

‘Liz’ and ‘Rocco’ Strawberries

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‘Liz’ and ‘Rocco’ are new short-day (June-bearing) strawberry (*Fragaria* × *ananassa* Duch. ex Rozier) cultivars from the North Carolina State University strawberry breeding program in Raleigh, NC. The most outstanding characteristic of ‘Liz’ is its consistently high yields. Total and marketable yields of ‘Liz’ were higher than those of other cultivars tested most years in our trials in North Carolina. Firmness of ‘Liz’ is comparable to ‘Camarosa’. Because of its consistent high yields and moderate firmness, ‘Liz’ can be considered an alternative to ‘Camarosa’. The most outstanding characteristics of ‘Rocco’ are its early season ripening and high soluble solids content. Total yield of ‘Rocco’ is higher than that of ‘Sweet Charlie’ and comparable to cultivars that ripen later in the season. ‘Rocco’ should be considered an alternative to ‘Sweet Charlie’ for early production. U.S. Plant

Patents have been submitted for ‘Liz’ and ‘Rocco’.

Origin

‘Liz’ was selected from seeds from an open-pollinated fruit in 2010. The female parent was NCH 08-07, which was among more than 100 other North Carolina State University (NCSU) strawberry selections in a planting in a completely random design at the Piedmont Research Station in Salisbury, NC. The selection was tested as NCS 10-038 (Fig. 1). The female parent was an unreleased selection that was identified to improve the NCSU strawberry breeding program gene pool and includes genetic background from both eastern and western sources. The paternal lineage includes ‘Chandler’, and the maternal lineage includes the eastern cultivar Honeoye from Cornell Experimental Station

in Cornell, NY, and breeding selections from the University of Florida, University of Arkansas, and USDA-ARS in Poplarville, MS.

‘Rocco’ was selected in 2010 from open-pollinated seeds of fruit from the female parent NCH 05-73P and was tested as NCS 10-156 (Fig. 2). The female parent was an unreleased selection that was made to improve and diversify the germplasm base of the NCSU breeding program gene pool. ‘Rocco’ has a genetic background that includes ‘Northeaster’ from the USDA-ARS in Beltsville, MD, and selections from USDA-ARS in Poplarville, MS. ‘Rocco’ has two sources of *Fragaria chiloensis* germplasm. The selection NCC 86-56 was a seedling from OPSP-11. This germplasm was from wild material collected in the Pacific Northwest area of North America (J.R. Ballington, personal communication). NCS 93-21 (2 MAR-1A inbred) is *F. chiloensis* from southern Chile in South America, which was originally collected as part of a germplasm collection effort (Cameron et al., 1993). According to Ballington, 2 MAR-1A was collected on a beach near a steam entering the Pacific Ocean. The fruit of 2 MAR-1A was small and round with very dark skin and dark flesh color. The juice from the fruit was very dark red and clear (J.R. Ballington, personal communication).

A trial comparing tunnel and field production was conducted for 1 year at the University Farm of North Carolina Agricultural and Technical University in Greensboro, NC (lat. 36°04′N, long. 79°43′W). A replicated trial was conducted for 1 year at the Chilton Research and Extension Center at Auburn University in Clanton, AL (2017–18) (lat. 32°92′N, long. 86°67′W) and at the Southwest Research and Extension Center in Hope, AR (lat. 33°70′N, long. 93°56′W). An on-farm replicated trial was conducted in 2017–18 in Virginia Beach, VA (lat. 35°80′N, long. 80°88′W). In addition, small unreplicated on-farm trials were conducted at 12 farms in North Carolina, 2 farms in South Carolina, 2 farms in Virginia, and 1 farm in Georgia for at least 1 year at each location. Growers who conducted on-farm trials usually provided verbal feedback regarding performance. The most thorough replicated trials were conducted and harvested in North Carolina for 3 years (2015, 2016, and 2018) at the Piedmont Research Station (PRS) in Salisbury, NC (lat. 35°69′N, long. 80°62′W) and for 4 years (2015–18) at the Central Crops Research Station (CCRS) in Clayton, NC (lat. 35°66′N, long. 78°47′W). Data for a total of 7 years of harvest at two locations are reported here. Data from on-farm trials and other states are available upon request.

