TOTAL BIOLOGY OF COTTON PLANTING SEED QUALITY RELATIVE TO OBTAINING PRODUCTIVE PLANT POPULATIONS

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Abstract

The history and development of the seed quality curve is reviewed. Germination data obtained with the 65°F test are used to show how to position a lot of planting seed on the curve. The seed position on the curve determines the equivalent exposure units (EEU's) to 100% relative humidity and 50°C. Performance data are given that show the expectations of seed lots having different EEU's when planted under controlled cold conditions and under natural field wet-cold conditions. The results show how resistance of seed and seedlings to wet-cold conditions decrease as EEU's increase from 0 to 6. Seed coats increasingly support mold growth as EEU's increase from 0 to 6. Final field stands are negatively correlated with 65°F germination and damping-off as EEU's increase from 0 to 2.5. With EEU's of 2.5 to 6, final field stands are positively associated with germination. Other associations of EEU's with seed and seedling performance are given.

Real early planting with seed of zero, one and no more than two EEU's greatly enhances success in establishing healthy stands and preventing, in part, yield losses caused by Verticillium Wilt, Phymatotrichum Root Rot and mid to late season insect damage.

Introduction

Biology is extensive relative to getting good stands of productive cotton. Understanding all components of the biology and optimizing favorable levels will make producers more efficient with a high certainty of economic gain. The components of the broad biology are:

a) Identifying and using planting seed having a certainty of performing under adverse cold and moist conditions,
b) Planting early when soil temperatures are less favorable for activity of soil inhabiting pathogenic fungi,
c) Using seed which produce seedlings that resist damage from secondary saprophytic fungi,
d) Using seed that produce seedlings having healthy root systems with certainty of sustaining plant growth by taking up moisture and nutrients as needed.

This paper covers the broad biology of getting a stand and how seedsmen can contribute improvements that benefit producers.

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Procedures

All seed used in the experiments were acid delinted, not culled and untreated. This provided performance of seed and seedlings not confounded with processing and protectant chemicals. The seed were obtained either from locations or harvested to assure minimum exposure in the field to high temperatures and moisture, whether as high humidity or rain.

For some experiments a common seed lot was used to establish eight classes of seed having zero, one day, two days consecutively to seven days of exposure to 100% humidity and 50°C. This simulated various intervals of natural exposure of seed to moisture and heat. The technique was initiated by Presley (1958) to facilitate experimentation relative to seed quality and seedling disease control. After treatment, the seed lots were allowed to dry under air conditioning until used in formal randomized and replicated experiments.

Other experiments used seed lots representing various conditions of natural production. Also seed of varieties having the same history of production, harvesting, processing and storage were used.

Experiments involved measuring total germination, abnormal seedlings and mold growth on the seed coat. The experiments were done primarily in 20 x 100 mm petri plates with a 2 mm layer of 1.5% water agar. This facilitated daily recording of data and dissipating the heat of germination. In some experiments the rag doll system was used. These experiments were randomized and replicated in a water curtin germinator. A constant temperature of 65°F (18°C) was used.

The standard measure of radical length in germination test to distinguish germination and nongermination was not used. Seed having radicals one-eighth inch long or longer were counted as germinated. Abnormal seedlings were those not forming the crook, exhibiting loss of tropism and nub-root (no radicle formation). The degree and percentage of seed coats that supported mold growth was determined. Velocity of germination was calculated using Kotowski's (1926) formula.

Performance of the seed lots in natural soil was determined by:

a) Planting in trays placed in controlled temperature tanks calibrated to maintain soil temperatures at seed depth,
b) Early March 1 outside tray plantings at College Station provided natural variations of soil and atmospheric temperatures,
c) Early field plantings (March 15 at College Station) where the field soil was naturally infested with *Rhizoctonia solani* (Kuhn), *Pythium* spp., *Thielaviopsis*

basicola (Berk. and Br.) and the normal flora of saprophytic fungi,

d) Glass front boxes with natural soil placed in controlled temperature cabinets,
e) Later, clear plastic goblets were used in the controlled temperature tanks so root development could be observed.

Measurements in the soil plantings were daily emergence (for calculating velocity of emergence), daily damping-off marked by using colored toothpicks, and final stand usually taken about 30 days after planting.

All experiments were mostly six replications using the triple lattice design.

