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Stand failures can result from any one or a combination of factors: poor seed bed preparation, low temperatures, excessive or insufficient moisture, soil microorganisms and other pests, chemical injury, and low quality seed. Low quality seed are probably a major contributing factor in most stand failures for they are very susceptible to adverse conditions and stresses in the seed bed environment and will usually produce a satisfactory stand only under very favorable conditions.

Obtaining a stand is an important milestone, but all problems arising from use of poor quality seed do not end with stand establishment. The idea apparently persisted until fairly recently that the influence of physiological condition of seed on performance extended up to the time seedlings became autotropic and not beyond. Now, however, it seems quite clear that the physiological conditions of seed can and does influence growth and development of plants throughout their life cycle.

We have used the term "seed quality" several times with and without qualifying adjectives. Niles has pointed out the difficulty in rigorously defining an abstract term such as quality. Nevertheless, he did provide a very acceptable definition of high quality seed that will serve the purposes of this discussion. He defined high quality seed as those capable of "establishing full stands of vigorous, uniform seedlings that will grow into productive mature plants." While this definition is generally applicable, it is well to bear in mind that the meaning of seed quality varies somewhat with the perspective of the person using the term. We must also recognize that the term quality as applied to seed encompasses several important and distinct characteristics of seed lots: varietal purity, physical purity, physical condition and appearance, physiological condition, infections and infestations with pests, and others.

The present discussion will be confined to physiological quality of seed—specifically cottonseed—and other quality attributes will be considered only as they are directly related.

Seed Deterioration

The physiological quality of seed is ultimately determined by the nature and progress of the deteriorative process in seed. For our purposes, deterioration of seed can be considered as any impairment in function resulting from changes occurring over time.

While it is not possible to rigorously define deterioration, it can be characterized in terms that are of some practical significance. Seed deterioration is inexorable, irreversible, minimal at time of maturation, and variable in rate among seed kinds and varieties, lots of the same kind, and individual seeds within a lot.

Although they contribute little toward a clear concept or definition of seed deterioration, these characteristics do define both the limits and direction of our efforts in producing and marketing seed of the highest physiological quality. We are limited by what must be considered—at least for the present—as biological facts. Deterioration of seed cannot be prevented although rate of deterioration can be closely controlled. The process of deterioration cannot be reversed. And, some kinds and/or varieties of seed are inherently longer lived than others. Accepting these limitations, effort must then be directed toward reducing rate of deterioration to a minimum.

Rate of deterioration of seed is conditioned by their developmental and post-maturation "history." The normal pattern of morphological and physiological development of cottonseed can be interpreted as a result of boll rots, invasion of fungi after insect damage, low temperatures, untimely defoliation, and so on. Influences such as these prevent the normal maturation of the seed and attainment of maximum physiological quality that normally occurs just before boll opening. After boll opening, the degree of deterioration sustained up to the time of harvest probably has the greatest influence on physiological quality.

It has been well established that the principal factors involved in field deterioration of cottonseed (opened bolls) are high temperatures, high humidities, frequent precipitation, heavy dews and time. The time factor—length of exposure—is particularly important for deterioration is a time dependent process. Six weeks exposure to a moderately adverse field environment can result in as much deterioration as one or two weeks exposure to very adverse conditions.

Modern cotton production practices have tended to increase deterioration by lengthening the period opened bolls are exposed in the field and increasing the adversity of the environment. This has been unavoidable and it is unlikely that we will return to weekly pickings and low fertility rates even for seed production.

