Foundations of Yield Improvement in Watermelon

Gabriele Gusmini and Todd C. Wehner*

ABSTRACT

High yield is a major goal for watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] breeders. The objective of this study was to measure yield in a diverse set of watermelon cultivars to identify high-yielding germplasm for use in breeding programs. Phenotypic variation for fruit yield in a diverse set of 80 watermelon cultivars was studied in the field in North Carolina. Yield was evaluated in replicated experiments of three environments (combinations of 2 yr and two locations), and two to four replications per environment. Plots were harvested one to two times, depending on the average maturity of the fruits at the first harvest. The highest yield overall was obtained from 'Mountain Hoosier' and 'Starbrite'. Some of the new, elite hybrid cultivars were in the top-yielding group, but there were old, inbred cultivars in the top group as well. Consistent and significant yield differences among the 80 cultivars across environments indicates genetic variation for the trait. In addition, high-yielding cultivars for use in breeding programs were identified. Watermelon breeders interested in developing new, high-yielding cultivars should make use of top performers in this study in their breeding programs.

High yield is a major goal for watermelon breeders (Mohr, 1986). Earlier efforts in watermelon breeding involved development of new cultivars of different types with high fruit quality and early maturity in the late 1800s. By 1900, 'Angeleno', 'Chilean', 'Florida Favorite', 'Georgia Rattlesnake', 'Cole Early', 'Kleckley Sweet', and other open-pollinated cultivars had been on the market for many years (Whitaker and Jagger, 1937). In the 20th century, high-yielding cultivars became a major goal for public and private breeders. Hybrids were popular among private breeders for protection of intellectual property and because of the results of many studies, mainly in the 1950s and 1960s, showing heterosis in watermelon. The studies measured heterosis as well as general (GCA) and specific (SCA) combining ability in watermelon (Brar and Sidhu, 1977; Brar and Sukhija, 1977; Nandpuri et al., 1974, 1975; Sidhu and Brar, 1977, 1985; Sidhu et al., 1977a, 1977b). Major problems with those studies were that heterosis was inconsistent across experiments, and that results were based on diallel or top crosses of elite inbreds, not on a random set of lines from a population. More recent studies of the effects of reciprocal crosses on yield components in watermelon have been contradictory (Gill and Kumar, 1988; Rajendran and Thamburaj, 1993; Sachan and Nath, 1976). Often, the experiments included only a small number (N_{max} = 10) of nonrandomly chosen elite cultivars as parents, so the results are valid only for those specific crosses and are not generally applicable.

Dep. of Horticultural Science, North Carolina State Univ., Campus Box 7609, Raleigh, NC 27695-7609. Received 9 Mar. 2004. *Corresponding author (todd_wehner@ncsu.edu).

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677 S. Segoe Rd., Madison, WI 53711 USA

Taken as a group, the studies indicate the presence of heterosis in watermelon and the importance of GCA in the choice of parents for hybrid production. Ferreira et al. (2002) substantiated these conclusions, testing seven intercrossing populations with evaluation of reciprocal crosses. There were significant GCA, SCA, and reciprocal combination effects, along with additive effects for all yield traits, except for the number of days to first female flower and number of seeds per fruit. A second study evaluated GCA and SCA for tetraploid females crossed with diploid males for the production of triploid seeds (Souza et al., 2002). This study confirmed a higher magnitude of GCA effects than SCA effects and strong additive effects for yield components, except for earliness and some qualitative indexes (i.e., hollowheart incidence). Today, watermelon breeders are less interested in studying heterotic effects and combining ability as reasons to prefer hybrids to inbreds for cultivar release. Hybrids have proven their advantage for protection of valuable parent lines. Furthermore, seedless cultivars are in high demand and can be produced only as triploid hybrids. However, in the future it might be possible to develop transgenic diploid seedless watermelons. In that case, the question of the advantage in using heterotic hybrids vs. inbred cultivars will still be important.

