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Influence of Cotton Genotypes on Floral Visits of Honey Bees[1]

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ABSTRACT

Cotton genotypes (*Gossypium* spp.) were studied for their floral attractiveness to honey bees (*Apis mellifera* L.) in Pima County, Ariz. The genotypes varied greatly in floral attractiveness, but differences tended to be consistent.

Genotypes containing at least some cytoplasm from species other than *G. hirsutum* L. were generally more attractive than normal lines developed from *G. hirsutum*. The most attractive genotypes were three late blooming tetraploids developed from crosses involving *G. arboreum* L., *G. thurberi* Todaro, and *G. hirsutum*. A purple-flowered hexaploid developed from an 'Acala 44-10-1' × *G. sturtianum* Willis cross also ranked high in attractiveness.

None of the genotypes of cytoplasms studied were sufficiently attractive to overcome the mid-season drop in bee visits that occurs in southern Arizona. Some of the more attractive genotypes may be used in hybridization programs to increase the floral attractiveness of the parental A, B, and R-lines that will be used to produce hybrid cotton seed.

Additional index words: **Male sterile cotton, Hexaploid, Hybrid cotton, *Apis mellifera* L., *Gossypium* spp.**

INSECT pollination probably will be needed for economical production of hybrid cotton (*Gossypium* spp.) in the United States (3). Honey bees (*Apis mellifera* L.) are the most promising insect pollinating agents (5). Cotton flowers differ sharply in their attractiveness to honey bees. Large numbers of honey bees visit cotton flowers at certain times of the year in some areas; however, at other times it is difficult to find honey bees visiting cotton flowers, even when apiaries are located on the borders of the field (6).

Differences in floral attractiveness to honey bees have been found among genotypes of other cultivated crops (8, 9). If similar differences occur in cotton and if attractiveness can be transferred to the A, B, and R-lines, the production of hybrid cotton seed would be enhanced. Studies were therefore undertaken to determine the floral attractiveness to honey bees of the parent cotton genotypes and/or cytoplasms.

MATERIALS AND METHODS

The experimental plots were located in irrigated fields owned by the Univ. of Ariz. Exp. Stn. at either the Campbell Ave. farm (1972) or the Casa Grande Highway farm (1972, 1974).

Ninety-one genotypes (*G. hirsutum* L. and *G. barbadense* L.) were planted in 256, 10-m single row plots at the Campbell Ave. farm. Seven of the genotypes containing cytoplasm from species other than *G. hirsutum* were each grown in eight plots, one was planted in seven plots, and two were tested in four plots each. Fifty genotypes, largely consisting of commercial or named cultivars, were each planted in three plots. Due to a scarcity of their seed or other factors, four genotypes were each grown in two plots, and 27 were each planted in single plots.

Three genotypes growing in small fields at the Casa Grande Highway farm were observed in 1972 and 1974. One was a purple-flowered hexaploid developed by Muramoto (7) by crossing 'Acala 44-10-1' × *G. sturtianum* Willis. The other two were Arizona experimental Pima #5—1 (*G. barbadense*) and Arizona experimental Superokra #1 (*G. hirsutum*).

Apiaries containing approximately 100 colonies were located within 1 km of the Campbell Ave. farm plots, while approximately 50 colonies were located within 1 km of the Casa Grande Highway farm fields.

Attractiveness of the genotypes was measured by having observers walk slowly through the field and count the honey bees visiting the flowers as described by McGregor (2). The number of bee visits was divided by the number of open flowers observed to obtain a percentage visitation. For example, 10 bees observed in 100 open flowers would give 10% visitation. Counts were made at least once a week and more frequently if time permitted during the main cotton flowering season at Campbell Ave.; thus in 1972 at Campbell Ave., bee visits were counted on 29 of the first 50 days of main bloom between July 7 and August 25. Only the first 20 days of bee counts taken from July 7 to Aug. 5, 1972 were used to compare the relative attractiveness of genotypes blooming at normal times. These dates were chosen because, first, overall bee

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Table I. Honey bee visits to cotton flowers of different genotypes, July 7 to Aug. 5, 1972.

