Chapter 30

DEVELOPMENTAL ASPECTS OF PLANTING SEED QUALITY

Harry R. Leffler[1]
USDA-ARS
Stoneville, Mississippi

INTRODUCTION

Cotton seed planting quality has become the subject of increasing interest to both producers and research scientists in recent years. A grower's primary interest in seed quality stems from the inherent requirement to establish a stand as rapidly as possible, to assure the production of a harvestable yield as economically as possible. Cotton seeds with high planting quality can be expected to germinate quickly and produce seedlings that emerge rapidly from the soil, under both favorable and adverse environmental conditions. Cotton seeds produced under diverse conditions possess varying levels of quality that can be associated with the ultimate yield potential of the seedlot (Peacock and Hawkins, 1970). Planting seed quality is also associated with the development of yield, in that the majority of a crop of seedcotton is produced by plants originating from the most rapidly-emerging seedlings (Wanjura *et al.*, 1969). Germination and stand establishment consequently form not only the basis for the term "planting seed quality", they can also have a pronounced effect upon a grower's success in producing a cotton crop.

Unfortunately, however, the planting quality of cotton seeds has been of only peripheral interest to many experimentalists, particularly those who are investigating the processes of seed development. There is, therefore, a relative paucity of research information that lends itself to the definitive identification of cotton seed planting quality characteristics. In this review, some aspects of seed development are described that may influence the planting quality of cotton seeds. Initially, a brief summary of seed development will be presented; this topic was covered in detail earlier by Stewart (Chapter 20). Then, attention will be directed to aspects of seed development that are responsive to the physiological status of the plant upon which the seeds develop. Finally, a description will be made of the seasonal and developmental aspects of planting seed quality, which will lead to a discussion of a physiologically oriented system for the production of high quality cotton seeds.

[1]Presently with DeKalb-Pfizer Genetics, DeKalb, Illinois

CHRONOLOGY OF SEED DEVELOPMENT

Boll development from anthesis to maturity can be divided into three distinct phases. The first developmental phase lasts for about three weeks; most growth during this period is enlargement. During this initial period, the final volumes of the boll and seeds are established and most of the fiber elongation occurs. As elongation of the fiber and enlargement of the boll and seed begin to slow, the boll enters the second developmental phase, the filling period. Most of the dry weight of the boll components accumulates during the filling period, which begins after the third week postanthesis and continues until about 10 days to two weeks before boll opening. During this phase, most fiber growth occurs through secondary wall formation, while seed growth is through accumulation of oil and protein by the embryo developing within the volume established by the integuments. Very little dramatic change in the dry matter distribution occurs in the final period of boll development, the maturation phase. This period does, however, cover the time during which some significant physiological processing takes place; boll development is generally considered to be complete upon opening of the boll.

Similarly, seed development can be considered to span the three phases of enlargement, filling and maturation. Accumulation of dry matter by developing seeds is nearly linear through the enlargement and filling periods; it becomes essentially nonexistent, or sometimes even negative, during the maturation phase (Leffler, 1976c). Although the general tendency is for weight accumulation to be nearly linear with time, the occurrence of a period of stress—even for a short time—may disrupt this pattern (Leffler, 1976c). The pattern of dry matter accumulation by cotton seeds becomes considerably more intriguing once attention is given to the composition of the dry matter that is being accumulated.

When investigating mineral nutrient accumulation in cotton seeds, Leffler and Tubertini (1976) found that the percentage of most nutrients decreased during the first two and one-half weeks of development. Once the minimum concentrations were reached between 15 and 20 days postanthesis, the nutrients then accumulated throughout the filling period.