Overall, watermelon yield in the USA has been increasing during the last 4 yr from 24 000 Mg ha^{-1} in 1998 to 29 000 Mg ha^{-1} in 2002 (USDA-ARS, 2003). Part of the increase in yield might be due to more reliable production practices and to the availability of more effective pesticides (Maynard, 2001). The impact of environmental factors such as irrigation or general water availability on yield was important in contrasting inbred cultivars vs. hybrids in Florida in 1985. The hybrids outyielded inbred cultivars only in irrigated fields, while in dry conditions yield was the same for both groups, although fruit quality was higher among the inbred cultivars (Rhodes, 1985).

Many watermelon yield trials are run each year in the USA, and often few differences among the experimental entries in the trial are observed. Our question was whether that was due to a lack of genetic variation for yield in the crop species, or a lack of genetic variation for yield among the new experimental entries being tested. Genetic diversity among currently grown watermelon cultivars in the USA appears to be narrow, with many derived from 'Allsweet'. Therefore, a diverse set of obsolete inbred cultivars that do not trace to Allsweet and that represents as wide an array of cultivars as possible was included in this study. The objective of this study was to measure yield in a diverse set of watermelon cultivars. In addition, we were interested in identifying high-yielding cultivars for use in breeding programs.

Abbreviations: GCA, general combining ability; SCA, specific combining ability.

MATERIALS AND METHODS

The experiment was conducted at the Horticultural Crops Research Station at Clinton, NC (2001 and 2002), and at the Cunningham Research Station at Kinston, NC (2002). The experiment at Clinton was a randomized complete block with four replications, 80 cultivars, and 2 yr. At Kinston, the experiment had two replications and 80 cultivars. All 80 cultivars were evaluated for all traits, except 'Weeks NC Giant', which had a low emergence rate at Clinton in 2001.

Field rows were direct seeded on raised, shaped beds on 3.1-m centers. Plots were 3.7 m long, with 0.6 m between hills, and 2.5-m alleys at each end of the plot. At Kinston, rows had black polyethylene mulch and drip irrigation. The experiment was conducted using horticultural practices recommended to the growers by the North Carolina Extension Service (Sanders, 2001). Soil type at Clinton was an Orangeburg loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudults). Soil type at Kinston was a Norfolk sandy loam (fine-loamy, kaolinitic, thermic Typic Kandiudults).

Field preparation at Clinton included the soil incorporation of a 10.0–8.3–4.4 (N–P–K) fertilizer applied at 561 kg ha^{-1}. Fertilizer application for the remainder of the growing season consisted of 224 kg ha^{-1} of 13.5–0–19.8 and 112 kg ha^{-1} of calcium along with 15.5–0–0. Kinston field preparation included soil incorporation of a 10–16.6–8.8 fertilizer applied at 336 kg ha^{-1} and the fumigant Telone C-17 (1,3-Dichloropropene + chloropicrin) applied at a rate of 60 L ha^{-1}. At transplanting, 20.0–16.6–8.8 fertilizer was applied ($<$5.6 kg ha^{-1} or a water-diluted equivalent of a 1.00–0.83–0.44 fertilizer). The differences in cultural practices between the two locations reflected the two most common production systems adopted by watermelon growers, bare ground and overhead irrigation vs. black polyethylene mulch and drip irrigation.

A total of 80 cultivars were evaluated for fruit yield and quality. There were 72 obsolete cultivars obtained from seed companies, the Seed Savers exchange, and the National Seed Storage Laboratory (Fort Collins, Colorado). Eight elite hybrid cultivars were included as checks (Starbrite, 'Stars-N-Stripes', 'Legacy', 'Sangria', 'Fiesta', 'Sultan', 'Regency', and 'Royal Flush').

Plots were harvested twice (26 July and 9 August) at Clinton in 2001, once (25 July) at Clinton in 2002, and twice (23 July and 6 August) at Kinston in 2002 for fruit yield and quality measurements. Fruit were determined to be ripe by looking for a dried tendril nearest the fruit, a light-colored ground spot, and a dull sound of the fruit when thumped (Maynard, 2001). In addition, the sugar content of a test sample was measured at harvest. Individual cull and marketable fruit were weighed to the nearest pound for each plot. Numbers of cull and marketable fruit were also recorded. Yield was calculated as total and marketable weight (Mg ha^{-1}) and number (thousands ha^{-1}) of fruit by summing plot yields across the harvests.

