The Plant Geneticist's Contribution Toward Changing the Lipid and Amino Acid Composition of Cottonseed[1]

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ABSTRACT

Gossypol is well known to be responsible for the troublesome dark color of cottonseed oil. It may depress growth, cause discoloration of eggs, and create metabolic disturbances when fed to nonruminant animals in excessive amounts. All but a trace of seed gossypol is contained in pigment glands present in the cottonseed kernel. Genetical research conducted by USDA scientist, S.C. McMichael, led to his discovery of a glandless seeded cotton in 1953. Glandless cottonseed are essentially free of gossypol. Using McMichael's genetic lines as gene sources, cotton breeders have developed breeding programs in the last 10 years from which three commercial glandless cotton varieties have so far been released. More glandless cotton varieties are on the way. Due to the elimination of gossypol, the color of the oil and utility of the meal from glandless cottonseed is distinctly superior to that from glanded cottonseed. The advent of glandless cottonseed, its potential value in the field of human protein nutrition, and the success in breeding improved oil and protein quality in other oilseeds, have recently caused cotton geneticists to become interested in the possibility of genetically manipulating lipid and amino acid composition in cottonseed. However specialized genetic techniques involving interspecific gene transfer or use of wild photoperiodic uplands may be required in making such improvements.

If the reader has not yet heard of glandless cottonseed, it is sure that, in the coming years, he will be hearing a lot about this genetic innovation in cotton. Figure 1 shows what glandless cottonseed is. The seed with the specks in the kernel is glanded. The seed without the specks is glandless. The specks are the glands. Pigments deposited in these glands are predominantly the polyphenol, gossypol.

Pigment glands are present on the stems, leaves, flowers and bolls of cotton plants which produce glanded seed. Glandless cotton plants are completely devoid of glands, yet such plants retain the capacity to synthesize gossypol. Pigment glands are believed to be the primary storage organs for gossypol and other pigments. Glandless cottonseed contains less than 0.01% total gossypol, and produces a very light colored crude oil and meal.

Freedom from gossypol is the reason glandless cottonseed is such an important genetic and breeding achievement. Cottonseed processing has traditionally been a compromise between oil quality, gossypol inhibition, and protein quality. Among cottonseed products, oil is of primary economic importance and protein is secondary to it. The presence of gossypol requires that during processing a very careful balance be maintained between oil quality and meal quality especially when the meal is to be used in monogastric animal nutrition. Glandless cottonseed can be processed for optimum quality oil and protein without compromising on the quality of either.

[1]One of seven papers presented at the Symposium, "The Plant Geneticist's Contribution Toward Changing the Lipid and Amino Acid Composition of Oilseeds," AOCS Meeting, Houston, May 1971.

The glandless seed characteristic in cotton was discovered in 1953 by USDA cotton geneticist S.C. McMichael. He discovered glandless cottonseed produced by offspring from planned crosses between a wild cotton with few glands which was formerly cultivated by the Hopi Indians, and a genetic marker stock which had the usual complement of seed glands but no glands on the stems or bolls. Later McMichael produced glandless seeded cottons from crosses between the wild Hopi cotton and normally glanded cottons. (Thus McMichael's glandless cottons were not mutants.) McMichael determined the inheritance of glandless seed to be under the primary control of recessive genes on two different chromosomes. J. Lee has reported on additional genes that modify the effect of the primary genes, but these modifiers are of no consequence in the breeding of glandless cottons.

The breeding behavior of glandless cottonseed is simple and straightforward. No costly chemical analyses are required to breed "no gossypol" cottonseed. Thanks to McMichael all the cotton breeder has to do is select glandless seed and he automatically achieves not only freedom from gossypol in the seed but from all the pigments contained in the glands as well.

The winter of 1959-1960 marked the real beginning of the breeding of glandless cottons. For it was at the winter cotton breeding nursery in Iguala, Mexico that pollens from McMichael's glandless genetic lines were first used in crosses with a wide array of commercial type cottons. The first commercial production of a glandless cotton variety came in 1966, but like the Wright brothers' failure to fly on their first attempt, this cotton didn't catch on. in 1969 another glandless variety went into commercial production. This variety, 'Watson GL 16,' has met with good farmer acceptance and was planted to 15,000 acres in 1970. Acreage in 1971 could more than double that of 1970. Also in 1971 another glandless variety, 'Gregg 35W,' will make its first appearance and will be planted on scattered limited acreage. Besides these varieties two other glandless cottons will also be planted on farms in 1971, but that's all the seedsman-breeder wishes to divulge at this time. All four of these glandless cottons will be grown on the high plains of Texas, primarily in the Lubbock area.

