Laboratory Screening Test for Cotton Seed Germination and Emergence Under Low Temperatures

N. Hopper[1,2], D. Schultze[1], and B. Duesterhaus[1]
[1]Texas Tech University and [2]Texas Agricultural Experiment Station; Lubbock, TX USA

ABSTRACT

Cotton is a tropical perennial plant that is grown in the U.S. as a temperate annual. Approximately 20% of the U.S. crop is produced in the Texas High Plains, an area characterized by a short growing season in terms of accumulated heat units. Cool spring nights can reduce the germination of seeds and establishment of seedlings. The objective of this study was to develop a breeding strategy for accurately, cheaply and quickly screening a large number of genotypes for cold tolerance. Sensitivity to low temperatures occurs during the imbibition phase (imbibition chilling) and again during the germination and emergence phases (metabolic chilling). This test involves rolling the seed in a polyturethane foam pad, wetting with water at 5°C, allowing excess water to drain and then placing in a chamber at 5°C. Seed rolls are removed after 8, 16 and 24 h. Seeds are then placed on the surface of 5cm sand wetted to field capacity and placed in a chamber at 18°C for 21 days. The percentage of emerged seedlings is then determined and corrected by dividing this number by the warm germination test percentage. This allows test results to be based on viable seeds only. In one study, the corrected emergence percentages ranged from 35 to 81 % and in another from 9 to 65% Both these studies had seed subjected to 24 h of imbibition chilling at 5°C. Data from 8 and 16 h of imbibition chilling are reported in addition to imbibition rate data.

Introduction

Profitable cotton (*Gossypium hirsutum* L.) production is dependent on an interaction of many environmental and physiological factors that vary from year to year. The first goal in cotton production, as in most agronomic crops, is the establishment of a uniform, vigorous, healthy stand of seedlings in the field. In many parts of the world, establishment of an ideal stand of cotton seedlings is often impaired by sub-optimum environmental conditions during the planting season. Environmental conditions during planting are often characterized by cool nights. On the High Plains of Texas this is due to the area's high elevation, low relative humidity, and the possibility of cold fronts. These environmental conditions allow for temperatures to fall to levels which cause chilling injury, which in cotton is characterized by low germination, low vigour seedlings, aborted radicle tips, and delayed crop maturation (Christiansen, 1969). Producers often must plant in these sub-optimal and potentially detrimental conditions because of the area's short growing season. The optimum temperature for cotton seedling germination and establishment is between 30-35°C (Fowler, 1979). Physiological zero for cotton is considered around 15°C, although chilling damage has been reported as high as 20°C (Cole and Wheeler, 1974).

To enhance profitable cotton production in areas that are currently limited by a short growing season, cotton cultivars with the ability to germinate and establish as well as mature under lower temperatures are needed. It is believed that traditional cotton breeding programs have attempted to identify and select for this trait in breeding lines. The approach to identifying lines with higher cold tolerance has historically been through planting many lines in early spring and evaluating responses after being subjected to low environmental field temperatures. Although this approach allows for selection of cold tolerance among breeding lines, it has disadvantages and limitations. The resources needed include money, space and time and it is difficult to predict when environmental conditions will be ideal to impose chilling conditions for screening but not so low that the study is subjected to freezing.

The objective of this study was to overcome the shortcomings of the traditional methods of screening for cold tolerance by developing a more efficient and effective method to screen for this trait under accurately controlled conditions. This goal was accomplished by developing a laboratory screening technique that would accurately screen for this trait.

Material and Methods

Entries

The following twenty commercial cotton cultivars of divergent genetic backgrounds and production environments were evaluated during these tests:

Altex Atlas	Holland 186
Stoneville BG 4740	JH 126

AFD 2525	NuCotton 33b
DP 50	PM 2200RR
DP 2156	PM 2326RR
DP 2379	AFD Rocket
DP 5415	Stoneville 239
DP 5690	Suregrow 125
AFD Explorer	Tejas
Altex Express	Ute

Controlled Temperature Room Experiment

From each cultivar, 160 seeds were placed on a polyurethane foam pad. (34x42x1cm). The pads were rolled, placed inside plastic tubes (36 cm long x 5 cm diameter) and soaked with the approximately 750 ml of 5$_o$C water. Tubes were drained and held at 5$_o$C for 24 hours. (chilling treatment) After chilling, the seed in each pad were separated in three lots of 50 seed replications and planted in plastic boxes (20x33x8 cm) on top of 3.8 cm (1.5 inches) of sand at field capacity. The seeds were then covered with 2.54 cm (1 inch) of dry sand and held at a constant temperature of 18$_o$C for 21 days. An establishment index (percent emergence) was then calculated for each cultivar. (EI 21). This entire procedure was repeated with the chilling treatment of 12 hours.

