Research Updates

Yield and Virus Resistance of Summer Squash Cultivars and Breeding Lines in North Carolina

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SUMMARY. Yellow and zucchini squash (*Cucurbita pepo* L.) cultigens (breeding lines and cultivars) were evaluated over a 2-year (1995 and 1996) period in North Carolina. Yellow squash cultigens that performed well (based on total marketable yields) were 'Destiny III', 'Freedom III',

'Multipik', XPHT 1815, and 'Liberator III' in Fall 1995 and HMX 4716, 'Superpik', PSX 391, 'Monet', 'Dixie', XPH 1780, and 'Picasso' in Spring 1996. Some of the yellow squash cultigens evaluated had superior viral resistance: XPHT 1815, XPHT 1817, 'Freedom III', 'Destiny III', 'Freedom II', TW 941121, 'Prelude II', and 'Liberator III' in Fall 1995 and XPHT 1815, 'Liberator III', 'Prelude II', and 'Destiny III' in Fall 1996; all these cultigens were transgenic. The yellow squash cultigens that performed well (based on total marketable yields) in the Fall 1995 test had transgenic virus resistance ('Destiny III', 'Freedom III', XPHT 1815, and 'Liberator III') or had the *Py* gene present in its genetic background ('Multipik'). Based on total marketable yields, the best zucchini cultigens were XPHT 1800, 'Tigress', XPHT 1814, 'Dividend' (ZS 19), 'Elite', and 'Noblesse' in Fall 1995; and 'Leonardo', 'Tigress', 'Hurricane', 'Elite', and 'Noblesse' in Spring 1996. The zucchini cultigens with virus resistance were TW 940966, XPHT 1814, and XPHT 1800 in Fall 1995 and XPHT 1800, XPHT 1776, XPHT 1777, XPHT 1814, and XPHT 1784 in Fall 1996. Even though TW 940966 had a high level of resistance in the Fall 1995 test, it was not as high yielding as some of the more susceptible lines. Viruses detected in the field were papaya ringspot virus (PRSV) and watermelon mosaic virus (WMV) for Fall 1995; while PRSV, zucchini yellow mosaic virus (ZYMV), and WMV were detected for Fall 1996. Summer squash cultigens transgenic for WMV and ZYMV have potential to improve yield, especially during the fall when viruses are more prevalent. Most transgenic cultigens do not possess resistance to PRSV, except XPHT 1815 and XPHT 1817. Papaya ringspot virus was present in the

squash tests during the fall of both years. Thus, PRSV resistance must be transferred to the transgenic cultigens before summer squash can be grown during the fall season without the risk of yield loss due to viruses.

Summer squash includes several types including scallop, crookneck, straightneck, vegetable marrow, cocozelle, and zucchini (Paris, 1996), and refers to those cultivars of these types that are used at the immature stage (Whitaker and Davis, 1962). Zucchini and yellow summer squash are important types grown in the United States. About 5000 acres of zucchini and yellow summer squash are harvested annually in North Carolina (North Carolina County Agents' Estimates, 1995). Production problems in North Carolina from July to November include distortion and discoloration of fruit due to virus infection. Viruses can also suppress squash production at other times of the year in other states depending on location. Problematic viruses include cucumber mosaic virus (CMV), papaya ringspot virus (PRSV, formerly known as watermelon mosaic virus 1), watermelon mosaic virus (WMV, formerly known as watermelon mosaic virus 2), squash mosaic virus (SqMV), and zucchini yellow mosaic virus (ZYMV) (Zitter et al., 1996). The precocious yellow gene (*Py*) in yellow squash offers an advantage by masking the green symptoms in virus-infected fruit. Fruit from plants with *Py* tend to remain yellow in color when infected with viruses compared to virus susceptible cultivars that do not have the gene (Snyder et al., 1993).

Recommendations for squash cultivars in the southeastern United States are often based on the season (spring or summer) in which they are grown due to the increase in viruses as the season progresses. In North Carolina, several cultivars are recommended for spring planting (Sanders et al., 1996), including the yellow types 'Dixie', 'Goldbar', 'Lemondrop L', 'Seneca Prolific', 'Picasso', and 'Prelude II' and the zucchini types 'Elite', 'Noblesse', 'Tigress', and 'Dividend'. The cultivars recommended for summer planting (Sanders et al., 1996) in North Carolina include 'Multipik' (*Py*), 'Sunbar' (*Py*), 'Superpik' (*Py*), 'Supersett' (*Py*), 'General Patton' (*Py*), 'Prelude II', 'Tigress' (zucchini), and

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'Dividend' (zucchini). So, there is an extensive list of summer squash cultivars (yellow or zucchini) from which a grower can choose. Asgrow SVS is the first to submit squash cultigens (cultivars or breeding lines) for evaluation that have been transformed to condition resistance to several viruses. Genes

that produce a coat protein were transferred from the different viruses into the DNA of squash. Squash that have the coat protein genes in their genetic background have resistance to viral infection. These transgenic squash lines have resistance to ZYMV, WMV, and in some cases CMV. Several transgenic

squash hybrids had outstanding virus resistance in field trials (Arce-Ochoa et al., 1995). Other seed companies are using traditional breeding methods to provide virus resistance. The objective of these trials was to evaluate field performance in terms of yield, quality, and virus resistance of current culti-

Table 1. Seed source, characteristics, plant vigor, and yield (number of 20 lb. boxes/acre) for the yellow squash cultigens evaluated during Fall 1995 and Spring 1996.^a

