Chapter 31

WEATHERING: CHANGES IN PLANTING SEED QUALITY BETWEEN RIPENING AND HARVEST

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INTRODUCTION

Weathering of cottonseed is a term used to describe a series of processes, usually deteriorative, occurring between the times of boll opening and harvesting. Typically, weathered seeds exhibit an increase in free fatty acids, a decrease in germinability and vigor and a change in embryo color from creamy white to greenish or greenish-brown (Altschul, 1948). Plants derived from weathered seeds frequently are less robust, more prone to seedling diseases and less fruitful than those from nonweathered seeds.

INCREASES IN VIGOR AND GERMINABILITY

Apparently sound cottonseed occasionally exhibit transient low percentages of germination. For example, samples from two lots of seed harvested immediately following boll opening in 1980 exhibited germinations of 31 and 42 percent, when tested within a week of harvesting. When retested two months later, they germinated 90 and 94 percent, respectively. Because such dramatic increases in germinability seldom are observed in commercial seed samples, it is likely that loss of dormancy occurs as a natural consequence of field exposure. Transient dormancy was first described by Simpson (1935a). Investigators studying the effects of accelerated aging on cottonseed occasionally observe slight increases in germination percentage or vigor during the early stages of aging (Bird and Reyes, 1967) and have referred to this phenomenon as "quality conditioning". Abscisic acid, an endogenous constituent of developing cottonseed, decreases in concentration as seeds near maturity (Davis and Addicott, 1972). This compound inhibits the percentage and rapidity of cottonseed germination (Halloin, 1976a) and is, therefore, likely to be the cause of both transient dormancy and quality conditioning.

DECREASES IN VIGOR AND GERMINABILITY

CHANGES IN SEEDS ASSOCIATED WITH WEATHERING

The most commonly observed manifestations of weathering of planting seeds are decreases in germination and seedling vigor, which may be viewed as end products of the deteriorative processes involved. Although considerable work has been done on weathering and its associated processes and consequences, little is known of the physiological processes that lead to reductions in vigor and germinability.

Lipolysis, the breakdown of glycerides to free fatty acids, commonly is associated with reduced seed performance. Rusca and Gerdes (1942) reported an inverse correlation between the free fatty acid contents and germination, with little or no germination in lots of seeds containing more than 8% free fatty acids. Hoffpauir *et al.* (1947) in an elegant experiment on individual seeds, demonstrated that seeds containing more than 2% free fatty acids fail to germinate. These observations suggest that free fatty acid formation might be involved in reduction of germinability. But Lewis (1969) and Bartkowaki *et al.* (1978) failed to detect an adverse effect on seedling performance when seedlings were treated with exogenously applied fatty acids. Failure of exogenous free fatty acids to inhibit germination is not surprising, since high concentrations of these materials are present within seedlings during normal germination (St. Angelo and Altschul, 1964). These observations indicate that accumulation of free fatty acids and loss of germinability are independent manifestations of deterioration.

A high incidence of abnormal seedlings also is associated with weathered seeds. Wiles and Presley (1960) described "nub-root," a condition in seedlings from weathered seeds in which part or all of the tap root fails to develop. Hunter and Presley (1963) later referred to this phenomenon as "pinched root tip" and observed that there was a complete lack of cell division in the tips of these roots. This condition leads to the development of weakened seedlings completely lacking a tap root.

High specific gravity of seeds is commonly associated with good planting seed quality (Chapter 33). However, Ray and Minton (1973) observed no reduction in seed weight as a consequence of weathering. I have repeatedly looked for and not observed decreases in seed density during weathering. Additionally, I have found no differences in susceptibility to weathering among high and low buoyant density seeds. Thus, degree of and changes in seed density do not appear to be associated with weathering.

THE INFLUENCES OF ENVIRONMENTAL FACTORS ON WEATHERING

The main environmental factor influencing weathering of cottonseed is moisture. The association between moisture and weathering of cottonseed was first reported by Simpson and Stone (1935) who observed that cottonseed exposed to rain or high humidity deteriorated, whereas those harvested before exposure to moisture retained high quality. Additionally, cottonseed ripening during humid or wet weather were more prone to deterioration than those ripening during dry weather. Later, Meloy (discussed in Altschul, 1948) observed that cottonseed produced in humid areas adjacent to rivers exhibited more deterioration than seeds produced in the same vicinities, but under less humid conditions. He concluded that the humidity under which seeds developed and ripened was the only significant factor influencing weathering. Woodruff *et al.*, (1967) also reported that humidity during boll ripening was the only factor that influenced seed quality. Light intensity and temperature had little or no influence. Exposure to rainfall, dew deposition and high humidity after ripening also contribute to weathering, but the influence of moisture on seeds during ripening appears to exert the major influence on predisposition to weathering.