During all the NCSU research trials, the plants were grown using the annual hill plasticulture (AHP) system (Poling et al., 2005). The soil at the CCRS was a Wagram loamy sand (WaB), with 0% to 6% slope. The soil at the PRS was a Lloyd clay loam (LdB2) with 2% to 8% slope and moderately eroded. Plug plants were established in soil

fumigated with a 65:35 mixture of 1,3-dichloropropene and chloropicrin (Telone C35 Agrosiences). A plastic mulch applicator and bedder applied black plastic mulch on top of the raised-bed soil, and a single drip line was placed during the fumigation process at least 3 weeks before transplanting. The raised beds were 30.5 cm tall, 81.3 cm wide at the base, and 76.2 cm wide at the top; they were established with 1.52 m between the rows. Plug plants were set at 30.5 cm between plants in double staggered rows during the first week of October at the CCRS and during the last week of September at PRS. The trials had three replications of 20 plants in each plot. Fertilizer was applied before planting in the fall at 67 kg·ha⁻¹ N. In the spring, an additional 67 kg·ha⁻¹ N was applied via drip lines at 7.84 kg·ha⁻¹ N per week. Pest and weed control and irrigation schedules followed standard cultural practices recommended for North Carolina (Poling et al., 2005). Leaf debris from the base of the plants was manually removed once in the fall after plants were dormant. Frost and freeze protection using floating rowcovers (spunbound polypropylene) 50.9 g·m⁻² (AgroFabric) and overhead irrigation were implemented at least once every season as needed to protect flowers and developing fruit from injury caused by cold temperatures.

The CCRS and PRS represent two different regions of North Carolina. The CCRS is in the Coastal Plains and has sandy soils and warmer monthly minimum temperatures. The PRS is further inland, has red clay soils, is located in the Piedmont physiographic region, and has cooler monthly minimum temperatures. During the 3 years of these trials, the PRS received an average of 195 more chilling units (1 unit when temperature

is between 0 and 7 °C). These cooler conditions result in a fruiting season that commences ≈5 to 10 d later at the PRS.

Ripe fruit was harvested twice per week at each location. Total fruit weight, marketable fruit weight, and the average weight of 25 berries were collected at each date. Total fruit weight included all fruit harvested from the plots, whereas the marketable weight was the fruit that were heavier than 15 g each and did not have blemishes or significant distortions. Data presented in tables were the cumulative total and marketable weights over the growing season. The average fruit weight for a season was calculated as the mean based on the weight of a randomly selected subsample of 25 marketable fruit from each harvest. Individual fruit weight was calculated from the 25-berry weight at the end of the season. Statistical analysis was performed using PROC GLM (SAS Institute, Cary, NC). Fisher's least significant difference test was conducted using $\alpha = 0.05$. Replicated trials at each North Carolina location included the

industry standards 'Chandler', 'Camarosa', and 'Sweet Charlie' (Chandler et al., 1997; Voth and Bringhurst, 1984; Voth et al., 1994).

Description and Performance

'Liz' is a short-day cultivar adapted to the southeastern United States. 'Liz' is considered a midseason cultivar, and yield peaks 4 weeks after the initial harvest (Fig. 3). 'Liz' continues to produce more fruit than any other cultivar in subsequent weeks.

The total and marketable yields of 'Liz' were higher or comparable to those of the standard cultivars 'Chandler' and 'Camarosa' in both of our replicated trials (Tables 1 and 2). The total and marketable yields of 'Liz' were higher than those of 'Sweet Charlie' in all years and locations except in 2017 at the CCRS, where yields of both cultivars were comparable. In most years at both locations, both total and marketable yields of 'Liz' were higher than those of 'Rocco'.

