

GERMINATION OF COTTON SEED IN RELATION TO TEMPERATURE¹

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ABSTRACT – The effect of constant temperature on the germination rate and percentage of two cotton seed lots was determined using a thermogradient plate. A gradient of 10 °C to 40 °C was established across the plate so that temperatures changed 2 °C for each 5 cm increment in length, resulting in sixteen different temperature treatments. The optimal temperature zone for germination was 28 °C to 30 °C. As temperature decreased from the optimal zone, the rate of germination also decreased but germination percentages during the 10-day period were significantly lower only below 20 °C. As temperature increased above the optimal zone, the rate of germination decreased and the percentage of germination sharply decreased above 32 °C - 34 °C. As expected, high quality cotton seed performed better than medium quality seed for a low temperature range (16 °C to 22 °C), but the most intriguing results were observed for the high temperatures range (36 °C to 38 °C). The germination of medium quality cotton seed was consistently higher than for high quality seed, especially at 38 °C after the second day of evaluation. This response has not been reported in the literature and further research is needed to better understand the germination physiology of cotton seed at high temperatures.

Index terms: *Gossypium hirsutum*, thermogradient plate, temperature range.

GERMINAÇÃO DA SEMENTE DE ALGODÃO EM RELAÇÃO À TEMPERATURA

RESUMO – O efeito da temperatura constante na velocidade e na porcentagem de germinação de sementes de algodão oriundas de dois lotes foi determinada usando a mesa termogradiente. Um gradiente de 10 °C a 40 °C foi estabelecido ao longo da mesa de forma que a temperatura mudava em 2 °C a cada 5 cm de incremento no comprimento entre elas, resultando em 16 tratamentos de temperaturas. A zona de temperaturas ótimas para a germinação foi determinada entre 28 °C a 30 °C. Com o decréscimo da temperatura abaixo da zona ótima a velocidade de germinação reduziu, mas a porcentagem obtida no período de 10 dias de avaliação foi significativamente reduzida apenas abaixo de 20 °C. Com a temperatura aumentando acima da zona ótima a velocidade de germinação reduziu e a porcentagem foi drasticamente reduzida acima da faixa 32 °C – 34 °C. Semente de algodão de alta qualidade tem desempenho fisiológico ótimo na faixa de baixa temperatura (16 °C a 22 °C) em relação as sementes de qualidade média como esperado, mas o resultado mais intrigante foi observado na faixa de alta temperatura (36 °C a 38 °C). As sementes classificadas como de qualidade média germinaram consistente em maior porcentagem do que as de alta qualidade, especialmente a 38 °C após o segundo dia de avaliação. Resultados como este não têm sido reportados na literatura e futuras pesquisas devem ser realizadas para um entendimento melhor da fisiologia de germinação da semente de algodão em alta temperatura.

Termos de indexação: *Gossypium hirsutum*, placa de termogradiente, faixa de temperatura.

¹Submetido em 06/11/2009. Aceito para publicação em 14/02/2010.

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INTRODUCTION

Many investigators have studied the influence of temperature on cotton seed germination under laboratory conditions. Toole and Drumond (1924), studying the cause of germination problems in cotton seed, concluded that the seed germinated satisfactorily at 20 °C (although slowly), 25 °C and at alternating temperatures of 15 °C-36 °C. The optimum temperature, however, was an alternating 20 °C-30 °C, when both germination rate and percentage were considered. Lehman (1925) evaluated cotton seed germination at several different temperatures and found that at 15 °C it progressed slowly with a lower percentage. The optimum temperature for germination appeared to be about 30 °C, when it proceeded most rapidly without any appreciable reduction in percentage germination. On the other hand, Camp and Walker (1927) reported that the optimum temperature for cotton seed germination was about 34 °C and, similarly, Arndt (1945) stated that this optimum range was 33 °C to 36 °C.

