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Strawberry dose response to preplant and spring nitrogen rates in annual hill plasticulture production

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Abstract: The purpose of this research was to determine the effect of different N rates as preplant and spring applications on yield and fruit quality of three popular strawberry varieties. The trail was conducted at the Hampton Roads AREC in Virginia Beach, VA, during the 2021-2022 season. Strawberry varieties (Chandler, Camarosa and Ruby June) were planted on October 6 in a split-plot randomized complete block design with three replicates and received three preplant rates of 30 (0.5x), 60 (1.0x), and 90 (1.5x) lb N/acre, as well as three liquid N fertilizer applications of 0, 3.5 (0.5x), and 7 (1x) lb N/acre in the spring of 2022. The highest average marketable yield, total yield and diseased fruits per plant was obtained with preplant N fertilizer at 90 lb/acre rate for all strawberry varieties, and the lowest marketable yield per plant was obtained with 30 lb/acre. Further, preplant and spring N fertilizer applications had no effect on other fruit ratings, such as small fruits, deformed fruits, insect, animal, and bird damage, and TSS, although these varied amongst the three strawberry varieties. We concluded that the preplant application of N fertilizer had significant effects on the marketable and total yield of strawberry plants, but the spring application of N fertilizer did not influence the marketable and total yield of strawberry plants.

Introduction: The strawberry (*Fragaria* × *ananassa* Duch.) is an important small fruit throughout the world due to its delicious flavor, adaptability, and high nutritional value (Giampieri et al., 2012). The south-Atlantic region which includes the Commonwealth of Virginia and the Carolinas ranks third in fresh strawberry production after California and Florida (Samtani et al., 2019). There are limited studies on understanding nitrogen needs of strawberry plants in the south-Atlantic regions. Current strawberry recommendations for preplant nitrogen

are based on a single variety, Chandler, done at North Carolina State University (Miner et al., 1997). Although 'Chandler' continues to remain popular for our region, in the current decade, growers have adopted other varieties because of replicated variety trials done in our region (Flanagan et al., 2020; Gu et al., 2017). Most strawberry growers grow more than one variety. Excessive nitrogen can result in excessive leaf production, greater susceptibility to diseases, reduced fruit firmness and increase in cull fruits (Papadopoulos, 1987). Over application of nitrogen can consequently have economic and environmental concerns (Carranca et al., 2018). We proposed a dose-response study of nitrogen on multiple strawberries varieties to characterize effects on production and nutritional quality.

Material Method: We initiated a field study in fall 2021 at the Hampton Roads AREC, Virginia Beach, VA. to include three commonly grown strawberry varieties in the south-Atlantic region of the U.S -Chandler, Camarosa and Ruby June. Raised beds spaced 6 ft. from center to center were formed in late September 2021 with a subsurface drip irrigation line centered in each bed at a depth of 3 to 4 inches (7 to 10 cm). Treatments include three preplant rates at 30 (0.5x), 60 (1x) and 90 (1.5x) lb N/acre. In the spring season, liquid applications of N fertilizer of 0, 3.5 (0.5x) and 7 (1x) lb N/acre were applied every week from late March until June. The study was arranged in a split-split-plot design with spring fertigation rates as main plot and nitrogen preplant rates as sub-plots and strawberry varieties as sub-sub plot. The treatments were replicated thrice.

Timeline and data collection. Strawberry plants were transplanted in early October 2021. Fall nitrogen treatments were added as preplant fertilizer at the time of making raised beds. These plants were overwintered, produced flower blooms in the spring season, and the strawberry harvest season was from April to June. Marketable and non-marketable fruit yield were collected by hand-harvesting berries twice a week from 5 April through 16 June 2022. In the non-marketable category, which comprises of small berries <10 g wt., misshapen berries, insect, animal, and bird damage, and diseased fruits were weighed separately. Fruit size, fruit firmness, and total soluble solids (TSS) were collected once a week during the harvest season.

