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Breeding Potentials of Noncultivated Cottons. V. Productivity of Cultivars, Race Stocks, and F_1 Hybrids Among Them in Long- and Short-Day Environments[1]

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ABSTRACT

Twelve primitive race stocks of cotton (*Gossypium hirsutum* L.), four Upland cultivars, and 24 race stock × cultivar F_1 hybrids were grown in three replicated tests in the summer at Phoenix, Ariz. and in the winter at Isabela, Puerto Rico. Objectives of this research were to compare productivity, to study hybrid expression of agronomic properties, and to determine the effects of cultivar × race stock and genotype × environment interactions on parents and their F_1 hybrids when grown in long- and short-day environments.

Six of the 12 race stocks produced no bolls at Phoenix and few bolls at Isabela. Hybrids of four of the six also produced no bolls at Phoenix, but produced more bolls than either parent at Isabela. The other six race stocks, representatives of race *latifolium* (from which Upland cotton was derived) produced from 2 to 29 bolls/plant at Phoenix. Five of the latter six produced more bolls at Isabela than at Phoenix; two of these five produced more bolls than the cultivars at the Puerto Rican location. None of the *latifolium* race stock × cultivar hybrids produced more bolls than the cultivars at Phoenix, but 5 of the 12 produced a larger number at Isabela.

Genetic variability among the hybrids was caused by differences among the race stocks. Lack of cultivar × race stock interactions suggested that the genetic variability may be attributed largely to additive effects. Numerous instances of heterosis, however, also suggested the presence of nonadditive genetic effects. For hybrids from 8 of the 12 race stocks, location × race stock interactions were significant for all six agronomic characters studied, indicating the inconsistency of hybrid performance for those traits between the two locations. For the other four hybrids, however, the location × race stock interaction was significant only for lint yield/plant, but not for its components. Significant location × cultivar interactions were much more infrequent than location × race stock interactions. Positive heterosis for F_1 vs. cultivar comparisons was shown by 26% of all hybrid/character combinations at Isabela and by 9% of those combinations at Phoenix. Several race stocks, potentially useful for specific characters, were noted for future breeding efforts.

Additional index words: *Gossypium hirsutum* L., Heterosis, Genotype × environmental interactions, Photoperiodism.

THE regional collection of primitive cottons (*Gossypium hirsutum* L.) maintained at the Texas Agric. Exp. Stn. as Texas race stocks, contains a wide array of morphological and physiological variants (1). Specific characters are readily accessible in the day-neutral race stocks (i.e., those which flower and fruit during the longer days of the growing season in latitudes away from the equator). In photoperiodic stocks, however, characters are less easily utilized because hybrids must be selected for flowering and fruiting as well as for the character desired.

We grew day-neutral and photoperiodic race stocks, Upland cultivars, and race stock × cultivar hybrids during the summer growing season at Phoenix, Ariz., and the winter growing season at Isabela, Puerto Rico. Our objectives were to compare productivity, to study hybrid expression of agronomic properties, and to determine the effects of cultivar × race stock and genotype × environment interaction on day-neutral and photoperiodic parents and their F_1 hybrids grown in long- and short-day environments.

MATERIALS AND METHODS

Seeds of cultivars, race stocks, and their F_1 hybrids were planted in a greenhouse at Phoenix (33°27'N Lat, 112°4'W Long), on 24 Mar. 1977. Seedlings were transplanted to the field, 46 cm apart within the rows on 7 Apr. 1977. Seeds were hand planted in the field at Isabela (18°30'N Lat, 67°2'W Long) on 25 Aug. 1977. Seedlings were subsequently thinned to 30 cm apart within the row.

At each location, a plot was a single row 9.1 m long; rows were spaced 1.0 m apart. Experimental design was a randomized complete-block with two replications at Phoenix and four at Isabela. Standard cultural practices were used at each location, except that no insecticides were applied at Isabela.