Attractiveness rank and genotype†	Cytoplasmic origins‡	No. flowers observed, (no. plots)	Visits/100 flowers and 95% CL§
1. AZ 66 Meyer (B_1 × MDR) F_1	$B_1 \times (AD)_1$	688 (1)	4.51 ± 1.55
2. AZ 119 King, Pollen deficient	–	919 (2)	4.24 ± 1.30
3. AZ 67 Meyer (B_1 × Stoneville 213) F_1	$B_1 \times (AD)_1$	661 (1)	4.08 ± 1.51
4. AZ 1, *G. anomalum* (A-line)	B_1	6,021 (8)	3.80 ± 0.48
5. AZ 4, *G. arboreum* (B-line)	A_2	1,483 (3)	3.78 ± 0.97
6. AZ 103, *G. anomalum* × Stoneville 213	B_1-BC_4 to $(AD)_1$	536 (1)	3.54 ± 1.56
7. *G. harknessii* × Yugoslav (A-line)	$D_{2\text{-}2}$-BC_6 to $(AD)_1$	4,461 (7)	3.25 ± 0.52
8. AZ 114 (449)	$(AD)_1 A_2/D_{2\text{-}2}$	410 (1)	3.17 ± 1.70
9. AZ 123, New Mexico B-8111-2	–	556 (1)	2.88 ± 1.39
10. AZ 3, *G. arboreum* (A-line)	A_2	3,289 (8)	2.74 ± 0.56
11. AZ 2, *G. anomalum* (B-line)	B_1	2,623 (4)	2.67 ± 0.62
12. AZ 65 Meyer (B_1 × MDR) F_1	$B_1 \times (AD)_1$	488 (1)	2.66 ± 1.43
13. AZ 120, Sel 6401, Semi-sterile	–	1,033 (2)	2.61 ± 0.97
14. AZ 99, *G. herbaceum* (cytoplasmic source)	A_1 ♀	3,442 (8)	2.59 ± 0.53
15. AZ 68 Meyer (B_1 × Delcott 277)	$B_1 \times (AD)_1$	627 (1)	2.55 ± 1.23
16. AZ 21, Dunn 56-C	–	914 (3)	2.52 ± 1.02
17. AZ 3, *G. arboreum* (A-line)	A_2	2,379 (4)	2.52 ± 0.63
18. AZ 93, *G. harknessii* (A-line) ($D_{2\text{-}2}$ × M-8) BC_4	$D_{2\text{-}2}$-BC_4 to $(AD)_1$	4,083 (8)	2.52 ± 0.48
19. AZ 19, Lankart 611	–	1,131 (3)	2.48 ± 0.91
20. AZ 104, *G. harknessii* (A-line) × Stoneville 213, (BC_7)	$D_{2\text{-}2}$-BC_6 to $(AD)_1$	920 (2)	2.39 ± 0.99
21. AZ 99, *G. herbaceum* (cytoplasmic source) × Stoneville 213	A_1 ♀	504 (1)	2.38 ± 1.33
22. AZ 125, New Mexico B-8112-2	–	550 (1)	2.36 ± 1.27
23. AZ 80 (AZ 64)	–	1,075 (3)	2.33 ± 0.90
24. AZ 27, Dunn 119	–	905 (3)	2.32 ± 0.98
25. AZ 9, LE-3-70 × FT, High Cross	–	518 (1)	2.32 ± 1.30
26. AZ 18, Lankart 57	–	527 (3)	2.28 ± 1.27
27. AZ 82, LE-11-76	–	1,113 (3)	2.25 ± 0.87
28. AZ 24, Tamcot 788	–	788 (3)	2.16 ± 1.01
29. AZ 94, *G. longicalyx* (B-line)	F_1	1,033 (3)	2.13 ± 0.88
30. AZ 84, Kekchi	–	1,514 (3)	2.11 ± 0.72
31. AZ 105, *G. harknessii* × Stoneville 213 (A-line)	$D_{2\text{-}2}$-BC_6 to $(AD)_1$	807 (2)	2.10 ± 0.99
32. AZ 29, Lambright	–	636 (3)	2.04 ± 1.10
33. AZ 17, Lankart 3840	–	977 (3)	1.94 ± 0.86
34. AZ 102, *G. tomentosum*, cytoplasmic source	$(AD)_3$ ♀	2,282 (8)	1.93 ± 0.56
35. AZ 44, Quapaw	–	1,316 (3)	1.90 ± 0.74