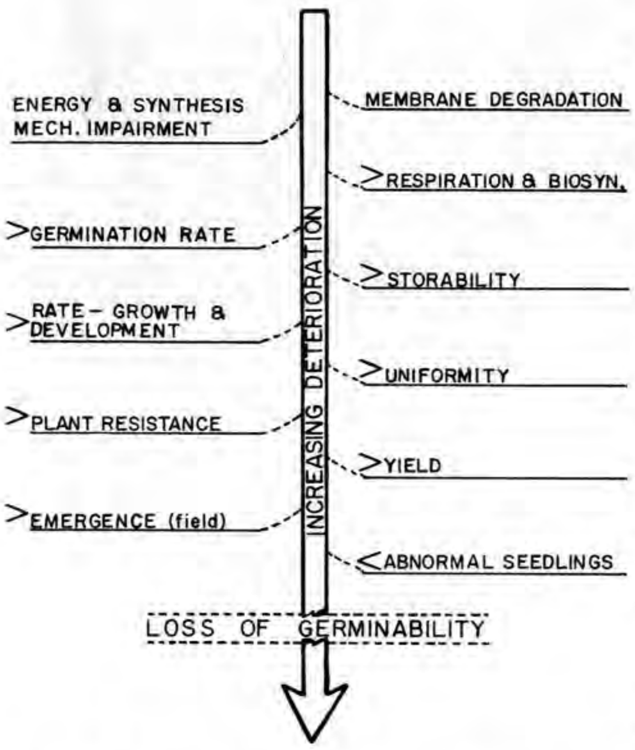

Figure 1. Progress of deterioration in seed and its possible effects on consequences.

The troubles of cottonseed do not end with harvest—although high quality seed at harvest usually means high quality seed in the bag. The mechanical picker, particularly if not properly adjusted and in a state of good repair, can severely injure seed. High seed cotton moisture, dense packing, and long periods of storage on the trailer before ginning can result in heating which greatly accelerates deterioration. Ginning, conveying and inadequate aeration are sources of additional injury to seed. Even after these hurdles are passed, the seed must still be reginned or flamed or acid delinted, cleaned, and treated—any one or all of which might cause additional injury.

The physiological quality of processed and packaged seed is conditioned by all the traumas sustained by them during development and until completion of processing. Since cottonseed are exposed to more potential sources of injury than most other kinds of seed, it is not surprising that production and supply of high quality cottonseed are perennial problems.

Storage of processed and packaged cottonseed is another factor that must be considered. Periods of storage range from three to six months for the bulk of the seed that are marketed and planted the first season after production to 15 to 18 months for that portion of the inventory that is carried over.

Storage of processed-packaged cottonseed for periods up to about 18 months does not appear to be a major problem provided reasonably dry, high quality seed are placed in storage. Most "storage" problems originate in the field, trailer, gin, or seed house. Seed that have begun to rapidly deteriorate as a result of adverse field conditions, heating in the trailer or seed house, improper delinting, or inadequate drying after treating continue to deteriorate rapidly in storage. The sudden and often considerable reductions in germination percentage during the first few months of storage are usually latent effects of pre-storage damage that were not reflected in germination percentage until some time time after the damage occurred.

Measuring Deterioration Effects

In our consideration of the characteristics of deterioration we might have added yet another one: that deterioration is characterized by change. Deterioration is identifiable only in terms of measurable or observable changes in response reactions or patterns of seed. Our thesis—as stated earlier—is that the physiological quality of seed is determined by the progress of the deteriorative process. Thus, evaluations of physiological quality are measurements of degree of deterioration and can be based on any one or a combination of changes or consequences of deterioration.

The consequences of deterioration of seed—other than loss of germinability—have been only recently considered. This recent work, however, does rather clearly show that deterioration is progressive, that specific components of performance are affected by different levels of deterioration, and that loss of germinability is a final consequence of deterioration.

The nature and sequence of deteriorative changes in seed and their effects have not yet been clearly defined and much more effort and time will have to be expended before this is accomplished. We can, however, postulate at least a tentative sequence of probable stages in the deterioration process as follows (See Figure 1):

(1) Degradation of cellular membranes and subsequent loss of control of permeability.
(2) Impairment of energy yielding and biosynthetic mechanisms.
(3) Reduced respiration and biosynthesis.
(4) Slower germination and early seedling growth.
(5) Reduced storage potential.
(6) Slower plant growth and development.
(7) Less uniformity in growth and development among plants in population.
(8) Increased susceptibility to environmental stresses.
(9) Reduced growth and development (lower quantity and quality of yield).
(10) Reduced stand producing potential.
(11) Increased percentage of morphologically abnormal seedlings.
(12) Loss of germinability.

