Some Problems in Altering the Gossypol Content of Cottonseed Through Breeding[1]

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Abstract

Cultivated cottons have small, pigment-bearing glands in their embryonic tissues or seed meats. These glands contain gossypol, a polyphenolic substance toxic to various animals. The presence of glands in cottonseed is controlled by alleles at two loci. Substitution of mutant alleles for active alleles at both loci produce cottons that are devoid of glands and gossypol. Glandlessness is thus a character of great potential worth, and breeders seek to develop glandless varieties of cotton which give high yields of quality fiber. Although some success has been achieved, recent work shows that both glandless genes are linked to factors which reduce yield of fiber. Methods for ameliorating these difficulties are discussed.

Introduction

A serious quality defect of cottonseed is the presence of varying amounts of a polyphenolic substance, gossypol, in the embryonic tissues or seed meats. Gossypol is toxic to nonruminants and produces an objectionable pigment in expressed oil. Thus the presence of gossypol seriously reduces the competitive position of cottonseed among other oilseeds as a source of protein supplement in animal diets, and as a source of vegetable oil for human consumption. Any method that would remove gossypol from cottonseed prior to processing would be of great value to growers and processors of cottonseed. Although gossypol can be removed from oil and protein cake by chemical methods, breeding seems to offer the best opportunity for economically achieving this end.

As far as workers have been able to determine (1,8), gossypol is largely confined to the glands. McMichael (6) produced cottons free of glands. He also showed that glandlessness in cotton is dependent upon the concerted action of mutant alleles at two independent loci. Moreover, the seeds of these cottons were free of gossypol. Further work proved that the glandless character, per se, renders cottonseed gossypol-free. This thesis is borne out by the fact that when glandlessness is transferred from one variety of cotton to another, the recipient strain is freed of gossypol.

Lee (4) described the active, gland-producing alleles normally found in cotton. One of these, Gl_2, is about twice as expressive as the other, Gl_3. Table I summarizes the approximate gossypol levels one obtains from the progressive addition of more and more gland producing alleles up to the point where the plants are homozygous for active alleles at both loci. The linear (additive) component accounts for 94% of the total genetic variance in each varietal array (5). According to Dalton Gandy (9) the acceptable level of gossypol, from the standpoint of animal nutrition, is less than 0.10% of the dry weight of the seed meat. Therefore the only homozygous genotype that provides an acceptable level is the combination which eliminates gland, $gl_2gl_2gl_3gl_3$.

Workers at various stations, publicly supported and privately managed, have attempted to transfer the glandless genes from genetic stocks to commercial varieties of upland cotton. Success has been variable. There are undoubtedly several causal agents involved, some biological and others largely technical. However, these agencies are by no means mutually exclusive in their effects. Some of the more broadly recognized difficulties will be discussed.

Cotton varieties are usually the products of continually evolving populations. Putting a character like glandless into such a population is fraught with technical difficulties which many breeders feel might impede the overall rate of breeding progress for other traits thought to be more desirable. One of the most widely recognized of these problems stems from the fact that breeders have a problem identifying plants of the gentoype $gl_2gl_2gl_3gl_3$ in segregating populations. Plants that bear a single active allele at either gl_2 or gl_3 resemble closely plants of the genotype $gl_2gl_2gl_3gl_3$. Yet these plants segregate glandular plants whose seed gossypol is above the tolerance level. There is good reason to believe that natural selection favors glandular plants (2). Thus unless constant, and costly, roguing is practiced, a contaminated population might be expected to revert back to the glandular condition in a few generations.

Glandless is an example of a potentially valuable character which probably cannot be considered as an imperative alongside some other characters such as lint strength and length. Thus it does not receive top priority in breeding programs as long as these problems remain pressing.

