GERMINATION, EMERGENCE, AND SEEDLING DEVELOPMENT OF 16 COTTON LINES

by

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ABSTRACT

Experiments were conducted with 16 cotton lines to determine rate and percent germination using the standard (Experiment 1) and accelerated aging (Experiment 2) tests, to determine emergence and seedling development in the greenhouse (Experiment 3), and to determine correlation of the above three methods and their relationships with field emergence and mature plant height.

The Regression Index in Experiment 1 indicated a highly significant difference among the lines. In Experiment 2, both percent germination and Regression Index means were different for the 16 lines. Experiments 1 and 2 were poorly correlated.

Significant differences among emergence of the 16 lines were found from the 7th to the 11th day after planting. There were significant negative correlations between Regression Index from the standard test and emergence in the greenhouse. Hypocotyl length of 14-day-old seedlings was significantly correlated with greenhouse emergence 14 days after planting and mature plant height in the field. All means, except percent germination under the accelerated aging test, from the three experiments were insignificantly correlated with field emergence 46 days after planting.

The germination, emergence, and seedling development characteristics determined in these experiments were found to have limited value in predicting field emergence. Hypocotyl length of 14-day-old seedlings

grown in the greenhouse provided a fairly reliable method of predicting mature plant height in the field.

INTRODUCTION

Laboratory germination of seed has remained a common practice for many years although its importance in predicting seed performance in the field was inconsistent for some crop types and/or seed samples (Munn, 1926; Perry, 1973). Laboratory tests could be used as reliable guides to the emergence of crops planted under favorable greenhouse and field conditions according to Das Gupta and Austenson (1973a), Hay (1928), and Sherf (1953). The favorable conditions in the standard germination test made the detection of low vigor cotton (Gossypium hirsutum L.) seed samples difficult (Wiles, 1960). The need for better methods of measuring the capacity of seed to germinate under less favorable conditions was suggested by Abdulahi and Vanderlip (1972).

The increasing demand for agricultural products has forced many researchers to look for better techniques that could help growers estimate the amount of seed to plant per given area to insure an economical plant stand.

The present experiments were conducted with 16 cotton lines to fulfill the following objectives:

1. To determine the rate and percent of germination under standard germination conditions.
2. To determine the effect of an accelerated aging treatment on the rate and percent of germination.

3. To determine emergence and seedling development in the greenhouse.
4. To determine the relationships between the above methods and correlate the above methods with field emergence and mature plant height.

REVIEW OF LITERATURE

Several methods of determining quality of cotton planting seed have been investigated. Wanjura, Hudspeth, and Bilbro (1969) stated that germinating seed under a controlled temperature regime, staining the seed embryo with tetrazolium, or measuring the respiration rate of germinating seed are useful to determine seed quality. Comer (1968) studied several tests to predict the performance of cottonseed planted under adverse field conditions. There was a poor correlation (0.41) for the standard germination percentages and the actual seedling emergence percentages in the field. Significant coefficients were found for seedling emergence in the field check plots and those obtained in the 1200 ppm CO_2, enclosed environment, tetrazolium test, and pre-soaked seed in the field.

Wiles (1960) suggested that both the low-temperature germination test (20 C) and the standard germination test should be used in testing cotton seed for planting until more precise methods of measuring seed quality are developed. He noted the importance of the low-temperature germination test as a means of detecting low vigor cotton seed samples. Toole and Drummond (1924) reported average germination of 12 cotton seed samples as follows: standard method, 65.6%; in soil in a laboratory, 84.1%; in sphagnum moss, 85.1%; in soil in a cool greenhouse, 72.9%; and in soil in a warm greenhouse, 92.3%. They pointed out that the seed samples performed differently under various germination conditions depending on the relative vigor of the seed samples.

Comparing the reliability of the standard germination test, a modified germination test, which separated normal and abnormal seedlings, and an accelerated aging test (seed exposed to high temperature and relative humidity before planting) in predicting field emergence of 24 cotton seed lots, Rogers (1971) indicated highly significant correlations between percent germination, accelerated aging test, and field emergence after 14 days. However, there was no significant correlation between percent normal seedlings and field emergence.

Christiansen (1962), working with two genetic selections of cotton, suggested that the percent of cotyledon dry weight to total seedling dry weight could be used as a quantitative measure of heritable vigor and/or treatment influence.

Results of the comparisons of two laboratory germination methods and field emergence for 18 monogerm sugar beet (Beta vulgaris L.) cultivars were reported by Tekrony and Hardin (1966). Correlation coefficients were all highly significant. Higher germination was found with seed treated with a 0.1% hydrogen peroxide solution for 16 hours than with the standard method where seed were soaked in water for 2 hours. In studies by Perry (1973), with four commercial cultivars of monogerm sugar beets, the relation between laboratory germination and the number of emerged seedlings was variable and followed no obvious trend. There was no consistent rank order in the emergence ability of the cultivars.

