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# Interrelationships Among Gland Density, Gossypol Content, and Lint and Seed Characters in Cotton[1]

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## ABSTRACT

We crossed a heavily glanded, agronomically inferior strain of cotton, (*Gossypium hirsutum* L.), to a normally glanded, agronomically acceptable strain. The former has a high percentage of gossypol (2.63%) in flower buds (squares) whereas the latter has a much lower percentage (0.95%). In the $F_2$ none of the five visual methods of selection for high gossypol content that we used were particularly efficient, but some were significantly correlated with gossypol content. Probably the most useful one in this population was a rating of the number and size of glands on the calyx lobes. Stigma glands/mm identified as many plants with a high gossypol content, but was not as practical because glands had to be counted. Boll glands/cm$^2$ was uncorrelated with gossypol content. The two other visual methods that we used, distribution of glands on the style, and rugose, heavily glanded bolls, were impractical in this population because too many $F_2$ plants were saved. Even though gossypol content was significantly negatively correlated with boll size and lint percentage, correlations were low and should not constitute formidable barriers to improvement.


*Additional index words:* *Gossypium hirsutum* L., Host-plant resistance.

A current breeding objective in cotton (*Gossypium hirsutum* L.) is the development of stocks containing increased levels of flower-bud gossypol and related terpenoids as a deterrent to insect attack (Lee, 1974; Sappenfield, et al., 1974). Because these chemicals occur in visible pigment glands, workers are using several methods to estimate gland density as an alternative to expensive chemical analyses.

Two areas of concern are 1) the efficiency of visual methods of estimating gossypol content and 2) relationships of gossypol content to agronomic and fiber-quality characters. This paper compares several of these visual methods and shows the relationships on a plant basis of some of them and of gossypol content to three lint and seed characters in an $F_2$ population. The $F_2$ population was a cross between a normally glanded upland strain and heavily glanded experimental one with high gossypol content in flower buds.

## MATERIALS AND METHODS

The strain designated 247-1 has more than three times as much square (flower-bud) gossypol as that found in an upland cotton designated Empire Dimeric-glanded. The former cotton was crossed, as pistillate parent, to the latter, and $F_1$ plants were selfed to produce an $F_2$ generation. Forty parental, 40 $F_1$, and 200 $F_2$ plants were grown in two replications at the Cotton Research Center, Phoenix, Ariz., in 1973. Wilson and Smith (1976) described the cultural methods used in growing the plants and the sources of the parental strains.

One flower and one boll per plant were harvested for estimates of stigma- and boll-gland density, respectively. Counts were made under a dissecting microscope. Smith's (1967) method was used to determine gossypol content from a bulked sample of four squares/plant. Plants were scored in the field for an index of the number and size of calyx-glands (rated 1 to 4) by the method of Sappenfield et al. (1974). Plants that had pistils with glands extending to the base of the style were also noted by a method suggested by R. H. Dilday (personal communication), as were those that had rugose bolls.

Three bolls from each plant were harvested to determine boll size (g seed cotton/boll), lint percentage (the percentage of the seed cotton that is lint), and seed index (g/100 seeds).

Means were compared after analysis of variance with the use of the restricted L.S.D. (Carmer, 1976). Phenotypic correlation coefficients were calculated for each pair of characters measured.

## RESULTS

Table 1 compares the high gland density and gossypol content of 247-1 and its inferior lint and seed properties with those of Empire-glanded. All $F_1$ and $F_2$ means (except the calyx-gland size-density index) were closer to the Empire parent than to 247-1.

All correlation coefficients were small among the visual estimates of gland density, percent gossypol, and lint and seed characters (Table 2). However, 10 of the 21 coefficients, four positive and six negative, were statistically significant.

Selecting the upper 5% of the $F_2$ for stigma- and boll-gland density increased the gossypol mean 7%, had minimal effects on lint percentage and seed index, and decreased boll size (Table 3). Selecting directly for the upper 5% of the population in gossypol content increased the mean 32%, with little effect on lint and seed characters.

Selecting the upper 10% of the $F_2$ for stigma-gland density, or all plants rated "4" for the calyx-gland size-density index (9% of $F_2$), increased gossypol content 9 to 10% with only minor effects on lint and seed parameters (Table 3). Selecting the upper 10% of the $F_2$ for boll-gland density lowered the gossypol-content mean about 5%. Selecting those plants with glands extending to the base of the style (29% of the $F_2$) increased gossypol content 9%, but decreased boll size by about the same amount. Selecting plants with rugose bolls, as an index of gossypol content, failed because 90.5% of the $F_2$ population had rugose bolls. Selecting the upper 10% of the $F_2$ directly for gossypol content increased its mean 22% but decreased both boll size and seed index considerably.