Measurements of fruit quality were fruit length and diameter, hollowheart, rind pattern, flesh color, and soluble solids. Quality evaluations were not a major focus in this study, but meant to better describe the cultivars for future breeding efforts. Therefore, quality data were recorded only in Clinton in 2001. Fruit length and diameter were measured in millimeters. The total number of fruit with hollowheart were counted and the width of the defect was recorded in millimeters. Rind pattern was evaluated using a scale of 0 to 9 (0 = special rind patterns of solid light green, irregular striping, or yellow spotting; 1 = gray; 2–3 = narrow stripe; 4–6 = medium stripe; 7–8 = wide stripe; 9 = solid dark green). The stripes were considered to be the dark green area over a light or medium green background (Maynard, 2001). Flesh color was noted as red, orange, salmon yellow, or canary yellow. Soluble solids were measured in degrees brix using a refractometer that was dipped three times into the flesh in the center of the fruit.

Data were analyzed using the MEANS, CORR, and GLM procedures of SAS-STAT Statistical Software Package (SAS Institute, Cary, NC). We measured repeatability of ranking among replications at the same location and in the same year by comparing the rankings for each replication with the others. We also recorded the frequency of ranking in the top 20% for each cultivar in each replication as an indicator of variability. The ANOVA was performed on a balanced dataset including three year–location combinations referred to as environments (Clinton 2001, Clinton 2002, and Kinston 2002). Datasets were balanced by using only two replications from Clinton, which had four rather than two. The analysis was performed after discarding different replications to determine whether there was a significant effect; there was none. The regression model used was Y = Environment + [Replication (Environment)] + Cultivar + (Cultivar $\times$ Environment) + Error. The term [Replication (Environment)] was used as the error to perform the F test on Environment. The ANOVA was not performed on quality traits measured in only one environment (length–diameter ratio and hollowheart percentage).

RESULTS AND DISCUSSION

The ANOVA (Table 1) showed a large and significant effect of environment for all traits (total weight, total fruit number, fruit size, and soluble solids) except for percentage of marketable weight. The large environment effect was expected in our experiment due to the different cultural practices, which resulted in higher weed incidence with bare ground and overhead irrigation vs. polyethylene mulch and drip irrigation. Watermelon yield is reduced by the presence of some species of weeds in

Table 1. Analysis of variance (degrees of freedom and mean squares) for yield and relevant quality data of the 80 cultivars evaluated in three environments.†

		Total fruit yield				
Source of variation	df	Weight	Number	Percentage marketable weight	Fruit size	Soluble solids
Environment	2	145 715.7**	2853.8**	233.3ns	114.3*	21.7*
Rep. (Env.)	3	1 723.1*	33.5**	48.6ns	4.7ns	1.4ns
Cultivar	79	1 715.5***	61.1***	121.8*	43.2***	3.8***
Cultivar × Env.	158	790.5ns	14.7***	74.8ns	2.9**	0.7ns
Error	236	649.9	7.8	87.9	1.9	0.7

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† Environments: Clinton 2001, Clinton 2002, and Kinston 2002 (year × location).

the field (Maynard, 2001). In 2002, mean yield at Kinston was 110 vs. 61 Mg ha^{-1} at Clinton. Cultivation on bare ground at Clinton also promoted a higher growth rate of the fruit that were on average 0.45 kg heavier than at Kinston. Nevertheless, the range/LSD ratio was similar for the two locations (4.9 at Clinton and 5.1 at Kinston), indicating that the test at both locations was effective in separating the cultivars for average fruit size. The Clinton fields were intended to simulate growers using bare ground and overhead irrigation, while the Kinston location simulated growers using black polyethylene mulch and drip irrigation, both common production systems worldwide for this crop. Our interest was more generally to determine the possibility of improving yield in watermelon regardless of cultural practices.

In the ANOVA, replications within environment had a large effect only on total fruit weight. For all parameters, the repeatability index for ranking indicated consistency of performance of the cultivars across replications in each environment.