In the comparison of germination percentages of 17 pea (Pisum sativum L.) seed lots in the field, a laboratory test at 30 C, and a standard laboratory test, Cladwell (1960) found that the correlation with field emergence and the 30 C test was higher than that between field emergence and the standard germination test. The rank of the lots in the 30 C test showed less deviation than the field emergence rank. Similarly, Hay (1928) compared two laboratory germination methods with field emergence. One of the laboratory methods involved soaking the seed for 6 hours before starting the test and the other was the standard method. He concluded that field tests closely agreed with the laboratory results in either of the techniques used.

Burris, Edje, and Wahab (1969), working with six naturally and artifically aged soybean (Glycine max (L.) Merr.) cultivars, reported that glucose levels, respiration of the imbibed seed, and tetrazolium tests showed excellent correlations with seed quality and subsequent seedling vigor. In studies by Egli, Tekrony, and Hatfield (1973), standard germination of soybeans adequately predicted field emergence under optimum field conditions. They also indicated that under conditions of temperature stress, combinations of seedling length or artificial aging with standard germination resulted in reliable estimates of seedling field emergence.

Grabe (1967) found that low vigor seed in corn (Zea mays L.), soybeans, and oats (Avena sativa L.) resulted in lower yield even when their germination ability was high. Artificially aged soybeans stored under unfavorable moisture and temperature conditions resulted in poor field stands although laboratory germination of the seed was still over 90%.

Woodstock (1965) reported a highly significant correlation between initial respiration rates and subsequent seedling growth of corn seed that were incubated in darkness at 25 C. He found similar relationships for corn seed that were exposed to 45 C and 95 to 100% relative humidity for 0, 2, 2.5, 3, or 4 days. In similar studies by Woodstock (1967), significant positive correlations were observed between respiration rates during the first few hours of imbibition and the growth rate of barley (Hordeum vulgare L.) and corn seedlings. Woodstock and Feeley (1965), working with two corn cultivars, reported significant correlations between respiration rates of seed during the first hour of germination and subsequent seedling growth and field emergence.

In studies comparing the following seed vigor tests, artificial aging of seed; soil cold test; soaking of seed in NH_4Cl; and standard germination; Abdulahi and Vanderlip (1972) found that all tests showed significant correlations with seedling establishment of grain sorghum (Sorghum bicolor (L.) Moench) in the field. The NH_4Cl treatment gave better correlations than the other treatments. They regarded conditions provided in the standard germination test as highly favorable, and hence indicated the need for better methods of measuring seed capacity to germinate under less favorable field conditions.

Results of work of Grabe (1965) with corn indicated that seed longevity was associated with pre-storage glutamic acid decarboxylase activity (GADA) and seedling growth rate but not with germination at 25 C or cold test performance at 10 and 25 C for 7 and 4 days, respectively. Field emergence was more closely related to germination and cold test performance than to GADA or growth rate. Woodstock and Grabe (1967), working with corn seed lots stored for 4 years under different moisture and temperature regimes, reported that respiration rates and GADA were significantly correlated with germination and seedling growth.

In studies with six ages of wheat (*Triticum aestivum* L.) seed ranging from 1 to 6 years, under the standard laboratory condition for wheat, Kittock and Law (1968) found no effect of seed age on germination percentage. However, they observed a decrease in total field emergence and vigor as seed age increased.

In an experiment conducted to study the correlation of germination of corn and soybean seed lots under laboratory, greenhouse, and field conditions, Sherf (1953) reported that laboratory tests provided a reliable guide to field emergence of both crops planted under favorable conditions. Sherf stated that previous studies, which were not in agreement with his observation, might have been accomplished under more severe environmental conditions.

In laboratory and field germination studies of 17 cultivars of sorghum, Swanson and Hunter (1936) reported 95 and 50% average germination for laboratory and field conditions, respectively. They observed considerable differences among the response of individual cultivars when grown under laboratory and field conditions. Munn (1926) studied garden peas in the laboratory at constant 20 C and under field conditions. He found that the average laboratory and field germination percentages were 79 and 45%, respectively.

Stahl (1931a) reported a high correlation coefficient between normal sprouts in the laboratory in 7 days and percentage of field germination in 20 days for 99 seed samples of white cabbage (*Brassica oleracea* var. *capitata* L.) and 100 samples of cauliflower (*Brassica oleracea* var. *botrytis* L.). Also, Stahl (1931b) reported results of studies with swedes (*Brassica napobrassica* (L.) Reichb.), turnips

(Brassica rapa L.), red clover (Trifolium pratense L.), and grass seed. Laboratory germination tests were conducted at an alternating temperature of 18 and 30 C. Germinating capacity for perennial ryegrass (Lolium sp.) and speed of germination for field bromegrass (Bromus arvensis L.) gave the best estimation of field germination. For swedes and turnips, the best estimation of their planting values was obtained by counting only fully normal germinated seedlings. In the case of red clover, the best estimation of field germination was obtained by counting only the normal germinated sprouts plus 1/3 or 1/2 of the total hard seed.

In studies with five leguminaceae and five gramineae crops, Whitcomb (1924) concluded that there was a close relationship between laboratory and field germination tests. The laboratory tests were conducted under a constant temperature of 20 C and an alternating temperature of 20 C for 18 hours and 30 C for 6 hours. He indicated that large differences in germination were observed in crops with small seed, while small differences were found in large seeded crops.