Nearly every commercial breeder has glandless cotton lines under evaluation and test. There is no question that more glandless cottons will be released in the next few years. By 1975 there could very well be seven or eight glandless cotton varieties on the market. Most of these will be grown in the Lubbock area, the rolling plains of Texas and Oklahoma, the Texas black lands area around Dallas, and some also in other parts of Oklahoma, in Arkansas and in Louisiana. In the second half of this decade I expect glandless cotton production will begin to spread to other areas of the Cotton Belt as suitably adapted glandless cottons become available for these areas.

Our biggest obstacle to glandless cotton production is no longer in the breeding of varieties. It is in demonstrating to the producer the economic advantage of growing glandless cottons. It will be necessary to show him in terms of cold hard cash that glandless cottons are more profitable to grow than glanded cottons. This extra profit will have to come from increased value of the glandless cottonseed products with no sacrifice in lint yield and quality or in necessary agronomic properties. The sooner the market value of

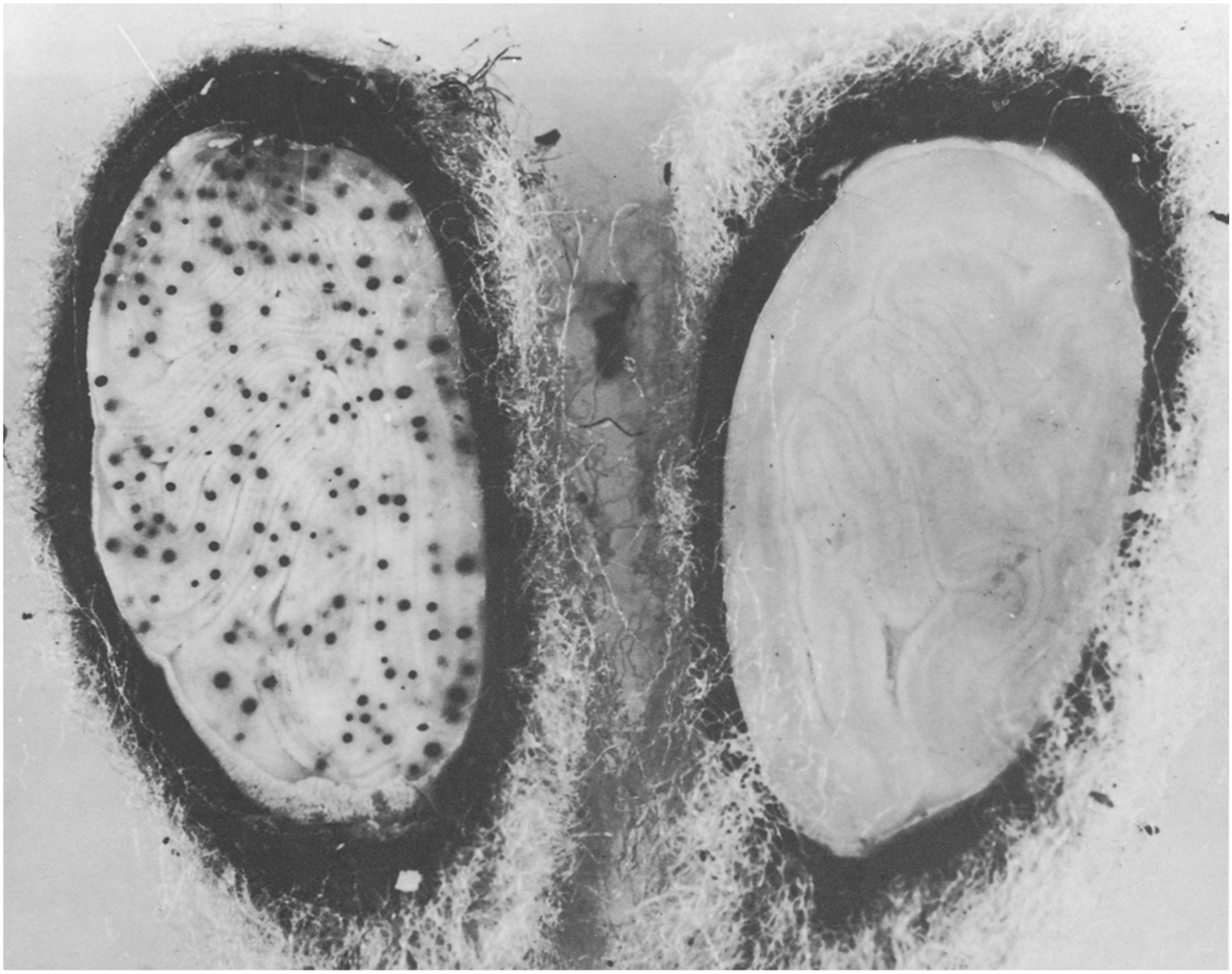

FIG. 1. Longitudinally sectioned cottonseed: glanded seed on the left (dark spots in the kernel are glands) and glandless seed on the right.

glandless cottonseed is demonstrated, the sooner we will see the expansion and growth of glandless cotton acreage.

