EFFECT OF GERMINATION TEMPERATURE ON GERMINATION PARAMETERS IN COTTON

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Abstract

Especially in cases where abiotic stress conditions occur, the germination and emergence period is of vital importance for the sustainability of plant life. Considering this situation, this research was conducted to determine the most suitable temperature degree in terms of germination parameters in cotton. In this research, which was conducted in a laboratory incubator with controlled conditions (±1 oC precision), the germination parameters of 2 cotton varieties (May 344 and Candia) were tested at 8 different temperature levels (8, 12, 16, 20, 24, 28, 32 and 36°C). Laboratory experiment was conducted according to the Split Plots Experimental Design in Randomized Blocks with 6 replications. Before germination, 9 cm diameter glass petri dishes containing two pieces of blotting paper were sterilized and the seeds were planted on the drying dishes with the help of forceps. After 25 seeds were planted in each petri dish, the petri dishes were watered with the required amount of sterile water (approximately 25 ml per petri dish), the lids were closed and left to germinate in the incubator. Checks were made daily in the incubator and records were kept. The research result; It was determined that the tested parameters were significantly affected by temperature. The average of both cotton varieties and the highest germination rate for both varieties were obtained at 20 oC. No germination was recorded at 8 oC. In May-344 cotton variety, the germination percentage was 45.17%, the average germination time was 4.06 days and the emergence rate index was 1.89, while in Candia cotton variety, the germination rate was 16.17%, the average germination time was 3.94 days and the emergence rate index was 0.58. Considering the data obtained from this research on germination parameters; 20 oC can be recommended as the most suitable germination temperature for both varieties.

Keywords: Cotton, Germination temperature, Germination parameters

Özet

Özellikle abiyotik stres koşullarının oluştuğu durumlarda çimlenme ve çıkış periyodu bitki yaşamının sürdürülebilirliği açısından hayatı derecede öneme sahiptir. Bu durum dikkate alınarak, bu araştırma; pamukta çimlenme parametreleri açısından en uygun sıcaklık derecesinin tespit edilmesi amacıyla yürütülmüştür. Laboratuvarda, kontrollü koşullara sahip inkubatörde (±1 ^{o}C hassasiyete sahip) yürütülen bu araştırmada, 2 pamuk çeşidinin (May 344 ve Candia) çimlenme parametreleri 8 farklı sıcaklık seviyelerinde (8, 12, 16, 20, 24, 28, 32 ve 36°C) test edilmiştir. Deneme; Tesadüf Bloklarında Bölünmüş Parseller Deneme Desenine göre, 6 tekerrür olarak yürütülmüştür. Çimlenme öncesi, içlerinde iki adet kurutma kağıdı bulunan 9 cm çapındaki cam petri kapları sterize edilmiş ve tohumlar kurutma kapları üzerine cımbız yardımıyla ekilmiştir. Her bir petri kabına 25adet tohum ekildikten sonra petriler, gerekli miktarda (petri başına yaklaşık 25 ml) steril su ile sulandıktan sonra kapakları kapatılarak, inkubatörde çimlenmeye bırakılmışlarıdır. İnkübatörde kontroller günlük olarak yapılmış ve kayıt tutulmuştur. Araştırma sonucu; test edilen parametrelerin sıcaklıktan önemli ölçüde etkilendiğini belirlenmiştir. Her iki pamuk çeşidinin ortalaması ve her iki çeşit için ayrı ayrı en yüksek çimlenme oranı 20 ^{o}C'de elde edilmiştir. 8 ^{o}C'de ise çimlenme kaydedilmemiştir. May-344 pamuk çeşidinde çimlenme yüzdesinin %45,17, ortalama çimlenme süresinin 4,06 gün ve çıkış oranı indeksinin 1,89 olduğu, Candia pamuk çeşidinde ise çimlenme oranının %16,17, ortalama çimlenme süresinin 3,94 gün ve çıkış oranı

indeksinin 0,58 olduğu belirlenmiştir. Çimlenme parametrelerine ilişkin bu araştırmadan elde edilen veriler dikkate alındığında; her iki çeşit için en uygun çimlenme sıcaklığı olarak, 20 °C tavsiye edilebilir.
Anahtar Kelimeler: Pamuk, Çimlenme sıcaklığı, Çimlenme parametreleri

INTRODUCTION

Cotton (Gossypium hirsutum L.) is one of the world's most important industrial crops. It generates income and welfare for over 250 million farmers across the globe. Although, fiber properties of cotton depend on the genetic potential of cotton varieties, its production requires a substantial investment to achieve profitable yields.

Cotton is successful cultivated in the tropical and temperate regions where the frost-free period is less than 180 days. It is mainly grown in areas where abiotic stress such as high temperature, drought, salinity and chemical toxicity are common constraints for the production of the crop (Jing xiang et al., 2023). In the growth of cotton plant, the primary environmental factor influencing growth and maturity is temperature. Temperature directly controls plants on the rate of many chemical reactions including respiration and photosynthesis, indirectly by causing genetic and environmental interactions (Khetran, et al., 2015).