Clark (1973) compared the effectiveness of four laboratory tests in predicting the potential field performance of peanut (Arachis hypogaea L.) seed lots. Laboratory tests with alternating temperatures of 20 and 30 C for 10 days gave the highest predictive value of field emergence where climatic conditions were nearly ideal. However, laboratory tests of 5 C for 3 days plus alternating temperatures of 20 and 30 C for 7 days resulted in the highest predictive value of field emergence and survival where conditions were less favorable. Mohammed, Zafar, and Kidar (1933), working with peanut seed, reported less field emergence for cultivars that gave higher percent germination in the laboratory. According to these workers, poorer field emergence might have been due to insufficient soil moisture and/or injury to the testa and cotyledons during pod shelling.

Erickson and Porter (1938) obtained higher germination values in laboratory studies than in the field for soybean, sorghum, red clover, alfalfa (Medicago sativa L.), and sweet clover (Melilotus alba Desr.) seed lots. They suggested that laboratory and field response comparisons for a given crop be carried out for several years to have a reliable relationship of seed quality, as measured by a laboratory test, to predict crop production.

Working with spring wheat, Das Gupta and Austenson (1973b) reported field stands positively correlated with standard, cold, and modified-cold germination percentages. Grain yields were positively correlated with all estimates of germination and with their respective field stands. In addition, the rate of O_2 uptake by seed during the 8th and 9th hours of water uptake could be used as a satisfactory indicator of seed vigor. In similar studies with hard red spring wheat, Das Gupta and Austenson (1973a) observed significant positive correlations among yield and standard germination, cold germination, O_2 uptake, and stand.

Buxton et al. (1973) observed variability among 12 lines of G. hirsutum L. and 14 lines of G. barbadense L. that were germinated at 25 and 15 C. These workers reported the results of four field experiments with G. barbadense L. They noticed little difference in emergence among entries when soil temperatures were favorable and greater difference when soil temperatures were unfavorable. Wanjura, Hudspeth, and Bilbro (1969) indicated a higher correlation for plant survival and yield with emergence time than with germination percentage and planting depth of cotton seed. The seed lots were deteriorated by being exposed to high relative humidity and 50 C for 0, 48, and 72 hours and then tested under laboratory and field conditions.

Bird and Ergle (1961) studied 12 cotton cultivars grown in flats under greenhouse conditions. They found that the cultivars studied differed in rate of seedling emergence and seedling height and suggested a possibility of developing rapidly emerging cultivars by selecting only for seedling height. This would be easier to measure than rate of emergence since a positive correlation has been observed between rate of emergence and seedling height.

Woodstock and Combs (1964) compared length of root, shoot, embryo axis, and seedling fresh weight of corn as criteria for predicting growth. The seed were germinated in the laboratory at a constant temperature of 25 C and 95% relative humidity. The greenhouse study was conducted in flats at a controlled temperature of 25 C and 90 to 100% relative humidity. Shoot length was the best criteria for predicting subsequent seedling performance.

MATERIALS AND METHODS

Three experiments were conducted in 1973 and 1974 at The University of Arizona, Tucson, with 16 cotton lines ('Acala SJ-1,' 'Lockett BXL,' 'Tamcot SP21,' 'Tamcot SP37,' 'Lankart LX571,' 'Stoneville 213,' 'Deltapine 16,' 'Deltapine 45A,' 'Coker 201,' 'Coker 310,' 'Westburn,' 'Delcot 277,' 'Watson GL-16,' 'Acala 1517-70,' H^2-8-70, and H^2-4-70). These lines were increased in 1971 at Texas A & M University, College Station, for use in Regional Research Project S-72. The seed lots were uniformly acid delinted and did not receive any chemical seed treatment.

Standard Germination Test -- Experiment 1

Fifty seed of each entry were placed on two germination paper towels with the micropile end of each seed oriented toward the base of the towels. They were then covered with a third towel and moistened with 60 ml of tap water. The towels were rolled from both sides to the center and were placed upright in plastic bags which were held on a special rack. Two seed lots were placed in each plastic bag and the racks were placed in a growth chamber using alternating temperatures of 20 C for 16 hours and 30 C for 8 hours. The chamber did not have humidity control and moistened sponges were kept in the chamber to reduce evaporation from the towels (relative humidity, 59 ± 1% at 30 C and 79 ± 1% at 20 C). Towels were checked daily and water was added as needed to maintain a moist condition. Four replications were used with a randomized block design.

On the 3rd day after the start of the test, and each successive day until the 12th day, the seed were examined and healthy seedlings of 5 or more cm in radicle length were removed and their number recorded. Diseased seed and seedlings were also removed and their number noted. On the 12th day, any remaining seedlings were categorized as normal or abnormal based on the description listed in Agriculture Handbook No. 30, U. S. Department of Agriculture (1952).

Accelerated Aging Test -- Experiment 2

In this experiment, the seed were exposed to a temperature of 49 C and a relative humidity of 88% for 72 hours before placing in the growth chamber.

