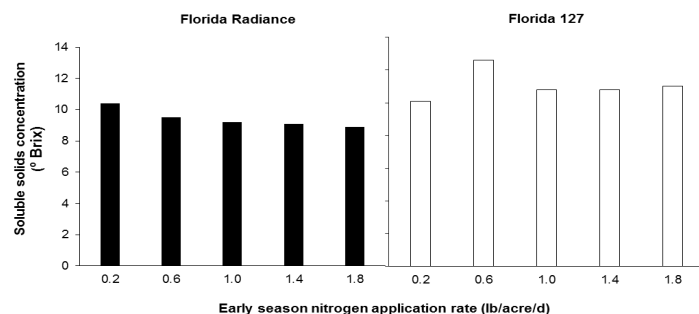


Fig. 4. Soluble solids concentration of 'Florida Radiance' and 'Florida 127' fruit as affected by early season N rates.

The N demands of strawberry in Florida sandy soils decreases in the root and crown portion of the plant as the plants continue to grow, with the fruit accumulating more N, P, and K than all other plant parts combined. Only small nutrient quantities are required during the late season to replace nutrients removed by the fruit (Albregts and Howard, 1979; Albregts and Howard, 1980; Albregts and Howard, 1981). Fertilizers injected during late season (March) have no effect on yield (Albregts et al., 1989). Thus, even though the nutrient requirement of plants in the initial stages is low, the small root system has a very low uptake efficiency as it cannot access a greater portion of bed for nutrients. So, there is a need to apply more nutrients to meet the plant needs in the initial stages. As the plants continue to grow, roots have greater access to comparatively larger areas of the bed. Thus application of smaller N rates during later parts of season is sufficient to meet the plant needs.

There was no trend observed for non-marketable yield as fruit quality is affected by environmental factors, time of the season and cultivar. There is more non-marketable fruit by end of strawberry season because of changes in weather conditions. Increasing temperature results in increased disease incidence, overripe fruit and decayed fruit. So, the variation in non-marketable yield cannot just be explained as a result of treatment differences.

Increased N treatments result in increased vegetative growth (leaf area), early marketable yield and nonsignificant effect on total soluble solids (El-Sawy et al., 2012). The results were in agreement with this study. Increased N rates during the early season helped to develop a productive canopy as indicated by increased leaf area. This productive canopy helped to increase marketable yield, not only during early season but also total

marketable yield as indicated by a correlation between total marketable yield and leaf area. The increased leaf area resulted in an increased shoot biomass that helped increase marketable yield.

Conclusions

The results of the experiment suggest that higher initial N rates during the early season improves marketable yield not only during the early season but also total marketable yield by developing a productive canopy. Though the increase in N rates during the early season was responsible for increased yields for both the cultivars, its effect on fruit quality were minimal. Overall, 'Florida Radiance' was more responsive than 'Florida 127'.

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