36. AZ 14, Westburn	–	1,006 (3)	1.89 ± 0.82
37. AZ 58 (AZ 6701)	–	1,105 (3)	1.81 ± 0.79
38. AZ 2, *G. anomalum* (B-line)	B_1	1,516 (3)	1.78 ± 0.67
39. AZ 85, Acala 1517-70	–	1,377 (3)	1.74 ± 0.69
40. AZ 34, Western 44	–	576 (3)	1.74 ± 1.07
41. AZ 81, L-5-11-58	–	1,339 (3)	1.72 ± 0.70
42. AZ 25, Tamcot SP 37	–	525 (3)	1.71 ± 1.11
43. AZ 87, SJ-1	–	1,035*(3)	1.64 ± 0.77
44. AZ 91, Pima S-4	$(AD)_2$	1,310 (3)	1.60 ± 0.68
45. AZ 8, LE-2-70 × T, High Cross	–	644 (1)	1.55 ± 0.95
46. AZ 98, *G. barbadense*, cytoplasmic source	$(AD)_2$ ♀	4,390 (8)	1.53 ± 0.36
47. AZ 59, Sel 6608	–	1,331 (3)	1.50 ± 0.65
48. AZ 36, TPSA 110	–	758 (3)	1.45 ± 0.85
49. AZ 31, Lockett 4789 A	–	1,005 (3)	1.39 ± 0.72
50. AZ 83 (AZ 6206)	–	1,230 (3)	1.38 ± 0.65
51. AZ 121, Thin Hull	–	512 (1)	1.37 ± 1.01
52. AZ 96, *G. tomentosum* cytoplasmic source × Stoneville 213	$(AD)_3$ ♀	530 (1)	1.32 ± 0.97
53. AZ 22, Rilcot Stripper N	–	1,133 (3)	1.32 ± 0.66
54. AZ 23, Rilcot Stripper Cala S	–	837 (3)	1.31 ± 0.77
55. AZ 7, LE 1-70 V, High Cross	–	692 (1)	1.30 ± 0.84
56. AZ 138, Stoneville 86419 N	–	1,387 (3)	1.30 ± 0.60
57. AZ 76, Rowden	–	1,553 (3)	1.29 ± 0.56
58. AZ 77, GKW	–	938 (3)	1.28 ± 0.72
59. AZ 15, Paymaster 202	–	545 (3)	1.28 ± 0.94
60. AZ 20, Blanco 3363	–	711 (3)	1.27 ± 0.82
61. AZ 28, Dunn 118	–	1,184 (3)	1.27 ± 0.64
62. AZ 78 (AZ 6218)	–	1,191 (3)	1.26 ± 0.63
63. AZ 98, *G. barbadense* cytoplasmic source × Stoneville 213	$(AD)_2$ ♀	324 (1)	1.23 ± 1.20
64. AZ 88, Coker 310	–	1,387 (3)	1.23 ± 0.58
65. AZ 152, Tamcot SP 23	–	591 (3)	1.18 ± 0.87
66. AZ 43, Rilcot 90	–	725 (3)	1.10 ± 0.76
67. AZ 89, Coker 413	–	1,096 (3)	1.09 ± 0.61
68. AZ 137, Stoneville 88519 G1	–	1,105 (3)	1.00 ± 0.59
69. AZ 42, Coker 4104	–	1,423 (3)	0.98 ± 0.51
70. AZ 30, Blightmaster A5	–	728 (3)	0.96 ± 0.71
71. AZ 127, New Mexico B-8115-2	–	212 (1)	0.94 ± 1.30
72. AZ 16, Paymaster 266	–	744 (3)	0.94 ± 0.69
73. AZ 45, Stoneville 213	–	328 (1)	0.91 ± 1.03
74. AZ 90, Del Cerro	–	1,113 (3)	0.90 ± 0.55
75. AZ 47, Deltapine 16	–	1,225 (3)	0.82 ± 0.51
76. AZ 154, Coker CNF (Smooth)	–	1,003 (3)	0.70 ± 0.52
77. AZ 32, Lockett BXL	–	1,008 (3)	0.69 ± 0.51
78. AZ 26, Tamcot SP 21	–	290 (3)	0.69 ± 0.95
79. AZ 153, Coker CNF (Pubescent)	–	1,218 (3)	0.66 ± 0.45
80. AZ 35, Watson G1 6	–	334 (3)	0.60 ± 0.83
81. AZ 101, *G. longicalyx* (A-line)	F_1	833 (8)	0.60 ± 0.52

