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'NC-Davie' and 'NC-Duplin' Pickling Cucumber Hybrids

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Four pickling (processing) cucumber inbreds (NC-54, NC-55, NC-56, and NC-57) and two pickling cucumber hybrids ('NC-Davie' and 'NC-Duplin'), were developed at North Carolina State University. As with most cucumber cultivars released from N.C. State, 'NC-Davie' and 'NC-Duplin' were named for places around the state. 'NC-Davie' is the F_1 of NC-54 × NC-55, and 'NC-Duplin' is the F_1 of NC-56 × NC-57. The four inbreds have been self-pollinated past the S_{12} generation, and were developed from the North Carolina Elite Determinate Pickling (NCEDP) cucumber population. The NCEDP population was developed by 1) crossing elite hybrids and inbreds with NCSU M 21 dwarf-determinate inbred in 1983; 2) intercrossing the determinate F_2 with determinate hybrids and inbreds; and 3) intercrossing the F_1 to form a population for use in recurrent selection. Selection methods were developed that optimized gain for yield and other traits (Wehner, 1989). Selection in the NCEDP population was for fruit shape, and total, marketable and early yield in the spring season, as well as for resistance to foliar fungal diseases in the summer season. The main diseases in the summer were anthracnose [*Colletotrichum orbiculare* (Berk. and Curt.) Arx] and gummy stem blight [*Didymella bryoniae* (Auersw.) Rehm]. In addition to yield, earliness, quality and disease resistance, the cucumber families were selected for production of sufficient seeds to plant the test and intercross plots, rapid seed germination and emergence, rapid vine growth and flowering, and proper fruit type.

Origin

The NC-54, NC-55, NC-56, and NC-57 inbreds, and 'NC-Davie' and 'NC-Duplin' hybrid pickling cucumbers were developed from crosses of dwarf-determinate NCSU M 21 with elite pickling cucumbers having high yield, earliness, fruit quality, and disease resistance (Fig. 1). NCSU inbred M 21 was used to introduce the dwarf-determinate plant type into elite inbreds and hybrids. All had high disease resistance and American pickling type fruit. Half the inbreds used were gynoecious and half were monoecious. In addition, Gy 2 and 'Clinton' had small seedcell, Gy 4 had high yield, Harris 4J73 F_1 had good general performance, and WI 2757 had seedling resistance to 7 diseases. The inbreds were crossed to make elite gynoecious hybrids, the hybrids crossed with NCSU M 21, the F_1 self pollinated, and the F_2 selected for determinate type (Fig. 1). The determinate F_2 were backcrossed to the elite gynoecious hybrids, the BC_1 self pollinated, and 64 plots of the BC_1S_1 intercrossed in a field isolation block with 24 plots of determinate M 21, M 27, 'Castlepik 2012', and Castlehy 2014. That intercross block was used as the cycle 0 of the North Carolina Elite Determinate Pickle (NCEDP) population. The NCEDP population was then improved for disease resistance, yield, earliness, and fruit quality through 9 cycles of recurrent selection.

Populations were improved by testing in the spring season followed by intercrossing the best families in isolation blocks in the summer season. Once-over harvest was simulated by spraying the foliage with paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) at 0.6 $kg \cdot ha^{-1}$ when the checks had approximately 10% oversized fruit by number (Wehner et al., 1984). Oversized fruit exceeded 51 mm in diameter. Half-sib families were evaluated for 5 traits: total yield (number of fruit per plot), early yield (number of oversized fruit per plot), marketable yield (total yield minus crooked and nubbin fruit), fruit shape rating (1 = poor to 9 = excellent), and a simple weighted index (Wehner, 1982). The simple weighted index was calculated as SWI = 0.2(total yield)/2 + 0.3(early yield) + 0.2(% marketable yield)/10

Fig. 2. Fruit of 'NC-Davie' (**top**) and 'NC-Duplin' (**bottom**) hybrid pickling cucumbers.

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+ 0.3(fruit shape). Total yield was divided by 2 and percentage marketable yield was divided by 10 to give them the same range (1 to 9) as the other traits. Each trait was then given a weight (20% or 30%) to reflect its importance in the breeding program. SWI was weighted (70%) toward yield traits, but with significant emphasis on quality since shape rating (30%) is related to fruit appearance, and marketable yield (20%) accounts for crooked and nubbin fruit.