Results

The 65°F germination test was developed in our laboratory and adopted March 1967 by the Texas State Testing Laboratories. We learned by additional experimentation that the original and present interpretation of the results is faulty. I want to show you why the old interpretation is faculty and give you the interpretation that will greatly improve identification of very desirable planting seed.

The seed quality curve must be accepted and understood in order to properly interpret results of the 65°F test (Bird and Reyes 1967). Presley (1958) rediscovered the research of Simpson and Stone (1935) relative to the effect of field exposure to moisture and heat on seed quality and seed storage. To facilitate controlled exposure to moisture and heat in a short period of time in the laboratory, Presley (1958) developed the procedure of exposing seed to 100% relative humidity at 50°C over increments of seven days. With this procedure he learned that as seed are exposed to moisture and heat under controlled conditions seed coats become increasingly susceptible to infection by fungi. During his fall visit to locations conducting seedling disease research he explained the procedure and pointed out how it could be used to gain better understandings for control of seedling disease. In Arizona, Blank developed a seed lot of Acala 44 by hand harvesting as bolls opened to reduce field exposure to moisture and heat. At College Station, Bird used the same procedure to establish seed lots for each of 14 varieties. The 14 varieties represented those bred at several locations across the cotton belt (Bird and Reyes 1967). Blank (1966) developed seven sublots using Presley's procedure of exposure to moisture and heat. Bird and Reyes (1967) using the same procedure developed sublots of 0, 3 and 6 days exposure to moisture and heat for each of the 14 varieties. After drying the sublots under air conditioned room temperature for two weeks germination was determined. Blank germinated seed at 72-74°F and Bird and Reyes (1967) used 58 and 68°F. Both laboratories terminated germination tests after 7-days (Bird and Reyes 1967).

The results were unexpected as the seed lots exposed for zero, one and two days to 100% humidity at 50°C had lower germination percentages than those exposed for three to four days. From zero to 2.5 days germination percentage increased and after 2.5 days the percentage decreased to five and zero percent in 6 to 7 days. Bird and Reyes (1967) used averages of Blank's and their data to establish the seed quality curve (Figure 1). Germination percentage was plotted against days of exposure to moisture and heat. Simpson and Stone's (1935) terminology was used for grouping seed lots relative to their equivalent exposure to moisture and heat.

The seed quality curve made it possible to interpret and understand differences among varieties and seed lots that otherwise were confusing. Days of exposure to moisture and heat are equivalent exposure units (EEU's). Changes and reversal of trends occurring, as equivalent exposure units increased, as measured in the laboratory and germinator were:

a) Glucose content of seed leachate decreased,
b) Germination percentage increased then decreased with changes being greater at 58°F than at 68°F,
c) Velocity of germination increased from zero to two exposure units then decreased.

Changes occurring in soil tray plantings placed outside relative to increases in EEU's were:

a) Velocity of emergence was steady then decreased,
b) Final stands decreased,
c) Seedling disease grades increased,
d) The frequency of *R. solani* and *T. basicola* on seedlings decreased to zero after two exposure units,
e) The frequency of *Pythium* spp., *Fusarium* spp. and *Alternaria* spp. on seedlings increased from 2 to 4 exposure units.

The seed quality curve made it possible to relate germinator, laboratory and greenhouse data with field performance with repeatable understandings.

Adoption of the 65°F test and understandings gained with the seed quality curve occurred in 1967. At that time research was initiated to meld the 65°F test results with the seed quality curve. It became clear that the measure of radicle length in determining germination was misleading for the 65°F test. Since the better (unconditioned) seed germinated at a slower rate in the cold test their radicals were shorter. Not counting short radicle normal seedlings caused failure to recognize the best seed for seeding survival under unfavorable conditions (Figure 1).

Seed sublots, from a common lot having little natural exposure to moisture and heat, representing one through six exposure units were established. The sublots were evaluated at controlled seed depth soil temperatures of 65, 75 and 80°F for 30 days. At 65°F only seed with exposure units of one, two and three gave surviving stands. At 75°F only seed with exposure units of one, two and three gave surviving stands (Figure 2). This shows that cotton planting seed have resistance to cold and seedling pathogens and the resistance is nullified with exposure to excessive moisture and heat. The six seed lots were also evaluated at 80°F (Figure 3). Seed lots with exposure units of one through five gave reasonable surviving stands and the sixth lot about half a stand. Note that seedlings of lots four, five and six are shorter and have mottled yellow to white tissues. The hypocotyls, not visible, have similar mottled discoloration. The discolored tissues are basically half-dead and are easily invaded by saprophytic soil organisms. These results extends the biological understanding of seed quality relative to establishing stands. It is clear that farmers and seedsmen would be better managers of their operations if they distinguished seed lots like zero, one and two from three and four.