Cultigen	Seed source ^y	Plant type ^x	Plant vigor ^w	Early harvest				All harvests			
				1	Marketable	Culls	Total	1	Marketable	Culls	Total
Fall 1995											
Destiny III	AG	C(T)	9.0	231	285	122	407	807	1041	479	1,520
Freedom III	AG	C(T)	7.8	237	354	115	469	695	966	440	1,406
Multipik	HM	S(Py)	6.3	194	218	20	238	786	960	93	1,053
XPHT 1815 ^v	AG	S(T)	7.5	134	164	16	180	751	942	86	1,028
Liberator III	AG	S(T)	8.3	184	239	76	315	671	902	453	1,355
General Patton	AG	S(Py)	7.0	217	278	32	310	750	885	150	1,035
XPHT 1817 ^v	AG	S(T)	7.3	158	216	66	282	709	877	313	1,190
Prelude II	AG	C(T)	7.8	156	213	54	267	626	858	341	1,199
Bandit	AC	C	7.5	174	208	16	224	758	837	115	952
PSX 391	PS	S(Py)	8.8	100	179	13	192	601	834	349	1,183
Freedom II	AG	C(T)	7.8	155	259	93	352	592	793	394	1,187
SR 1807	SS	S	6.3	47	66	4	70	583	649	83	732
TW 941121	AG	C(T)	8.8	125	174	65	239	429	587	485	1,072
HMX 4716	HM	S(Py)	7.3	40	58	7	65	466	552	44	596
Dixie	AG	C	7.0	100	165	83	248	296	454	583	1,037
Goldbar	PS	S	7.5	113	162	66	228	306	428	510	938
Medallion	AC	C	6.8	65	101	54	155	281	412	530	942
Pavo	AG	C	8.3	105	170	167	337	255	396	780	1,176
Suncx 9651	SS	S	6.5	195	268	136	404	287	382	677	1,059
SR 1840	SS	S	6.0	2	4	8	12	156	215	220	435
Lemondrop L	AG	S	6.5	38	60	10	70	150	178	246	424
SR 1839	SS	S	3.5	20	23	24	47	86	101	160	261
LSD ($P \leq 0.05$)	---	---	1.2	70	88	37	100	48	63	42	73
Spring 1996											
HMX 4716	HM	S(Py)	---	329	329	5	334	1,727	1,755	22	1,777
Superpik	HM	S(Py)	---	366	438	30	468	1,637	1,723	47	1,770
PSX 391	PS	S(Py)	---	272	300	107	407	1,665	1,707	125	1,832
Monet	FM	S(Py)	---	435	437	41	478	1,628	1,640	63	1,703
Dixie	AG	C	---	426	458	22	480	1,506	1,639	77	1,716
XPHT 1780	AG	C	---	289	409	38	447	1,327	1,556	121	1,677
Picasso	FM	C	---	409	457	107	564	1,379	1,552	211	1,763
Multipik	HM	S(Py)	---	312	314	20	334	1,471	1,494	65	1,559
Supersett	HM	C(Py)	---	349	356	28	384	1,458	1,467	75	1,542
Prelude II	AG	C(T)	---	276	347	58	405	1,267	1,412	107	1,519
Sunre 9613	SS	C(Py)	---	141	398	113	511	839	1,387	300	1,687
General Patton	AG	S(Py)	---	349	353	0	353	1,350	1,373	19	1,392
Lemondrop L	AG	S	---	282	290	49	339	1,138	1,364	84	1,448
Seneca Prolific	RB	S	---	247	279	120	399	1,204	1,335	151	1,486
Sunre 9657	SS	S(Py)	---	143	145	9	154	1,242	1,251	23	1,274
XPHT 1817 ^v	AG	S(T)	---	192	219	9	228	1,030	1,121	97	1,218
XPHT 1790	AG	S(T)	---	171	222	3	225	1,014	1,113	88	1,201
LSD ($P \leq 0.05$)	---	---	---	120	123	75	155	270	245	102	285

^aData presented are the mean of four replications. Early harvest is the sum of harvests 1, 2, and 3 (Fall 1995) or 1, 2, 3, and 4 (Spring 1996); and all harvests are the sum of harvests 1 to 11 (Fall 1995) or 1 to 12 (Spring 1996). Cultigens are ranked by total marketable yields of all harvests. Marketable yield is the sum of grade 1 fruits and grade 2 fruits (yields for grade 2 can be obtained by subtracting yields of grade 1 from total marketable yields).

^bSeed source is AC = Abbott and Cobb, AG = Asgrow, FM = Ferry-Morse, HM = Harris Moran, PS = Petoseed, RB = Robeson, and SS = Sunseed.

^cPlant type is crookneck (C) or straightneck (S). T indicates that cultigen is transgenic and Py indicates that cultigen has precocious yellow gene.

^wPlant vigor rated 25 Sept. 1995 and measured by 1 = low and 10 = high.

^xCultigen was dropped from the seed company's breeding program.

gens supplied by various seed companies.

Materials and methods

Yellow and zucchini squash cultigen evaluations were conducted over a 2-year period with three planting dates (Fall 1995, Spring 1996, and Fall 1996) at the Horticultural Crops Research Station in Clinton, N.C. (fall plantings) and the Central Crops Research Station in Clayton, N.C. (spring planting). The most promising cultigens from several seed companies were tested each year. Yellow squash cultigens and their sources evaluated in 1995 and 1996 are listed in Tables 1 and 2 and zucchini squash cultigens and their sources evaluated in 1995 and 1996 are listed in Tables 3 and 4. Some of the cultigens were tested both years.