To obtain the desired temperature and humidity, a 25 by 30 by 13 cm plastic pan with 2500 ml water was placed in an incubator. A hygrothermograph to record temperature and humidity was placed on a screen floor in the pan. The pan and hygrothermograph were partly covered with aluminum foil. The opening in the aluminum foil was adjusted until the desired temperature and humidity were obtained.

A minimum of 200 seed from each seed lot were enclosed in cheese cloth sacks. The hygrothermograph was removed and the sacks were placed on the screen floor, and the pan, filled with 2500 cc of tap water, was placed in the incubator. The aluminum foil over the pan was maintained throughout the 72-hour period. The seed lots were periodically moved to different positions on the floor to allow uniform exposure. At the end of 72 hours, the seed were removed from the incubator and 50 seed per seed lot were put on germination paper towels as in Experiment 1 with four replications in a randomized block design. The standard germination temperature for cotton was used with alternating temperatures of 20 C for 16 hours and 30 C for 8 hours with the relative humidity 82 ± 1% and 62 ± 1%, respectively. Measurement of radicle length was begun after 3 days and continued daily until the 12th day as in Experiment 1.

The rapidity of germination in Experiments 1 and 2 was determined by the Regression Index Method (Tucker and Wright, 1965). In these experiments, the number of plants germinated daily from the 3rd to the 7th day were used in calculating the Regression Index.

Greenhouse Study -- Experiment 3

The seed in the greenhouse experiment were planted January 7, 1974, in galvanized metal flats (36 by 51 by 9 cm) filled with a 1:1:1 mixture of peat moss, vermiculite, and soil by volume. Thirty seed from each line were planted approximately 2.5 cm deep with spacings of approximately 2 cm between the plants and rows. A randomized complete block design was used with four replications. Four flats were required per replication. After planting, the flats were watered with tap water; subsequent waterings were done every other day throughout the experiment to maintain a desirable moisture condition for germination. The average maximum and minimum temperatures and relative humidities recorded throughout the experiment were 34 and 23 C, and 61 and 39%, respectively.

Emergence counts were started on the 6th day after planting, and cumulative counts were made every day for 8 days after the initial emergence count. Emergence of the entire cotyledon above the soil surface was used in determining seedling emergence.

On the 14th and 15th days after planting, the seedlings were cut at the soil surface and hypocotyl length from the cotyledons to the soil was measured. Replications 1 and 2 were 1 day younger than replications 3 and 4 at harvest. The cotyledonary leaves were cut from the stem portions and dried separately for 4 days at 38 C. Dry weights of stems and cotyledonary leaves were determined with an electric analytical balance. Data from all experiments were analyzed statistically.

Field Study

A field experiment with the same seed lots of the 16 cotton lines was conducted in 1973 at The University of Arizona Cotton Research Center, Phoenix, under the direction of Dr. Robert E. Briggs.

From the above experiment, emergence counts 46 days after planting and mature plant height were used to determine correlations with data of the present study.

RESULTS AND DISCUSSION

Three experiments were conducted in 1973 at The University of Arizona, Tucson, using 16 short staple cotton lines to determine rapidity of germination and seedling development.

Standard Germination Test -- Experiment 1

The average percent germination of the 16 seed lots was not significantly different 12 days after the start of the test (Appendix, Table 7). The average percent germination ranged from 98.5% for Deltapine 45A to 88.6% for Acala SJ-1 (Table 1). Wiles (1960) indicated that the highly favorable conditions provided in the standard germination test make the detection of low vigor cotton seed samples difficult.

The Regression Index means of the 16 entries were highly significantly different (Appendix, Table 7). The Regression Index estimates the number of days required to germinate 50% of the seed planted. The Regression Index mean value for Deltapine 45A was significantly less than any of the other entries (Table 1). This indicates that Deltapine 45A was the fastest germinating seed lot. The Regression Index Method would be useful to plant breeders in selecting rapid germinating cotton lines.

Accelerated Aging Test -- Experiment 2

A highly significant difference was found in the percent germination of the 16 cotton seed lots (Appendix, Table 8). The percent germination and Regression Index values for Experiment 2 are shown in Table 2. Tamcot SP21 had the highest germination (99.5%) 12 days after

Table 1. Average percent germination and Regression Index of 16 cotton lines 12 days after planting (Experiment 1).

Line	Germination	Regression Index
Acala SJ-1	88.6†	4.33 cd*
Lockett BXL	94.0	3.25 bc
Tamcot SP21	95.0	4.58 d
Tamcot SP37	96.5	3.80 bcd
Lankart LX571	97.5	4.22 bcd
Stoneville 213	96.0	3.40 bc
Deltapine 16	97.0	3.33 bc
Deltapine 45A	98.5	2.34 a
Coker 201	94.0	3.27 bc
Coker 310	93.5	3.16 b
Westburn	93.0	4.84 d
Delcot 277	95.0	3.40 bc
Watson GL-16	89.7	4.61 d
Acala 1517-70	94.9	3.72 bcd
H^2-8-70	96.5	3.89 bcd
H^2-4-70	97.0	4.07 bcd
C.V.	4.2%	12.1%

†No significant difference.
*Means followed by the same letter are not significantly different at the 0.05 level according to the Student-Newman-Keuls' Multiple Range Test.