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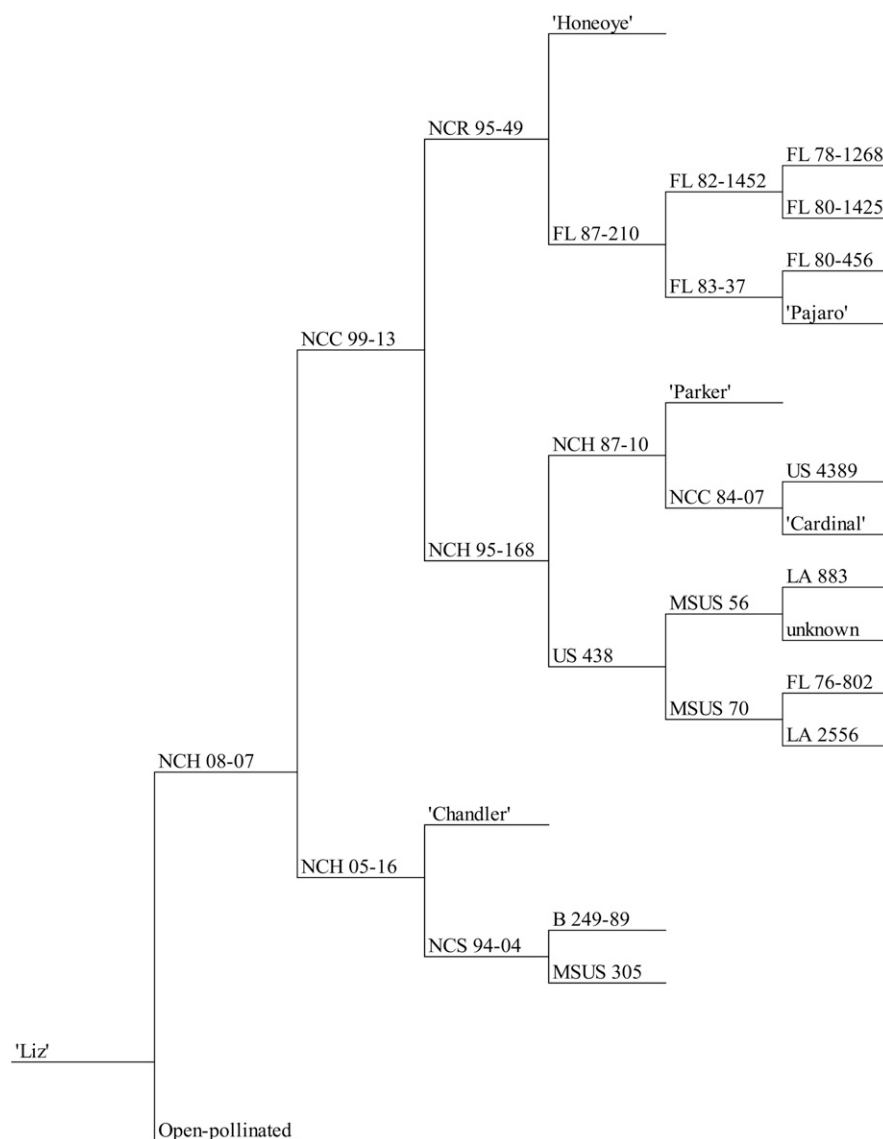


Fig. 1. Pedigree for 'Liz' strawberry. The female parent is listed on the upper side of each bifurcation.