The experiments were set up in a randomized complete-block design with four replications. Plots were 20 ft long with a 5-ft alley between plots. Center-to-center row spacing was 3.5 (Clinton, N.C.) or 3.75 (Clayton, N.C.) ft and in-row spacing was 2 ft (10 plants/plot). Standard cultural practices for squash grown in North Carolina were used. Before planting, 800 lb/acre of 10-10-10 (fall tests) or

500 lb/acre of 12-6-24 (spring test) was applied, and plots were sidedressed with 125 lb/acre (fall tests) or 250 lb/acre (spring test) of 15-0-14. Recommended pest control was used (College of Agriculture and Life Sciences, 1995). For weed control, Prefar 4E was applied preplant at 4 qt/acre (fall tests) or Prefar 2E at 5 qt/acre (spring test). Several insecticides were applied during the growing season, including Ambush, Lannate, Sevin, and Thiodan. Fungicides applied included Benlate, Bravo, Dithane, and Manzate.

FALL 1995 TEST. Yellow (22) and zucchini (14) squash cultigens were evaluated. Seeds were planted 8 Aug. Harvest frequency was every 2 to 4 days for a total of 11 harvests. Harvest of the zucchini began 18 Sept. [41 days after planting (DAP)] and ended 19 Oct. (72 DAP). Harvest of the yellow squash began 15 Sept. (38 DAP) and ended 16 Oct. (69 DAP).

Plant establishment data were taken $\approx$ 4 weeks after planting. The fruit weight for one, two, and cull grades were collected at each harvest and classified according to USDA specifications (USDA, 1984). However, when oversized fruit were collected, they were classified into each category based on shape (since fruit were not

harvested as frequently had they been in a commercial situation). Yields were reported as the number of 20 lb boxes/acre, which is the standard packaging unit for the commercial industry. Plant vigor ratings were taken for yellow and zucchini squash on 25 Sept. Plant vigor was rated as 1 = low to 10 = high. Fruit color (rated from 1 = white to 5 = dark green) and overall fruit appearance (rated from 1 = poor to 10 = excellent) of the zucchini were rated on 25 Sept. The number of broken plants per plot were counted on 6 Oct. Virus ratings (the number of plants with foliage showing visible virus symptoms based on 10 plants/plot) were made three times over the growing season for yellow and zucchini squash: rating 1 was taken 14 Sept., rating 2 was taken 25 Sept., and rating 3 was taken 6 Oct. Plant foliage samples were taken at or near completion of the last harvest from several yellow squash plants and sent to Asgrow SVS (San Juan Bautista, Calif.) to assay for the presence of CMV, PRSV, SqMV, tobacco ring-spot virus, tomato ringspot virus, WMV, and ZYMV.

SPRING 1996 TEST. Yellow (17) and zucchini (13) squash cultigens were evaluated. The Spring 1996 yellow and zucchini squash tests were

Table 2. Seed source, characteristics, plant vigor ratings, and field grades of yellow squash cultigens tested during Fall 1996.^z

Cultigen	Seed source ^y	Plant type ^x	Plant vigor ^w	Marketable (%)	Misshapen ^v (%)	Virus ^u (%)	Cull ^t (%)
Multipik	HM	S(Py)	6.8	76.9	18.1	5.0	23.1
Supersett	HM	C(Py)	6.3	45.0	30.1	24.9	55.0
Monet	FM	S(Py)	6.5	56.6	30.4	13.0	43.4
XPHT 1815 ^s	AG	S(T)	7.0	59.2	---	---	40.8
Destiny III	AG	C(T)	7.7	15.3	52.1	32.6	84.7
Liberator III	AG	S(T)	7.0	21.9	43.3	34.8	78.1
Superpik	HM	S(Py)	6.8	23.4	42.2	34.4	76.6
SS-6	RG	S(Py)	6.0	48.8	33.4	17.8	51.2
PSX 391	PS	S(Py)	8.0	23.8	39.0	37.2	76.2
Dixie	AG	C	6.0	0.7	49.7	49.6	99.3
Prelude II	AG	C(T)	8.0	3.0	52.0	45.0	97.0
HMX 4716	HM	S(Py)	7.0	37.5	31.3	31.2	62.5
Lemondrop L	AG	S	6.3	0.0	49.6	50.4	100.0
Seneca Prolific	RB	S	6.5	0.0	50.0	50.0	100.0
Sunex 9602	SS	S	5.3	0.0	50.0	50.0	100.0
Sunre 9657	SS	S(Py)	5.5	---	---	---	---
LSD ($P \leq 0.05$)	---	---	1.3	28.2	16.8	15.1	28.2

^zPlants were harvested only once 5 Sept. 1996. Data presented are the means of four replications. Cultigens are ranked according to percentage marketable fruit number/plant.

^ySeed source is AG = Asgrow, FM = Ferry-Morse, HM = Harris Moran, PS = Petoseed, RB = Robeson, RG = Rogers, and SS = Sunseed.

^xPlant type is Crookneck (C) or Straightneck (S). T indicates that cultigen is transgenic and Py indicates that cultigen has precocious yellow gene.

^wPlant vigor rated 29 Aug. 1996 and measured by 1 = low and 10 = high.

^vPercentage of misshapened or malformed fruit.

^uPercentage of fruit with virus symptoms.

^tPercentage of cull fruit includes misshapened and fruit with virus symptoms.

^sCultigen was dropped from the seed company's breeding program.

planted 25 Apr. Harvesting began 5 June (41 DAP) and ended 28 June (64 DAP) for both squash types. Harvests were every 2 to 3 days (three times per week). The number of plants surviving in each plot were taken $\approx$ 4 weeks after planting and the weight of one, two, and cull fruit grades were obtained at each harvest.

FALL 1996 TEST. Yellow (16) and zucchini (15) squash cultigens were evaluated. The Fall 1996 tests were planted 1 Aug. with only one harvest on 5 Sept. (36 DAP) due to total plot destruction caused by hurricane Fran. Plant stand for each plot was taken $\approx$ 4 weeks after planting. The percentage of one, two, and cull fruit grades (misshapen fruit and virus infected fruit) based on fruit number were collected.