Comparing the results from a cotton seed germination test made at a constant 30 °C with those obtained at an alternating temperature of 20 °C - 30 °C, Weir (1959) observed that germination for 39 out of 46 samples was higher at 30 °C, and that it was also completed 2 to 5 days earlier at 30 °C than at 20 °C - 30 °C. In a similar study, Stanway (1960) evaluated three different temperatures for testing cotton seed germination: alternating 20 °C -30 °C and 20 °C - 35 °C, and a constant 30 °C. Results for the alternating temperature, 20 °C- 30 °C, were similar to those obtained at the other temperatures. Medeiros Filho et al (2006) obtained similar results for delinted seed, whereas the alternating temperature of 20 °C- 30 °C was the best one for the linted cotton seed. Novembre and Marcos-Filho (1999) observed that the most favorable temperature was 25 °C with the first count at the third day after sowing.

Cole and Wheeler (1974) used a thermogradient plate to study the effect of temperature on cotton seed germination. The rate of germination was highest at 30 °C, the highest temperature used, but an equivalent germination percentage was obtained at temperatures between 24 °C to 30 °C in 7 days. In a similar study, Cole and Christiansen (1975) found that seed of the *Gossypium hirsutum* strain germinated equally well at all temperatures between 22 °C and 30 °C over a seven-day period. Bohorquez (1977) also used a thermogradient plate to evaluate the influence of temperature on the germination temperature

of cotton seed. The highest germination percentages for three of the four lots used were obtained at rather specific temperatures: 26 °C, 28 °C and 30 °C - 32 °C. At temperatures 2 °C higher or lower than the optimum for each lot, the percentage was significantly reduced. The fourth seed lot germinated equally well within the range 20 °C - 28 °C over a 14-day period.

Several studies have focused on limiting temperatures for cotton seed germination. Results of investigations conducted by Camp and Walker (1972) and Arndt (1945) indicate that the maximum temperature for cotton seed germination is about 39 °C to 40 °C. Most research emphasis, however, has been on the low temperature limits for germination because cotton is planted during spring when low soil temperatures are a major hazard. Ludwig (1932) reported that the minimum temperature for the germination of cotton seed is approximately 12 °C, whereas Camp and Walker (1927) did not observe germination 14 °C, which was supported by similar results from Pereira et al. (2005).

Although the factors affecting cotton seed germination are generally well known, interactions between factors and their influence on germination require more investigation. The objective of the present study was to study the effect of cotton seed vigor on optimum germination temperatures.

MATERIAL AND METHODS

Seed from two lots of cotton cv. Deltapine 55, representing high and medium quality seed, were used. The seed was commercially processed, treated and stored at 10 °C and 50% relative humidity to maintain quality levels during the study.

The initial evaluation of seed quality was made using the standard germination, the Texas cool germination and the cold tests (AOSA, 1976, 1978). Lot H was rated as having high vigor and Lot M medium vigor (Table 1).

The effect of constant temperature on germination rate and percentage was determined using a thermogradient plate, described in detail by Larsen (1971). A gradient of 10 °C to 40 °C was established across the plate by adjusting the temperature of the two water baths. When operating, the plate was inclined at about 25° so that the warm side was higher than the cool side. This plate inclination stratified the air under the clear plastic cover and minimized convection currents. The plastic cover was turned over daily to prevent warping and to maintain a closed system.

TABLE 1. Initial quality of two lots of cotton cv. Deltapine 55.

Lot Identification	Quality Level	Germination Test (%)	Cold Test (%)	Texas Cool Test (%)
H	High	92	79	85
M	Medium	79	64	73

Thermister sensors were placed at each edge of the gradient and at the midpoint to monitor temperature with a scanning thermometer.

The 75 x 75 cm plate was covered with three layers of moistened, blue germination blotter paper and divided into two 37.5 x 75 cm areas with the temperature gradient along the 75 cm dimension (one way gradient). This permitted the evaluation of one replication of two seed lots at the same time.

The temperature gradient was adjusted so that the temperature changed 2 °C for each 5cm across the plate. The temperature lines were marked in 2 °C increments to facilitate accurate seed placement. Sixteen temperature treatments, from 10 °C to 40 °C at 2 °C intervals, were established for lots H and M. Twenty seeds were assigned for each temperature treatment and the two lots were randomly assigned to the two equal areas of the plate.

To prevent seed shifting from one temperature band to another, narrow strips of blotter paper were placed between each seed row. Moistened blotters were used to cover the seeds after placement.

The experiment was conducted four times in succession to provide four replications.