We are mindful that this construction is vastly oversimplified, that some "events" are undoubtedly out of sequence, that others are omitted, and that specific cause and effect relationship are not clear. Nevertheless, it is useful in illuminating the over all process of deterioration and its consequences and in indicating some possible relationships. The relationship of loss of germinability to the other possible consequences of deterioration is especially significant.

The standard germination test is the most widely used and accepted means of measuring the physiological quality of seed. Germinability of seed is an important component of seed performance and loss of germinability a significant consequence of deterioration. In emphasizing germinability, however, we have focused on the most biologically disastrous consequence of deterioration and ignored its "lesser effects" such as reduced stand producing potential, slower growth and development, reduced yield, and so on. In our modern high input, mechanized agriculture, the lesser effects of deterioration are becoming of greatest importance. No one knowingly plants non-germinable seed, but we can only guess at how often weak, highly deteriorated seed are planted. We cannot be sure because the germination percentage of a seed lot—the only information on physiological quality normally available—is neither an adequate nor consistent measure of the performance potential of seed.

The inadequacy of germination percentage as the sole measure of the physiological potential of seed is evident in the data presented in Tables 1 and 2.

It is obvious that some measure of cottonseed quality other than or in addition to the standard germination test needs to be used. Several different alternative methods for evaluating cottonseed quality has been proposed. Development of some of them has progressed to the point that standardization and routine application might be possible in a few years. The more important and potentially useful quality tests are based on the tetrazolium reaction, respiratory activity, germinative responses after accelerated aging, responses to low temperature (in soil or germinator), and seedling growth rate.

Implications of Deterioration

The implications of seed deterioration in terms of possible effects on performance and productivity of plants have already been discussed. Before considering other implications, we should state clearly what is not implied in this discussion. The performance and productivity of crops and quality of the produce is influenced by a host of factors and their inter-relationships: variety, fertility, temperature, moisture, insects, diseases, weeds, etc. It is widely accepted that unfavorable levels of any one or a combination of these factors can severely limit production. Except for its influence on stand establishment, however, the physiological quality of planting seed has not been accorded similar recognition.

If the physiological condition of seed can influence performance and productivity in a farmer's field, then its influence must also extend to the research plot. It is certainly ironic that researchers after carefully designing experiments

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Table 1. Comparison of laboratory germination percentages and field emergence of eight lots of cottonseed (1968 data).

Lot	Laboratory Germination (%)	Field Emergence (%) 14 Days	35 Days
A-16	84	36	32
A-15	86	46	34
A-18	80	56	50
A-8	82	65	51
A-12	82	76	72
A-11	85	82	82
B-2	68	64	60
B-14	72	11	7

Table 2. Comparative performance of cottonseed from the same lot at three levels of induced deterioration obtained by accelerated aging for different periods.

Performance Component	Level of Deterioration Low	Medium	High
Germination (%)	84	80	78
Cold Test Emergence (%)	84	56	39
Seedling Growth Rate (mm. length/5 days)	207	150	110
Free fatty acids (%)	1.20	1.40	1.50
Yield Seed Cotton (lbs./plot)	4.33	3.96	3.63

to control all variables except the one(s) under study, plant the experiments with seed of dubious origin and uncertain quality. Such procedures are most likely to affect experimental results when several seed sources are used such as in varietal tests, fertility research, interaction studies, etc. We've been told by several experienced commercial breeders that selection of seed stocks submitted to Experiment Stations for varietal tests can influence yield of a particular variety by as much as five to ten percent.

Physiological condition of seed can also influence experimental results and conclusions derived therefrom even when a single seed source is involved. Much of the research on seed storage is of questionable value because a single lot of seed was used, and it has been clearly demonstrated that seed lots of the same kind and variety and with equivalent germination percentages do respond differently to storage under the same conditions. Differences in storage potential are related to differences in degree of deterioration. The results of many environmental and physiological studies involving plants produced from a single source of seed can also be affected. Is it reasonable to expect that a plant produced from a weak seed will respond to fertilizers or temperature or moisture in the same way and to the same extent as a plant produced from a vigorous seed?