Plant vigor ratings (described previously) were taken 29 Aug. for both squash types. Virus symptom severity, rated from 0 = no foliage symptoms to 10 = severe symptoms including leaf strapping, mottling, and mosaic over the plant, and the number of plants with foliage showing virus symptoms (mild or severe) based on 10 plants/plot, were recorded for both squash types on 29 Aug. Plant foliage samples were obtained from remnants of the yellow and zucchini plants following hurricane Fran and sent to Asgrow SVS to assay for the presence of CMV, PRSV, SqMV, WMV, and ZYMV.

Results

Yellow squash evaluations

FALL 1995 TRIALS. High early mar-

ketable yields (sum of first three harvests) $>$ 235 boxes/acre were obtained for 'Freedom III', 'Destiny III', 'General Patton', 'Freedom II', Sunex 9651, and 'Liberator III' (Table 1). 'Destiny III' and 'Freedom III' produced more culls than the other early high-yielding cultigens. The greatest total marketable yields ($>$ 900 boxes/acre) were obtained for 'Destiny III', 'Freedom III', 'Multipik', XPHT 1815, and 'Liberator III'. However, 'Multipik' and XPHT 1815 produced considerably fewer culls than 'Destiny III', 'Freedom III', and 'Liberator III'. Sunex 9651 also produced a high number of culls for early and total yields, with marketable total yields being substantially lower due to the excessive number of fruit with virus symptoms. Three

Table 3. Seed source, characteristics, plant vigor, and yield (number of 20 lb boxes/acre) for zucchini cultigens evaluated during Fall 1995 and Spring 1996.^z

Cultigen	Seed source ^y	Plant vigor ^x	Early harvest				All harvests			
			1	Marketable	Culls	Total	1	Marketable	Culls	Total
Fall 1995										
XPHT 1800 ^w	AG	8.0	339	569	16	585	1,399	1,902	131	2,033
Tigress	HM	8.0	368	551	117	668	1,517	1,845	200	2,045
XPHT 1814 ^w	AG	8.8	331	474	72	546	1,154	1,627	235	1,862
Dividend (ZS 19)	RG	7.3	264	350	56	406	1,284	1,555	214	1,769
Elite	HM	7.8	264	381	69	450	1,206	1,519	143	1,662
Noblesse	HM	8.3	331	461	79	540	1,062	1,462	336	1,798
Revenue (ZS 15)	RG	7.8	332	432	30	462	1,235	1,397	169	1,566
Hurricane	SS	6.5	289	469	127	596	776	1,156	296	1,452
TW 940866 ^w	AG	8.5	204	338	101	439	885	1,124	229	1,353
Jaguar	HM	7.5	118	206	84	290	727	1,110	302	1,412
XPHT 1774 ^w	AG	8.8	266	340	86	426	829	1,034	170	1,204
Sunre 9732	SS	7.5	111	125	65	190	695	797	278	1,075
SR 1705	SS	6.3	8	8	3	11	391	495	114	609
Puma	HM	7.0	46	74	4	78	373	481	82	563
LSD (P ≤ 0.05)	---	1.0	119	124	65	130	333	403	132	387
Spring 1996										
Leonardo	FM	---	1653	741	198	939	2,042	2,255	303	2,558
Tigress	HM	---	464	546	216	762	1,945	2,161	288	2,449
Hurricane	SS	---	656	689	223	912	1,699	2,055	278	2,333
Elite	HM	---	549	622	187	809	1,745	2,016	226	2,242
Noblesse	HM	---	527	583	177	760	1,531	1,912	223	2,135
Sunre 9732	SS	---	272	303	94	397	1,768	1,875	102	1,977
Senator	AG	---	405	423	286	709	1,591	1,776	379	2,155
HMX 4715	HM	---	472	610	24	634	1,402	1,754	124	1,878
XPHT 1814 ^w	AG	---	294	320	151	471	1,480	1,695	163	1,858
Dividend (ZS 19)	RG	---	277	297	183	480	1,344	1,654	206	1,860
Revenue (ZS 15)	RG	---	279	307	147	454	1,260	1,540	200	1,740
XPHT 1776 ^w	AG	---	279	297	106	403	1,357	1,388	124	1,512
XPHT 1805 ^w	AG	---	123	124	37	161	1,193	1,323	100	1,423
LSD (P ≤ 0.05)	---	---	146	165	121	208	466	467	140	497

^zData presented are the mean of four replications. Early harvest is the sum of harvests 1, 2, and 3 (Fall 1995) and 1, 2, 3, and 4 (Spring 1996); all harvests are the sum of harvests 1 to 11 (Fall 1995) and harvests 1 to 12 (Spring 1996). Cultigens are ranked by the marketable yield of all harvests. Marketable yield is the sum of grade 1 fruit and grade 2 fruit (yields for grade 2 can be obtained by subtracting yields of grade number 1 from total marketable yields).

^ySeed source is AG = Asgrow, FM = Ferry-Morse, HM = Harris Moran, RG = Rogers, and SS = Sunseed.

^xPlant vigor rated 25 Sept. 1995 and measured by 1 = low and 10 = high.

^wVirus-resistant transgenic cultigen.