Developing seeds were examined for carbohydrate composition because the integuments appeared to be heavily ladened with a white storage product during the third developmental week (Leffler, 1976b), even though Grindley (1950) had reported extremely low levels of carbohydrate during early seed development. It was found upon direct examination, however, that there was considerable starch present; its concentration peaked, at or above 20 percent, at the same time as the mineral nutrient concentrations reached their respective lows (Leffler, 1976b). The developmental pattern of cotton seed starch concentration is illustrated in Figure 1. Subsequently, histochemical staining illustrated the deposition of starch, primarily in the integuments and secondarily in the gelatinous matrix of the endosperm; this starch was later consumed as the seed developed (Leffler and King, 1977). A similar developmental pattern was identified with the soluble

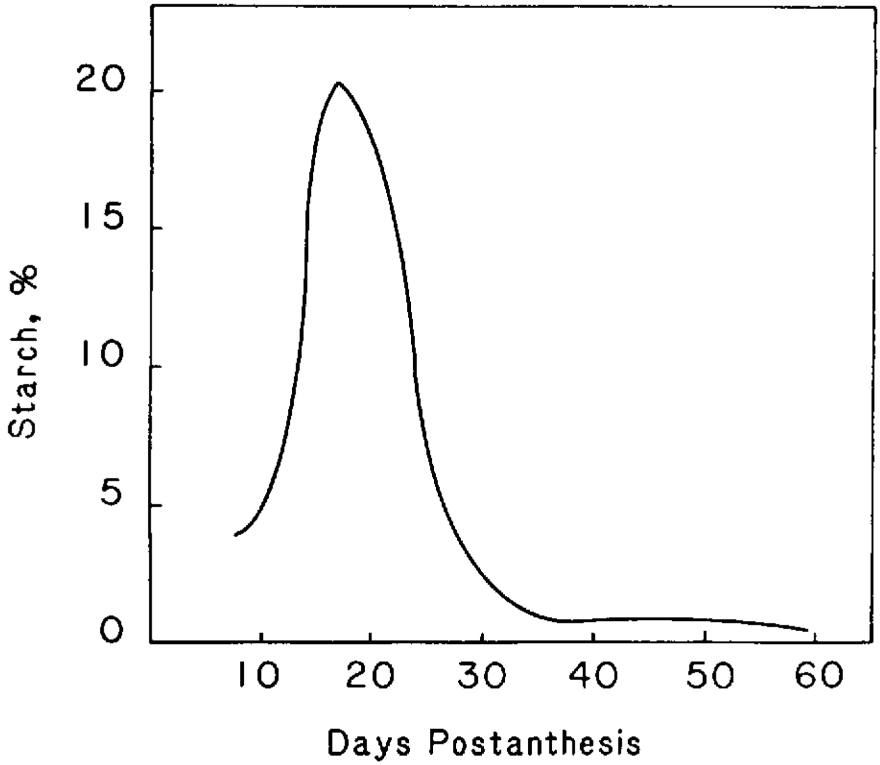

Figure 1. Starch concentration during development of cotton seeds.

sugars, although their concentrations did not diminish as rapidly as did that of starch. Analysis of the components of the soluble sugar pool revealed that maltose was the predominant sugar throughout seed development. Among the other sugars, glucose and fructose predominated during the enlargement phase, while sucrose was the second most prevalent sugar during the seed filling period. The predominance of maltose would be consistent with the degradation of starch by amylase, while the level of sucrose would indicate the arrival of photosynthate to the seed directly from translocation.

Seale (1942) described the accumulation of oil in developing cotton seeds and identified the period from 25 to 40 days postanthesis (DPA) as that during which most oil accumulation occurred. This general pattern was also described by Grindley (1950). When, however, samples were taken earlier in development, it was found that the concentration of oil in the seed followed a pattern similar to that of the major mineral nutrients (Ali and Ullah, 1963). After declining from anthesis to about 17 days postanthesis, the seed oil concentration increased until near the end of the seed-filling period (Ali and Ullah, 1963). The fatty acid composition of the triglyceride fraction changes throughout the enlargement period; once major oil deposition is underway during the filling period, however, the fatty acid profile changes little (Kajimoto *et al.* 1979).

Essentially similar patterns of the amino acid profiles were identified during the phases of seed development by Elmore and Leffler (1976). Their data showed few changes in the cotton seed amino acid profiles after about the fourth week of development. The predominant group of proteins accumulating during this phase of development was shown by King and Leffler (1979) to be storage proteins. The amino acid profiles during enlargement (early seed development) were markedly influenced by the presence of a substantial non-protein nitrogen pool (Elmore and Leffler, 1976). Relative concentrations of seed oil and protein in developing cotton seeds are shown in Figure 2.