Table 2. Average percent germination and Regression Index of 16 cotton lines 12 days after planting (Experiment 2).

Line	Germination	Regression Index
Acala SJ-1	92.5 ab*	4.10 ab*
Lockett BXL	94.4 ab	3.85 ab
Tamcot SP21	99.5 a	4.07 ab
Tamcot SP37	96.6 ab	3.85 ab
Lankart LX571	91.0 b	4.21 ab
Stoneville 213	96.9 ab	4.04 ab
Deltapine 16	98.0 ab	3.72 a
Deltapine 45A	98.5 ab	3.81 ab
Coker 201	93.0 ab	3.98 ab
Coker 310	93.2 ab	4.04 ab
Westburn	96.0 ab	4.09 ab
Delcot 277	94.9 ab	4.40 b
Watson GL-16	94.5 ab	4.16 ab
Acala 1517-70	98.0 ab	3.95 ab
H^2-8-70	96.5 ab	3.90 ab
H^2-4-70	97.5 ab	3.96 ab
C.V.	3.2%	6.0%

*Means followed by the same letter are not significantly different at the 0.05 level according to the Student-Newman-Keuls' Multiple Range Test.

the seed were put in a growth chamber, although this value was statistically different only from Lankart LX571 whose germination was 91.0%. The rapidity of germination of Deltapine 16 was significantly earlier than Delcot 277 as determined by the Regression Index.

A comparison between percent germination in Tables 1 and 2 shows that germination of some entries improved when exposed to the accelerated aging test conditions while other entries did not compare as favorably. Lankart LX571 is an example of a seed lot that was greatly reduced with the accelerated aging test. The germination percentages of Tamcot SP21, Westburn, Watson GL-16, and Acala 1517-70 were favorably increased by the accelerated aging test. The Regression Index means showed a much wider range in the standard germination test than in the accelerated aging test. It was assumed that the accelerated aging test would result in greater differences in percent germination than the standard test. It is possible that if a longer time period had been used in the preconditioning of the seed before placing in the growth chamber, greater differences between the lines would have resulted. There were insignificant correlations for germination at 12 days and the Regression Indices between the standard and accelerated aging tests as shown in Table 9 in the Appendix.

Greenhouse Study -- Experiment 3

Emergence percentages on days 6 and 7 after planting are shown in Table 3 with the analyses of variance in the Appendix (Table 10). On the 6th day, there were no significant differences among the 16 entries. There was a high degree of variability on the 6th day data as indicated

Table 3. Average percent emergence of 16 cotton lines 6, 7, 8, and 9 days after planting (Experiment 3).

Line	Days after planting			
	6	7	8	9
Acala SJ-1	12.5†	62.5 abcd*	85.0 ab*	89.2 ab*
Lockett BXL	15.0	65.0 abcd	79.2 ab	85.0 ab
Tamcot SP21	6.7	29.2 ef	38.3 de	49.2 f
Tamcot SP37	19.2	71.7 abcd	82.5 ab	86.7 ab
Lankart LX571	9.2	40.0 ef	53.5 c	70.8 de
Stoneville 213	12.5	81.7 a	93.4 a	98.3 a
Deltapine 16	29.2	61.7 abcd	82.5 ab	93.3 ab
Deltapine 45A	24.2	62.5 abcd	70.8 b	79.2 bc
Coker 201	25.0	75.0 abc	86.7 ab	93.3 ab
Coker 310	30.8	70.0 abcd	85.9 ab	90.0 ab
Westburn	21.7	30.9 ef	38.3 de	50.0 ef
Delcot 277	15.0	55.8 abcde	72.5 b	85.8 ab
Watson GL-16	7.5	25.0 f	30.8 e	44.2 f
Acala 1517-70	36.7	78.3 ab	85.9 ab	90.8 ab
H^2-8-70	20.0	48.4 bcdef	70.8 b	78.3 cd
H^2-4-70	15.0	44.2 bcdef	49.2 cd	59.2 e
C.V.	67.9%	22.8%	10.6%	7.9%

†No significant difference.
*Means followed by the same letter are not significantly different at the 0.05 level according to the Student-Newman-Keuls' Multiple Range Test.

by the high coefficient of variation (C.V. = 67.9%). On the 7th day, there were highly significant differences among the cumulative percent emergence of the seed lots. There was a wide range in emergence, with Stoneville 213 having an average of 81.7% emergence and Watson GL-16 with only 25.0%.

Cumulative percent emergence on days 8, 9, 10, and 11 are given in Tables 3 and 4 with analyses of variance in Tables 10 and 11 in the Appendix. There were significant differences in cumulative percent emergence among the seed lots on days 8 through 11. Stoneville 213 consistently had the highest percent emergence and Watson GL-16 the lowest on all 4 days although these entries were not satistically different from some other seed lots. Also, H^2-4-70, Tamcot SP21, and Westburn were consistently slower in emerging than most of the other entries for this 4-day period. Under stress conditions in the field, one might expect these four entries to have the poorest chance of obtaining a satisfactory final plant stand.