For each nitrogen rate and variety, soil samples were collected twice during the growing season- in late fall on 9 November 2021 and before fertigation on 15 March 2022. To analyze nitrogen content in the soil, samples were taken at each replicate at 6-inch depth. Soil samples were sent

on ice to NC State University (co-PI Hoffmann) and stored at -20 °C. Soil samples were ground, weighed, and prepared for Nitrogen extraction. NH4+ and NO3- content wase measured by the Environmental & Agricultural Testing Services (EATS) at NC State University. Adjusted NH4+ and NO3- (mg/L) rates were reported after measuring soil dry weights.

Nitrogen estimation in the plant by nitrogen rates and by variety were done using plant tissue and petiole analysis once during flowering/fruiting, by sending samples to the North Carolina Department of Agriculture, and Consumer services (NCDA&CS) Agronomic Division Lab.

Data analysis. All data were analyzed using by JMP v.14 (SAS Institute Inc., Cary, NC, USA). The data were checked for normality and homogeneity of variance assumptions and transformed where appropriate. The interaction between preplant and spring fertigation rates and varieties was analyzed to understand their influence on soil nutrient differences, crop yield, fruit rots, fruit firmness and total soluble solids.

Results: The preplant N rate influenced the marketable yield on all three strawberry varieties, and 'Camarosa' had the highest marketable yield compared with the other two varieties. Preplant application of N fertilizer at 90 lb/acre had the highest marketable yield compared with other N rates on all three strawberry varieties (Fig. 1). Nitrogen application rates in the spring did not influence the marketable yield of three strawberry varieties. Furthermore, both preplant and liquid fertilizer applications in the spring had no effect on the NH^{4+} and NO^{3-} content in the soil. For plant tissue analysis, although the leaf samples collected were representative of each treatment, the tissue analysis was not replicated. No specific pattern was observed among varieties and nitrogen treatments.