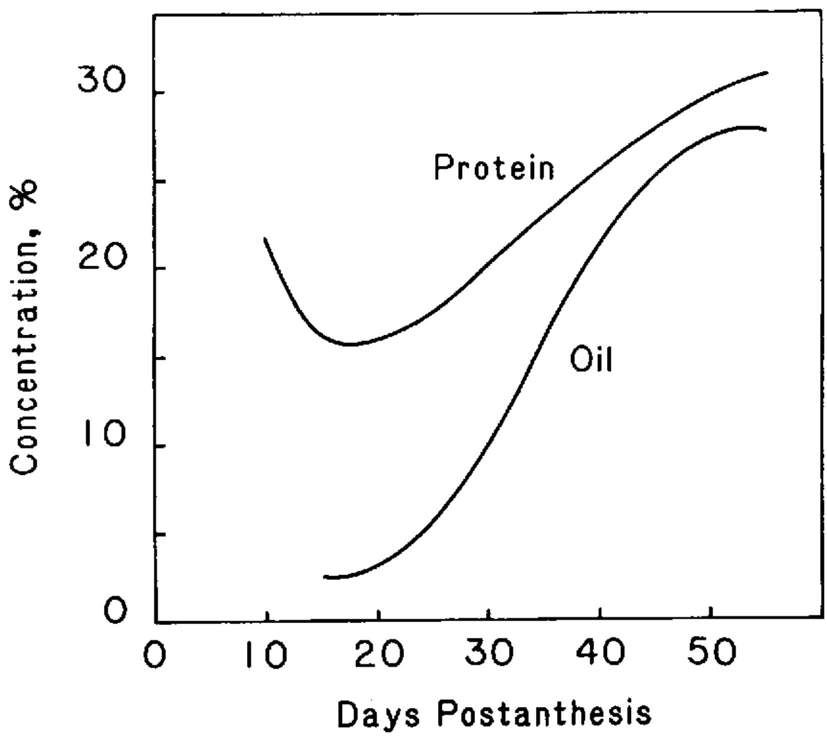

Figure 2. Protein and oil concentrations during development of cotton seeds.

EFFECTS OF DATE OF BLOOM ON SEED DEVELOPMENT

Because of the indeterminate flowering pattern of cotton, the reproductive development of a cotton crop may span a period of several months, even without considering the preliminary period of floral initiation (squaring). While the actual period of bloom may be restricted to a two-month interval, it may continue for a longer time, depending upon the cultivar and the production environment in which the crop is grown. Subsequent boll development then extends the effective reproductive season by an additional six weeks to two months.

As the cotton crop progresses through the reproductive period, a plot of the number of blooms per day per unit area approximates a bellshaped curve (Verhalen *et al.*, 1975). Within this distribution of blooms, there is another distribution—that of the number of bolls forming from these blooms. A comparison of these two distributions reveals a nearly linear decline, over time, in the percentage of fruiting forms retained (Chapter 12).

Because of the extended period of bloom, bolls develop under a pronounced range of environmental conditions. These conditions are defined by both meteorological and physiological parameters. The combined effects of these shifting conditions on the cotton seeds can be identified through the use of stratified (periodic) harvests. This method of harvesting produces seedlots that can be generally traced to different dates of bloom and development within the different portions of the parental canopy. Comparisons of the boll components from stratified harvests reveal the influences of bloom-developmental period on a number of parameters (Meredith and Bridge, 1973). Generally, seeds from late bolls are considerably smaller than those from early bolls (see Chapter 20).

Ali and Ullah (1963) followed the development of seeds from bolls tagged periodically throughout the bloom period. Their data, and those of Leffler (1976c), illustrate the contrast in weight accumulation by seeds from early blooms and those from late blooms. A very similar pattern was found for the development of oil content by these seeds. Data collected over several seasons at Stoneville, Mississippi, indicate that both oil and protein concentrations of cotton seeds change from early-season bolls to late-season bolls (Leffler, H.R., unpublished data). Significantly, however, the degree of change of these storage products in bolls from various positions in the canopy is highly dependent upon the production environment (year). Generally, the late-season seeds weigh less and have a higher oil:protein ratio than do the early-season seeds (Nelson, 1949; Tharp *et al.*, 1949), although there have been exceptions to this pattern for the oil:protein ratio (Kohel, R.J., and J.P. Cherry, personal communication).