Three separate tests were grown at each location. The entries in Test 1 were chosen because previous tests had shown that the race-stock parents, Texas 336 (T-336), T-339, T-960, and T-1177, and their F_1 hybrids with the two cultivars 'Deltapine 16' (DPL-16) and 'Stoneville 7A' (St-7A) were photoperiodic (largely non-fruiting) at Phoenix. The entries in Test 2 were chosen because the F_1 hybrids all produced bolls at Phoenix even though two of the four race-stock parents, T-25 and T-1182, produced none at that location. The other two race stocks, T-245 and T-1180, and the two cultivars, DPL-61 and St-7A, were day-nuetral. All hybrids and parents in Test 3 were day-neutral [T-33, T-226, T-775, T-1125, 'Deltapine 61' (DPL-61), and 'Stoneville 256' (St-256)]. At Phoenix, the wrong entry was transplanted into the T-226 plots, necessitating the use of 1976 data for comparison.

At Phoenix, date of first flower was recorded for each plant. At both locations, the following data were obtained: bolls/plant, boll size (seed cotton/boll), lint percentage (percentage of seed cotton that is lint), seed index (100-seed wt), seeds/boll, and lint yield/plant. Lint yield/plant was reduced at Isabela because of damage by pink bollworm, *Pectinophora gossypiella* (Saunders). Bolls/plant was unaffected because this insect causes boll damage, not abscission; the other parameters were estimated from uninfested, undamaged bolls. Combined hybrid

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data were analyzed (two replications/location) to determine the relative contribution of locations, cultivars, race stocks, and various interactions among them to the variation among hybrid populations (12).

We calculated estimates of positive and negative heterosis for the hybrid combinations in each test. With positive heterosis, the mean of the hybrid exceeded the midparent (MP) or cultivar (C) mean by more than the L.S.D. value at the 0.05 level of probability; with negative heterosis the hybrid mean was less than the MP or C mean according to the same criterion. No attempt was made to estimate "favorable" or "unfavorable" heterosis, as we have done in previous papers (10, 11, 12), because of the extreme diversity of the race stocks used in these experiments.

RESULTS

The environment at Isabela was characterized by a much smaller range in temperature (15 to 32 C) than the environment at Phoenix (2 to 46 C). The plants required no irrigation at Isabela, except to germinate the seeds, but required regular irrigation at Phoenix. Rainfall was over 19 times greater at Isabela (88.8 cm) than at Phoenix (4.6 cm) during their respective growing seasons. All parents and hybrids flowered and produced bolls at Isabela during the days of shortening then lengthening fall and winter (11.0 to 12.3 hours), whereas, several race stocks and hybrids failed to flower and produce bolls (a few did flower, but set no bolls) at Phoenix during the lengthening then shortening days of spring and summer (10.9 to 14.4 hours).

At Phoenix in all three tests, the cultivars flowered within 1 to 3 days of each other (Table 1). In Test 1, the race stocks did not flower, and only one of the eight hybrids, T-1177 × DPL-16, did. In Test 2, the race stocks flowered some 11 to 27 days later than the cultivars, but the latest hybrid was only 12 to 13 days later than its cultivar parent. In Test 3, the latest race stock flowered only 9 days later than the earliest cultivar, and the latest hybrid was slightly over 5 days later. Analyses of variance among the hybrids showed a significant effect caused by race stocks in Test 2 only (analyses not shown).

In Test 1, the cultivars produced many more bolls at Phoenix than at Isabela (Table 2). The race stocks and race stock × cultivar hybrids, however, produced no bolls at Phoenix (except for T-1177 × DPL-16 which produced an average of 0.3 bolls/plant). At Isabela, the hybrids produced significantly more bolls, with few exceptions, than did the cultivars or race stocks. The cultivars also produced larger bolls, lower lint percentages, larger seeds, and higher lint yield/plant at Phoenix than at Isabela. At Isabela, hybrid means were usually intermediate to those of the parents for boll size, lint percentage, and seeds/boll. Some hybrids had slightly larger seeds and higher lint yield/plant than the cultivars.

Analyses of the Test 1 hybrids at Isabela showed significant differences among hybrids for bolls/plant, lint percentage, and lint yield/plant. Those differences were

Table 1. Days from planting to first flower in cotton cultivars, race stocks, and F_1 hybrids among them at Phoenix, Ariz. in 1977.