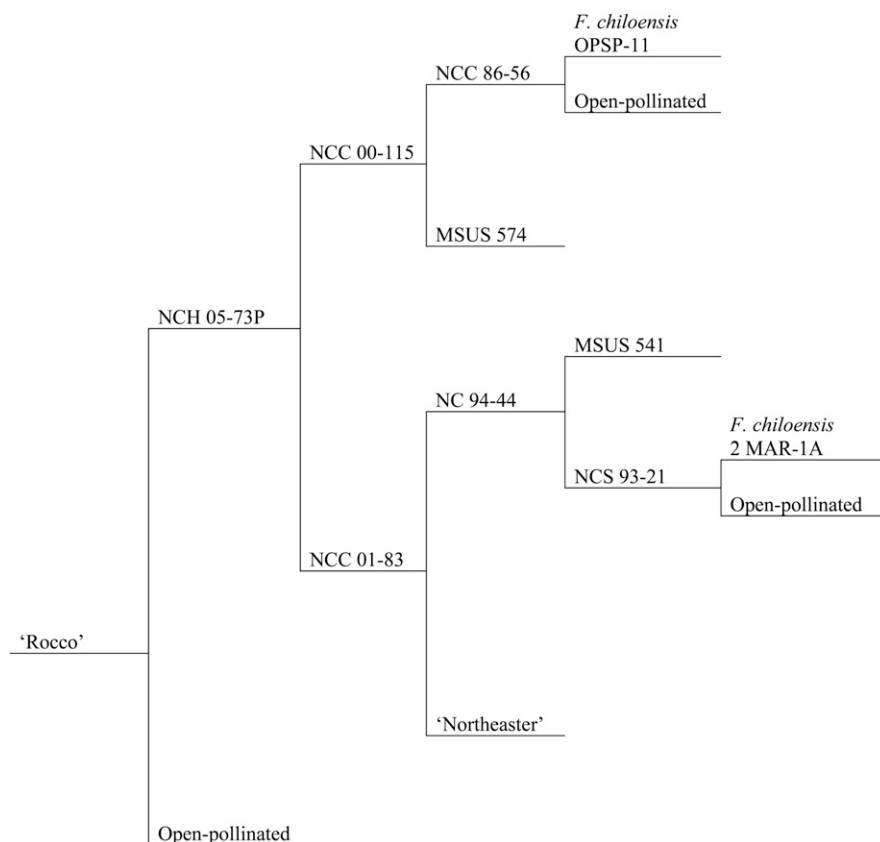


Fig. 2. Pedigree of 'Rocco' strawberry. The female parent is listed on the upper side of each bifurcation.

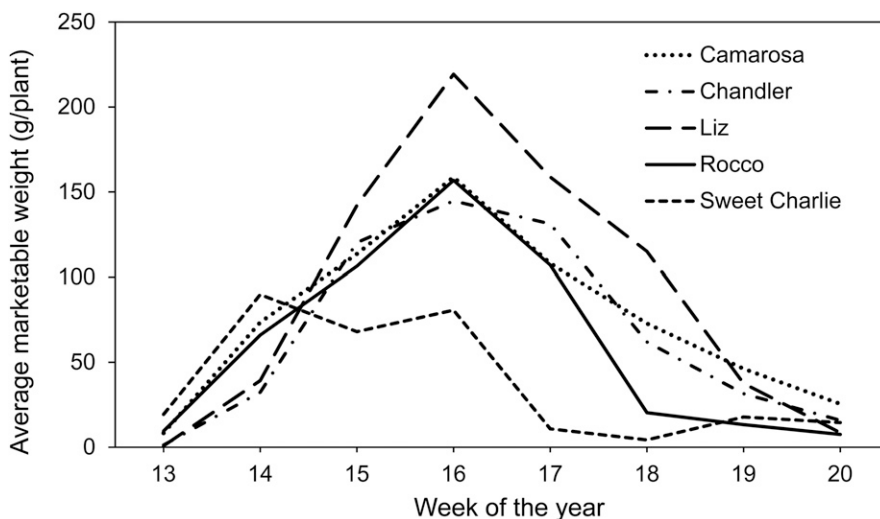


Fig. 3. Average weekly marketable yield per plant of 'Rocco', 'Liz', and three other strawberry cultivars in a replicated trial at the Central Crops Research Station, Clayton, NC, during the 2015–16 growing season.

Table 1. Fruit weight, marketable yields, and total yields for 'Liz' and 'Rocco' and other strawberry cultivars in replicated trials at North Carolina State University, Central Crops Research Station, Clayton, NC, during four seasons.