† Where AZ is a part of a genotype designation, the AZ refers to accession records maintained by the Arizona cotton breeders. First AZ is by Lee S. Stith.
‡ Unlisted cytoplasms are $(AD)_1$. § CL = Confidence limits.

visits were above 1% on all these dates, but dropped below 1% on August 6 and did not rise again to the 1% level until Sept. 1, and secondly, the majority of cotton bolls in southern Arizona are set by the end of the first week of August so this is the most important pollinating period. The number of blooms of many of the genotypes was dropping sharply by this time due to a heavy boll set.

Three late blooming genotypes developed by Endrizzi were compared with two other genotypes which had approximately the same number of flowers/plot. Flowers and bee visits were counted once on each of 10 days between Sept. 1 and Oct. 17, 1972.

Observations were summarized for 11 days of observation in 1972 and 15 days in 1974 for the genotypes grown at Casa Grande Highway farm. The male-sterile genotypes and various cytoplasmic sources were obtained from Vesta Meyer, geneticist, Delta Branch, Miss. Agric. Exp. Stn., Stoneville, Miss. She also developed the isogenic B-lines for *G. anomalum* Wawra and Peyr and *G. arboreum* L. Then some of these lines were backcrossed to Stoneville 213 by L. S. Stith.

The induced polyploids are designated by capital letters and subscripts (1). The genome designation for the crosses used in this study are: A_1, *G. herbaceum* L.; A_2, *G. arboreum*; B_1 *G. anomalum*; D_1, *G. thurberi* Todaro; $D_{2\text{-}2}$, *G. harknessii* Brandegee: F_1, *G. longicalyx* Hutchinson and Lee; $(AD)_1$ *G. hirsutum;* $(AD)_2$ *G. barbadense;* and $(AD)_3$, for *G. tomentosum* Nutt.

The genotypes containing cytoplasm from species other than *G. hirsutum* have the cytoplasm of the species listed, but have been repeatedly backcrossed with Deltapine M8 until they resemble Deltapine M8 very closely. Endrizzi hybrids: Az 115, Az 116, and Az 118, were developed by crossing the diploids A_2 and D_1, doubling the chromosomes to obtain tetraploids $[2(A_2D_1)]$, and then crossing with *G. hirsutum*.

A χ^2 test for percentages or proportions was run on data on the 81 genotypes which had bloomed sufficiently by August 5 so that at least 200 flowers had been observed for each genotype. A χ^2 test was also run on the bee visits to the late-flowering genotypes and on the data from Casa Grande Highway farm.

RESULTS AND DISCUSSION

Flowers of genotypes containing cytoplasm from species other than *G. hirsutum* or *G. barbadense* were generally more attractive to honey bees than flowers from lines developed from *G. hirsutum* and *G. barbadense* (Table 1). Twenty-six of the 29 most attractive plots (90%) observed during the first month of flowering at Campbell Ave. contained such cytoplasm, while a pollen-deficient genotype (AZ 119 King) was growing in two of the three most attractive plots. Yet only 25% or 90 of the 256 plots were planted to genotypes containing foreign cytoplasm. The major cultivar grown in Arizona, 'Deltapine 16,' ranked low in attractiveness (75th out of 81), while the most im-

Table 2. Honey bee visits to cotton flowers of five different late-flowering genotypes.