ESTIMATIONS OF PLANTING SEED QUALITY

Within a seedlot, the percentage of seeds that germinate and produce seedlings that emerge from the germination medium can be used as an index of the planting quality of that seedlot. Evaluation of planting quality can be conducted either in the laboratory (in germinators or greenhouses) or in the field. Laboratory evaluations are indirect measures of planting quality while field measurements are direct measures of planting quality. Each approach to evaluation has advantages—and disadvantages. When the experimental procedures are appropriate, however, some parallels can be generated.

Pinckard and Melville (1977), for example, generated a seed quality index for each of several seedlots in greenhouse tests, then measured yields of the same seedlots in field tests; yields were directly related to the seed quality index. Wanjura *et al.,* (1969) found that the plants from the most rapidly-emerging seedlings contributed the most to the yield of that plot. Seedlots of a given cultivar, produced in different environments, possess different levels of seed quality that are associated with differential yield potential (Peacock and Hawkins, 1970).

Direct examinations of the effects of developmental/seasonal phenomena upon seed size, composition and planting seed quality are relatively scarce, however. Although their principal objective was to investigate the deterioration of cotton seeds in the field, Simpson and Stone (1935) collected some data that suggested that early-formed seeds might germinate better than late-formed seeds.

Caldwell (1962) studied, in Mississippi, the influences of many production practices upon the planting quality of the cotton seeds that were harvested. Among the production management factors identified as influencing seed quality were row spacing, nitrogen fertilization and boll position in the parental canopy. Within the experimental limitations of his study, he found that relatively poor quality seeds were produced in narrow rows, under high levels of nitrogen fertilization and at boll positions low in the canopy. Maleki (1966) subsequently provided some confirmation of the beneficial influence of low population density on seed quality. Fertilization with less than 67 kg/ha nitrogen was associated with the production of the highest-quality cotton seeds (Caldwell, 1962). Both Caldwell (1962) and Maleki (1966) reported that seeds from bolls low within the parental canopy were inferior to seeds produced at higher positions. Each of these studies, however, was primarily concerned with in-field preharvest deterioration, and this determinant of seed quality would be most severe in the lower strata of the parental canopy.

From their investigations of the influences of night temperature (between 5 and 25C) on cotton growth and development, Gipson and Joham (1969b) found there to be a positive relationship between germination and the night temperature during seed development. Night temperature was more influential than day temperature on cotton seed weight increase (Gipson *et al.,* 1969).

We have used seedlots obtained from stratified harvests to evaluate the planting quality of seeds produced during various portions of the production season. Seedlots produced under differing conditions, but from within the same canopy, differ not only for the ability to produce a stand, but also for the ability to produce a crop of seedcotton.

Initial field evaluations were conducted at Stoneville in 1977 on seeds of 'Stoneville 213' cotton produced in 1976. The experiment was repeated the following year with seeds of the same cultivar produced in 1977. Both stand and yield data were collected each year. Stands in both years were significantly influenced by the date of the source harvest (period of seed development), as were seedcotton yields in 1977. In 1978, the yields were affected more by the stands that survived a hail storm that occurred immediately after the initial stand counts were recorded than they were by the initial stands themselves. The best seedlots in the 1977 evaluation were obtained from the middle of the parental canopy; seeds with much lower productivity potential were obtained in the later source harvests (Figure 3). Both earliness and total seedcotton yield were affected by the developmental period of the seeds; the major determinant of total yield was the first-harvest yield, a measure of earliness.