The Cottonseed Lot

Seed quality is most often thought of as a property of a lot of seed. Thus, discussions of seed quality usually center on differences in quality among lots. Intralot variations in quality are also significant and equally revealing.

A seed lot consists of a population of seed varying in level of deterioration from those that are highest in vigor (for the lot) to those that are completely dead. If this were not true then germination percentage would be either 0 to 100 percent. The performance of each individual, germinable seed, therefore, is determined by its own physiological condition. Non-uniformity of germination, emergence, and seedling growth can largely be attributed to differences in quality among the seeds within a lot.

The nature and extent of intralot variability in quality are more pronounced and erratic in cottonseed than most other kinds of seed. The indeterminate fruiting habit of the plant, defoliation and poor mixing properties of the seed are the principal causes of this peculiar intralot variability. A cottonseed lot can be a mixture of very low-quality seed and very high quality seed with little gradation between—as was apparently the case of lot B-2 in Table 1. Germination was only 68 percent but nearly 100 percent of the germinable seed emerged and survived, as compared to only 32 percent emergence from Lot A-16 which germinated 84 percent.

Gregg's study on the associations among physical and biological properties of gravity graded cottonseed are especially revealing of intralot variations in quality. Selected data from his study are given in Table 3.

Among the 19 lots studied, bulk density of the seed ranged from 32 to 47 lbs./bu. Higher free fatty acid contents and frequencies of mechanical damage, lower germination and emergence were associated with the lower bulk densities. The light seed were not only lower in germination percentage but the seedling produced by germinable seed were much weaker and smaller.

Improving Quality

The problem of cottonseed quality is complex and difficult but not hopeless. Substantial improvement in quality is possible even now. Timely defoliation and harvesting, careful picking, ginning, and delinting, proper storage of both seed cotton and cottonseed, effective processing including density grading, adequate treating and efficient quality control could eliminate many low quality seed lots from the marketplace.

Researchers need to address themselves to the still unfinished business in the area of cottonseed physiology and research. Specifically, they need to:

(a) Develop a rigorous definition and concept of physiological seed quality.

(b) Identify and determine the relative importance of specific attributes of quality.

(c) Develop methods for adequately evaluating quality.

(d) Identify the factors affecting seed quality and develop technical and/or management procedures for minimizing or eliminating their effects.

(e) Establish a maximum level of deterioration in cottonseed that can be sustained without adversely affecting significant components of performance.

(f) Develop efficient and effective procedures for removing low quality seed from seed lots.

Intensive and sustained effort on the part of seed producers, processors, and researchers will be required to improve cottonseed quality up to the level of corn seed (and corn seed is not without problems). Both the effort and results are likely to be costly and can only be justified if the consumer is willing to bear some of the load in increased seed prices. We believe that he is willing, that he recognizes or will recognize that quality does not cost—it pays.

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Table 3. Average physical and physiological properties of separates from 19 lots of acid delinted gravity graded cottonseed.

Separate	BD	FFA	MD	LG	FE	SW
	Property					
1 (low end of gravity table)	32	5.7	19	36	21	.014
2	39	3.2	19	68	49	.018
3	41	2.8	17	72	56	.019
4	42	2.6	15	71	59	.020
5	44	1.7	13	79	62	.024
6	45	1.3	11	84	68	.024
7	45	1.0	12	86	71	.024
8	46	0.9	11	86	74	.025
9	46	0.9	13	84	72	.026
10 (high end of gravity table)	47	1.0	13	83	69	.025

BD: Bulk density: lbs./bu.
FFA: Free fatty acids: %
MD: Mechanical damage: % damaged seed
LG: Laboratory germination: %germination
FE: Field emergence: % seedlings emerged after 14-16 days
SW: Seedling weight: dry weight (grams) per seedling exclusive of cotyledons 7 days after planting on paper media at 20-30°C.