The effect of the cultivars tested was strong and significant for all traits, indicating the useful parents for improvement of yield in watermelon. Furthermore, cultivar × environment interactions were small and mostly nonsignificant, indicating that cultivars ranked similarly in the three environments, and permitting the use of the mean across environments for cultivar summaries.

The correlations of total vs. marketable fruit weight, total vs. marketable fruit number, percentage marketable fruit number vs. weight, and total vs. marketable average fruit weight were high and significant. Therefore, among these traits, only total yield, percentage marketable weight, and average marketable fruit weight are presented (Table 2).

The highest yielders (Table 2) were the inbreds Mountain Hoosier, 'Hopi Red Flesh', 'Early Arizona', 'Stone Mountain', 'AU-Jubilant', 'Sweetheart', 'Calhoun Gray', 'Big Crimson', 'Moon & Stars', Cole Early, 'Yellow Crimson', and Blacklee, and the F_1 hybrids Legacy, Starbrite, and Stars-N-Stripes. These high yielders included cultivars producing an intermediate number of fruit of medium size, except Early Arizona, Stone Mountain, Sweetheart, and Cole Early, which had small-size fruit. Small fruit were those weighting 6 to 9 kg, and medium were those weighing 9 to 12 kg. However, the correlation between total weight and single fruit weight was low (r = 0.13, P value = 0.0002).

In general, the cultivars had high fruit quality, with 81 to 99% marketable fruit (except for 'Weeks North Carolina Giant', with 69%). Hollowheart was unacceptably high in Hopi Red Flesh, with 55% of the fruit affected. However, hollowheart incidence was recorded only at Clinton in 2001 and, would probably be lower in most years. Old cultivars often have hollowheart, possibly because they are not adapted to the modern fertilization and irrigation regimes (Maynard, 2001). Also, rainy, hot, and humid conditions at Clinton favored hollowheart formation in that year. 'Klondike Striped Blue Ribbon' was developed in California and had 38% hollowheart. Florida Favorite was introduced by Girardeau in 1887 from a cross between 'Pierson' and Georgia Rattlesnake (Whitaker and Jagger, 1937) with adaptation to the Southeast, and had only 9% hollowheart. Its parent Georgia Rattlesnake had 0% hollowheart.

For soluble solids content, the highest-yielding group of cultivars represented a wide range of sweetness, with 7.1 to 11.2 degrees brix. Soluble solids content was not correlated with total weight (r = 0.09, P value < 0.01) or total number of fruit (r = 0.01, P value = 0.85). Soluble solids content was similar at the two locations, with a mean of 10.0 at Clinton (σ = 1.26) and 10.9 at Kinston (σ = 0.99). An intermediate correlation was observed between cultivar means by location (r = 0.67, P value = 0.0001) and by year at Clinton (r = 0.62, P value = 0.0001), indicating that cultivars changed rank somewhat for soluble solids content. A similar scenario was recorded in comparison by year at Clinton, with a mean of 10.0 in 2001 (σ = 1.19) and 10.0 in 2002 (σ = 1.32).

The highest-yielding cultivars ranged in fruit shape from round to elongate, making it easier for plant breeders to develop high-yielding cultivars having a particular fruit type. The length/diameter ratio (L/D) measured on a vertical section of the fruit ranged between 1.1 and 2.3. Yellow Crimson was a high yielder in the yellow flesh group, but the color was salmon yellow (*y* gene) rather than canary yellow (*C* gene), the preferred color because of its improved appearance. The top yielders can be grouped by rind pattern for use by plant breeders interested in developing high yield with parents close to the target fruit type as follows. Dark solid cultivars were Mountain Hoosier, Hopi Red Flesh, Early Arizona, and Blacklee. Gray cultivars were Sweetheart and Calhoun Gray. Striped cultivars were Stone Mountain, Stars-N-Stripes, Legacy, Yellow Crimson, Starbrite, and Big Crimson. The only spotted cultivar was high-yielding as well: Moon & Stars. Surprisingly, one of the most popular cultivars, 'Sugar Baby', was the lowest yielding among the dark solid group, although its popularity is probably based on high fruit quality (deep red and crisp flesh of sweet and distinctive flavor).