## DISCUSSION

Even though statistically significant, the low phenotypic correlations between the calyx-gland size-density index and gossypol content, and stigma glands/mm and gossypol content, show that neither method is efficient in identifying plants with high percentages

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Table 1. Means for gland density, gossypol content, and lint and seed characters in two cotton parents and their $F_1$ and $F_2$ progenies.

| | Stigma glands/mm | Boll glands/cm$^2$ | Calyx-gland size-density index (1–4) | Gossypol | Boll size | Lint | Seed index |
|---|---|---|---|---|---|---|---|
| | | | | % | | % | |
| Empire glanded (EG) | 4.6 b* | 37.9 c | 1.0 c | 0.95 c | 6.2 a | 33.2 a | 15.9 a |
| 247-1 | 9.0 a | 114.3 a | 4.0 a | 2.63 a | 1.1 d | 21.6 c | 9.6 d |
| EG X 247-1 $F_1$ | 5.1 b | 55.3 b | 3.1 b | 1.43 b | 4.9 b | 31.1 b | 13.2 c |
| EG X 247-1 $F_2$ | 5.1 b | 57.6 b | 2.6 b | 1.45 b | 4.3 c | 29.4 b | 14.4 b |

* Means with letters in common not significantly different at the 0.05 level of probability.

Table 2. Phenotypic correlations of gland density, gossypol content, and lint and seed characters for Empire dimeric glanded × 247-1 $F_2$.

| | Boll glands/cm$^2$ | Calyx-gland size-density index | Gossypol | Boll size | Lint | Seed index |
|---|---|---|---|---|---|---|
| | | | % | | % | |
| Stigma glands/mm | 0.07 | 0.25** | 0.22** | −0.12 | −0.14* | 0.05 |
| Boll glands/cm$^2$ | | 0.10 | 0.11 | −0.19** | −0.10 | −0.09 |
| Calyx-gland size-density index | | | 0.34** | −0.14* | −0.13 | 0.01 |
| Gossypol % | | | | −0.35** | −0.14* | −0.09 |
| Boll size | | | | | 0.05 | 0.43** |
| Lint % | | | | | | −0.37** |

* $P < 0.05$. ** $P < 0.01$.

Table 3. Percentage increase or decrease from the unselected $F_2$ mean for gossypol content and lint and seed properties by plants selected for gland density and gossypol content.

| | | Percent increase or decrease (−) from unselected $F_2$ mean | | | |
|---|---|---|---|---|---|
| Character selected | Percentage of $F_2$ selected | Gossypol % | Boll size | Lint % | Seed index |
| Stigma glands/mm | Upper 5.0 | 6.9 | −8.6 | −0.9 | 0.0 |
| | Upper 10.0 | 10.3 | −1.4 | −0.9 | 6.1 |
| Boll glands/cm$^2$ | Upper 5.0 | 6.9 | −8.6 | −1.0 | −0.6 |
| | Upper 10.0 | −4.8 | 0.0 | 1.2 | −3.4 |
| Gossypol % | Upper 5.0 | 31.7 | −3.9 | −1.8 | −1.9 |
| | Upper 10.0 | 22.1 | −9.3 | 0.8 | −5.9 |
| Calyx-gland size ("4") | Upper 9.0 | 9.0 | −2.3 | −1.0 | 3.5 |
| Style-gland index ("2") | Upper 29.0 | 9.0 | −8.7 | −2.0 | −2.0 |

of square gossypol. Sappenfield et al. (1974), who proposed the calyx-gland method, obtained similar low but significant correlations in high-gossypol X normal-gossypol $F_2$ populations. However, these workers selected visually for plant type, boll size and number, and pollen fertility among plants that they rated at least "3" for the calyx-gland size-density index, whereas we attempted no visual selection for agronomic characteristics.

Phenotypic correlations are of course calculated from data that contain both genetic and environmental sources of variation and may not be particularly helpful to plant breeders who want to know how much progress can be expected through selection. In this instance, we believe that they are useful because this $F_2$ population was extracted from a diallel set of five parents and their hybrids which showed a preponderance of additive genetic variation and high heritability estimates for five of the six characters included in the correlation matrix (unpublished data; calyx-gland size-density index data were obtained only for this population).

Fortunately, the negative correlations were small, even though sometimes statistically significant, between the various estimates of gossypol content and lint and seed characters. Selecting for high gossypol content either directly through chemical analysis or indirectly through gland-density estimates did not reduce the variability in lint and seed characters enough to constitute serious breeding problems. For example, the 18 plants that we rated "4" for the calyx-gland size-density index varied from 2.99 to 6.34 g seed cotton/boll, 16.7 to 36.3% lint, and 12.3 to 20.0 g/100 seeds. Only two plants in the population of 200 combined acceptable gossypol content, boll size, and lint percentage, and both plants had seeds as large as the Empire parent. Chemical analysis of gossypol content was the only selection method that recovered both plants, although one was recovered by counting stigma glands.

Our results emphasize the relative inefficiency of visual methods of selecting for increased gossypol. Several workers, however, have used some of these methods to improve breeding stocks (Dilday, personal communication; Lee, 1974; Sappenfield et al., 1974).

Possible breeding problems in this particular population stem from the significant positive correlation between boll size and seed index and the negative correlation between lint percentage and seed index. Because the correlation coefficients are small, these relationships should not constitute formidable obstacles to the development of favorable combinations of gossypol content with lint and seed properties.

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