Warm Germination Correction Factor

Standard warm germination was conducted on four replicates of 50 seeds of each cultivars. The seeds were placed on wetted germination towels in a growth chamber where temperatures alternated between 30$_o$C for eight hours and 20$_o$C for 16 hours. After ten days, the normal seedlings with radicles of at least 3.8 cm (1.5 in.) in length were counted to determine germination percent. Each cultivar's ten day germination percent was divided into the corresponding cultivar's EI-21 from the controlled temperature room to determine the corrected EI-21 for each cultivar. This correction allowed cold tolerance to be determined on the actual viable seed.

Imbibition

Seven 10gram seed samples of each cultivar were distributed on foam pads. The samples were allowed to imbibe for 0.5, 1, 2, 4, 8, 16, or 24 hours. The foam pads were rolled, placed into the same tubes, and soaked with the equivalent of 750 ml of 5$_o$C water. Tubes were drained and held at 5$_o$C for the predetermined time. After each time period, seeds were weighed to determine the percent weight gain from its initial weight. This value is reported as the percent weight gain and was evaluated for all seven times. This procedure was replicated three times.

Results and Discussion

Establishment Index

Corrected establishment indexes ranged from 22.5 to 0.0 for the twelve hour chilling treatment and 17.7 to 0.0 for the twenty-four hour chilling treatment (Table 1). In the twelve-hour treatment, three cultivars developed for the Texas High Plains, AFD Explorer, Ute and JH 126, performed best but in the twenty-four hour trial, cultivar establishment was atypical.

Imbibition

Rates of imbibition are difficult to interpret. The three cultivars with the highest imbibition ranked from last to first in the corrected establishment index twelve hour treatment (Table 2).

Discussion

Correlation between chilling index and imbibition rates (data not shown) was low. Rate of imbibition had no affect on plant establishment, suggesting that imbibitional chilling is less important in determining cold tolerance than metabolic chilling. Imbibition rates do not appear accurate in determining cold tolerance. The twelve hour treatment appears to best represent field performance of these cultivars. Factors like seed coat integrity and osmotic concentrations affect imbibition so the twenty-four hour treatment was too severe to represent field performance. A Spearman coefficient of rank correlation between the twelve and twenty-four hour treatments (r_s = 0.38; ns) showed the treatment's corrected establishment indexes were not the same so the trials were not alike. Future trials will reduce the chilling index until satisfactory ranges of controlled temperature establishment indexes are observed.

References

Christiansen, M.N. (1969): Season-long effects of chilling treatments applied to germinating cottonseed. Crop Sci. 9:672-673.

Cole, D.F. and J.E. Wheeler. (1974): Effects of pre-germination treatments on germination and growth of cottonseed at sub-optimal temperatures. Crop Sci. 14:451-454.

Fowler, J.L. (1979): Laboratory and field responses of preconditioned upland cottonseed to minimal germination temperature. Agron. J. 71:223-228.

Table 1. Corrected establishment index of 20 cotton cultivars screened with 12 and 24 hour chilling treatment.

Cultivar	Chilling Treatment	
	12 Hour	24 Hour
Altex Atlas	8.5	8.8
Stoneville BG 4740	16.2	8.5
AFD 2525	14.4	0.0
DP 50	8.5	4.8
DP 2156	12.2	1.5
DP 2379	14.7	17.7
DP 5415	17.3	14.7
DP 5690	14.0	16.2
AFD Explorer	22.5	12.5
Altex Express	9.6	9.2
Holland 186	12.5	3.0
JH 126	19.5	11.8
NuCotton 33b	16.2	2.2
PM 2200RR	16.6	7.7
PM 2326RR	16.2	2.2
AFD Rocket	11.8	12.2
Stoneville 239	0.0	0.0
Suregrow 125	3.7	2.2
Tejas	15.5	8.1
Ute	21.7	7.4
Mean13.6	7.9	
LSD 0.05	7.9	6.4

Table 2. Percent seed weight increase at 5ºC of 20 cotton cultivars.

Cultivar	Imbibition Time (hrs.)			
	0.5	1	2	4
Altex Atlas	4.9	6.3	7.5	11.0
Stoneville BG 4740	7.1	6.5	8.6	14.0
AFD 2525	6.0	8.0	15.8	24.1
DP 50	7.0	10.7	19.4	27.6
DP 2156	9.0	12.0	17.7	26.3
DP 2379	6.5	8.8	9.5	17.2
DP 5415	9.3	11.0	14.9	24.6
DP 5690	5.7	7.4	10.2	18.3
AFD Explorer	7.1	10.3	17.4	29.6
Altex Express	10.0	9.4	15.6	24.1
Holland 186	7.3	10.6	16.1	29.4
JH 126	9.3	10.6	13.5	30.3
NuCotton 33b	3.4	3.4	5.2	7.3
PM 2200RR	5.0	4.4	6.7	15.2
PM 2326RR	4.3	6.2	7.8	13.9
AFD Rocket	4.9	7.5	8.9	19.0
Stoneville 239	10.1	14.5	29.5	53.0
Suregrow 125	4.5	6.1	8.3	16.6
Tejas	5.3	8.5	10.3	21.0
Ute	4.5	6.5	8.8	16.7
Mean	6.6	8.4	12.5	21.9
LSD 0.05	0.03	0.03	0.04	0.06