The experimental design used was a 2 x 16 factorial,

CRD, with the replication over time. Germination counts were made daily during 10 successive days. A seed with a complete radicle-hypocotyl axis at least 2 cm long was considered as having germinated and seed counted as germinated was removed from the plate. Dead or diseased seed was also recorded and removed at each count while abnormal seedlings were recorded only at the final count. The tests were terminated after 10 days.

RESULTS AND DISCUSSION

The results of the F test (Table 2) demonstrate that cotton seed quality is sensitive to temperature.

Germination for both the H and M lots (Tables 3 and 4) began on the 2nd day in the temperature range 24 °C-38 °C. No germination for lot M was recorded at 24 °C. The highest germination percentage at day 2 was obtained at 32 °C for both lots. On the 3rd day, germination of Lot H had reached 77% at 28 °C and the range of temperature within which some seed had germinated extended from 20 °C - 40 °C. In lot M, on the 3rd day germination had occurred in the 22 °C to 40 °C temperature range, with the highest percentage at 30 °C.

TABLE 2. Summary of the F Test results from an analysis of variance of the data obtained in the thermogradient plate study.

Source of Variation	Cumulative Germination (%)									Non-Germination Seed Status		
	Day of count									Dead	Abnormal	Ungerminated
	2	3	4	5	6	7	8	9	10			
Quality level(QL)	**	*	**	**	**	**	**	**	**	**	ns	Ns
Temperature(T)	**	**	**	**	**	**	**	**	**	**	**	**
QL x T	**	**	**	**	**	**	**	**	**	**	**	**

Ns – not significant

* significant at the 5% level of probability

** significant at the 1% level of probability

TABLE 3. Cumulative germination percentages of Lot H cotton seed at temperatures across a thermogradient plate, 10 °C- 40 °C.

Temperature		Cumulative Germination % by Days							
°C	2	3	4	5	6	7	8	9	10
10	0.0	0.0	0.0	0.0g	0.0	0.0	0.0	0.0	0.0i
12	0.0	0.0	0.0	0.0g	0.0	0.0	0.0	0.0	0.0i
14	0.0	0.0	0.0	0.0g	0.0	0.0	0.0	0.0	37.50f
16	0.0	0.0	0.0	1.25g	21.25	52.5	65.0	67.75	81.25cd
18	0.0	0.0	11.25	47.50d	77.50	87.50	90.0	92.50	95.00a
20	0.0	1.25	50.00	75.00	81.25	87.50	90.0	92.50	93.75ab
22	0.0	28.75	83.75	88.75a	93.75	96.25	96.25	96.25	96.25a
24	1.25	53.75	78.75	85.00a	90.00	91.25	92.50	92.50	92.50ab
26	16.25	67.50	85.00	88.75a	90.00	91.25	91.25	91.25	91.25ab
28	27.50	77.50	86.25	88.75	90.00	91.25	91.25	91.25	91.25ab
30	31.25	76.25	85.00	88.75a	90.00	91.25	91.25	91.25	91.25ab
32	32.50	62.50	80.00	82.50a	86.25	86.25	86.25	86.25	86.25bc
34	18.75	43.75	60.00	67.50c	71.25	71.25	73.75	76.25	77.50
36	6.25	21.25	25.00	35.00e	40.00	45.00	48.75	51.25	57.50e
38	2.50	7.50	12.50	12.50f	12.50	15.00	17.50	17.50	23.75
40	0.0	2.50	7.50	8.75f	8.75	11.25	11.25	11.25	12.50h

Means not sharing a letter in common within columns differ significantly at the 0.05 level of probability as determined by DNMRT.

TABLE 4. Cumulative germination percentages of Lot M cotton seed at temperatures across a thermogradient plate, 10 °C- 40 °C.