There is evidence that both glandless genes are linked to factors which tend to lower fiber yield. Among the adverse associations noted is a slight reduction in lint percentage (the ratio of seed to lint), and a tendency for glandless cottons to mature more slowly than glandular lines from a similar background (3). Rapid maturity is essential, or at least desirable, in all regions where cotton is grown for the obvious reason that the more rapidly a crop can be grown the less the cost per unit of production. Research at North Carolina State University shows that after five generations of backcrossing a glandless donor strain to four upland varieties the recovered glandless siblings were yielding about 10% less fiber than their

TABLE I

Gossypol Level as Per Cent of Dry Weight of Seed Meat in Two Varieties of Upland Cotton

Genotype	Variety	
	Empire	Coker 100-A
$Gl_2Gl_2Gl_3Gl_3$	1.252	1.406
$Gl_2Gl_2Gl_3gl_3$	1.168	1.329
$Gl_2gl_2Gl_3Gl_3$	0.868	1.012
$Gl_2Gl_2gl_3gl_3$	0.848	0.947
$Gl_2gl_2Gl_3gl_3$	0.619	0.702
$gl_2gl_2Gl_3Gl_3$	0.332	0.406
$Gl_2gl_2gl_3gl_3$	0.090	0.137
$gl_2gl_2Gl_3gl_3$	0.047	0.044
$gl_2gl_2gl_3gl_3$	0.012	0.021

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TABLE II

Lint Yields and Fiber Properties of Two Lines of Glandless Cotton and Their Recurrent Parent, Acala 4–42

Variety	Lint yield, lb/acre	2.5% span length, inches	Uniformity ratio	Yarn strength, 22 count	Micronaire
Acala 4–42	1019	1.14	0.47	139	4.2
63–75	974	1.14	0.47	140	4.2
63–69	950	1.12	0.48	136	4.5

glandular parents. However, linkages can be broken, or their effects ameliorated through selection, if the required variability is available. Breeders are now using larger populations of glandless material involving various sources of germ plasm. The aim is to breed, de novo, varieties of glandless cotton rather than attempt to introduce glandless into current varieties; varieties which historically become obsolete a few years after their introduction. Miller and Rawlings (7) have shown that linkage relationships are more easily changed in relatively large, crossbreeding populations of cotton, than in small populations where opportunities for crossfertilization are restricted.

Breeders have experienced some success in breeding varieties of glandless cotton with near-competitive fiber yields. At the USDA Cotton Field Station, Shafter, California, Dr. Hyer has for several years conducted a large-scale breeding program aimed at converting the Acala 4–42 variety to glandlessness. Results from extensive testing (Table II) show that his best strains yield about 95% of the fiber of Acala 4–42, and that they have similar fiber properties. However, Acala 4–42 is now being replaced by a higher yielding variety. Recently, Dr. Meredith at the Delta Branch Research Station, Stoneville, Mississippi, reported yield trials (Table III) which contained glandless cottons yielding as much fiber as their glandular, recurrent parents. Their trials, however, were limited as to the number of environments sampled. New strains commonly interact with environments in ways which limit their commercial worth over broad areas. More extensive testing will

TABLE III

Lint Yields and Fiber Properties of Two Upland Cotton Varieties and Their Glandless Equivalent Lines

Variety	Phenotype	Lint yield, lbs./acre	2.5% span length, inches	Uniformity ratio	Fiber strength, T_1 units	Micronaire
DPL-Sl	Glandular	922	1.16	0.48	19.0	4.6
	Glandless	880	1.15	0.46	19.0	4.6
Stoneville 7A	Glandular	885	1.18	0.47	18.9	4.7
	Glandless	1042	1.19	0.48	18.8	4.7

be needed before it can be known whether or not some of these new glandless lines are of true commercial worth.

The examples given are from publically supported research stations where extensive programs have been devoted to glandless cottons. The only private firm which has reported commercial glandless cottons is the Gregg Seed Company of Lubbock, Texas. This firm had about 15,000 acres of a glandless variety Gregg 25V in production in 1966.

Glandless is thus a potentially valuable character which should be incorporated into commercial cottons. It is simply inherited and seems to offer no breeding problems that cannot be overcome through application of knowledge currently available. There is thus reason to expect that the cottonseed processing industry can look forward in the near future to increasingly larger stocks of high quality, glandless cottonseed.

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