The recent decision by the Plains Cooperative Oil Mill in Lubbock to build a plant for processing cottonseed into food grade protein is a tremendous stride forward in establishing food markets for undenatured cottonseed protein. The heart of this plant will be a new process engineered to mechanically separate intact pigment glands from glanded cottonseed. This process is known as the Liquid Cyclone Method. Based upon pilot plant runs the total gossypol content in the resulting meal will be under 0.30%. Protein flours, concentrates and isolates can be made from meals processed by the Liquid Cyclone Method. The Liquid Cyclone Method is not limited to processing glanded seed only. It can and has processed glandless cottonseed as well. Since the Liquid Cyclone is inherently self cleaning regarding pigment glands and hence gossypol, it should be an easy matter to switch back and forth between glanded and glandless cottonseed as needs dictate.

Glandless cotton isn't going to push glanded cotton out of production overnight. There will be plenty of glanded cottonseed around for a while. Since meal from glandless cottonseed can be processed in such a manner as to retain a higher feed nutritive value, in addition to its being free of gossypol, than can be made from glanded cottonseed, it should command a higher price than glanded meal. A price which ought to come close to that of soybean meal. But there are even brighter prospects in the offering that higher values for protein from glandless cottonseed are possible in the area of food uses. These enhanced values for glandless cottonseed products should be reflected back to the producer in higher average prices for glandless cottonseed. The Liquid Cyclone-produced protein from glanded cottonseed will be sufficient to establish these food use markets. Protein from glandless cottonseed can exploit these markets once they are established by the Liquid Cyclone-processed protein from glanded cottonseed. This can result in an immediate improvement in cottonseed receipts to the producer of glandless cotton which in turn can provide the inducement for him to grow more glandless cotton. The alternative would be to somehow build up sufficient glandless cotton production and use protein from glandless cottonseed to establish food use markets. Solution of the chicken or the egg type controversy over which comes first–production of glandless cottonseed or establishment of glandless cottonseed product markets–should be aided tremendously by the food plant being planned for construction at the Plains Cooperative Oil Mill.

Glandless cottonseed may already possess the ingredients necessary to impart to it an inherent price advantage over glanded cottonseed. Cottonseed is traded on the basis of seed grade. Seed grade is a worth index which is largely affected by oil and protein contents and the level of free fatty acids. Frequently glandless cottonseeds have had high seed grades. Apparently this is due to higher oil content, higher protein content and lower levels of free fatty acids.

Not all glandless cottonseed possess these features but enough of them do to warrant a thorough investigation into the phenomenon. In the meantime cotton breeders have been alerted to the possibility of bringing about an immediate increase in the value of their glandless cottonseed by looking for and selecting for higher seed grades among their glandless cotton progenies.

This writer's comments regarding genetical research, specifically related to improving fatty acid and amino acid composition in cottonseed, will of necessity be brief because there has been little or no interest in this area. While it is true that surveys have been run on the fatty acid and amino acid composition of Gossypium species, the research has not been carried beyond the survey inquiry. A good part of this lack of interest in cottonseed quality on the part of cotton geneticists is due to their natural preoccupation with the economically more important lint, but this appears to be changing. Sparks of interest in cottonseed quality have surfaced among a few cotton geneticists recently. One cotton geneticist has even reoriented his entire research program toward the improvement of lysine content. It will be some time though before he has anything to report, but this is the type of commitment required to effect desired changes. The glandless cottonseed development has helped to bring about an awareness of the importance of cottonseed to the cotton industry, but probably a more important cause behind this budding interest in cottonseed quality among cotton geneticists is the well publicized need for more food proteins and better vegetable oils in the coming decades.

But what are the goals? Probably everyone would agree that the amino acid lysine should be increased as a first order goal. But what about oil quality? Should, for example, the proportion of saturated fatty acids be reduced? Some say yes; an equal number, no. Should the cotton geneticist attempt to eliminate the cyclopropenoid fatty acids, malvalic and sterculic acids, from cottonseed?

Eliminating gossypol was financially easy compared to what the job of improving oil and protein quality will be. The cotton geneticist must rely completely upon chemical analyses for direction, for there are no "glands" to guide him here. It should be abundantly clear that crop geneticists require adequate analytical and nutritional back-up support in order to improve oil or protein quality, or both. Unfortunately such support has not been adequate. The level of analytical and nutritional support for cottonseed quality genetical research needs to be increased tremendously if we are to expect cotton geneticists to engage in this type of research.

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