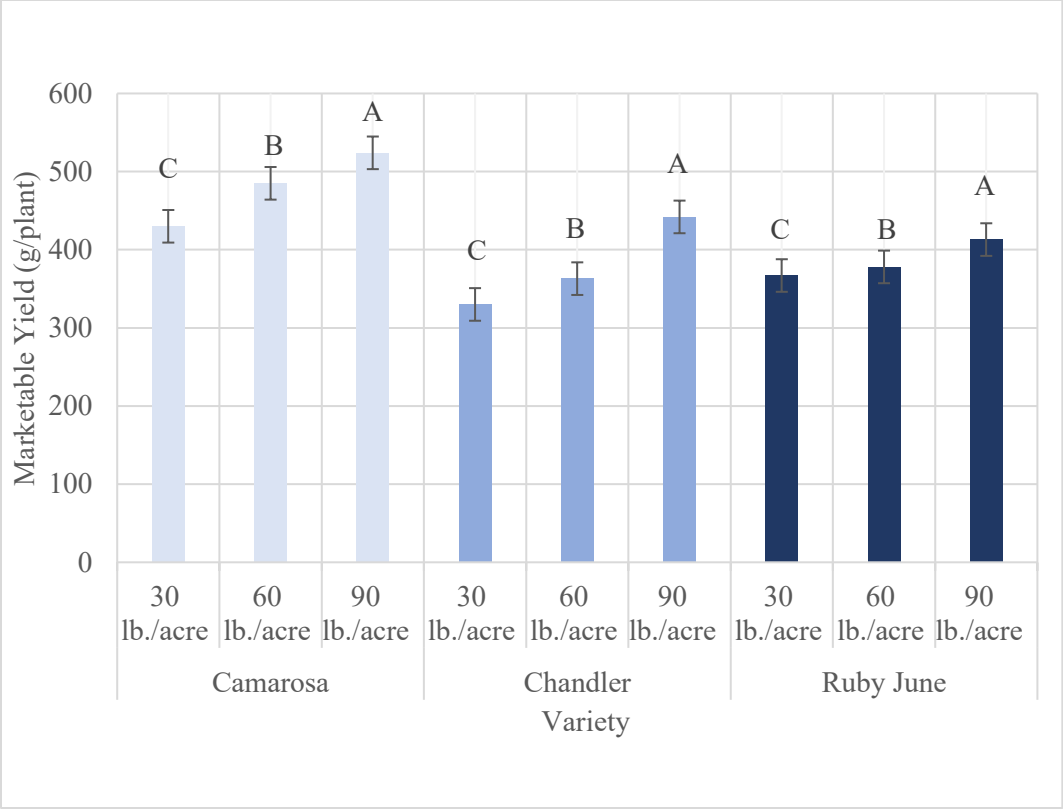

Figure 1: Marketable yield (g/plant) of three strawberry varieties with three different preplant applications of N fertilizer (lb/acre).

Total Yield: Total yields were calculated by adding the marketable yield to the non-marketable yield. The non-marketable yield was mainly caused by fruit rot diseases such as anthracnose, botrytis, and water rot due to rain events. The total yield of all three strawberry varieties improved by the increase in the application of preplant N fertilizer. The highest yield was produced by the 'Camarosa'. Spring application did not influence the total yield on all three strawberry varieties. (Fig.2).

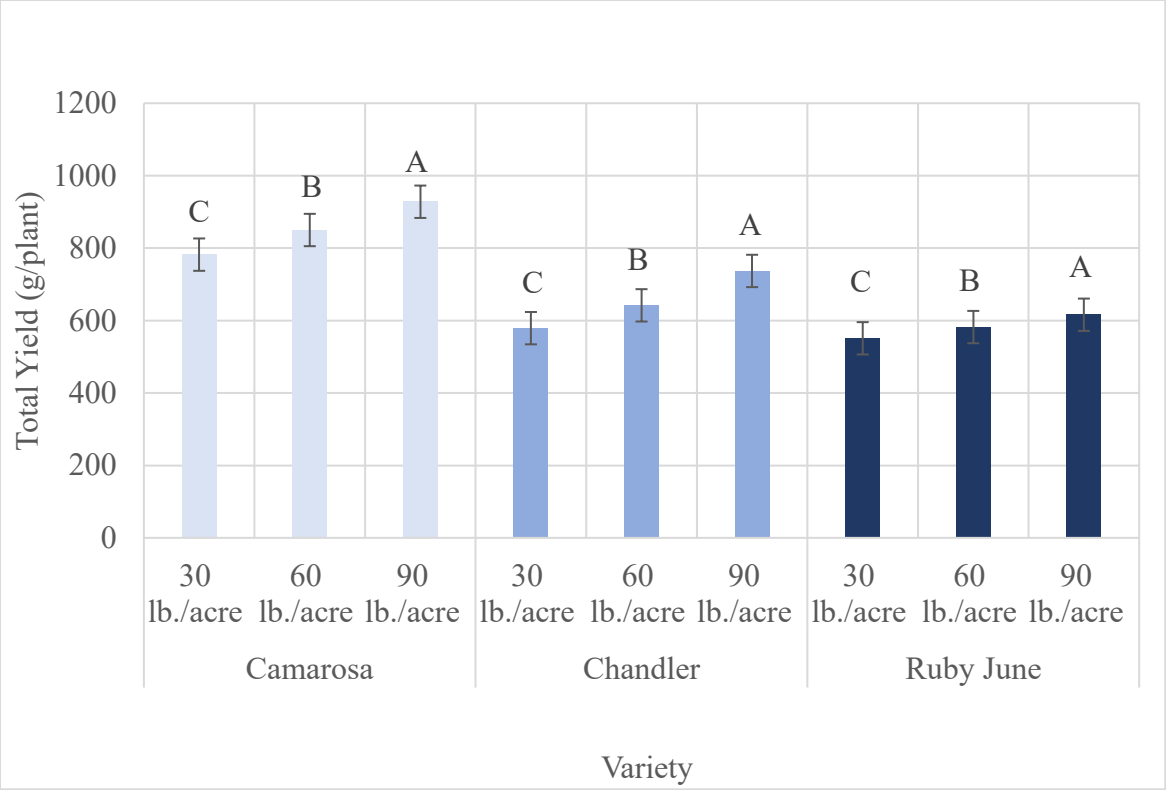

Figure 2: Total yield (g/plant) of three strawberry varieties with three different preplant application of N fertilizer (lb/acre).