Inbred lines were evaluated in trials for yield, earliness, fruit quality, and disease resistance using optimized trialing methods (Wehner, 1987). Recommended cultural practices (summarized by Schultheis, 1990) were used throughout the experiments. Monoecious inbred 'Sumter' was planted in field border rows and end tiers as a pollenizer, and to provide border competition for the trial. Irrigation was applied when needed for a total of 25 to 40 mm per week (including rainfall). Fertilizer was incorporated at a rate of 90–39–74 kg·ha^{-1} (N–P–K) before planting, with an additional 34 kg/ha N applied at the vine-tip-over (4 to 6 true leaf) stage. Herbicide [Curbit, ethalfluralin, *N*-ethyl-*N*-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine] and insecticide (Sevin, carbaryl, 1-Naphthyl N-methylcarbamate) were applied at recommended rates.

In the Spring 1996 greenhouse, 384 half sib families from the NCEDP C9 population were tested in the seedling stage for resistance to scab and anthracnose, and the most resistant plants transplanted for testing with powdery mildew. The most resistant 346 plants were self pollinated to produce S1 lines. The 346 S1 lines were then tested in the seedling stage in the greenhouse for resistance to scab and anthracnose, and the most resistant plants transplanted for testing with powdery mildew. Simultaneously, the 346 S1 lines were tested in the field for gynoecy, determinate habit, yield, earliness, and fruit quality. The lines with the best performance were then planted in the greenhouse to advance the materials to S9 inbred lines.

Table 1. Horticultural performance (yield, earliness, quality, and disease resistance) of new semi-determinate pickling cucumber hybrids (NC-Davie and NC-Duplin) compared with standard cultivars (all others). Data are summarized over three replications and six harvests for two crop production seasons (spring and summer) at the Horticultural Crops Research Station near Clinton, N.C., for 2001 through 2003.

Population	Total yield[z] (Mg·ha^{-1})	Early yield[y] (%)	Cull yield (%)	Fruit shape[x]	Fruit color[w]	Seed cell[v]	Firmness (lb)	Length to diam ratio	Anthracnose rating[u]
2001[t]									
NC-Davie	32.2	70	18	7.9	7.5	4.8	14	2.9	3.3
NC-Duplin	29.4	63	19	7.8	7.4	4.5	14	3.1	2.5
Napoleon	34.5	73	26	7.3	8.3	6.3	13	3.3	5.3
LSD (5%)	8.8	12	12	0.8	0.6	0.8	2	0.2	1.3
Spring 2002									
NC-Davie	24.3	42	28	6.3	7.3	4.7	17	3.1	2
NC-Duplin	20.4	41	28	6.7	7.7	5.3	18	3.0	2
M 21	12.4	18	25	7.3	6.7	6.7	15	3.6	1
Napoleon	12.6	21	25	6.0	8.0	6.5	16	3.2	1
Calypso	13.1	17	28	6.7	6.0	6.0	18	2.9	2
Raleigh	18.5	50	33	6.7	7.3	5.3	17	3.4	2
Johnston	26.2	38	32	8.0	8.0	6.7	18	3.5	2
Wis. SMR 18	7.8	9	41	5.0	3.7	3.7	17	3.0	6
LSD (5%)	12.7	14	17	1.7	0.9	1.9	2	0.4	2
Summer 2002 (hot, dry conditions)									
NC-Davie	8.4	54	44	5.7	6.7	5.7	14	3.1	3
NC-Duplin	6.6	50	43	6.3	7.0	4.7	14	2.9	4
M 21	3.0	42	45	6.0	6.7	5.7	12	3.4	4
Napoleon	6.4	54	35	5.3	7.8	5.0	14	3.1	4
Calypso	8.1	61	32	6.0	6.0	5.0	14	3.0	4
Raleigh	8.1	62	33	5.7	6.7	5.7	14	3.3	3
Johnston	5.1	53	46	6.3	6.7	7.3	14	3.2	3
Wis. SMR 18	6.2	64	39	6.0	4.3	4.3	12	3.3	7
LSD (5%)	3.7	17	18	1.5	1.5	2.2	3	0.5	1
Spring 2003									
NC-Davie	24.7	42	17	8.0	6.3	5.0	14	3.0	1
NC-Duplin	24.8	45	20	6.7	7.0	4.7	15	3.2	1
M 21	23.6	48	21	6.7	6.7	7.0	13	3.7	2
Napoleon	24.9	47	13	7.7	8.7	6.3	13	3.0	2
Calypso	28.3	45	19	7.0	5.0	6.0	15	3.1	2
Raleigh	29.4	57	15	7.7	7.3	6.3	14	3.2	2
Johnston	29.0	51	18	6.7	7.0	7.0	15	3.9	1
Wis. SMR 18	22.9	38	32	7.0	3.7	5.0	15	3.0	6
LSD (5%)	7.0	10	8	1.5	1.5	1.6	3	0.5	1
Summer 2003									
NC-Davie	22.2	62	32	7.3	6.0	4.7	16	2.9	3
NC-Duplin	20.6	59	20	7.3	6.7	6.0	15	3.1	2
M 21	19.1	54	18	7.0	7.3	6.3	15	3.8	3
Napoleon	22.4	61	12	7.7	9.0	8.0	14	2.9	3
Calypso	22.0	67	22	7.0	5.7	6.7	17	3.0	3
Raleigh	25.0	71	20	7.0	6.3	5.3	16	2.9	3
Johnston	25.5	70	17	6.0	8.0	7.0	15	3.5	2
Wis. SMR 18	16.5	54	30	6.0	4.0	3.7	15	2.9	6
LSD (5%)	12.2	13	15	1.4	1.2	1.7	3	0.4	1