The indeterminate and dispersed fruiting habit of the cotton plant enhances moisture retention of bolls, and thus, weathering. The earliest ripening bolls have the most frequent exposure to moisture. This problem is compounded by the fact that the bolls closest to the ground or enclosed within the plant canopy, which normally are the earliest ripening ones, generally dry out more slowly than other bolls and, thus, have more prolonged exposure to moisture during each moist period. Hofmann and Taylor (1980) found that seeds from early- and late-set bolls were about equal in their predisposition to weathering; hence, the major difference in weathering between these two groups is the amount of exposure to moisture.

The constant association of high moisture with seed deterioration during weathering does not mean that water is the cause of this deterioration. Water merely provides a favorable environment for its occurrence.

THE CONTRIBUTION OF BIOLOGICAL PROCESSES TO WEATHERING

Nearly as constant as the association between moisture and weathering, is the association between infection of seeds by microorganisms, primarily fungi, and weathering. In experiments on individual weathered seeds, nearly all seeds that failed to germinate in 7 days at 22C were infected by microorganisms. Of the few noninfected seeds that failed to germinate at 22C, nearly all germinated within 2 days at 30C (Halloin, 1981a).

The variety of microorganisms which infect seeds during field exposure varies with moisture availability. In the relatively moist eastern portion of the United States cotton belt, infection by "field fungi," such as *Aspergillus niger* and species of *Alternaria, Fusarium, Diplodia, Rhizopus* and *Colletotrichum* (Davis, 1977; Roncadori *et al.*, 1971; Simpson *et al.*, 1973), is common. In the more arid western portion of the U.S., infection by field fungi is less pronounced, and infection by osmophilic fungi or "storage fungi" such as *Aspergillus flavus* is more common. Generally, the field fungi require higher water potentials for growth than do the osmophilic fungi. This requirement for water is reflected in the geographic distribution of these fungal groups in infected cottonseed. However, moisture in the environment also affects the activity of osmophilic fungi. Russell *et al.* (1976) demonstrated that early termination of irrigation in Arizona cotton fields reduced production of aflatoxins by *A. flavus* in cottonseed.

Infestation of weathered cottonseed by bacteria is more common in the eastern than in the western portion of the U.S. cotton belt, reflecting the requirement of high water potential for growth of bacteria. Among bacteria isolated from cottonseed are species of *Bacillus, Pseudomonas* and *Xanthomonas* (Mayne, 1956). Infection of seeds by *X. malvacearum*, the cause of bacterial blight of cotton, is a major factor in the spread of this organism (Brinkerhoff and Hunter, 1963).

The contribution of microorganisms in post-ripening boll rot is well accepted. This phenomenon is most pronounced in bolls exhibiting "hard loc", a condition in which bolls crack and partly open under moist conditions but fail to fluff. Extensive growth of fungi in hard loc bolls is easily visible and causes rapid rotting of both lint and seeds. Apparently, slow drying of these bolls provides a highly satisfactory environment for growth of fungi. Hard loc bolls normally are excluded from harvest during picker harvesting, but they are collected during stripper harvesting, and their seed can contribute to decreased performance of seed lots. A more subtle manifestation of this problem is described as "microbial tight loc" (Marsh *et al.*, 1954); bolls exhibiting this phenomenon are partially fluffed. This phenomenon occurs under the same environmental conditions as hard loc but may also occur under arid conditions when bolls open prematurely due to moisture stress. The partial fluffing of tight loc bolls results in their being harvested both in stripper and in picker harvesting. A sheen that persists on the matted fibers, and the visible growth of fungi, suggest that materials that may provide a nutrient base for fungi are present. Normally these materials are resorbed by boll tissues or fibers during the latter stages of boll development. In a recent study, I observed (unpublished) that seeds from tight loc and the most nearly adjacent fully fluffed bolls exhibited 97 and 93 percent infection by fungi, and 45 and 61 percent germination, respectively. Clearly, many infected seeds in both groups germinate, but germination of seeds from tight loc cotton was more severely reduced.

Production of toxins by seed-infecting microorganisms may be important in reducing seed performance. *Alternaria tenuis*, a common resident of cottonseed, produces a toxin called tentoxin (Templeton *et al.*, 1967). This toxin causes a chlorosis of infected cotyledons (Fulton *et al.*, 1960) by specifically inhibiting chloroplast coupling factor 1 (Steele *et al.*, 1976). Affected seedlings fail to mature due to their failure to photosynthesize. Aflatoxins produced by fungi in the *Aspergillus flavus* group inhibit seed germination and chlorophyll synthesis (Dashek and Llewellyn, 1977). Other fungi found in cottonseed produce compounds which elicit various necrotic responses in plants, but their role in deterioration of cottonseed is unexplored.