Table 4. Seed source, plant vigor ratings, and field grades of zucchini, Fall 1996.^z

Cultigen	Seed source ^y	Plant vigor ^x	Marketable (%)	Cull (%)
XPHT 1800 ^w	AG	6.8	92.2	7.8
XPHT 1777 ^w	AG	6.8	94.2	5.8
Tigress	HM	8.0	87.5	12.5
Revenue (ZS 15)	RG	6.0	85.1	14.9
XPHT 1814 ^w	AG	6.8	90.6	9.4
XPHT 1776 ^w	AG	6.8	93.6	6.4
Hurricane	SS	7.0	64.9	35.1
Noblesse	HM	7.5	50.7	49.3
Dividend (ZS 19)	RG	7.3	72.9	27.1
Puma	HM	6.8	72.9	27.1
Bella	SS	7.0	54.7	45.3
Senator	AG	7.8	32.4	67.6
Elite	HM	7.5	26.1	73.9
XPHT 1784 ^w	AG	7.5	83.3	16.7
HMX 4715	HM	6.3	6.0	94.0
LSD ($P \leq 0.05$)	---	1.1	24.2	24.2

^zPlants were harvested only once 5 Sept. 1996. Data presented are the mean of four replications. Cultigens are ranked according to percentage marketable fruit.

^ySeed source is AG = Asgrow, HM = Harris Moran, RG = Rogers, and SS = Sunseed.

^xPlant vigor rated 29 Aug. 1996 and measured by 1 = low and 10 = high.

^wVirus resistant transgenic cultigen.

cultivars ('Destiny III', 'Freedom III', and 'Liberator III') produced high early and total marketable yields compared to the other cultigens, but a substantial number of culls were associated with these cultigens. These transgenic cultigens lacked PRSV resistance, which apparently infected more plants and became more widespread as the season progressed. This resulted in more cull fruit with virus symptoms in cultigens that lacked or had resistance to other viruses. Only XPHT 1815 and XPHT 1817 did not develop virus symptoms on fruit, since PRSV resistance has been incorporated into these cultigens through traditional breeding methods. Cultigens that were not transgenic tended to produce more culls as a result of other viruses that were present in the field earlier than PRSV. Three cultivars recommended for spring planting in North Carolina ('Dixie', 'Goldbar', and 'Lemondrop L') yielded substantially less marketable fruit since they are highly susceptible to viruses. Total yields (including culls) of several cultivars lacking virus resistance were comparable to cultigens with virus resistance. The cultigens that yielded >900 marketable boxes/acre had some level of virus resistance ['Destiny III' (transformed 'Dixie'), 'Freedom III' (transformed 'Pavo'), XPHT 1815, and 'Liberator III' (transformed 'Lemondrop L')] or had *Py* present in its genetic back-

ground ('Multipik'). The number of plants per plot showing symptoms of virus infection were determined and the number of plants with symptoms increased as the season progressed (Fig. 1). Several transgenic cultigens tested (all from Asgrow SVS) had a high level of resistance to the viruses present. These were XPHT 1815, XPHT 1817, 'Freedom III', 'Destiny III', 'Freedom II', TW 941121, 'Prelude II', and 'Liberator III' (Fig. 1). The viruses detected in foliage samples (Table 5) were PRSV in 'Liberator III', which has resistance to WMV, CMV, and ZYMV, and WMV in XPH 1780, 'Multipik', and SR 1807, which lacks

specific virus resistance.

Plant stands in most cases were $\geq 93\%$; however, five cultivars had stands <90% (data not shown). 'Lemondrop L' only had a 60% stand but produced a lot of culls due to virus susceptibility (Table 1). Increasing the stand to 95% would not have increased the marketable yield substantially due to the presence of viruses. HMX 4716 had a 73% stand, and more fruit would have been produced with an adequate stand, but this increase would not have equalled the highest-yielding cultigens. XPHT 1817 also produced a 73% stand and, with a good stand ($\geq 95\%$), it might have been ranked 2 or 3 for total yields. XPHT 1815 produced a 80% plant stand and might have been the second or third best cultigen in total marketable yields with an adequate stand. TW 941121 had a good stand at 88%, and the increased yield with a 95% stand would not have increased yields substantially.

Broken plants were generally not a problem in this test, but 'Goldbar' and XPHT 1815, had significantly more broken plants, at 17% and 13%, respectively (data not shown). All other cultigens had <8% broken plants, with most having 0% broken plants. Plant vigor ratings indicated that the transgenic lines were generally more vigor-

Fig. 1. Incidence of virus symptoms (number of plants with foliar virus symptoms per 10 plants evaluated) in 22 yellow squash cultigens on three dates, Fall 1995. Cultigens are ranked by the third rating. LSDs (≤ 0.05) were 1.3, 2.0, and 2.3 for 14 Sept., 25 Sept., and 6 Oct., respectively.

Table 5. Viruses detected in foliage of various squash cultigens in fall plantings in 2 years.²

Cultivar	1995	1996
Yellow squash		
Destiny III	---	PRSV
Dixie	---	PRSV, ZYMV
Liberator III	PRSV	PRSV
Multipik	WMV	PRSV, ZYMV, WMV
Prelude II	---	PRSV
SR 1807	WMV	---
Sunre 9657	---	PRSV, ZYMV, WMV
XPH 1780	WMV	---
XPHT 1776	---	None detected
Zucchini		
Dividend	---	PRSV, ZYMV, WMV
Elite	---	PRSV, ZYMV, WMV
Tigress	---	PRSV

²Plant foliage during the fall trials of 1995 and 1996 was mailed to Asgrow SVS and assayed for the presence of papaya ringspot virus (PRSV), watermelon mosaic virus (WMV), cucumber mosaic virus (CMV), zucchini yellow mosaic virus (ZYMV), squash mosaic virus (SqMV), tobacco ringspot virus (fall 1995 only), and tomato ringspot virus (fall 1995 only).

ous than nontransgenic cultigens; however, notable exceptions were PSX 391 and 'Pavo' (Table 1). PSX 391 has a zucchini plant type, possibly contributing to its better vigor, but produces a yellow summer squash fruit.