[z]Weight of all grades including oversized and cull fruit.
[y]Percent of the six-harvest yield that occurred in the first two harvests.
[x]Fruit shape was rated 1 to 9 (1 to 3 = pointed, crooked, constricted; 4 to 6 = tapered, curved, necked; 7 to 9 = blocky, straight, cylindrical).
[w]Fruit color rated 1 to 9 (1 to 3 = light green, 4 to 6 = medium green, 7 to 9 = dark green).
[v]Seedcell size rated 1 to 9 (1 to 3 = large, 4 to 6 = medium, 7 to 9 = small).
[u]Disease rating taken 1 week after the final harvest, and rated 0 to 9 (0 = none, 1 to 2 = trace, 3 to 4 = slight, 5 to 6 = moderate, 7 to 8 = severe, 9 = dead).
[t]Mean of four environments: spring, summer, Clinton field 1, Clinton field 2.
[s]All four cultivars had a dwarf-determinate rating of 4 to 5 (1 to 3 = dwarf, 4 to 6 = medium dwarf, 7 to 9 = tall), and a gynoecious rating of 5 to 6 (1 to 3 = androecious, 4 to 6 = monoecious, 7 to 9 = gynoecious).

Table 2.

Year	Season	Location–Event
1983	Fall	Greenhouse–M21×(Gy2×Clinton), M21×(Gy4×M21), M21×Harris 4J73, M21×WI2757
1984	Spring	Greenhouse–F_1 (self all)
1984	Fall	Greenhouse–F_2 (backcross elite parents with det F_2)
1985	Spring	Greenhouse–BC_1 (self all)
1985	Summer	Field–Cycle 0 of NCEDP population (isolation intercross of 64 plots of BC_1S_1 with 24 plots of M21, M27, Castlepik2012, Castlehy2014)
1986–92	---	Field population improvement, with cycles C_1–C_7
1993	---	---
1994–95	---	Field population improvement, with cycles C_8–C_9
1996	Spring	Greenhouse–384 HS (test scab, anth, PM, self 1 plant each)
1996	Summer	Greenhouse–346 S_1 (test scab, anth, PM, self 1 plant each)
1996	Summer	Field–352 S_1 (test gyn, det, yield, earliness, quality)
1996	Fall	Greenhouse–36 S_2 (test scab, anth, PM, self 1 plant each)
1997	Spring	Greenhouse–22 S_3 (test scab, anth, PM, self 1 plant each)
1997	Summer	Greenhouse–140 S_4 (test scab, anth, PM, self 1 plant each)
1997	Summer	Field–140 S_4 (test gyn, det, yield, earliness, quality)
1997	Fall	Greenhouse–30 S_5 (test scab, anth, PM, self 1 plant each)
1998	Spring	Greenhouse–57 S_6 (test scab, anth, PM, self 1 plant each)
1998	Summer	Greenhouse–96 S_7 (test scab, anth, PM, self 1 plant each)
1998	Summer	Field–27 S_7 (test gyn, det, yield, earliness, quality)
1999	Spring	Greenhouse–42 S_8 (test scab, anth, PM, self 1 plant each)
1999	Summer	Field–137 S_9 (test gyn, det, yield, earliness, quality)
1999	Fall	Greenhouse–12 S_9 (self, cross 6 gyn × 6 mon)
2000	Spring	Greenhouse–12 S_{10} (self, cross 6 gyn × 6 mon)
2000	Summer	Greenhouse–37 S_{11} (self 10 gyn, 27 mon)
2000	Summer	Field–36 F_1 (test gyn, det, yield, earliness, quality)
2000	Fall	Greenhouse–15 S_{10} (make 15 inbreds, 13 hybrids)
2001	Fall	Greenhouse–6 S_{11} (make 6 inbreds, 3 hybrids)
2002	Spring	Greenhouse–6 S_{12} (make 4 inbreds, 2 hybrids)

In 1999, 12 hybrids were tested in the field using the best 6 gynoecious inbreds as female parents in crosses with the best 6 monoecious inbreds. Hybrids and inbreds were tested in the field for gynoecy, determinate habit, yield, earliness, and fruit quality. Inbreds of the hybrids with the best performance were then planted in the greenhouse to advance the materials to S10 inbred lines. The process was repeated in 2000. Finally, the top three hybrids were then put into the cooperative trials for 2001, 2002, and 2003 (Table 1).