Small Fruit: Fruits weighing less than 10 g in weight were considered small fruits. For the strawberry fruit weight, among the three varieties of strawberry plants, Chandler was consistent in producing berries that weighed less than 10g/plant. Neither preplant nor spring application of N fertilizer influenced fruit weight for three strawberry varieties (Fig. 3).

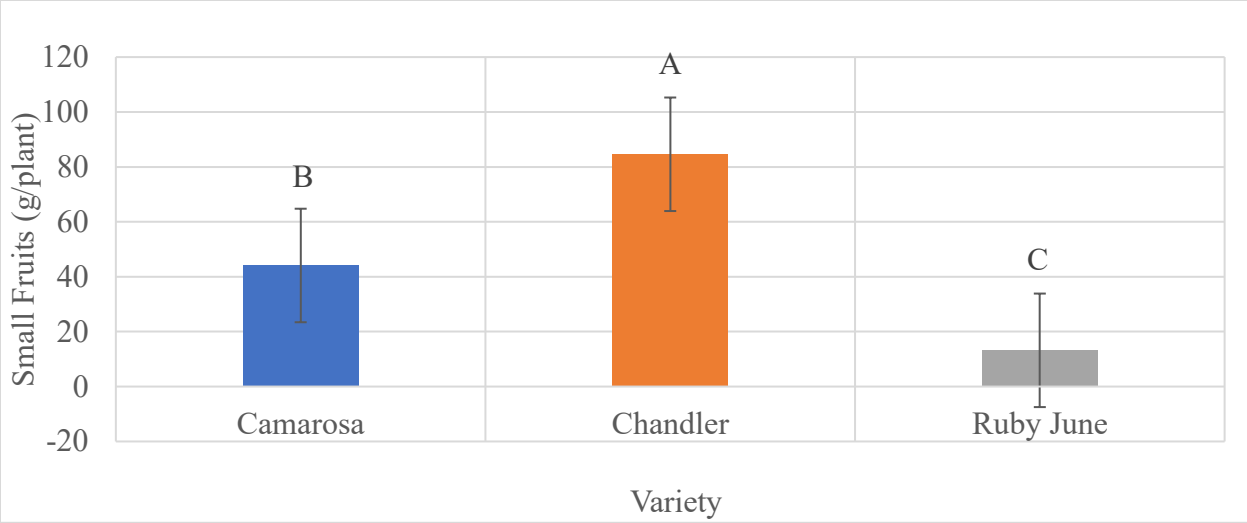

Figure 3: Small fruits yield (g/plant) of three strawberry varieties.

Deformed and water rot: Deformed strawberries were classified as those with poor pollination, abundant seeds build-up, and misshaped berries. Furthermore, berry quality lost due to substantial rain were also classified as deformed. 'Ruby June' had the least deformed fruit (fig. 4).