The next sequence of experiments was to relate the 65°F test results with field performance. Results which represents ten years of experiments were with 36 seed lots naturally produced in the field and representing a full range of equivalent exposure units (EEU's). The test was planted March 25 at College Station. Fifty feet long plots were planted to 150 hand counted seed. During the four weeks following planting, the seed depth night low soil temperatures ranged from 52 to 70°F and daily highs ranged from 70 to 84°F. Total rainfall per week for the first three weeks was 0.47, 3.99 and 1.39 inches respectively.

Simple correlation coefficients reveal relationships among germinator and field performance traits. Cold test high germinating seed lots had the highest initial emergence but they had the lowest final stands (Table 1). Paralleling this, seed lots with early field emergence had high rates of damping-off while those with slow field emergence had less damping-off (Table 1). These results are clear in showing that seed lots with zero to two EEU's had less damping-off and higher stands than seed lots having three and higher EEU's. Seed lots supporting more mold growth gave lower field stands and seed lots giving the highest final stands had more plants with good root systems (Table 1). Correlations among final averages clearly show that seed lots with high cold test germination had the highest damping-off and less plants with good roots. Also the trend was for seed lots with more mold growth (Figure 5) to have more plants with poor roots (Table 2). Yield average for the seed lots ranged from 272 to 542 pounds lint per acre. Correlation with yield showed that seed lots having plants with more good roots and the highest stands at 45 days gave the higher yields. Also, the trend was for seed lots with the lowest 65°F germination, least mold growth and lowest damping-off to give the highest yields (Table 3). The relationships shown in Table 3 illustrates the span of biology following a meaningful germination test and events leading to favorable yield.

Discussion

The information presented in this paper represents results of experimentation with cotton planting seed over a number of years. The results were highly repeatable and consistent over years. The seed quality curve is shown to be a valuable tool to use in forecasting performance of planting seed. The 65°F 7-day germination test provides data to indicate the position of a seed lot on the quality curve (Figure 4). Directly below the curve position is the days of exposure to 100 percent relative humidity at 50°C. These are the equivalent exposure units (EEU's). Directly above the equivalent exposure units one can tell the expectation of damping-off and final stand in early season field plantings (Figure 4). For example, a seed lot germinating at 75 percent with short normal radicals, good crooks formed and having few abnormal seedlings has an EEU of one indicating an expectation of not more than 25 percent damping-off and a final stand of at least 50 percent. Compare this with a seed lot with 95 percent germination, radicals 2.5 inches long or longer, good crooks formed with 5 to 10 percent abnormal. Its EEU is three indicating an expectation of 51 percent damping-off and a final stand of 31 percent. It would be extremely important for seedsmen and producers to know the EEU of seed they sell and plant. Such knowledge would enhance the efficacy of cotton production.

The changes that occur in seed, then seedling and plants as the equivalent exposure units (EEU's) increase from zero to seven as determine with the 65°F cold test follows:

a. With EEU's of 0 to 2.5, final stands are negatively correlated with germination,
b. With EEU's 2.5 to 6, final stands are positively associated with germination,
c. Cold resistance of seed and seedlings decrease as EEU's increase from 0 to 6,
d. Seed coats increasingly support mold growth as EEU's increase from 0 to 6,
e. With EEU's of 0 to 2.5, post emergence damping-off is negatively correlated with final stand and positively correlated with 65°F germination,
f. With EEU's from 0 to 2.5, seedlings are infected primarily by true pathogenic fungi while those from 2.5 to 6 are infected and infested primarily by saprophytic fungi (these results, reported earlier by Bollenbacher and Fulton (1959) were confirmed by our work),
g. Seed with EEU's of 0 to 2.5 will store well for several years while those with EEU's greater than 2.5 continue deterioration in storage (Bollenbacher and Fulton 1959).

