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Optimization of Early-season Nitrogen Fertilization Program for New Strawberry Cultivar 'Florida Beauty'

Sana Shahzad[1], Tiare Silvasy[2], and Shinsuke Agehara*[2]

[1]University of Agriculture, Faisalabad, Pakistan

[2]Gulf Coast Research and Education Center, University of Florida/IFAS, 14625 CR 672, Wimauma, FL 33598

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Strawberry (*Fragaria ×ananassa* Duch.) growers in Florida generally apply 168–224 kg of nitrogen (N) per hectare during the growing season, starting with 1.96–2.24 kg/ha/d during establishment (e.g. 3 weeks), followed by lower rates at 0.56–1.12 kg/ha/d. The initial high-dose fertilization is beneficial for improving the establishment of strawberry transplants, but this practice must be tailored for each cultivar based on its growth characteristics and nutrient requirements. The objective of this study was to determine the optimal early-season fertilization program for 'Florida Beauty', which is a newly developed early-yielding cultivar. Treatments were different durations of high N fertilization at 2.24 kg/ha/d during establishment: 0, 3, 6, and 9 weeks. After these treatment durations, all treatments were subjected to the lower rate of 1.12 kg/ha/d, providing 149 to 243 kg of N in the entire growing season. Transplants were planted in the field on Sep. 28, 2017 and harvests were performed 30 times between 2 Nov. 2017 and 26 Feb. 2018. Extending the high N fertilization duration from 0 to 9 weeks accelerated initial canopy development and increased leaf area by 30% at the end of the season. It also increased the early yield (Nov.–Jan.) by 33% and the total season yield by 28%, while reducing thrips damage fruit by up to 53% in the entire season. These results suggest that initial high N fertilization (2.24 kg/ha/d) can be extended slightly longer for 'Florida Beauty' than for other major cultivars in Florida. Delayed establishment of an ideal canopy size can result in yield reductions and increased insect damage.

'Florida Beauty' is a new strawberry cultivar released by the University of Florida in 2017. It originated from a cross between the Queensland Australia selection 2010-119 and 'Florida Radiance'. This cultivar has a compact plant habit, low chilling requirement and excellent fruit quality. The combination of these traits makes this cultivar suitable for early planting in Florida from 20 Sept. to 1 Oct. (Whitaker et al., 2017).

Nitrogen (N) is a major component of chlorophyll and plays a critical role in vegetative growth of plants because chlorophyll allows plants to capture energy from the sun and produce carbohydrate molecules in the photosynthesis process. It is also the basic element of plant proteins, including the genetic material DNA and RNA (El-Sawy et al., 2012). In strawberry, N is one of the most abundant mineral nutrients, with optimal leaf N concentration ranging from 3% to 4% (Hochmuth et al., 1996). Optimal N fertilization in strawberry ensures maximum yield and quality. It has been reported that higher strawberry yields can be achieved by a continuous supply of N irrespective of the N source (Hochmuth and Hanlon, 1999; Simonne et al., 2001). Nitrogen deficiency results in reductions in total dry biomass and relative growth rate mainly through reductions in leaf area ratio and plant N concentration (Deng and Woodward, 1998). Increasing N fertilization increases leaf N concentration and promotes the development of greener leaves (Albregts and Howard, 1982). Excessive N fertilization can promote vegetative growth parameters (plant length, leaf number and leaf area) and early marketable yield but reduce the number of flowers per plant and total marketable yield (El-Sawy et al., 2012).

*Corresponding author. Email: sagehara@ufl.edu

Current fertilization practices for strawberry production in Florida are based on previous studies that evaluated different N sources, fertilizer placement methods, the need for pre-plant fertilization, and N fertilization rates (Hochmuth and Hanlon, 1999; Albregts and Howard, 1982; Agehara et al., 2017). In general, Florida strawberry growers apply 168–224 kg of nitrogen (N) per hectare during the growing season, starting with 1.96–2.24 kg/ha/d during establishment (e.g. the first 3 weeks) followed by lower rates at 0.56–1.12 kg/ha/d (Sangha and Agehara, 2016). The initial high-dose fertilization is beneficial for improving the establishment of strawberry transplants, but this practice must be tailored for each cultivar based on its growth characteristics and nutrient requirements.