A reduction in the coefficient of variation from day 6 to 11 was observed. There was even a further reduction on day 14 (Table 4) after planting. This might be due to the reduction in the difference among the means of the seed lots since the slow emerging entries were given time to emerge and increase their respective cumulative means of percent emergence. No significant difference in average percent emergence of the 16 seed lots was observed 14 days after planting (Appendix, Table 11). Therefore, selection for fast emerging lines based on daily cumulative means of percent emergence under the conditions of this experiment should be made on days 7 through 11.

Table 4. Average percent emergence of 16 cotton lines 10, 11, and 14 days after planting, and hypocotyl length of 14-day-old seedlings (Experiment 3).

Line	Days after planting 10	11	14	Hypocotyl length cm
Acala SJ-1	90.9 abc*	91.7 ab*	93.4†	9.0 a*
Lockett BXL	94.2 abc	95.0 a	97.5	6.5 c
Tamcot SP21	68.3 ef	80.0 cd	95.0	6.7 bc
Tamcot SP37	93.3 abc	95.0 a	99.2	7.0 bc
Lankart LX571	83.3 cd	89.2 abc	97.5	6.6 c
Stoneville 213	99.2 a	99.2 a	99.2	6.1 c
Deltapine 16	95.8 ab	96.7 a	99.2	7.5 abc
Deltapine 45A	84.2 bcd	93.3 ab	98.4	7.6 abc
Coker 201	95.9 ab	95.9 a	95.9	8.5 ab
Coker 310	95.9 ab	96.7 a	97.5	7.5 abc
Westburn	68.3 ef	79.2 cd	96.7	6.0 c
Delcot 277	90.8 abc	92.5 ab	93.3	7.7 abc
Watson GL-16	61.7 f	73.3 d	90.8	6.3 c
Acala 1517-70	93.3 abc	95.9 a	95.9	7.7 abc
H^2-8-70	84.2 bcd	88.4 abc	95.0	7.0 bc
H^2-4-70	74.2 de	82.5 bcd	92.5	6.7 bc
C.V.	5.5%	5.6%	4.5%	10.2%

†No significant difference.
*Means followed by the same letter are not significantly different at the 0.05 level according to the Student-Newman-Keuls' Multiple Range Test.

The daily emergence data from Experiment 3 was correlated with the percent germination 12 days after planting with use of the standard and the accelerated aging tests (Table 12 in the Appendix). The only significant correlation was of germination at 12 days with the standard method and emergence in the greenhouse 14 days after planting. Significant negative correlations were observed for the Regression Index from the standard germination test and percent emergence in the greenhouse on days 6 through 14 while the Regression Index from the accelerated aging test had a significant negative correlation only with percent emergence 14 days after planting in the greenhouse (Table 12 in the Appendix).

Average hypocotyl length of the 16 seed lots 14 days after planting is shown in Table 4 with the analysis of variance in the Appendix (Table 13). Significant differences in average hypocotyl length were found. The fastest and slowest rates of hypocotyl elongation were with Acala SJ-1 and Westburn although each of these entries was not significantly different than a group of other entries. In this study, hypocotyl length was significantly correlated with average percent emergence in the greenhouse 14 days after planting (Appendix, Table 12). This is in agreement with the results of Bird and Ergle (1961) and Woodstock and Combs (1964) who reported that seedling height was the best criteria for selecting rapidly emerging cultivars and predicting subsequent seedling performance of cotton and corn.

Average stem, seed leaf, and total dry weight of 14-day-old cotton seedlings, and the percent of seed leaf dry weight to total seedling dry weight are shown in Table 5 with the analyses of variance in

Table 5. Average stem, seed leaves, and total dry weights, and percent of seed leaf dry weight to total seedling dry weight of 16 cotton lines 14 days after planting (Experiment 3).

Line	Stem dry weight g	Seed leaf dry weight g	Total dry weight g	Percent of seed leaf dry weight to total seedling dry weight
Acala SJ-1	.035†	.089†	.124†	72†
Lockett BXL	.028	.083	.112	75
Tamcot SP21	.030	.068	.098	71
Tamcot SP37	.031	.073	.105	71
Lankart LX571	.031	.075	.106	72
Stoneville 213	.025	.071	.097	75
Deltapine 16	.024	.068	.092	74
Deltapine 45A	.026	.065	.091	73
Coker 201	.030	.077	.107	72
Coker 310	.028	.076	.104	74
Westburn	.028	.071	.099	73
Delcot 277	.028	.075	.103	74
Watson GL-16	.025	.073	.098	75
Acala 1517-70	.027	.080	.107	75
H^2-8-70	.030	.075	.105	71
H^2-4-70	.024	.069	.093	76
C.V.	24.0%	12.2%	14.5%	23.2%

†No significant difference.