Mean or range of parent or hybrid	First flower		
	Test 1	Test 2	Test 3
	days		
DPL cultivar	78.1	73.4	78.1
St cultivar	77.5	75.6	76.2
Race stocks	N.F.†	86.8–N.F.	77.0–85.1
Race stock × cultivar F_1	90.4–N.F.	73.2–85.8	73.4–81.5
$L.S.D._{0.05}$	2.8	8.0	3.9

† N.F. means non-flowering 116 days after planting (19 July 1977); 116.0 used as the value for all non-flowering entries in the analysis of variance.

Table 2. Means for cotton cultivars, race stocks, and locations over hybrids, and ranges for race stock × cultivar F_1 hybrids for six agronomic characters measured in three tests at Phoenix, Ariz. and Isabela, Puerto Rico.

Mean and ranges within tests	Bolls/plant		Boll size		Lint percentage		Seed index		Seeds/boll		Lint yield/plant	
	Phoenix	Isabela	Phoenix	Isabela	Phoenix	Isabela	Phoenix	Isabela	Phoenix	Isabela	Phoenix	Isabela
	no.		g		%		g		no.		g	
Test 1												
DPL-16	39.2	16.3	5.2	4.6	37.5	39.5	11.1	9.8	29.6	27.9	75.5	21.9
St-7A	50.1	11.3	4.4	3.8	37.4	40.3	10.8	8.4	25.7	27.6	78.0	13.4
Race stocks	0.0–0.0	5.7–8.4	–	0.5–0.6	–	21.6–25.1	–	5.0–7.0	–	4.8–7.7	0.0–0.0	0.4–1.3
(Race stock × DPL-16)F_1	0.0–0.3	29.9–53.1	–	2.0–2.8	–	33.1–34.4	–	9.0–10.5	–	14.8–17.9	0.0	14.5–30.6
(Race stock × St-7A)F_1	0.0–0.0	30.7–45.5	–	2.3–3.3	–	33.1–35.6	–	9.0–10.0	–	16.8–20.3	0.0	11.4–25.9
Locations (over hybrids)	0.0	38.9	–	2.5	–	34.0	–	9.6	–	17.4	0.0	20.4
$L.S.D._{0.05}$	7.2	13.7	0.7	0.9	NS	1.9	NS	2.2	NS	5.5	NS	10.2
Test 2												
DPL-16	24.4	18.0	4.9	4.4	38.1	37.3	10.5	9.2	28.4	31.1	45.2	23.2
St-7A	29.7	15.1	4.6	2.9	35.9	35.5	11.0	9.9	25.9	19.6	50.2	15.0
Race stocks	0.0–27.3	2.9–44.8	2.2–3.9	1.4–3.8	23.1–24.1	26.2–26.5	10.1–10.2	6.2–9.5	16.1–27.6	12.7–28.5	2.0–16.0	1.6–13.9
(Race stock × DPL-16)F_1	4.6–19.4	17.0–49.6	2.1–5.6	1.3–5.3	23.3–30.4	27.9–32.1	10.7–11.7	7.9–11.3	14.0–34.8	11.7–36.0	5.4–27.8	14.9–32.5
(Race stock × St-7A)F_1	5.3–36.3	15.6–40.0	1.8–5.4	2.0–5.2	24.0–30.4	27.1–32.7	10.4–12.0	8.1–10.8	12.2–33.8	20.3–36.2	4.7–33.1	11.5–24.0
Locations (over hybrids)	14.4	25.1	3.7	3.7	27.4	30.4	11.0	9.6	23.6	25.8	14.7	19.8
$L.S.D._{0.05}$	8.7	11.9	0.9	1.4	4.6	3.6	1.6	2.1	7.3	9.6	15.9	13.6
Test 3												
DPL-61	40.1	27.1	4.5	3.4	38.9	36.7	9.4	8.7	28.7	24.9	61.0	19.0
St-256	35.6	17.5	4.6	3.4	37.4	38.4	9.9	8.4	28.8	22.3	61.5	16.7
Race stocks	1.9–29.0	4.2–26.6	3.3–7.0	2.8–10.0	22.5–31.6	25.5–28.8	9.3–14.0	9.6–16.8	21.6–32.2	21.2–40.3	3.8–23.5	6.7–14.5
(Race stock × DPL-61)F_1	16.0–27.9	11.7–41.1	4.6–5.8	3.9–5.9	30.9–35.8	31.4–33.4	10.3–11.8	9.2–11.2	26.8–34.1	28.9–32.8	26.0–41.6	20.6–27.1
(Race stock × St-256)F_1	20.1–32.0	22.4–31.1	5.3–5.9	4.1–6.0	32.3–36.2	30.9–35.8	10.1–13.2	9.7–11.0	27.7–31.2	28.5–35.9	31.4–52.8	23.9–27.5
Locations (over hybrids)	23.7	17.9	5.2	4.9	33.3	33.7	11.3	10.0	30.2	32.4	40.6	25.4
$L.S.D._{0.05}$	8.6	7.6	0.8	1.9	4.0	2.8	2.0	1.3	3.8	7.5	10.6	7.0