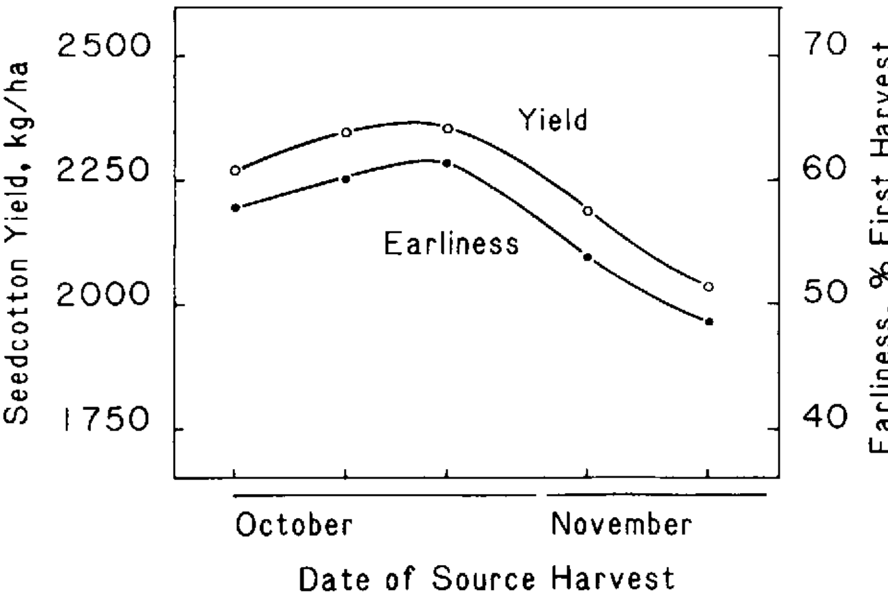

Figure 3. Seedcotton yield and earliness, as influenced by dates of planting seed maturation and harvest.

In each year, however, the effect of source harvest upon stand was highly significant. The source harvests evaluated in the 1978 test were gathered nearly a month earlier in the production season than those evaluated in the 1977 test.

Consequently, the mean temperatures during development were much higher for the former seedlots than for the latter seedlots. Thus, it appears that some physiological aspects of the parental canopy, not just night temperature, influence the germinability of the seeds produced (Leffler *et al.*, 1978). Similarly, the physiology of the germinating seedlings seems to have contributed to the yield differentials observed among seedlots, since there remained significant differences among seedlots after the effects of stand were removed by analysis of covariance. Leffler and Williams (1983) showed that seed quality differentials can affect sustained seedling growth.

In 1979, evaluations of the field germination of seedlots of three cultivars were conducted; as in previous experiments, relatively unweathered seedlots were obtained from stratified harvests. There was, however, a warm rainy period between the first and second harvests that contributed to weathering of the second-harvested seedcotton. Although the stand counts revealed a significant influence of cultivar on stand establishment (Leffler, 1980a), each cultivar responded similarly in terms of planting quality over the various stratifications.

There are indications that planting seed quality may be enhanced through genetic selections. The cultivar effects in the 1979 seed quality evaluations at Stoneville appear to be genetic background effects, separate from canopy maturity characteristics. Tupper (1969) reported that the density of cotton seeds was the most important predictor of planting seed quality, a conclusion supported by Krieg and Bartee (1975; see also Chapter 33). El-Zik and Bird (1969) found that the ability to establish a stand was a quantitatively inherited trait that could be improved through breeding. Hess (1977) subsequently reported the genetic improvement in seed density through three cycles of selection; this increased seed density was associated with a significant increase in lint yield. A possible limit to the desirability of high seed density was suggested by King and Lamkin (1979) who found that increases in seed density were associated with reductions in seed volume. The optimum seed density (1.04 to 1.08 mg/mm^{-3}) reported by King and Lamkin (1979) was found by Leffler and Williams (1983) to be that at which there was a maximum value for the ratio of oil content to protein content of the seeds; higher density seeds were so limited in storage reserves that their performance was severely restricted.

PRODUCTION OF QUALITY PLANTING SEEDS

The production of cotton seeds is imposed on the parental canopy structure, so the factors that influence either the physiological competence or the activity of that canopy also affect the quality of the seeds produced. There are many reports of the reduced seed weight of late-maturing bolls (Nelson, 1949; Tharp *et al.*, 1949; Meredith and Bridge, 1973; Leffler *et al.*, 1977) and of the compositional changes of seeds produced during different portions of the season (Nelson, 1949; Tharp *et al.*, 1949; Ali and Ullah, 1963; Leffler *et al.*, 1977). Two factors, more than any others, contribute to these seasonal profiles: 1) temperatures (Gipson and Joham, 1969b) and 2) the number of bolls developing on the same plant and competing for photosynthate. For these and other reasons, there is a seasonal distribution of cotton seed qualities. Generally, the best seeds appear to be produced near the middle of the parent canopy. The quality of early-forming seeds is restricted, either by the limited availability of photosynthate or by the less-than-ideal environmental conditions low in the canopy (Caldwell, 1962) that are conducive to post-maturity deterioration of seeds. Late-forming seeds, conversely, appear never to have acquired quality, because of restricted growth.