Table 13 in the Appendix. The means of each of the four parameters were not significantly different. Christiansen (1962), working with cotton, suggested that the percent of cotyledon dry weight to total seedling dry weight during the first 5 days of growth could be used as a quantitative measure of heritable vigor and/or treatment influence. The techniques used in this study where dry weight was taken 14 days after planting would not be useful in selection of cotton lines for vigorous seedling development.

Correlations with Field Emergence and Mature Plant Height

Field emergence percentages 46 days after planting and mature plant height are given in Table 6 with the analyses of variance in the Appendix (Table 14). Tamcot SP21 showed the highest percent emergence although it was significantly different only from Coker 310 and Acala SJ-1. Acala SJ-1 was the tallest among the 16 entries followed by Acala 1517-70 which was also different from the other lines. Lankart LX571 was the shortest among the lines although it was different only from Acala SJ-1, Acala 1517-70, and Lockett BXL.

Correlation coefficients between greenhouse seedling emergence; hypocotyl length; 12-day germination with the standard test, and the accelerated aging treatment; field emergence; and mature plant height are given in the Appendix (Tables 9 and 12). The correlation between the percent of germination from the standard test and field emergence 46 days after planting was 0.36. This non-significant value is similar to the results of Comer (1968) who reported a correlation coefficient of 0.41 for official germination percentages and the actual seedling emergence

Table 6. Average percent emergence 46 days after planting and mature plant height of 16 cotton lines, Phoenix, 1973.

Line	Emergence	Mature plant height cm
Acala SJ-1	69 c*	135 a*
Lockett BXL	83 ab	95 c
Tamcot SP21	88 a	83 cd
Tamcot SP37	79 abc	87 cd
Lankart LX571	77 abc	72 d
Stoneville 213	84 ab	88 cd
Deltapine 16	80 abc	93 cd
Deltapine 45A	80 abc	89 cd
Coker 201	79 abc	91 cd
Coker 310	74 bc	93 cd
Westburn	86 ab	87 cd
Delcot 277	76 abc	93 cd
Watson GL-16	78 abc	90 cd
Acala 1517-70	77 abc	112 b
H^2-8-70	80 abc	90 cd
H^2-4-70	79 abc	82 cd
C.V.	6.6%	9.8%

*Means followed by the same letter are not significantly different at the 0.05 level according to the Student-Newman-Keuls' Multiple Range Test.

percentages in the field. The accelerated aging test resulted in a significant correlation with field emergence 46 days after planting. In both laboratory tests, the Regression Indices were poorly correlated with field emergence and mature plant height. Greenhouse emergence on days 6 through 14 after planting had insignificant correlation coefficients with field emergence. Hypocotyl length of 14-day-old seedlings in the greenhouse showed a significant positive correlation with mature plant height in the field.

Percent germination under the accelerated aging test was better than the standard germination test or greenhouse emergence in predicting the performance of the 16 cotton lines in the field.

SUMMARY AND CONCLUSION

Experiments were conducted with 16 cotton lines to determine the rate and percent of germination using the standard method (Experiment 1) and with an accelerated aging test (Experiment 2), to determine emergence and seedling development in the greenhouse (Experiment 3), to compare the above three methods, and to determine the relationships of these methods with field emergence data. The seed lots in Experiment 2 were exposed to high relative humidity (88%) and high temperature (49 C) for 72 hours before placing into a growth chamber with the standard temperatures for cotton.

In the standard germination test, Deltapine 45A germinated faster than any other entry. In Experiment 2, Deltapine 16 had the fastest rate of germination although not statistically different from all but one of the other entries. Average percent germination of Tamcot SP21 was significantly higher than Lankart LX571. There were no significant correlations between the data obtained in Experiments 1 and 2.

In Experiment 3, there were no statistical differences among means of percent emergence 6 days after planting. There were highly significant differences among means of percent emergence on days 7 through 11. During this period, Stoneville 213 showed the highest percent emergence and Watson GL-16 showed the lowest percent emergence although each of these cultivars was not significantly different than a group of other entries. Fourteen days after planting, there were no statistical differences among means of percent emergence. Average stem, seed leaf, and total dry weights of 14-day-old cotton seedlings were not significantly different although statistical differences have been observed between the means of hypocotyl length. Hypocotyl length was significantly correlated with seedling emergence 14 days after planting.

Poor correlations were observed for percent germination at 12 days with the accelerated aging test and emergence in the greenhouse on days 6 through 14 although percent germination at 12 days with the standard method showed a significant correlation with emergence in the greenhouse 14 days after planting. Emergence in the greenhouse for all days showed significant negative correlations with the Regression Index from the standard germination test. However, the Regression Index from the accelerated aging test was negatively correlated only with emergence 14 days after planting.

In field emergence, Tamcot SP21 showed the highest percent emergence although it was significantly different only from Coker 310 and Acala SJ-1. Acala SJ-1 was the tallest among the 16 lines followed by Acala 1517-70. Lankart LX571 was the shortest although it was different only from Acala SJ-1, Acala 1517-70, and Lockett BXL.