Temperature		Cumulative Germination % by Days							
°C	2	3	4	5	6	7	8	9	10
10	0.0	0.0	0.0	0.0h	0.0	0.0	0.0	0.0	0.0f
12	0.0	0.0	0.0	0.0h	0.0	0.0	0.0	0.0	0.0f
14	0.0	0.0	0.0	0.0h	0.0	0.0	0.0	0.0	36.25d
16	0.0	0.0	0.0	0.0h	6.25	33.75	47.50	48.75	63.75c
18	0.0	0.0	6.25	33.75f	52.50	58.75	63.75	66.25	68.75c
20	0.0	0.0	27.50	50.00d	60.00	73.75	73.75	73.75	73.75ab
22	0.0	17.50	55.00	62.50c	71.25	73.75	73.75	73.75	75.00ab
24	0.0	37.50	70.00	72.50ab	73.75	75.00	75.00	77.50	77.50a
26	5.0	52.50	67.50	71.25ab	75.00	75.00	75.00	75.00	75.00ab
28	16.25	55.00	68.75	75.00a	75.00	75.00	75.00	75.00	75.00ab
30	31.25	66.25	70.00	71.25ab	71.25	72.50	73.75	73.75	73.75ab
32	38.75	57.50	65.00	66.25bc	66.25	66.25	66.25	66.25	66.25c
34	35.00	43.75	51.25	53.75d	56.25	56.25	56.25	56.25	56.25d
36	30.00	40.00	42.50	42.50e	43.75	43.75	43.75	43.75	43.75e
38	20.00	35.00	38.75	38.75ef	40.00	40.00	40.00	40.00	40.00cd
40	0.0	10.0	13.75	13.75g	13.75	17.50	17.50	17.50	17.50e

Means not sharing a letter in common within columns differ significantly at the 0.05 level of probability as determined by DNMRT.

Five days after planting, seed germination in lot H extended from 16 °C to 40 °C, while the range for lot M extended from 18 °C to 40 °C. There were no significant differences in the progress of germination of lot H at 5 days within the temperature range 22 °C to 32 °C, while for lot M germination percentages were the same from 24 °C to 30 °C. On the 10th, or final day of the study period, the temperature range over which some germination occurred extended from 14 °C to 40 °C for both lots, supporting the findings of Camp and Walker (1927). Germination did not differ significantly within the range 18 °C to 30 °C for lot M, averaging 93% for lot H and 75% for lot M. These results are similar to those obtained from the standard germination test (Table 1), and agree with Cole and Wheeler (1974) and Cole and Christiansen (1975), and to some extent with Bohorquez (1977). The results for this temperatures range, where high germination rates occurred, are similar to those obtained for alternate 20 °C- 30 °C temperatures (Toole and Drumond 1924; Weir 1959; Stanway, 1960).

Apart from the differences in percentage germination between lots H and M, which were established at the time they were selected for study, the two lots responded somewhat differently within sub-ranges of the temperature gradient. Assuming mean standard germination percentages of 90% and 75% for lots H and M, respectively, Lot H seed performed relatively better than Lot M within the low temperature range of 16 °C to 22 °C. For example, on the 6th day, the percentages of germinable seed for Lot H (90%), which had germinated within the range, 16 °C to 22 °C were: 16 °C, 23%; 18 °C, 85%; 20 °C, 90% and 22 °C, 100%. In comparison, the percentages of germinable seed (75%) for lot M that had germinated on the 6th day within the range 16 °C to 22 °C were: 16 °C, 8%; 18 °C, 69%; 20 °C, 80% and 22 °C, 95%. This was expected based on previous knowledge of cotton breeding and selection for high germination performance at low temperatures, according to the results of both the vigor test, Cold test and Texas Cool test, where lot H was 12% to 15% higher than lot M respectively (Table 1).

The most intriguing results occurred on the warmer side of the thermogradient plate, where lot M seed performed better than lot H seed within the high temperature range of 36 °C to 38 °C. Although the maximum germination of lot M was 15% lower than that for lot H, the percentage germination based on the percentage of germinable seed was generally higher, specifically at 38 °C. These differences were consistently observed for replications

after the second day of evaluation. However, the probable cause, based on current literature, could not be ascertained and further research is needed to better understand the germination physiology of cotton seed at high temperatures. Since the cotton plant is originally from an arid region, wild germplasm would require high temperature seed treatment to partially overcome reminiscent embryo dormancy. Bourland and Ibrahim (1982) have also observed that newly harvested seed from modern cotton cultivars performs better in the accelerated aging test than in the standard germination test

CONCLUSIONS

The optimal temperature zone for germination was determined to be 28 °C to 30 °C. As temperature decreased from the optimal zone, the germination rate decreased but percentage germination during the 10-day period was significantly lower only below 20 °C. As the temperature increased above the optimal zone, the germination rate decreased and the percentage germination sharply decreased above 32 °C- 34 °C.

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