Table 3. Mean squares from analyses of variance for six agronomic characters measured in three tests in cotton hybrids.

Source	df	Bolls/plant	Boll size	Lint percentage	Seed index	Seeds/boll	Lint yield/plant
		no.	g	%	g	no.	g
Test 1							
Replications	3	322.0	0.77	1.8	0.9	12.5	181.6
Hybrids (H)	7	297.6†	0.87	3.4**	1.1	13.4	204.5*
Cultivars (C)	1	296.5	0.97	3.5	0.2	33.2	143.4
Race stocks (R)	3	427.3*	0.81	5.5**	2.2*	11.4	393.6**
C×R	3	168.2	0.91	1.3	0.3	8.7	35.7
Error	21	122.7	0.46	0.8	0.5	17.7	62.9
Test 2							
Locations (L)	1	928.8**	0.01	713.0**	15.5**	39.8	204.0
Replications/L	2	139.5*	0.17	15.8*	0.3	13.3	150.6
Hybrids (H)	7	509.3**	9.54**	19.3**	2.8*	339.0**	283.0*
Cultivars (C)	1	27.4	0.01	3.4	0.8	12.9	100.8
Race stocks (R)	3	1,120.2**	21.92**	35.9**	5.9**	775.7**	573.5**
C×R	3	59.2	0.34	7.9	0.4	11.0	53.2
L×H	7	215.8**	0.90*	17.1**	1.5	38.2	294.0*
L×C	1	453.0**	0.89	3.0	0.2	68.2*	160.2
L×R	3	172.6*	1.31*	33.3**	3.1*	50.0*	333.5*
L×C×R	3	180.0*	0.50	5.5	0.2	16.5	299.1*
Error	14	36.8	0.32	2.7	0.6	14.5	77.8
Test 3							
Locations (L)	1	267.9**	0.73	1.1	14.5**	40.1	1,852.9**
Replications/L	2	24.8	2.24*	5.7	1.5	36.7	143.3*
Hybrids (H)	7	75.8**	1.82**	10.4**	2.8*	21.4	100.1†
Cultivars (C)	1	23.5	0.43	6.9	0.5	1.2	144.9
Race stocks (R)	3	149.4**	3.81**	18.1**	5.9**	44.4*	171.9*
C×R	3	19.7	0.29	3.8	0.5	5.3	13.3
L×H	7	35.6	0.17	2.2	0.7	20.0	111.4*
L×C	1	60.5	0.08	2.4	0.2	11.5	209.6*
L×R	3	43.9	0.19	3.1	0.2	10.1	155.3*
L×C×R	3	19.0	0.19	1.2	1.3	32.6	34.7
Error	14	13.4	0.35	2.6	0.8	12.6	37.6

*,** Significant F value at the 0.05 and 0.01 levels of probability, respectively. † Significant F value at the 0.10 level of probability.

apparently caused by differences in race stocks (Table 3). The race stock component was also significant for seed index even though the hybrids did not display significant differences for that trait.