Cultivar	Fruit wt (g) ^z				Marketable wt (kg·ha ⁻¹)				Total wt (kg·ha ⁻¹)			
	2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018
Liz	23.3 a	17.5 a	23.9 a	19.1 a	26,479 a	30,620 a	26,747 a	21,665 a	28,036 ab	33,784 a	42,179 a	36,122 a
Chandler	20.0 ab	14.4 b	20.6 ab	17.5 ab	25,932 a	23,207 b	14,715 a	17,365 ab	30,032 a	28,804 ab	25,198 a	28,962 ab
Rocco	20.3 ab	14.6 b	19.7 b	15.8 b	18,728 ab	20,858 b	18,868 a	11,762 b	20,855 b	23,994 b	23,378 a	19,314 b
Camarosa	19.6 ab	18.2 a	23.1 ab	15.3 b	6,915 c	26,113 ab	23,045 a	11,219 b	10,807 c	28,725 ab	33,283 a	23,909 b
Sweet Charlie	17.1 b	14.2 b	20 ab	NA ^y	11,063 bc	13,146 c	19,419 a	NA	12,243 c	14,510 c	23,372 a	NA

^zMeans within a column followed by the same letter are not significantly different ($P > 0.05$) according to the least significant difference test.

^yNot applicable, cultivar not included in the trial this year.

Fruit size of 'Liz' was medium to large, with weight ranging from 16.4 to 23.3 g (Fig. 4; Tables 1 and 2). In general, 'Liz' fruit weight was greater than that of 'Sweet Charlie' in all but 1 year, and in most years it was comparable to that of 'Camarosa' and 'Chandler'. The external fruit color of 'Liz' when ripe was 53A on the Royal Horticultural Society (RHS) (2007) Color Chart red group, and the flesh was 47A on the red group of the chart, with some white stripes (Fig. 4) (RHS, 2007).

Overall, trials at other universities indicated that the performance of 'Liz' was acceptable, and the researchers were in favor of recommending 'Liz' to growers in their state on a trial basis. When grown organically in Greensboro, NC, in high tunnels, the 'Liz' total yield was 60% higher and the marketable yield was 68% higher than when grown in the open field. A trial at the Chilton Regional Research and Extension Center at Auburn University (data not shown) included 12 cultivars, including 'Rocco' and 'Liz'. Total and marketable yields of 'Liz' were significantly lower than those of 'Camarosa' and 'Chandler' but comparable to those of 'Sweet Charlie'. Fruit weight of 'Liz' was comparable to that of 'Camino Real', 'San Andreas', and 'Strawberry Festival' (data not shown). At the on-farm trial conducted in Virginia Beach, VA, 'Liz' had total and marketable yields comparable to those of 'Chandler' and larger fruit than 'Chandler', 'Camarosa', 'Ruby June', and 'Rocco' (Samtani et al., 2018). During the single-year trial at the University of Arkansas in Hope, AR, marketable yield and fruit weight of 'Liz' were comparable to those of 'Chandler' and 'Camarosa' in 2018 (data not shown).

'Rocco' is a short-day cultivar adapted to the Southeastern United States. 'Rocco' was consistently among the first cultivars to ripen in our trials. The first harvest of 'Rocco' and 'Sweet Charlie' occurred on the same day in the same week (Fig. 3), 1 week ahead of the industry standard 'Chandler'. 'Rocco' continued to produce fruit in subsequent weeks and peaked at the same time as 'Chandler'.

The total and marketable yields of 'Rocco' were higher or comparable to those of 'Camarosa' at both CCRS and PRS in most of the trial years (Tables 1 and 2). The total and marketable yields of 'Rocco' were comparable to those of 'Chandler' in all but 1 year at one location. The total and marketable yields of 'Rocco' were higher than those of 'Sweet Charlie' in 4 years and comparable to

Table 2. Fruit weight, marketable yields, and total yields for ‘Liz’ and ‘Rocco’ and other strawberry cultivars in replicated trials at North Carolina State University, Piedmont Research Station, Salisbury, NC during three seasons.