SPRING 1996 TRIALS. The best early marketable yields (sum of first four harvests) were achieved with 'Dixie', 'Picasso', 'Superpik', 'Monet', XPH 1780, and Sunre 9613. 'Picasso' and PSX 391 produced many cull fruit early in the season. HMX 4716, 'Superpik', PSX 391, 'Monet', 'Dixie', XPH 1780, and 'Picasso' had high total marketable yields (>1500 boxes/acre) (Table 1). HMX 4716 had the greatest yield and produced few cull fruit. Whereas, 'Picasso', PSX 391, and XPH 1780 were high-yielding cultigens that produced many culls (>120 boxes/acre). 'Dixie', 'Picasso', 'Superpik', and 'Monet' produced high early and total yields compared to the other cultigens tested, but 'Picasso' produced many compared to the other three cultigens. All cultigens except XPHT 1817 had >98% plant stands, and, even with an increased plant stand from 83% to 95%, XPHT 1817 would not have improved substantially in yield to be in the top grouping for total yields since it was one of the lowest yielding cultigens (Table 1). All cultivars recommended for spring planting in North Carolina ('Dixie', 'Seneca Prolific', and 'Lemondrop L') yielded a sufficient crop, with 'Dixie' being the superior yielding cultivar. Some of the cultivars recommended for summer

planting in North Carolina were included in this spring test and yielded well: 'Multipik', 'Superpik', 'Supersett', and 'General Patton'.

FALL 1996 TRIALS. Fruits were harvested only once (yield data not shown) due to the destruction of the squash plants caused by hurricane Fran. Plant stands were >93% in most cases; only two cultigens—'Seneca Prolific' (88%) and XPHT 1815 (85%)—had slightly lower plant stands (data not shown). 'Multipik' produced the best percentage of marketable fruit (Table 2). Most of the fruit produced by the other cultigens were unmarketable, except for 'Monet' and XPHT 1815. All transgenic cultivars had <25% marketable fruit. Cultigens that were not transgenic or did not have *Py* ('Dixie', 'Lemondrop L', 'Seneca Prolific', and Sunex 9602) produced >99% cull fruit.

Cultigens that had the lowest percentage of cull fruit showing symptoms of virus infection were 'Multipik', 'Monet', SS-6, and 'Supersett'. All four of these cultigens have *Py*, which helps mask the virus infection on the fruit. Several other cultigens had *Py* in their backgrounds ('Superpik', PSX 391, and HMX 4716) but had >30% of their fruit showing symptoms of virus infection (Table 2). Cultigens with the best plant vigor ratings were transgenic ('Prelude II', 'Destiny III', 'Liberator III', and XPHT 1815) or had *Py* present in their genetic backgrounds (PSX 391, HMX 4716, 'Multipik', and 'Superpik') (Table 2). This did not, however, increase the percentage of marketable fruit.

Virus symptom severity ratings and the number of plants per plot with foliage showing symptoms of virus infection indicated that four cultigens had excellent resistance to the viruses present (Fig. 2): XPHT 1815, 'Liberator III', 'Prelude II', and 'Destiny III' (all transgenic resistant sources). All other cultigens tested had >90% of the plants showing virus symptoms. Viruses detected from foliage samples were PRSV in 'Destiny III', 'Dixie', 'Liberator III', 'Multipik', 'Prelude II', and Sunre 9657; ZYMV in 'Dixie',

Fig. 2. Fall 1996 virus ratings (virus symptom severity rating and number of plants with foliage showing virus symptoms based on 10 plants/plot) of the 16 yellow squash cultigens evaluated. Ratings were taken 29 Aug. 1996. Cultigens are ranked by virus symptom severity rating. LSDs (≤ 0.05) were 1.2 for virus severity symptom rating and number of plants with virus symptoms.

Table 6. Zucchini plant and fruit evaluations, Fall 1995.^z

Cultivar	Broken plants (%)	Color	Fruit appearance
Noblesse	0.0	3.8	6.3
SR 1705	0.0	3.3	3.3
XPHT 1814	2.5	3.0	7.3
Jaguar	2.5	5.0	5.5
XPHT 1800	3.1	3.5	7.0
Dividend (ZS 19)	3.1	2.8	8.0
Sunre 9732	6.4	3.4	2.0
Hurricane	15.6	3.8	6.8
Elite	18.1	3.1	7.3
Tigress	19.3	3.5	6.5
Puma	25.0	3.5	3.3
TW 940866	30.3	4.4	5.5
Revenue (ZS 15)	37.5	2.3	9.0
XPHT 1774	45.0	3.6	7.3
LSD	24.2	0.6	2.5

^zEvaluation for broken plants was 6 Oct. 1995, and color and overall fruit appearance were rated 25 Sept. 1995. Color was rated from 1 = white to 5 = dark green and fruit appearance was rated from 1 = poor to 10 = excellent.

'Multipik', and Sunre 9657; and WMV in 'Multipik' and Sunre 9657 (Table 5).

Zucchini squash evaluations

FALL 1995 TRIALS. XPHT 1800, 'Tigress', XPHT 1814, 'Hurricane', and 'Noblesse' produced the highest early marketable yields (>400 boxes/acre) (Table 3). Early marketable yields might have been much higher for 'Hurricane' and 'Tigress', except for their high percentage of culls. Highest total marketable yields (>1300 boxes/acre) were obtained with XPHT 1800, 'Tigress', XPHT 1814, 'Dividend' (ZS 19), 'Elite', 'Noblesse', and 'Revenue' (ZS 15). 'Noblesse' produced many cull fruit compared to the other high-yielding cultigens. XPHT 1800, 'Tigress', XPHT 1814, and 'Noblesse' had high early and total marketable yields. Plant stands were >90% for all cultigens except 'Puma', which had a 55% stand. If 'Puma' had ≥95% stand, yields would have increased greatly, although it probably would not have been the highest in the trial (Table 3). The cultivars recommended for North Carolina ('Tigress', 'Elite', and 'Noblesse') yielded well in this fall test; however, 'Noblesse' produced an excessive amount of cull fruit. Some cultigens were more prone to plant breakage: XPHT 1774, 'Revenue' (ZS 15), TW 940866, and 'Puma' had a large percentage of broken plants (at least 25%) (Table 6). Several zucchini cultigens produced dark green fruit, including 'Jaguar', TW 940866, 'No-

blesse', and 'Hurricane'. 'Revenue' (ZS 15), 'Dividend' (ZS 19), 'Elite', XPHT 1814, and XPHT 1774 produced some of the most attractive fruit.