In Test 2, the cultivars again produced more bolls/plant at Phoenix than at Isabela (Table 2). T-1180 produced as many bolls as the cultivars at Phoenix and significantly more at Isabela, even though it flowered 18 to 20 days later at the former location. On the other hand, T-245 produced less than two bolls/plant at Phoenix and approximately 12 bolls/plant at Isabella, even though it flowered only 11 to 13 days later at the Arizona location. T-25 flowered about a month later than the cultivars, and T-1182 did not flower at Phoenix. These last two stocks produced no bolls at Phoenix and few at Isabela. T-1180 × St-7A produced significantly more bolls than DPL-16 at Phoenix, but not more than ST-7A. T-1180 × DPL-16 and T-1180 × St-7A produced more bolls at Isabela than either cultivar. The cultivars had slightly larger bolls, higher lint percentages, larger seeds, and higher lint yield/plant at Phoenix than at Isabela. At both locations, the two race stocks for which there are complete data, T-245 and T-1180, had lower lint percentages and lower lint yields than the cultivars. Those race stocks also had smaller bolls than the cultivars at Phoenix. At Isabela, T-1180 had smaller bolls than the cultivars; bolls of T-245 were intermediate in size. Some hybrids displayed higher means than one or both cultivars at both locations for boll size, seed index, and seeds/boll. None had lint percentages as high as the cultivars at either location nor yielded significantly more lint/plant.

Analyses of the hybrids in Test 2 combined over locations showed significant differences between locations for bolls/plant, lint percentages, and seed index and among hybrids for all six characters (Table 3). The differences among hybrids were caused by differences in race-stock effects because neither cultivar effects nor cultivar × race-stock interactions were significant in any instance. Location × cultivar interactions were significant for bolls/plant and seeds/boll. The St-7A hybrids had more bolls/plant than the DPL-16 hybrids at Phoenix (17.3 vs. 11.6); but the DPL-16 hybrids had more at Isabela (28.9 vs. 23.4). Conversely, the St-7A hybrids had more seeds/boll at Isabela (27.9 vs. 23.7) and fewer at Phoenix (22.8 vs. 24.4) than the DPL-16 hybrids. Location × race stock interactions were significant for all characters. The second-order interaction was significant for bolls/plant and lint yield/plant.

In Test 3, the cultivars again had more bolls/plant at Phoenix than at Isabela (Table 2). Two of the race stocks, T-33 and T-226, had significantly more bolls at Isabela than at Phoenix but T-775 had few bolls at both locations while T-1125 had many. Six of the eight hybrids produced fewer bolls than the cultivars at Phoenix, but St-256 × T-226 and St-256 × T-1125 did not when compared to St-256. The two hybrids involving T-1125 produced more bolls than both cultivars at Isabela. As in Tests 1 and 2, the cultivars in Test 3 had larger bolls, larger seeds, and higher lint yield/plant at Phoenix than at Isabela. In this test, the cultivars also had more seeds/boll at Phoenix than at Isabela. Lint percentage in DPL-61 was higher at Phoenix than at Isabela, but did not differ significantly between the two locations for St-256. For some race

Table 4. Numbers of positive and negative heterotic combinations, F_1 vs. midparent (MP), and F_1 vs. cultivar (C), for six agronomic characters in cotton.

		Bolls/plant		Boll size		Lint %		Seed index		Seeds/boll		Lint yield/plant	
Test no.	Location	MP	C	MP	C	MP	C	MP	C	MP	C	MP	C
1	Isabela	8(0)†	7(0)	1(0)	0(6)	4(0)	0(8)	3(0)	0(0)	0(0)	0(8)	4(0)	1(1)
2	Phoenix	1(4)	0(5)	2(2)‡	0(4)	0(2)‡	0(8)	0(0)‡	0(0)	0(2)‡	1(4)	0(1)‡	0(0)
	Isabela	2(0)	2(0)	0(2)	2(2)	0(0)	0(7)	3(0)	1(0)	4(1)	2(2)	1(0)	0(0)
3	Phoenix	0(0)	0(6)	5(0)	4(0)	0(0)	0(5)	0(0)	3(0)	3(0)	1(0)	2(0)	0(7)
	Isabela	5(1)	3(1)	0(0)	2(0)	0(0)	0(7)	0(2)	6(0)	1(0)	5(0)	6(0)	6(0)