The modern cultivars were generally not the highest yielders. Sangria has been the leading cultivar in the southeastern USA for the last decade, but many obsolete cultivars outyielded it in this study. Of course, successful cultivars must have traits other than high yield. High fruit quality is of major importance, and includes bright flesh color, firm flesh texture, high sugar content, and proper fruit shape. Fruit quality of the obsolete cultivars was lower than that of the modern cultivars.

The market in the USA is currently oriented toward the Allsweet type, but there is also a demand for other types. This is shown by the popularity of the mini watermelons (up to 3.5 kg per fruit), seedless yellow-flesh type, and seedless dark-solid rind type. In this study, the obsolete cultivars had a wide range of types for fruit type, including shape, size, and flesh characteristics, all with medium to high soluble solids content. However, modern hybrids often yielded less than the obsolete cultivars tested, but had higher quality and uniformity.

Many of the yield trials run each year around the USA show few differences for yield among the experimental

Table 2. Yield and quality means obtained across environment(s) for the 80 cultivars tested in 2001 and 2002 at Clinton (four replications) and in 2002 (two replications) at Kinston, NC, and flesh (Fl) and rind (Rn) color descriptors.

	Yield†			Fruit size		Quality‡		Color§	
Cultivar	Fruit weight	Fruit number	%mk¶	Weight per fruit	L/D#,††	%HH#	%SS†	Fl	Rn
	Mg ha^{-1}	th ha^{-1}	Mg ha^{-1}	kg†	mm	%			
Mountain Hoosier	114.2	10.2	90	10.2	1.1	21	10.6	R	DS
Hopi Red Flesh	113.9	10.0	93	11.2	1.3	55	10.4	R	DS
Early Arizona	108.4	16.2	88	6.8	1.2	22	9.8	R	DS
Starbrite F_1	107.1	9.8	96	11.5	1.6	26	10.8	R	MD
Stone Mountain	103.4	12.6	99	8.2	1.2	6	7.4	R	WD
Stars-N-Stripes F_1	102.7	10.6	94	10.0	2.1	0	10.7	R	WD
AU-Jubilant	101.5	9.1	92	11.5	2.1	0	10.0	R	NR
Sweetheart	99.7	14.5	95	7.2	1.3	18	7.7	R	GR
Calhoun Gray	98.7	10.5	95	9.9	2.3	0	10.4	R	GR
Big Crimson	98.3	9.5	97	10.8	1.1	7	10.1	R	NR
Moon & Stars	94.4	10.0	85	10.2	2.1	13	9.8	R	SP
Cole Early	94.1	12.2	94	8.8	1.3	6	7.1	R	MD
Legacy F_1	92.7	9.0	98	10.8	1.8	7	11.2	R	WD
Yellow Crimson	91.4	10.1	96	9.2	1.1	10	11.0	S	WD
Blacklee	90.4	9.8	98	10.2	2.0	0	10.1	R	DS
Charleston Gray	89.2	8.9	95	10.8	2.0	13	11.0	R	GR
Tom Watson	89.0	11.5	82	8.7	2.2	0	8.3	R	DS
King & Queen	88.8	19.6	97	4.9	1.1	12	9.2	R	LS
Desert King	88.4	10.0	99	9.0	1.2	16	9.9	S	GR
Charlee	88.1	8.9	96	10.3	2.0	8	10.4	R	GR
Long Crimson	87.9	9.4	94	10.0	1.6	29	9.6	R	WD
Jubilee	87.9	7.4	93	12.9	2.0	8	10.7	R	MD
Sangria F_1	87.0	7.4	81	10.0	2.1	8	11.2	R	WD