The only significant correlation of field emergence and any of the factors from the three experiments in this study was germination percent of 12-day-old plants from the accelerated aging test. There was a significant correlation between hypocotyl length of 14-day-old seedlings in the greenhouse and mature plant height. Further research would seem warranted to investigate the possibility of using hypocotyl length of young seedlings as a breeding tool to indicate potential mature plant height. In addition, further testing of germination results from accelerated aging tests might be useful as a tool for predicting field emergence.

In conclusion, the germination, emergence, and seedling development characteristics determined in these experiments were found to have limited value in predicting field emergence of cotton. Hypocotyl length of 14-day-old seedlings grown in the greenhouse provided a fairly reliable method of predicting mature plant height in the field.

APPENDIX

CORRELATION AND ANALYSIS OF VARIANCE TABLES

Table 7. Analyses of variance of percent germination and Regression Index of 16 cotton seed lots 12 days after placing the seed in a growth chamber (Experiment 1).

		Mean squares	
Source	DF	Germination	Regression Index
Replication	3	15.125	.663*
Entry	15	29.272	1.742**
Error	45	15.704	.208
Total	63		

*Significant at the 5% level.
**Significant at the 1% level.

Table 8. Analyses of variance of percent germination and Regression Index of 16 cotton seed lots 12 days after placing the seed in a growth chamber (Experiment 2).

		Mean squares	
Source	DF	Germination	Regression Index
Replication	3	10.953	.348**
Entry	15	23.767**	.115*
Error	45	9.308	.058
Total	63		

*Significant at the 5% level.
**Significant at the 1% level.

Table 9. Correlations of hypocotyl length of 14-day-old seedlings in the greenhouse, percent germination and Regression Index from the standard and accelerated aging tests with percent germination and Regression Index from the accelerated aging test, percent field emergence, and mature plant height.

	Accelerated aging test		Field emergence 46 days	Mature plant height
	Germination 12 days	Regression Index		
Hypocotyl length	--	--	--	0.68**
Standard test germination 12 days	0.45	-0.39	0.36	--
Standard test Regression Index	-0.11	0.42	0.13	-0.002
Accelerated aging test germination 12 days	--	--	0.57*	--
Accelerated aging test Regression Index	--	--	-0.23	-0.02

*Significant at the 5% level.
**Significant at the 1% level.

Table 10. Analyses of variance of percent emergence of 16 cotton seed lots 6, 7, 8, and 9 days after planting (Experiment 3).

Source	DF	Mean squares			
		6 Days	7 Days	8 Days	9 Days
Replication	3	267.927	153.262	98.266	91.788
Entry	15	303.513	1312.885**	1651.911**	1244.553**
Error	45	161.588	164.804	53.358	37.142
Total	63				

**Significant at the 1% level.

Table 11. Analyses of variance of percent emergence of 16 cotton seed lots 10, 11, and 14 days after planting (Experiment 3).

Source	DF	Mean squares		
		10 Days	11 Days	14 Days
Replication	3	51.251	52.856	44.732
Entry	15	547.978**	230.685**	26.165
Error	45	22.337	25.352	18.390
Total	63			

**Significant at the 1% level.

Table 12. Correlations of percent emergence in the greenhouse with percent germination and Regression Indices from the standard and accelerated aging tests, hypocotyl length of 14-day-old seedlings in the greenhouse, and percent field emergence.

	Standard test		Accelerated aging test			
Greenhouse emergence	Germination 12 days	Regression Index	Germination 12 days	Regression Index	Hypocotyl length	Field emergence 46 days
6 days	0.22	-0.50*	0.20	-0.43	--	-0.18
7 days	-0.18	-0.71**	-0.02	-0.22	--	-0.29
8 days	-0.13	-0.68**	-0.11	-0.35	--	-0.38
9 days	-0.19	-0.70**	-0.15	-0.29	--	-0.40
10 days	-0.22	-0.69**	-0.18	-0.29	--	-0.34
11 days	-0.33	-0.76**	-0.09	-0.35	--	-0.28
14 days	0.55*	-0.51*	0.15	-0.54*	0.59*	0.28

*Significant at the 5% level.
**Significant at the 1% level.

Table 13. Analyses of variance of hypocotyl length, stem, seed leaves, and total dry weights, and percent of seed leaf dry weight to total seedling dry weight (Experiment 3).

		Mean squares				
Source	DF	Hypocotyl length	Stem dry weight	Seed leaf dry weight	Total dry weight	Percent of seed leaf dry weight to total seedling dry weight
Replication	3	11.421**	.001139**	.000747**	.003673**	260.107
Entry	15	2.787**	.000038	.000143	.000274	10.763
Error	45	.526	.000045	.000089	.000222	285.693
Total	63					

**Significant at the 1% level.

Table 14. Analyses of variance of percent field emergence 46 days after planting and mature plant height of 16 cotton lines, Phoenix, 1973.

		Mean squares	
Source	DF	Emergence	Mature plant height
Replication	3	82.384*	2164.557**
Entry	15	99.854**	787.724**
Error	45	26.605	82.424
Total	63		

*Significant at the 5% level.
**Significant at the 1% level.

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