† Number outside of parentheses is the number of positive heterotic combinations, and number inside the parentheses is the number of negative heterotic combinations (8 possible); heterosis = F_1 significantly different from MP or C, according to an L.S.D. test at the 0.05 level of probability.
‡ Data available from only four combinations because the others produced no (or too few) bolls.

stocks, means of these five characters were higher at Phoenix than at Isabela or vice-versa. T-775 had the largest bolls and seeds and the most seeds/boll at both locations, but those characters were particularly conspicuous at Isabaela. T-1125 was the only race stock in Test 3 that yielded more lint/plant at Phoenix than at Isabela. Some hybrid means were higher than those of the cultivars for boll size, seed index, and seeds/boll at both locations. Lint percentages, however, were lower in the hybrids than in the cultivars in every instance. Lint yield/plant was also lower in the hybrids than in the cultivars at Phoenix; but at Isabela, ST-256 × T-33 and St-256 × T-775 outyielded the Stoneville cultivar, and DPL-61 × T-775 and DPL-61 × T-1125 outyielded the Deltapine cultivar.

Analyses of the hybrid data in Test 3 combined over locations (Table 3) showed that location effects were significant for bolls/plant, seed index, and lint yield/plant, and differences among hybrids were significant for bolls/plant, boll size, lint percentage, and seed index. As in Tests 1 and 2 the significant differences among hybrids could be attributed to differences in race stock effects because neither cultivar nor C × R effects were significant. The L × C and L × R interactions were significant only for lint yield/plant whereas, the L × C × R interaction was not significant for any character.

The highest average F_1 vs. midparent (MP) positive heterosis was shown for bolls/plant at Isabela (15 of 24 possible character/hybrid combinations = 63%) and for boll size at Phoenix (7/12 = 58%; Table 4). The highest average F_1 vs. cultivar (C) positive heterosis was also shown for bolls/plant at Isabela (12/24 = 50%) and for boll size at Phoenix (4/12 = 33%). The highest average F_1 vs MP negative heterosis was shown for boll size and seed index at Isabela (2/24 = 8%) and for bolls/plant at Phoenix (4/16 = 25%). The highest average F_1 vs. C negative heterosis was shown for lint percentage at both locations (Isabela: 22/24 = 92%; Phoenix: 13/16 = 81%).

DISCUSSION

The character bolls/plant (or bolls/unit area) is not only a major genetic component of yield (7), but it is profoundly influenced by environmental variables as well, particularly daylength in the cottons that we studied. Insects were another possible influence on boll production at Isabela where the plots were not treated with insecticides.

In Test 1, the dominance of non-flowering in photoperiodic × dayneutral F_1 hybrids (except T-1177 × DPL-16) contrasted to earlier reports of intraspecific *G. hirsutum* hybrids in which flowering was partially dominant. Dominance had been shown, however, in intraspecific *G. barbadense* L. hybrids (5). Two race stocks in Test 1, T-336 and T-339, were representatives of race *palmeri* (3). [These race names for *G. hirsutum* have no status under the international code (2) and are used in this paper merely for convenience.] Johnson (4), on the basis of electrophoretic evidence, believed that the *palmeri* cottons could be given specific rank (*G. palmeri* Watt = *G. lanceolatum* Tod.). These two stocks were probably unproductive at Isabela because the plants had been established for only a few months. Hutchinson (3) reported that plants of race *palmeri* ". . . bear a prolific crop of small, widely opening bolls." The other two race stocks in Test 1, T-960 and T-1177, were collected by M. J. Lukefahr at Ursula Galvan, Veracruz, Mexico. They were similar to the two *palmeri* accessions (nonflowering at Phoenix, tall plants with glabrous leaves and stems, small bolls, low lint percentages, small seeds, and few seeds/boll), except that they lacked the laciniate leaves characteristic of *palmeri*.