Cultivar	Fruit wt (g) ²			Marketable wt (kg·ha ⁻¹)			Total wt (kg·ha ⁻¹)		
	2015	2016	2018	2015	2016	2018	2015	2016	2018
Liz	22.5 a	16.4 a	19.1 a	27,804 a	33,126 a	22,709 a	32,317 a	40,192 a	34,478 a
Chandler	18.0 bc	16.9 a	14.7 b	23,370 ab	21,452 b	15,772 bc	31,545 a	28,856 b	29,873 ab
Rocco	18.9 abc	18.3 a	14.5 b	14,884 bc	22,897 ab	16,757 ab	18,001 b	27,337 b	23,725 b
Camarosa	20.4 ab	21.8 a	14.9 b	8,925 c	23,187 ab	10,463 c	11,532 b	27,390 b	22,318 b
Sweet Charlie	14.9 c	16.7 a	NA ³	9,626 c	13,636 b	NA	12,427 b	16,487 c	NA

²Means within a column followed by the same letter are not significantly different ($P > 0.05$) according to the least significant difference test.

³Not applicable, cultivar not included in trial this year.



Fig. 4. Fruit of ‘Liz’ strawberries, whole and longitudinally sliced.



Fig. 5. Fruit of ‘Rocco’ strawberries, whole and longitudinally sliced.

those of ‘Sweet Charlie’ in 6 years of the trials. In most years at both locations, both total and marketable yields of ‘Rocco’ were lower than those of ‘Liz’.

Fruit size of ‘Rocco’ was considered medium (Fig. 5; Tables 1 and 2), with weights ranging from 14.5 to 20.3 g. In all but 1 year, the fruit size of ‘Rocco’ was comparable to that of ‘Sweet Charlie’, ‘Camarosa’, and ‘Chandler’. At the CCRS in 2016, the fruit size of ‘Camarosa’ was larger than that of all of the standard cultivars and ‘Rocco’. ‘Rocco’ fruit can have raised achenes some years, but this was not observed every year. The fruit external color was equivalent to 53A on the RHS Color Chart red group; when fruit was cut lengthwise, it had a 47A red core according to the chart, with some white stripes (Fig. 5) (RHS, 2007).

When organically grown for a spring crop in a high tunnel and in an adjacent open field at NC A&T in Greensboro, NC, the total and marketable yields of ‘Rocco’ were 34% and 50% higher in the tunnel than in the open field (data not shown). The trial at the Chilton Research and Extension Center at Auburn University (data not shown) included 10 cultivars in addition to ‘Rocco’ and ‘Liz’.

Total and marketable yields of ‘Rocco’ were significantly lower than those of ‘Camarosa’ and ‘Chandler’ but comparable to those of ‘Sweet Charlie’. In addition, ‘Rocco’ and ‘Liz’ appeared to have more resistance to leaf scorch (*Diplocarpon earlianum*) than other cultivars in the trial. During the on-farm trial conducted in VA, ‘Rocco’ had the highest marketable yield when compared with ‘Chandler’, ‘Camarosa’, ‘Ruby June’, and ‘Liz’ (Samtani et al., 2018). ‘Rocco’ produced fruit 4 d earlier than ‘Chandler’, and more than 1 week earlier than ‘Camarosa’. At the University of Arkansas in Hope, AR, marketable yield and fruit weight of ‘Rocco’ were comparable to those of ‘Chandler’ in 2018.

Fresh fruit postharvest attributes of ‘Rocco’ and ‘Liz’ were measured at the Plants for Human Health Institute in Kannapolis, NC, and those results have been reported previously (Perkins-Veazie et al., 2016). In brief, when stored for 8 d, ‘Rocco’ had soluble solids contents of 7.8 and 8.7 at 0 and 8 d after harvest, respectively. This was higher than that of other cultivars and selections tested in this study on these dates. It also had comparable or lower fruit-quality attributes (overall appearance, fruit shrivel, fruit darkness, firmness) than ‘Chandler’ and ‘Camarosa’.