Sometimes it may be difficult to decide which side of the quality curve a seed lot is on. The following maybe helpful:

a. untreated seed lots having low seed coat fungal growth are on the left side of the curve;

b. seed on the left side of the curve will have less abnormal seedlings;
c. if the cool test germination is less than the warm test the seed lot is on the left side, while if the cool test is higher than the warm test the lot is on the right side.

Seed laboratories reporting cool test results can provide information for placing a seed lot on the quality curve by reporting total germination of normal seedlings regardless of radical length.

Systems of seed evaluation maybe developed making it easier and quicker to place a seed lot on the quality curve. Such research should be encouraged and hopefully it will be successful (Bourland et al., 1988).

The standard alternating temperature test groups seed with EEU's of zero to four in the same pool. The warm-cool test favors seed lots with two to four EEU's while discriminating against the best seed which have EEU's of zero to two. As pointed out above it will be easy to identify seed lots using the 65°F test with slight changes in recording and reporting data.

Real early plantings with seed of zero, one and no more than two EEU's greatly enhances success in establishing healthy stands and preventing, in part, yield losses caused by Verticillium Wilt, Phymatotrichum Root Rot and mid to late season insect damage.

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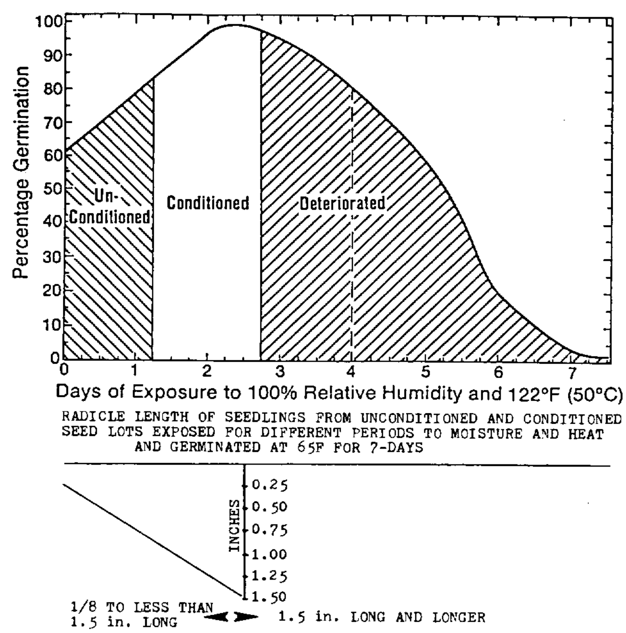


Figure 1. The seed quality curve obtained by plotting germination percent at 65°F after 7-days for seed lots with controlled exposure for the indicated days to 100% relative humidity and 50°C. The days of exposure are called equivalent exposure units (EEU's). The groupings for seed lots considered to be unconditioned, conditioned and deteriorated are shown. The lower sketch shows the approximate length of radicals expected for seedlings from seed with 0 to 2.5 EEU's when germinated at 65°F for 7-days.

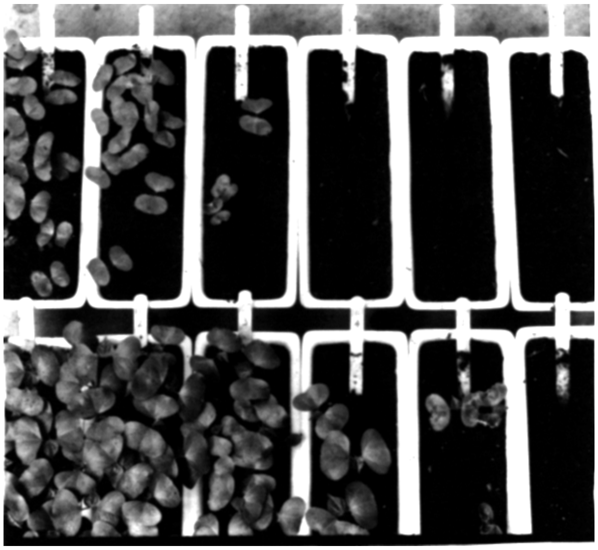


Figure 2. Performance in natural soil of seed lots exposed for one to six (L to R) days (EEU's) to 100% relative humidity and 50°C. The seed depth soil temperature was controlled at 65°F for the top row and 75°F for the bottom row. This shows that cotton planting seed looses the ability to perform at low temperatures when exposed to moisture and heat. Identifying seed lots with low (0 to 1) EEU's is important for use in early plantings.