Fiesta F_1	85.2	10.6	96	8.4	1.7	0	10.6	R	WD
Tendergold	85.1	9.0	96	9.6	1.7	19	10.4	S	WD
Sugarloaf	84.5	17.6	98	5.0	1.0	7	10.0	R	LS
Princeton	83.9	8.9	95	9.7	1.7	8	9.6	R	WD
Navajo Sweet	83.9	16.4	95	5.8	1.1	13	10.7	R	LS
Kleckley Sweet	83.1	9.2	79	9.1	2.0	5	8.9	R	DS
Black Diamond Yellow Flesh	83.1	10.1	98	8.8	1.3	27	10.3	S	DS
Verona	82.8	8.3	94	10.1	1.2	29	10.1	R	DS
Blackstone	81.9	9.4	97	9.3	1.2	46	10.0	R	DS
Sultan F_1	81.1	8.3	92	10.0	1.5	14	11.1	R	MD
Regency F_1	80.6	8.7	97	9.7	1.5	7	10.9	R	WD
RedNSweet	79.3	8.5	97	10.3	1.2	43	10.8	R	NR
Royal Flush F_1	79.3	9.2	97	9.0	1.8	0	11.2	R	WD
Fairfax	79.2	7.5	93	10.9	2.2	39	10.0	R	MD
Cobbs Gem	78.2	5.4	91	15.7	1.2	22	9.8	R	WD
Yellow Shipper	77.9	8.2	95	9.7	1.7	29	10.1	S	WD
Crimson Sweet	77.4	7.8	90	10.3	1.3	10	10.2	R	WD
Super Sweet	76.8	10.0	98	7.9	1.1	35	10.7	R	MD
Klondike Striped Blue Ribbon	76.1	10.8	93	8.2	1.6	38	10.9	R	NR
Peacock Shipper	75.7	9.3	90	6.6	1.6	17	10.2	R	DS
AU-Producer	75.6	8.1	98	10.0	1.1	9	10.6	R	MD
Wills Sugar	75.5	15.2	97	5.2	1.1	0	9.5	R	DS
Dixielee	74.7	7.8	94	10.1	1.1	0	10.9	R	NR
Golden Honey	72.4	10.6	98	7.0	1.3	56	10.3	S	MD
Dixie Queen	72.4	7.3	92	9.8	1.3	19	10.3	R	NR
New Winter	71.0	17.5	98	4.9	1.1	0	10.2	R	LS
Tastigold	70.5	8.5	96	8.4	1.1	18	10.3	S	GR
Georgia Rattlesnake	69.5	6.3	89	11.5	2.1	0	10.6	R	NR
Louisiana Sweet	69.2	7.7	97	9.5	1.1	30	10.9	R	NR
Florida Favorite	67.3	10.1	92	7.4	1.9	9	9.9	R	NR
Honey Red	66.5	11.5	99	6.2	1.1	3	10.3	R	DS
Mickylee	66.1	14.6	96	4.9	1.2	8	10.4	R	GR
Chubby Gray	66.1	6.2	92	11.0	1.4	19	9.9	R	GR
Allsweet	65.9	6.8	94	9.8	1.9	13	10.7	R	WD
Picnic	65.3	9.2	96	7.2	1.6	0	10.5	R	DS
Black Diamond Yellow Belly	64.9	6.5	98	11.6	1.2	18	10.6	R	DS
Carolina Cross #183	64.1	4.0	84	19.3	1.5	44	9.5	R	MD
Garrisonian	61.9	5.7	96	10.7	2.0	0	10.6	R	NR
Sugarlee	59.9	7.5	96	8.6	1.1	21	11.1	R	NR
Perola	59.9	8.4	98	7.1	1.2	4	10.1	R	GR

Continued next page.

entries being evaluated. The screening of a diverse set of watermelon cultivars for fruit yield presented herein showed that there is variation for yield, and that sources of high yield are available. Furthermore, yield was strongly dependent on cultivar, even though influenced by environmental factors (including cultural practices), and probably could be improved through plant breeding. It is now apparent that the lack of genetic variation and the slow improvement in yield often mentioned by watermelon breeders may most likely be a result of the greater emphasis on traits other than yield, as well as the lack of diversity for yield among the modern cultivars. In any case, there is a need to identify sources of high yield, both as fruit weight and fruit number, and to use

Table 2. Continued.