The physiological role of microorganisms in deterioration of seeds during weathering is frequently more subtle than in the examples discussed above and is poorly understood, partly because the processes involved in deterioration are poorly understood. Also, it is impracticable to obtain adequate samples of seeds or ripened cotton free of microorganisms to permit definitive determination of the relative roles of processes of seed and microbial origins. Our ignorance in this area can lead to erroneous assumptions, often evident, but seldom stated, in published work on seed deterioration. As an example of the confusion which can arise, I will discuss the process of lipolysis.

To determine the biological basis for lipolysis in deteriorated (weathered) cottonseed, we can consider the following known evidence: (1) Both deterioration and growth of microorganisms in seeds require moisture (normally in excess of 12 percent on a seed wet weight basis) (Roncadori *et al.*, 1971; Simpson and Stone, 1935); (2) essentially all deteriorated seeds are infected by microorganisms (Halloin, 1981a; Roncadori *et al.*, 1971; Simpson *et al.*, 1973); (3) frequently, embryo tissues are not infected until after some deterioration has occurred, but tissues surrounding the embryos are heavily infected (Halloin, 1975a); (4) both the embryos and the infecting microorganisms are capable of producing lipid degrading enzymes (Mayne, 1956; St. Angelo and Altschul, 1964); and (5) many of the infecting microorganisms produce a variety of metabolites during saprophytic growth, which have diverse toxic effects on plant tissues (Dashek and Llewellyn, 1977; Fulton *et al.*, 1960). Given this evidence, it is impossible to reach an incontestable conclusion as to the biological basis for lipolysis; seed processes, microorganismal processes or both working in concert. All seem likely. I suspect that lipolysis and various other processes involved in deterioration are a result of the joint action of seed and microbial systems.

Cottonseed contain a variety of broad spectrum antibiotic compounds including terpenoids (Halloin and Bell, 1979), flavanols (Halloin, 1982), flavanol glycosides (Blouin and Cherry, 1980) and cyclopropenoid fatty acids which may have an auto destructive role in seed deterioration during weathering. However, such a role for these compounds is largely unexplored. Glanded cottonseed contain the terpenoid aldehyde gossypol localized within lysigenous glands. Under extremely moist conditions, cottonseed also synthesize nonglandular terpenoid aldehydes in a phytoalexin-like response (Halloin and Bell, 1979). That glandular terpenoids are not involved in autodestructive processes is suggested by the fact that glanded and glandless cottonseed exhibit no apparent differences in their susceptibilities to weathering (Halloin *et al.*, 1978). Flavanols and nonglandular terpenoids, however, have been shown to be casually associated with necrosis of cotton tissues (Mace and Bell, 1981). Terpenoids, flavanols, flavanol glycosides and their oxidation products also may contribute to the discoloration (Altschul, 1948; Blouin and Cherry, 1980) observed in weathered cottonseed.

RESISTANCE TO AND AVOIDANCE OF WEATHERING

The possible contributions of the various antibiotic constituents of cottonseed to resistance to weathering have not been explored. The only documented mechanism of resistance to weathering in cottonseed is an impermeable seed coat (Christiansen and Justus, 1963; Christiansen *et al.*, 1960; Mayne *et al.*, 1969). The hard or impermeable seed coat, common in wild cottons, prevents 1) moisture uptake by seeds, 2) infection of seeds by microorganisms and 3) deterioration of seeds. It has disadvantages for use in cultivated cotton, however, as hard seed require scarification (either mechanical or solvent) which may damage the embryos or increase their vulnerability to infection by microorganisms in the soil. Additionally, residual, nonharvested seeds can produce volunteer cotton for years following cropping with a hard seeded variety (Endrizzi, 1974). Several reports have documented differences among cotton cultivars in their susceptibility to seed deterioration and to infection by microorganisms (Arndt, 1945a; Bourland and Ibrahim, 1980b; Brown *et al.*, 1975; Cabangbang and Covar, 1978; Leffler, 1980a; McMeans *et al.*, 1977; Simpson and Stone, 1935), but factors accounting for these differences have not been determined.

Avoidance of exposure of cottonseed to moist conditions through timely harvesting has long been known and continues to be the best way to circumvent weathering damage of planting seed. Scott (1979) proposed specialized production of cotton planting seed as a primary crop, with fiber yield on that crop being given secondary consideration. He felt that with production in favorable locations and timely harvesting, the economic return from increased seed value and subsequent plant performance would outweigh any loss in fiber yield.

SUMMARY

Weathering of cotton planting seed involves processes, usually deteriorative, occurring between the time of boll opening and harvesting. These changes normally result in decreases in germination, seedling vigor and yield potential of the

subsequent crop. The physiological bases of the deteriorative processes are poorly understood. Weathering occurs only when seeds are exposed to moisture and probably involves systems of both seed and microbial origin. Timely harvesting of cotton to avoid prolonged exposure to moisture is the best means of avoiding weathering.