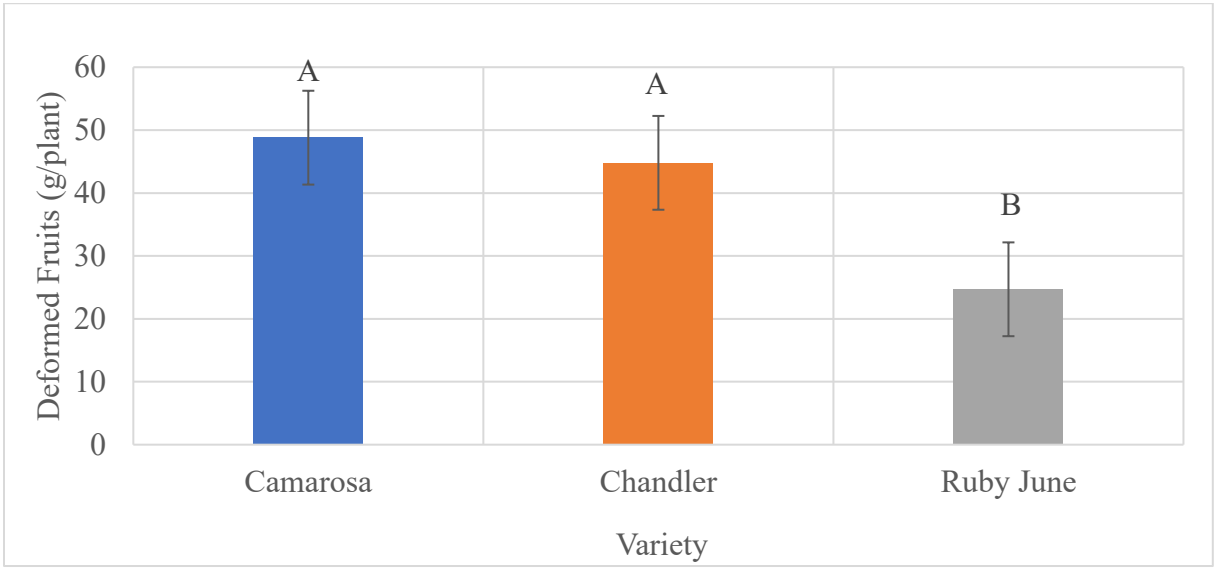

Figure 4: Deformed fruits yield (g/plant) of three strawberry varieties.

Insect/Animal/Bird Damage: We evaluated external damage to strawberries due to insects, animals, and birds. 'Camarosa' yield was damaged the most among all strawberry varieties. There was no significant difference in the weight of fruits damaged by insects, animals, and birds

in plants treated with preplant and spring N fertilizer treatments among all the strawberry varieties (Fig. 5).

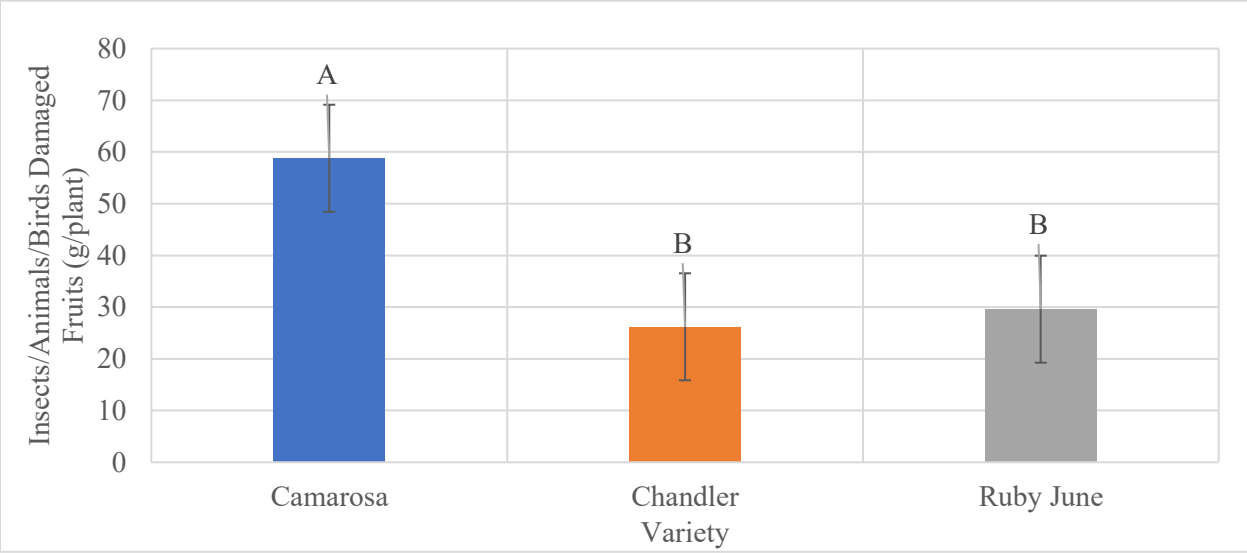

Figure 5: Insects, animals, and birds damaged fruits yield of three strawberry varieties.