Therefore, the objective of this study was to determine the optimal early-season N fertilization program for 'Florida Beauty'.

Materials and Methods

A field experiment was conducted at the Gulf Coast Research and Education Center in Balm, FL, during the 2017–18 season. Raised beds were 122 cm apart at the center, 68 cm wide on the top, 81 cm wide at the base, and 25 cm high. In each bed, one drip tape with emitters spaced 30 cm apart and a flow rate per emitter of 0.91 L/h (Netafim USA, Fresco, CA) was installed at 2-cm depth. Beds were fumigated with Pic-Clor 60 at 336 kg/ha and covered with black polyethylene mulch. Bare root strawberry transplants of 'Florida Beauty' were planted on 28 Sept. 2017 with 38 cm plant spacing in double rows and16 plants per plot. Sprinkler irrigation was used for 2 weeks following planting for 8–10 hours per day (h/d) to ensure good plant stand

Table 1. Nitrogen (N) fertilization treatments in this study.

Duration of high N rate	Nitrogen fertilization rate (kg/ha/d) Week 1–2	3–5	6–8	9–11	Thereafter	Total N rate (kg/ha)
0 week	0	1.12	1.12	1.12	1.12	149
3 weeks	0	2.24	1.12	1.12	1.12	196
6 weeks	0	2.24	2.24	1.12	1.12	219
9 weeks	0	2.24	2.24	2.24	1.12	243

establishment. Thereafter, drip irrigation was used for irrigation and fertilization.

Treatments were different durations of the high N fertilization rate at 2.24 kg/ha/d during the early season: 0, 3, 6, and 9 weeks, which are denoted thereafter as 0, 3, 6, and 9 weeks, respectively (Table 1). After these treatment durations, all treatments were subjected to the lower rate of 1.12 kg/ha/d, for totals of 149 to 243 kg of N over the growing season. Urea ammonium nitrate (UAN) was used as the N source while phosphorous (P) and potassium (K) were applied using a 0–2–8 ($N–P_2O_5–K_2O$) liquid fertilizer. Harvests were performed 30 times between 2 Nov. 2017 and 26 Feb. 2018. Fruits were graded according to USDA grade standards. Leaf area was measured at the end of season using a leaf area meter (LI-3100C Area Meter; LI-COR, Lincoln, NE). Treatments were arranged in a randomized complete block design with four replications per treatment. All data analyses were run in SAS (version 9.2; SAS Institute, Cary, NC, USA). *P* values < 0.05 were considered statistically significant. Multiple comparisons of least squares means were performed using the Tukey–Kramer test in the MIXED procedure.

Results and Discussion

Fig. 1 shows the positive treatment effects of initial high N fertilization on canopy growth 54 days after transplanting. Increasing the duration of the initial high N fertilization program accelerated development of the canopy.

Leaf area measured at the end of season increased by 30.1% by extending the duration of the initial high N fertilization from 0 to 9 weeks (1576 vs. 2051 cm^2) (Fig. 2). This observation suggests that initial high N fertilization has long-term effects on leaf area development of 'Florida Beauty' because N is major component of chlorophyll, which is essential for metabolic processes especially synthesis of proteins, nucleic acids, enzyme activation, energy transfer, osmotic regulation, respiration and photosynthesis (Taiz and Zeiger, 2002).

Sangha and Agehara (2017) examined root morphological responses of bare-root strawberry 'Florida Radiance' transplants to varying N rates of 0.56, 1.12, 1.68, 2.24, 2.80, and 3.36 (kg/ha/d) using a scanner-based rhizotron system. The increased N rates resulted in enhanced canopy and root growth. Shoot growth recorded a more rapid response to N relative to root growth. Both canopy area and crown diameter increased linearly with increasing N rates. The increased canopy area promoted root elongation whereas primary root formation was enhanced as a result of increased crown diameter. Their study suggests that shoot and root growth are closely linked. This relationship likely explains the responsiveness of canopy growth to initial N fertilization observed in this study.