Most zucchini cultigens evaluated were susceptible to the viruses present in the field. However, TW 940866 had a high level of resistance (Fig. 3) but was not as high yielding as some of the more susceptible lines (Table 3). Other cultigens having small numbers (≤4 of 10 plants/plot) of infected plants at the third rating were XPHT 1814, XPHT 1800, and 'Puma'. Another transgenic line, XPHT 1774, had ≈50% of its plants showing symptoms of virus infection (Fig. 3). 'Elite' and 'Noblesse' yielded well and are recommended for commercial production in

North Carolina. They had much less virus resistance than those cultigens mentioned above. 'Tigress' and 'Dividend', more recently released cultivars, produced high yields and maintained good virus resistance during the first two ratings (Fig. 3), but, by the third rating, foliar viral symptoms of these two hybrids had increased substantially. There was little symptom development for many of the cultigens in the first two ratings, while a rapid increase in viral symptom development occurred before the third rating. The number of plants with symptoms of virus infection increased as the season progressed. Plant vigor ratings indicated that four transgenic lines (XPHT 1774, XPHT 1814, XPHT 1800, and TW 940866) and two nontransgenic cultigens ('Noblesse' and 'Tigress') were the most vigorous (Table 3). Generally, it appears that increased plant vigor is associated with virus resistance.

SPRING 1996 TRIALS. Plant stands were 100% for all cultigens. The best early yielding cultigens (>500 marketable boxes/acre) were 'Leonardo', 'Hurricane', 'Elite', HMX 4715, 'Noblesse', and 'Tigress' (Table 3). All early yielding cultigens except HMX 4715 produced many cull fruit. The highest yielding cultigens based on the total marketable yields (>1800 boxes/acre) were 'Leonardo', 'Tigress', 'Hurricane', 'Elite', 'Noblesse', and Sunre 9732 (Table 3). All but Sunre 9732 produced many cull fruit. The cultivars recommended for North Carolina ('Tigress', 'Elite', and 'Noblesse') yielded well in this test. The cultigens

Table 7. Zucchini fruit quality, Spring 1996.

Cultivar	Color ^a	Shape ^b	Overall ^c
Noblesse	4.3	1.8	2.0
SU 9732	4.0	1.3	1.0
XPHT 1814	3.5	1.4	1.5
Dividend	3.5	1.5	1.8
Hurricane	3.1	1.5	1.5
Senator	3.1	1.4	1.5
Elite	3.0	1.3	1.3
XPHT 1776	3.0	1.3	1.3
Tigress	3.0	1.3	1.8
XPHT 1805	3.0	1.4	1.8
Revenue	2.5	1.3	1.5
HMX 4715	0.0	1.8	2.0
LSD	0.4	0.6	0.7

^aFruit color rated as 0 = orange-yellow, 1 = light green, and 5 = dark green.

^bShape rated as 1 = very straight and 3 = very crooked.

^cOverall rating was 1 = best and 2 = worst.

Fig. 3. Incidence of virus symptoms (number of plants with foliar virus symptoms/10 plants evaluated) in 14 zucchini cultivars on three dates, Fall 1995. Cultigens are ranked by the third rating. LSDs (≤ 0.05) were 2.2, 2.2, and 3.0 for Sept. 14, Sept. 25, and Oct. 6, respectively.

that had darker-green fruit were 'Noblesse', SU 9732, XPHT 1814, and 'Dividend', while HMX 4715 had an orange-yellow epidermis (Table 7). Cultigens were similar in shape (based on straightness). SU 9732, 'Elite', and XPHT 1776 had the best overall ratings of the zucchini cultivars evaluated.

FALL 1996 TRIALS. Fruit were harvested only once (yield data not shown) due to the destruction of the plants caused by hurricane Fran. Plant stands were >98% for all cultivars except 'Puma' (88%). XPHT 1800, XPHT 1777, XPHT 1814, XPHT 1776, 'Tigress', 'Revenue', and XPHT 1784 produced the fewest cull fruit (Table 4) and had better virus resistance than most other cultivars (Fig. 4). 'Noblesse' and 'Elite' produced $\approx 50\%$ and 75% cull fruit, respectively (Table 4). Most of the transgenic lines had few cull fruit (<20%). Virus symptom severity ratings indicated that XPHT 1800, XPHT 1776, XPHT 1777, XPHT 1814, XPHT 1784, 'Tigress', 'Puma', 'Dividend', and 'Revenue' had some level of resistance to the viruses present (Fig. 4). However, only XPHT 1800, XPHT 1776, XPHT 1777, XPHT 1814, and XPHT 1784 were more resistant than the other cultivars

to the viruses present based on the number of plants per plot that developed symptoms (all had less than three out of ten plants per plot showing symptoms of virus infection). 'Tigress', 'Puma', 'Dividend', and 'Revenue' had >70% of their plants exhibiting viral symptoms. Viruses detected from the plant foliage samples were PRSV in 'Dividend', 'Tigress', and 'Elite'; ZYMV in 'Dividend' and 'Elite'; and WMV in 'Dividend' and 'Elite' (Table 5). None of these viruses nor CMV or SqMV were detected in the foliage of XPHT 1776. The cultivars with a high amount of plant vigor were 'Tigress', 'Senator', 'Noblesse', 'Elite', and XPHT 1784 (Table 4).