Fruit Diseases: In this trial, we identified botrytis and anthracnose as our main fruit pathogens. Increasing the preplant application of N fertilizer for all strawberry varieties resulted in increased disease fruits. The highest diseased fruits were about 225 g/plant on 'Camarosa' with 90 lb/acre of N fertilizer applied in the fall. Spring N fertilizer was not a significant factor in the weight of diseased fruits per plant for all varieties (fig. 6)**.**

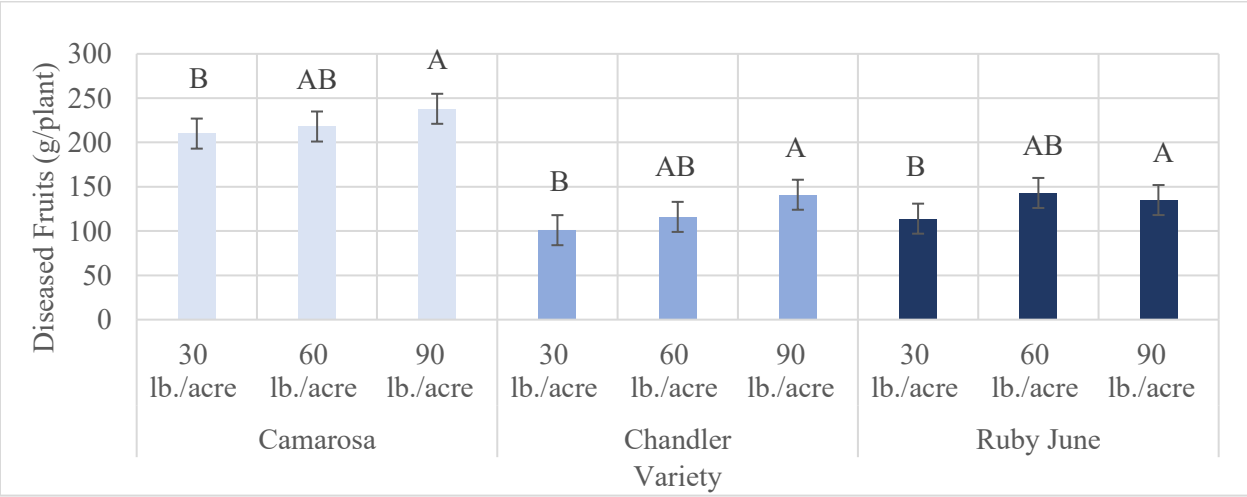

Figure 6: Total yield of three strawberry varieties with three preplant applications of N fertilizer.

Total Soluble Solids (TSS): TSS is an important internal factor for determining ripeness and flavor, which may influence the crop values and the acceptance level by consumers (Basak et al., 2022). Both fall and spring N fertilizer applications did not affect the TSS value for all strawberry varieties (fig.7). 'Ruby June' had the highest TSS value compared with the other two strawberry varieties.