In Tests 2 and 3, six of the eight race stocks were representatives of race *latifolium*, the group to which Upland cotton belongs. These six stocks could be divided into three groups, based on flowering and fruiting, as follows: 1) T-1125 and T-1180: produced many bolls at both locations (T-1180, however, flowered 16 days later than T-1125); gave rise to hybrids that produced as many bolls as the cultivars at Phoenix and more bolls than the cultivars at Isabela; 2) T-33 and T-226: flowered about the same time and produced few bolls at Phoenix, but produced as many bolls as the cultivars at Isabela; gave rise to fairly productive hybrids at both locations; 3)T-245 and T-775: produced few bolls but gave rise to reasonably productive hybrids at both locations (T-245 flowered about 10 days later than T-775 at Phoenix). The other two race stocks in Tests 2 and 3, T-25 (race *punctatum*) and T-1182 (unclassified; collected by Lukefahr in Baja, Calif.), produced no bolls at Phoenix and few at Isabela; both gave rise to hybrids that produced few bolls at Phoenix but more at Isabela.

Thus, in this small sample of 12 race stocks, limits to productivity were imposed not only by photoperiodic response but also by other genetic factors that were apparently independent of photoperiod. Even among the six "day-neutral" *latifolium* race stocks, date of first flower at Phoenix varied from about the same day to 20 days later than the cultivars, and boll production varied widely at the two locations. Wilson and Wilson (10, 12) found similar variation in several other *latifolium* race stocks. Waddle et al. (8) reported that another stock of *latifolium*, MW-84 (now designated as T-220), did not flower in the summer at College Station, Tex. In the winter greenhouse, however, it flowered at the same time as the check cultivar. Lewis and Richmond the same time as the check cultivar. Lewis and Richmond (6) reported that an accession of race *marie-galante* flowered only in short days; but even then, it flowered 54 days later than 'Deltapine 14.'

The generally significant effects from race stocks and the lack of C × R interactions in all three tests suggest the presence of considerable amounts of additive genetic variability among the race stocks for all characters tested (except for boll size and seeds/boll in Test 1). However, numerous examples of heterosis for individual combinations show that nonadditive genetic variability was also present.

In Test 1, genotype × environment interactions were overriding; hybrid productivity could be evaluated only in the short-day environment. In Test 2, the L × R interactions for all six characters and the L × C interactions for two characters emphasized the inconsistency of hybrid performance in the two environments. In particular, the large L × C interactions were unexpected because the two cultivars are phenotypically very similar and originated from two breeding programs located within 32 km of each other. In Test 3, however, the lack of genotype × environment interactions (except for L × C and L × R for lint yield/plant) suggested that hybrid performance could be evaluated at either location.

Various hybrid combinations showed heterosis, depending upon location, specific race stocks, and cultivars included in the tests. In general, positive heterosis was more prevalent in Puerto Rico than in Arizona. This result could be attributed to the removal of restrictions that the long-day environment placed on flowering and fruiting of the hybrids. The total percentages of F_1 vs. MP heterotic combinations (positive + negative) varied from 21 to 50% at the two locations. In earlier tests at two locations in Arizona, F_1 vs. MP heterosis for agronomic characters varied from 8 to 40% of the character/hybrid combinations tested (10, 12).

In earlier papers, we identified a few race stocks that were comparable to the cultivars in most of the agronomic and fiber properties measured. Some examples were T-40Y, [a yellow-pollen variant of T-40 (10)], T-40 (12), T-101 (12), and T-167 (9). We also identified other race stocks that may have been superior in one or a few characters such as bolls/plant, boll size, seed index, fiber strength, or micronaire.

No race stock reported in the present paper, however, approached the cultivars in overall agronomic properties. T-775 possibly could be useful as a source of large bolls, large seeds, and many seeds/boll. T-1180 could be a source for increasing bolls/plant, particularly if the resulting cultivars were grown under the short-day conditions encountered in many cotton-growing areas of the world. In fact, several race stocks showed good combining ability for bolls/plant under short-day conditions, as follows: in Test 1, 7 of 8 hybrids showed F_1 vs. cultivar positive heterosis) in Test 2, the two hybrids with T-1180 as one parent showed positive heterosis; and in Test 3, one hybrid with T-33 and two with T-1125 were heterotic for bolls/plant. In the long-day environment, however, good combining ability in the race stocks was limited to other yield components such as boll size, seed size, and seeds/boll.

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