Discussion

These summer squash evaluations are part of a continuous process for determining cultivar recommendations. Several tests over different locations and years are needed to deter-

mine the consistency of yield as new cultivars are released. Certain cultivars, such as 'Multipik' (yellow), 'Elite' (zucchini), 'Tigress' (zucchini), and 'Noblesse' (zucchini), yielded well in the spring and fall. Several cultivars (especially some of the transgenic lines) yielded well in one season but were not evaluated during another season; so, yield consistency over seasons could not be determined for these cultivars.

Most of the yellow squash cultivars recommended for use in North Carolina produced average to superior yields. 'Dixie' yielded well in the spring but did not produce well in the fall due to its virus susceptibility. However, when CMV, WMV, and ZYMV resistances were incorporated into 'Dixie' (named 'Destiny III'), superior marketable and total yields were obtained. Similarly, 'Lemondrop L' had low yields in the fall, but, when virus resistances were incorporated (named 'Liberator III'), yields improved. 'Goldbar' also did not yield well in the fall, again due to its lack of virus resistance, and it was not included in the spring trial. 'Multipik' produced fewer cull fruit compared to most cultivars evaluated and was a top-yielding cultivar in the fall and spring. 'Seneca Prolific' was one of the lowest yielders in the Spring

Fig. 4. Fall 1996 virus ratings (virus symptom severity rating and number of plants with foliage showing virus symptoms based on 10 plants per plot) of the 15 zucchini cultivars evaluated. Ratings were taken 29 Aug. 1996. Cultigens are ranked by virus symptom severity rating. LSDs (≤ 0.05) were 1.3 and 2.4, for virus symptom severity rating and number of plants with virus symptoms, respectively.

1996 test (not tested Fall 1995) but has yielded well compared to other cultivars when it was released. 'Superpik' was not tested in Fall 1995, but was a top yielding cultigen in the Spring 1996 test. 'Superset' was not tested Fall 1995; but, in the Spring 1996 test, it produced average yields. Other cultigens that yielded well (based on total marketable yields) in the coastal plain of North Carolina were 'Freedom III', XPHT 1815, 'General Patton', and XPHT 1817 in Fall 1995 and HMX 4716, PSX 391, 'Monet', XPH 1780, and 'Picasso' in Spring 1996. Cultigens (all transgenic) that had virus resistance in the Fall 1995 and 1996 tests were XPHT 1815, XPHT 1817, 'Freedom III', 'Destiny III', 'Freedom II', TW 941121, 'Prelude II', and 'Liberator III'. Two cultigens that had resistance to CMV, WMV, ZYMV, and PRSV—XPHT 1815 and XPHT 1817—were discontinued in the Asgrow SVS breeding program (D. Groff, personal communication) since they had unacceptable fruit shape. The highest yielding cultigens (based on total marketable yields) in the Fall 1995 test were those that were transgenic or had *Py* in their genetic background.

The zucchini cultivars recommended for growers in North Carolina ('Tigress', 'Noblesse', and 'Elite') yielded well in the fall and spring. Other zucchini squash cultigens that had superior yields were XPHT 1800, XPHT 1814, 'Dividend' (ZS 19), 'Revenue' (ZS 15) in Fall 1995 and 'Leonardo', 'Hurricane' and Sunre 9732 in Spring 1996. Even though 'Hurricane' yielded well in the spring test, it produced an average yield in the Fall 1995 since it was susceptible to viruses. Cultigens with the most virus resistance were transgenic: TW 940866, XPHT 1800, XPHT 1814, XPHT 1776, XPHT 1777, and XPHT 1784.

Virus resistance in summer squash

is usually not needed during the spring in North Carolina. Generally, the transgenic lines that were evaluated did not yield as well as most other cultigens in spring. However, the yellow and zucchini squash transgenic cultigens had a yield advantage (marketable fruit) in the fall over most other cultigens evaluated. Viruses can be one of the most limiting factors in squash production, especially during the fall; for a summer squash plant to be consistently productive during this time of the year, it must possess virus resistance or have *Py* in its genetic background. The virus resistance in these transgenic lines enabled them to produce a greater marketable yield during the fall than most other cultigens that did not have virus resistance. The incidence and severity of viruses varies from year to year in squash (Zitter et al., 1996). In our tests, the presence of viruses was much greater in Fall 1996 than 1995 (Figs. 1–4). Regardless if a cultigen was transgenic or had the *Py* gene, a greater percentage of marketable fruit was obtained for all cultigens when virus severity and incidence was less (i.e., Fall 1995 compared to Fall 1996). To date, most transgenic lines are not resistant to PRSV. The exceptions in our tests were XPHT 1815 and XPHT 1817, which had no virus symptom development the entire production season even when PRSV was present in the field; PRSV resistance has been incorporated into XPHT 1815 and XPHT 1817 via traditional breeding methods. Incorporation of PRSV resistance into susceptible transgenic cultigens would provide more complete protection from viruses that significantly affect squash production in the United States.

Virus resistance in summer squash is important, but there are cultural management strategies that can be used to control viruses. One such strategy for virus suppression is the use of a crop protectant (i.e., stylet oils) (Ad-

ams, 1991). These oils can effectively prevent virus transmission. Timing of spray application, the proper spray equipment, and added labor management and expense must all be factored in when considering this alternative method of disease control compared with resistant cultivars.

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