Other production practices may also influence seed quality. Both Caldwell (1962) and Maleki (1966) reported an enhancement of planting quality due to a reduced population density in the seed production field. Additionally, Caldwell (1962) found that nitrogen fertilization above about 65 kg/ha reduced the quality of the seeds produced. Both population density and nitrogen fertilization have significant effects upon the timing and duration of reproduction.

With these and other factors influencing the planting quality of cotton seeds, a physiological approach to the production of planting seeds might be in marked contrast to standard production practices. It would appear that plant population density might need to be reduced, although we do not now have a good estimate of the optimum planting density. The amount of nitrogen fertilizer applied to a production field should be limited, probably to 60 kg/ha or less, in an area such as the Mississippi Delta. While other production areas would likely have different optimum levels of nitrogen for cotton planting seed quality, these levels would undoubtedly be lower than those currently used in standard production systems. Additionally, the seed crop must be harvested so that weathering losses can be minimized and the latest-formed seeds, because of their inherently inferior seed quality, are excluded. Gipson and Joham (1969b) stated emphatically: "Thus, one may question the practice of producing planting seed in the northern areas of the Cotton Belt. In any case, the use of seed produced late in the season under low night temperatures could not be recommended unless adequate laboratory evaluations were made on the specific seed lot." Few data available today would diminish the thrust of their statement.

Specialized production of all cotton planting seeds in a selected production region, such as Arizona or California, has frequently been suggested. The advantages of this approach would include the implementation of production practices specifically designed for the development of planting seed quality in an environment that would be expected to have minimal weathering losses. This concentration of planting seed production would be expected to encourage the adoption of specialized harvesting, ginning and seed handling procedures that would preserve the quality parameters that the seeds had acquired during development. These modifications in production and processing practices should result in a reduction of producer problems in stand establishment.

There would, however, be logistical problems encountered in such a restructuring of cotton planting seed production procedures. The adoption of a specialized seed production region would, for most producers, greatly increase the transportation costs for planting seeds. Additionally, seeds of many cultivars would be produced outside the areas of adaptation for those cultivars. Therefore, a premium price for the seeds of those cultivars would be required to compensate for their relative yield disadvantage. Additional costs would be incurred for the preservation of varietal purity, both for the minimization of outcrossing and for the elimination of mechanical mixtures and contaminants. While these latter costs would also affect, to a degree, any specialized seed production system, the more broad geographically based systems would tend both to reduce them and also to minimize the transportation costs associated with the seeds. Consequently, the more localized production systems will probably have a better chance to develop.

SUMMARY

The planting quality of a cotton seed can be ultimately defined by its ability to germinate and produce a seedling that rapidly emerges from the soil under field conditions that may be considerably less than ideal. Both seedling growth rates and crop productivity potential can be significantly influenced by seed quality characteristics. Although the planting quality of a cotton seed is at its relative maximum immediately after boll opening, not all seeds in a crop possess equivalent planting quality at maturity. As the physiology of the production canopy is affected by numerous management factors, so is the planting quality of the seeds formed within this canopy. Seeds that are formed relatively late in the season are usually small and contain little storage reserve that can be drawn upon during germination and seedling establishment. Consequently, these seeds are usually identified as having poor planting quality. Production practices that tend to shift the development of the production crop to later maturity will, therefore, tend to reduce the relative planting quality of the seeds that are harvested. Conversely, if the crop is managed so that its development becomes relatively more determinate, the planting quality may also be penalized because of the internal competition among bolls for a relatively limited supply of photosynthate. Maximum planting seed quality should be obtained when the production crop is managed so that vegetative and reproductive development remain in balance and when the seed-cotton crop is harvested before any weathering deterioration has a chance to occur.