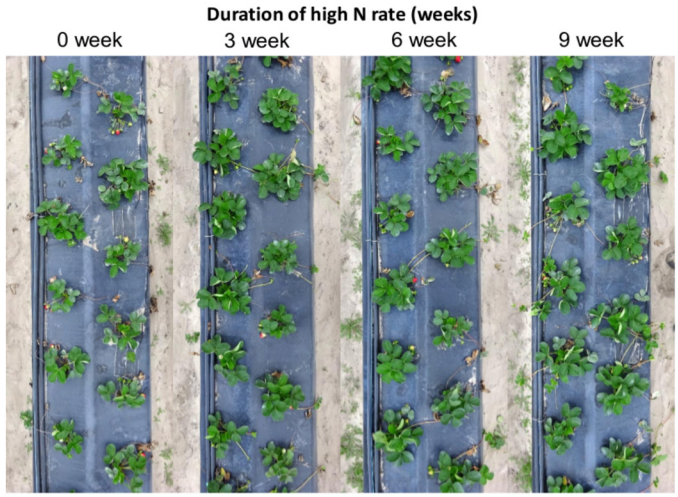

Fig. 1. Canopy growth of 'Florida Beauty' strawberry 54 days after transplanting (21 Nov, 2017).

Early-season (Nov.–Jan.) yields were more responsive to initial high N fertilization than late-season (Feb.) yields (Fig. 3). When initial high N fertilization was used for 0, 3, 6, and 9 weeks, early-season yields were 10.20, 11.44, 12.19 and 13.39 t/ha, respectively. Only the 9 week treatment was significantly different from the 0 week treatment, with a maximum yield increase of 31.3%. By contrast, duration of initial high N fertilization had no significant effect on late season yield. Total season yields increased 22.7% by increasing the duration of initial high N fertilization from 0 to 9 weeks. When the duration of initial high N fertilization was 3 to 6 weeks, yield increases were not statistically significant from 0 weeks.

Sangha and Agehara (2016) evaluated different N fertilization rates during the early season using two strawberry cultivars, 'Florida Radiance' and 'Florida127'. Their treatments were five N rates during the early season (22 Oct.–14 Dec.), 0.22, 0.67, 1.12, 1.56, and 2.0 N kg/ha/d, all of which were followed by 1.12 kg/ha/d during the rest of the season. 'Florida Radiance' showed continuous increases in total marketable yields of up to 57% (13.6

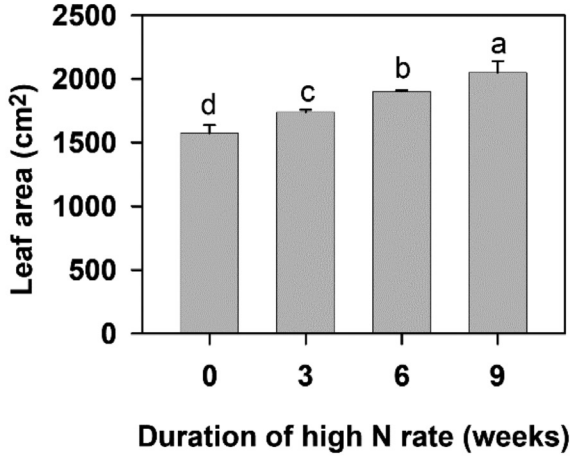

Fig. 2. Leaf area of 'Florida Beauty' strawberry at the end of the growing season as affected by the duration of high N fertilization (2.24 kg/ha/d and thereafter 1.12 kg/ha/d). Means followed by same letter are not significantly different at $P \leq 0.05$ according to Tukey-Kramer test.