Trials were run in the spring and summer production seasons using a randomized complete block design. Check cultivars (Napoleon and M21 in 2001, then adding Calypso, Raleigh, Johnston, and Wisconsin SMR 18 in 2002 and 2003) were chosen to represent an elite gynoecious hybrid and a determinate monoecious inbred that performed well over the years. Plots were harvested six times (twice weekly). Data were summarized over 3 replications, and 6 harvests for 2 crop production seasons (spring, summer) for 3 years (2001, 2002, 2003) at the Horticultural Crops Research Station near Clinton, NC.

Data from the performance trials were presented for 9 major horticultural traits (Table 1). Total yield was the weight of marketable grades, oversized, and cull fruit summed over six harvests. Early yield was the total weight for the first two harvests. Percentage culls was the weight of crooked and nubbin fruit relative to total fruit weight. The three major fruit quality traits presented were shape, color, and seedcell size. Fruit shape was rated 1 to 9 (1 to 3 = pointed, crooked, constricted; 4 to 6 = tapered, curved, necked; 7 to 9 = blocky, straight, cylindrical), and reflected how straight, uniform, and cylindrical the fruit in a plot were (Strefeler and Wehner, 1986). Fruit color was rated 1 to 9 (1 to 3 = light green, 4 to 6 = medium green, 7 to 9 = dark green). Seedcell size was rated 1 to 9 (1 to 3 = large, 4 to 6 = medium, 7 to 9 = small). Firmness was the amount of force (N) required to punch into the fruit exocarp (skin) and mesocarp (flesh) with an 8 mm diameter tester (McCormick Fruit Tech, Yakima, Wash.). Anthracnose damage to the foliage was rated one week after the 6th harvest (0 = none, 1 to 2 = trace, 3 to 4 = slight, 5 to 6 = moderate, 7 to 8 = severe, 9 = dead). Anthracnose was naturally occurring in the trials since the spring trials were not sprayed with fungicides, and all trials had overhead irrigation to encourage disease spread.

Description

The NC-54, NC-55, NC-56, and NC-57 inbreds, and 'NC-Davie' and 'NC-Duplin' hybrid pickling cucumbers have excellent horticultural characteristics, suitable for use by the processing industry in the U.S. The inbreds and hybrids have medium-sized seeds, with rapid germination and emergence from either cool or warm soil. Vines have semi-determinate growth habit, some lateral branching, and normal-sized, very dark-green leaves, with the crinkled surface characteristic of the determinate plant type. Plants are vigorous, with rapid growth, and flowers and fruit develop early in the vegetative growth stage. NC-54 and NC-56 have dwarf-determinate plant type, with gynoecious sex expression. NC-55 and NC-57 have tall-indeterminate plant type, with monoecious sex expression. All four inbreds produce numerous flowers beginning about 30 d after planting. Hybrids 'NC-Davie' and 'NC-Duplin' are monoecious (similar to 'Napoleon'), but with fewer pistillate flowers than 'Calypso', 'Raleigh', and 'Johnston' and more than NCSU M 21 and 'Wis. SMR 18'.

Fruit color for NC-54, NC-55, NC-56, and NC-57 inbreds, and 'NC-Davie' and 'NC-Duplin' hybrid pickling cucumbers is mottled, and medium- to dark-green, with lighter color at the blossom end. Fruit have few, large tubercles (warts), and are white spined. Fruit seedcell size of 'NC-Davie' and 'NC-Duplin' is medium (subjective rating of 5 to 6 vs. 6 to 7 for the checks, where 1 is large and 9 is small).

'NC-Davie' and 'NC-Duplin' are resistant to the major disease problems in the southeastern U.S., ranked in importance by St. Amand and Wehner (1991). They are resistant to anthracnose (*Colletotrichum orbiculare* (Berk. & Mont.) Arx), powdery mildew (*Sphaerotheca fuliginea* (Schlechtend.:Fr.) Pollacci), and scab (*Cladosporium cucumerinum* Ellis & Arth.). In addition to having semi-determinate habit for easy fruit harvest, 'NC-Davie' and 'NC-Duplin' were better than (or at least as good as) the gynoecious hybrid checks for all traits relating to yield, earliness, fruit quality, and disease resistance (Table 1).

Availability

Seeds of the inbreds and hybrids are available to interested plant breeders who sign an intellectual property agreement. 'NC-Davie' and its parental inbreds NC-54 and NC-55 were licensed exclusively to Zeraim Gedera in 2004.

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