Figure 3. The same seed lots shown in figure 2 held at a seed depth soil temperature of 80°F. The seed lots with EEU's of 4, 5 and 6 have seedlings which are shorter and the cotyledons are mottled yellow, white and green colors. Seed lots with EEU's of 4 and higher should never be used for planting seed.

Table 1. Correlation coefficients among cold test measurements and field plant data with emergence over time and final stand.

Germinator and Field Plant Data	Emergence and Final Stand Days from Planting			
	14	28	38	45
	Correlation Coefficients			
Germination, 7-day 65°F	+.41*	-.16	-.36*	-.35*
Moldy Seed, 7-day 65°F	+.01	-.37*	-.33*	-.31
P. E. Damping-off	+.80**	+.44**	-.14	-.22
Good roots	+.06	+.26	+.41*	+.44**

* Significant at the 5% level of probability.

** Significant at the 1% level of probability.

Table 2. Correlation coefficients among cold test measurements and total damping-off and undamaged roots in the field.

Plant Field Data	Total Germination 7-Days 65°F	Moldy Seed 7-Day 65°F
P. E. Damping-off	+.46**	+.04
Plant With Good Roots	-.55**	-.32

** Significant at the 1% level of probability.

Table 3. Correlation coefficients of yield data with germinator and plant field measurements.

Germinator and Field Measurements	Yield
	Correlation Coefficients
Germination, 7-day 65°F	-.25
Moldy Seed, 7-day 65°F	-.35*
P. E. Damping-off	-.28
Plants With Good Roots	.39*
Stand, 45 Days From Planting	.68**

* Significant at the 5% level of probability.

** Significant at the 1% level of probability.

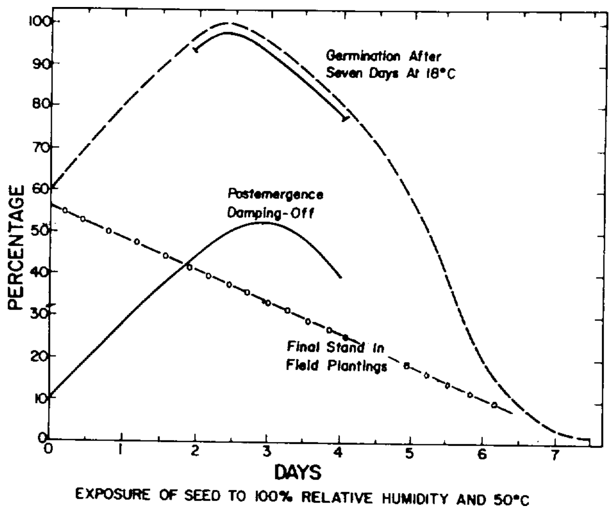
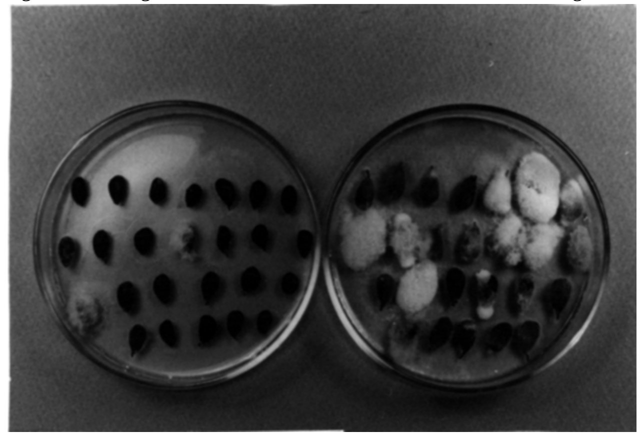


Figure 4. The seed quality curve with field performance data to show how expected final stands is linear and negatively related to EEU's (days of exposure to moisture and heat). The negative relationship between 0 to 2.5 seed germination and final stand is illustrated. The positive relationship between 0 to 2.5 germination and damping-off and between 2.5 to 6 germination and final stand is illustrated.

Figure 5. Mold growth on acid delinted cottonseed held on water agar for



7-days at 65°F. Left, seed exposed to moisture and heat for 0 to 1 days and right, seed exposed to moisture and heat for 3 to 4 days. The frequency of seed supporting mold growth and the density of the growth increases with each EEU of exposure to moisture and heat. Testing protectant fungicide treated seed neutralizer this measurement.