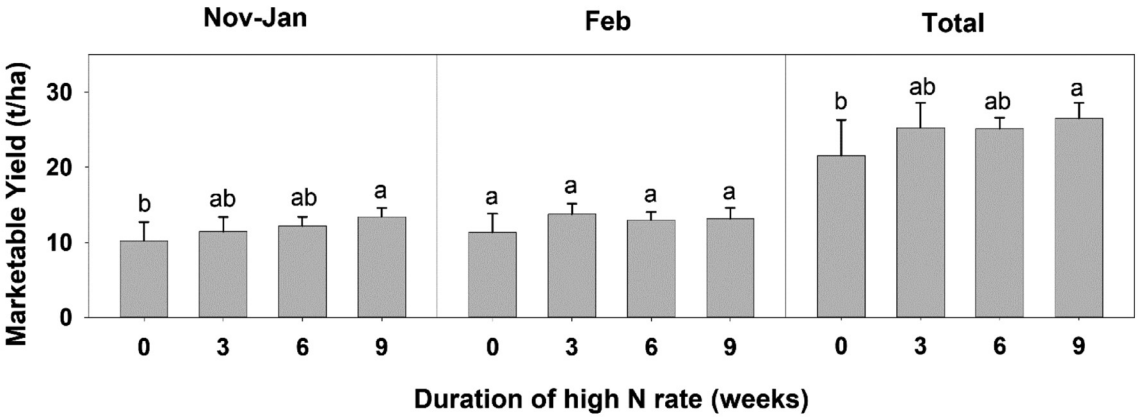

Fig. 3. Marketable yield of 'Florida Beauty' strawberry during growing season as affected by the duration of high N fertilization (2.24 kg/ha/d and thereafter 1.12 kg/ha/d). Means followed by same letter are not significantly different at $P \leq 0.05$ according to Tukey-Kramer test.

vs. 21.3 t/ha) by increasing the early season N rate from 0.22 to 2.0 kg/ha/d. By contrast, 'Florida127' increased total marketable yields by up to 53% (12.1 vs 18.5 t/ha) by increasing N rate from 0.22 to 1.12 kg/ha/d but there were no yield differences with further increases in N rate. Therefore, their results suggest that 'Florida Radiance' is more responsive to higher N rates than 'Florida127' during the early season. This is similar to our findings that initial high N fertilization increased total marketable yield of 'Florida Beauty'. The similarity between 'Florida Radiance' and 'Florida Beauty' was the high yield response to N fertilization during establishment.

Major Florida strawberry cultivars, such as 'Florida Radiance' and 'FL 05-107', require a moderate level of fertilization to produce excellent fruit yield. This includes up to 3 weeks of initial high N fertilization with a total N of 168–196 kg/ha (Whitaker et al., 2008; Whitaker et al., 2012). By contrast, 'Florida127' responds more strongly to N application in terms of vegetative growth and requires lower N fertilization rates for fruit production (Whitaker et al., 2014). Our study demonstrated that fruit yields of 'Florida Beauty' can be maximized using 9 weeks of initial high N fertilization with a total season rate of 243 kg/ha. This suggests that this cultivar is highly responsive to N fertilization. This cultivar generally has greater fruit loads than other cultivars in the early- to mid-season, especially when planted early (20 Sep. to 10 Oct.), possibly requiring higher N rates to maintain plant health and productivity.

Our results suggest that high N fertilization is beneficial for more efficient N uptake during establishment which results in improved fruit earliness and yield. Initial high N fertilization for 'Florida Beauty' can be extended up to 9 weeks to maximize fruit yield, thereby requiring a relatively large amount of N for establishment compared to other major Florida cultivars.

Conclusions

'Florida Beauty' is characterized by its compact plant habit. It is highly responsive to N fertilization during establishment. We recommend the use of high N fertilization at 2.24 kg/ha/d for 9 weeks during establishment, which is slightly longer than the recommendation for other cultivars (Whitaker et al., 2008; Whitaker et al., 2012). The negative impact of a high N rate appears to be minimal for this cultivar. Delayed establishment of an ideal canopy size can result in yield reduction, especially during the early season.

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