	Yield†			Fruit size		Quality‡		Color§	
Cultivar	Fruit weight	Fruit number	%mk¶	Weight per fruit	L/D#,††	%HH#	%SS†	Fl	Rn
	Mg ha^{-1}	th ha^{-1}	Mg ha^{-1}	kg†	mm	%	%		
Rhode Island Red	59.7	8.2	96	7.8	1.4	35	10.2	R	NR
Champion #2	59.7	7.9	93	8.3	1.5	3	10.6	R	GR
Giza	54.9	12.1	96	4.7	1.1	0	10.4	R	DS
Graybelle	54.7	9.3	95	6.1	1.2	0	10.9	R	GR
Congo	54.3	5.3	98	10.6	1.1	11	10.2	R	MD
Early Canada	53.1	10.7	95	5.0	1.1	34	9.5	R	GR
Black Boy	51.5	8.9	96	6.3	1.1	37	10.5	R	DS
Quetzali	49.1	9.2	99	5.7	1.2	23	11.1	R	MD
Weeks North Carolina Giant	48.8	3.1	69	17.3	n/a	n/a	9.1	R	MD
Sun Gold	48.6	7.3	99	6.9	1.1	5	10.5	C	NR
Peacock WR-60	47.9	7.6	97	6.9	1.8	0	9.8	R	DS
Sweet Princess	47.2	5.0	98	9.2	2.2	7	10.9	R	GR
Golden	46.1	9.0	91	5.2	1.1	48	10.5	C	NR
Sugar Baby	45.8	9.9	98	4.9	1.1	18	10.1	R	DS
Tendersweet Orange Flesh	45.5	5.4	93	9.5	1.6	75	9.2	O	WD
Minilee	45.1	12.2	96	3.6	1.2	8	10.8	R	GR
Calsweet	36.4	4.4	90	8.6	1.6	0	9.8	R	WD
Statistics									
Mean	75.5	9.4	94	9.0	1.5	16	10.2		
Maximum	114.2	19.6	99	19.3	2.3	75	11.2		
Minimum	36.4	3.1	69	3.6	1.0	0	7.1		
LSD ($\alpha = 0.05$)	24.2	2.9	9	1.4	0.3	28	0.8		
Range/LSD	3.2	5.7	3	11.2	4.3	3	5.1		
Ranking repeatability‡‡	0.31	0.43	0.39	0.51	–	–	0.30		
Correlation (tot. weight vs. market weight)				0.92**					
Correlation (tot. no. fruits vs. market fruit no.)				0.97**					
Correlation (% market weight vs. % market fruit no.)				0.91**					
Correlation (tot. weight vs. average market weight)				0.13**					

** Significant at the 0.01 probability level.
† Data averaged over two harvests, two to four replications, and three environments; th ha^{-1} = thousands per hectare.
‡ %HH = percentage of fruit with hollowheart over total yield measured as fruit number; %SS = percentage of soluble solids (measured by refractometer).
§ Fl = flesh color (R = red; O = orange; S = salmon yellow; C = canary yellow). Rn = rind pattern and color (NR, MD, WD = narrow, medium, and wide dark green stripes on light green background, respectively; GR = gray; LS = light solid green; DS = dark solid green; SP = yellow spots on solid green background).
¶ Percentage of marketable over total yield measured as weight.
# Data averaged across two harvests, four replications, one location, and 1 yr; descriptive information to support the choice of interesting high-yielding cultivars for future breeding efforts.
†† L/D = length/diameter ratio on a vertical section of the fruit from the peduncle to the blossom-end.
‡‡ Ranking repeatability = average frequency of cultivars included in the first 20% of the ranking in different replications, within year and location.

those sources to develop high-yielding but adapted lines for use by plant breeders. Important traits such as fruit quality and disease resistance should be incorporated into those high-yielding lines before they are used to develop new cultivars. This should also result in an increase in the genetic diversity of modern cultivars.

Significant genetic diversity in RAPD markers has been observed among watermelon accessions from different geographical areas and from related species such as *C. colocynthis* (Levi et al., 2001). Now that phenotypic variability for yield in watermelon has been demonstrated, and high-yielding cultivars identified, the next step would be to evaluate the USDA germplasm collection for fruit yield at several locations around the USA, including accessions originating from different areas of the world.

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