Genotype	Flowers observed	Honey bee visits/100 flowers
Az 115 Endrizzi hybrid 336,2(A_2D_1) X $(AD)_1$	116	26.72**
Az 116 Endrizzi hybrid 373,2(A_2D_1) X $(AD)_1$	156	26.28**
Az 118 Endrizzi hybrid 239,2(A_2D_1) X $(AD)_1$	106	20.75*
G. arboreum cytoplasm, (A-line)	141	9.93
Pima S-4 (Plot 1)	130	3.85
Pima S-4 (Plot 2)	110	2.73

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively, from the other three genotypes, but not from each other.

Table 3. Honey bee visits to cotton flowers of three genotypes at Casa Grande Highway farm.

	Bee visitation and number of flowers observed					
	Hexaploid		Pima		Okra leaf	
Month	Percent	No.	Percent	No.	Percent	No.
Aug. 1972	5.11	450	1.91	3,500	0.35	2,000
Sept.	19.12	2,500	4.58	7,200	4.17	3,600
Oct.	13.50	1,000	7.33	1,800	7.50	400
July 1974	6.33	2,039	3.95	1,999	2.56	2,692
Aug.	5.02	2,771	2.43	4,077	1.19	2,683
Sept.	9.84	1,250	6.31	1,775	4.14	1,135
Total	10.27	10,010**	4.03	20,351**	2.68	12,510**

** Significantly different from each other at the 1% probability level.

portant extra-long staple cultivar, 'Pima S-4,' was average in attractiveness (44th out of 81).

Neither the absence of glands (Stoneville 88519 G1) nor the lack of extra floral and leaf nectaries (Stoneville 86419N) greatly altered the number of bee visits compared to other cultivars which had glands as well as leaf and extra floral nectaries. Evidence from these observations suggests that the presence of glands and location of nectaries did not greatly change the floral visitation pattern of honey bees.

The flowers of the A-line containing *G. anomalum* cytoplasm were more attractive to honey bees than flowers of the other six cytoplasmic sources studied in the eight plot tests, while the genotype containing *G. barbadense* cytoplasm was the least attractive of the seven lines studied (4th and 46th respectively in Table 1).

The most attractive genotypes were three late-blooming tetraploids developed by Endrizzi (Table 2). Their flowers were two to eight times more attractive to honey bees than flowers in plots of the other two genotypes (*G. arboreum* A-line and Pima S-4) that had approximately the same number of blooms in September and early October.

The two genotypes with which they were compared, *G. arboreum* and Pima S-4, had ranked 10th and 44th respectively out of 81 genotypes tested (Table 1) for attractiveness in July and early August.

Another attractive genotype was a purple-flowered hexaploid developed by Muramoto (7). This genotype was much more attractive than the other two in the same field in 1972 and 1974 (Table 3). Similar visitation patterns concerning this hexaploid were seen in field studies in 1971 and also in greenhouse observations during the winter of 1974-75.

Many of the more attractive genotypes and/or cytoplasms had a higher sugar concentration in their nectar than the less attractive ones (4). Also some of the genotypes with cytoplasm from other species may be more attractive than normal lines because they often tend to be deficient in pollen.

Honey bees usually do not collect cotton pollen in the field and were observed to sometimes "scrape" from their bodies some of the pollen that collects as they are visiting cotton flowers.

All three of the most attractive types of cotton were composed at least partially of different species than are normally grown commercially in the United States (*G. arboreum* × *G. thurberi* × *G. hirsutum* crosses by Endrizzi, a *G. sturtianum* × *G. hirsutum* cross by Muramoto, and the cytoplasms from other *Gossypium* spp. developed by Meyer).

CONCLUSION

Large and consistent differences exist in the floral attractiveness of some cotton genotypes to honey bees. The more attractive genotypes should be considered when developing the parents of hybrid cotton because the pollination of the male-sterile parent may be a problem. Honey bees may dislike cotton pollen and so will preferentially visit those with the least amounts of pollen.

Some of the more attractive genotypes were a purple-flowered hexaploid, some of the lines containing cytoplasm from other species of *Gossypium,* and tetraploids developed by first crossing *G. arboreum* and *G. thurberi,* doubling the chromosomes of the resulting F_1, and then hybridizing with *G. hirsutum.*

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