Perkins-Veazie et al. (2016) also quantified major fruit chemical components in the strawberries. ‘Rocco’ had comparable total anthocyanin and phenolic content, but it had a lower flavonoid content (mg/100 g dry weight fruit) than the two standard cultivars.

‘Liz’ and ‘Rocco’ were not screened for major pathogens common to North Carolina. However, in our trials, plants of ‘Liz’ and ‘Rocco’ were as susceptible as ‘Chandler’ and ‘Camarosa’ to the soil-borne pathogens *Colletotrichum gloeosporioides* and *C. acutatum*. Pest chemical control was conducted throughout all years of the study based on North Carolina standard recommendations (Poling et al., 2005) to protect the crop from these pathogens; no plant mortality was incurred.

The most outstanding characteristic of ‘Liz’ was its consistently high yields. Growers should consider it as an alternative to ‘Camarosa’ in southeastern production systems. Postharvest evaluations indicated that the firmness of ‘Liz’ was adequate after 8 d of storage; therefore, it could be shipped only short distances (Perkins-Veazie et al., 2016).

The most outstanding characteristics of ‘Rocco’ were its high soluble solids content and early season of production. Growers looking for an early alternative to ‘Sweet Charlie’ in southeastern production systems should consider planting ‘Rocco’. Fruit of ‘Rocco’ was moderately soft; therefore, it is best suited for pick-your-own or local markets.

U.S. Plant Patent Applications have been submitted for ‘Liz’ (16/602,013) and ‘Rocco’ (16/602,017). The nuclear stock plants for propagation have been tested for 22 viruses by the NCSU Micropropagation and Repository Unit. Micropropagules are available from the North Carolina State University Micropropagation and Research Unit. Information regarding obtaining propagules, licensing, or a list of nurseries is available from G. Fernandez. Genetic fingerprints using a modified set of six simple-sequence repeats (SSR) markers developed by the USDA-ARS (Bassil et al., 2006) of ‘Liz’ and ‘Rocco’ are available on request.

Literature Cited

- Bassil, N.V., M. Gunn, K. Folta, and K. Lewers. 2006. Microsatellite markers for *Fragaria* from ‘Strawberry Festival’ expressed sequence tags. *Mol. Ecol. Notes* 6:473–476.
- Cameron, S.J., T.M. Sjulín, J.R. Ballington, S.H. Shanks, Jr., C.E. Muñoz, and A. Lavin. 1993. Exploration, collection and evaluation of Chilean *Fragaria*: Summary of 1990 and 1992 Expedition. *Acta Hort.* 348:65–74.
- Chandler, C.K., E.E. Albrechts, C.M. Howard, and J.K. Brecht. 1997. ‘Sweet Charlie’ Strawberry. *HortScience* 32:1132–1133.
- Perkins-Veazie, P., J. Pattison, G.E. Fernandez, and G. Ma. 2016. Fruit quality and composition of two advanced North Carolina strawberry selections. *Intl. J. Fruit Sci.* 16(Suppl.):220–227.
- Poling, E.B., G. Krewer, and J.P. Smith. 2005. Southeast Regional Strawberry Plasticulture Production Guide. 30 Dec. 2019. <<https://smallfruits.org/files/2019/06/2005culturalguidepart1bs1.pdf>>.
- Royal Horticultural Society. 2007. RHS colour chart. 5th ed. Royal Horticultural Society, London, UK.
- Samtani, J.B., D. Liu, S. Das, J. Christman, L. Yoder, T. Baker, and G. Fernandez. 2018. Variety and germplasm evaluations at grower farms in Virginia, 2018. *Virginia Strawberry Association News*. Fall 2018.
- Voth, V. and R.S. Bringhurst. 1984. ‘Chandler’. Plant Patent USPP5262P. 24 July 1984.
- Voth, V., D. Shaw, and R. Bringhurst. 1994. ‘Camarosa’. Plant Patent 8708P. 5 May 1994.