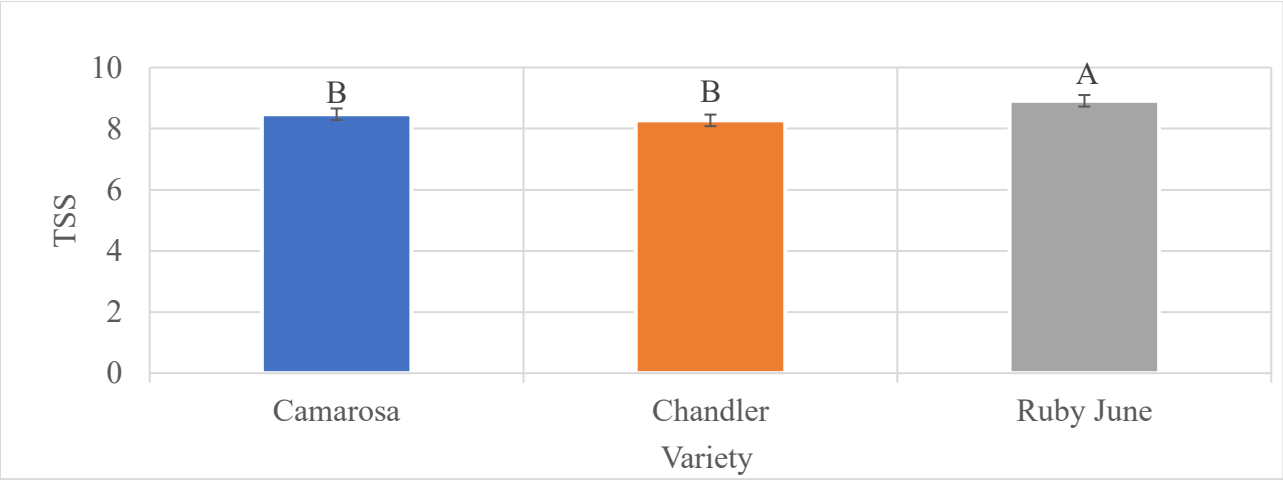

Figure 7: The fruit's total soluble solids (TSS) of three strawberry varieties.

*Plant Canopy***:** The preplant or spring application of N fertilizer did not influence the plant canopy among all strawberry varieties. However, 'Camarosa' had the highest plant canopy compared with other two varieties (Fig. 9).

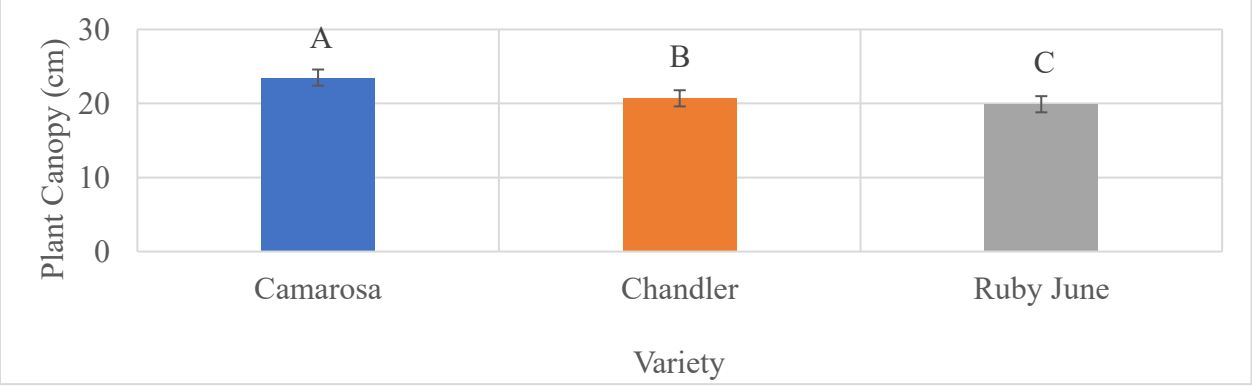

Figure 8: The plant canopy of three strawberry varieties.

Conclusion: The marketable and total yield of strawberry plants were significantly impacted by the preplant application of N fertilizer; however, these effects were not observed for the spring application of N fertilizer. Further, the number of diseased fruits increased with the increase in the preplant fertilizer rate for all strawberry varieties. Other fruit parameters, such as small fruits, deformed fruits, insect, animal, and bird damage, and TSS, were unaffected by preplant and spring N fertilizer applications, but they differed among all three strawberry varieties.

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