The temperature requirements of the cotton plant vary according to the phenological periods of the plant (Reddy et al., 1992). This difference may vary not only to phenological periods, but also the time of occurrence of the temperature, the physio-morphological and genetic structure of the plant. Cotton development and production depend on a uniform and vigorous initial stand. Emergence uniformity results from high-vigor, healthy seeds with high germination and field emergence rates (Raphael et al., 2017).

Seed germinating percentage under laboratory conditions is the standard measure of seed quality (ISTA, 1976). There are many studies on the influence of temperature on cotton seed germination under laboratory conditions. The results of previous studies show differences related to optimal temperature requirements of the cotton (Burke and Wanjura, 2010; khetran et al., 2015; Raphael et al., 2017; Fiaz et al., 2020). Comparing the results from a cotton seed germination test, it is therefore, concluded that temperature tolerance performances have genotypic variability in cotton.

Most of the available germination and emergence studies with cultivars developed and adapted to mild climate environments shows that cool temperatures may cause chilling injury to seedlings and reduce stand establishment (Bradow and Bauer, 2010). Initial injury starting from the imbibition of cold water and secondary injury can occur after the initiation of germination when temperatures remain below 18°C (Duesterhaus et al., 2000; Lyons, 2005). Simulation of field conditions in a controlled environment with a wider range of temperatures and genotypes will enable a more accurate understanding of the performance of new cultivars, but there are no studies on this. Therefore, the aim of this study is to determine the effects of different temperatures on the germination parameters of different cotton varieties.

MATERIALS AND METHODS

The laboratory experiment was carried out at the biotechnology laboratory, Department of Field Crops, Faculty of Agriculture, Ondokuz Mayıs University. In the study, the treatments were eight temperature regimes (8 °C, 12 °C, 16 °C, 20 °C, 24 °C, 28 °C, 32 °C and 36 °C) and two cotton varieties (MAY 344 and CANDIA). Seeds of each cotton variety was planted in ten petri dishes to provide ten replications. The design was 8 x 2 factorial laid out in a completely randomized design.

Seed Imbibition

150 seeds of each variety were placed in Petri dishes with a diameter of 147 mm and a depth of 22.4 mm, and then soaked in distilled water for an hour (60 mins). The seed imbibed were removed from the distilled water then sent into the sterile cabinet (laminal flow) for planting.

Sterilization of Petri Dishes

Before planting, Petri dishes (9 cm diameter, 19 mm depth) containing filter papers (Whatman 541) were placed in the sterilizing oven at 356 °F (180 °C) for three hours (180 mins). At the end of the time (after three hours) the oven was automatically turned off and the petri dishes were transferred to the sterile cabinet until next use.

Germination Test

The germination test was conducted according to the Rules for Seed Analysis following methodologies adapted from Raphael et al., (2017) with some modification. 15 cottonseeds imbibed were evenly distributed on double layer of Whatman filter paper in each sterilized Petri dish. Prior to planting, filter papers were moistened with 5 ml of sterilized water. Sowing was carried out on moistened filter papers. After planting, petri dishes were covered and then placed in an incubator with a sensitivity of ±1 °C and set at the corresponding temperatures. The number of germinated seeds were determined at 2 and 12 days from the beginning of the test. The germinated (plumule emergence) seedlings were recorded after 48 hours. The seeds were considered germinated when the radicle reached 2 mm using electronic digital caliper with 150 mm scale. During counting some petri dishes were kept moistened with distilled water. Diseased seeds or abnormal seedlings were removed once observed.

Germination Parameters

For each treatment, germination measurements were calculated and organized into the excel spreadsheets for statistical analysis.

i. Germinability (%) = $N_T / N_s * 100$. Whereas; N_T is the total number of seeds germinated at the 12th day and N_s number of sowed seeds. Calculation was based on Ranal et al., (2009).
ii. Mean germination time (days) [$t = \sum n_i.t_i / \sum n_i$, Whereas; t_i is the time since the onset of the experiment to the nth observation (days) and n_i is the number of seed germinated in time i]. Calculation was based on Lusembo et al., (1995).
iii. Mean germination rate is calculated as the reciprocal of the mean germination time. Calculation was based on Ranal et al., (2009).

Statistical analysis

All germination variables were statistically analyzed using a one-way ANOVA. The LSD value for mean comparison was calculated only if the general treatment F test was significant at a probability of ≤ 0.05 (Gomez and Gomez, 1984). All statistical analyses were performed with the aid of the SPSS (Version 17th) computer software.

RESULTS

Germination Parameters

Germinability was reduced for seeds from MAY 344 and CANDIA at low and higher temperature levels. Temperatures, genotypes and their interaction all had significant ($P \leq 0.01$) effects on cotton germination (Table 1). Germination at different temperature levels showed distinct patterns, with a higher germination percentage (66.33%) recorded at 20 °C and a minimum (1.67%) at 12 °C. As the temperature was lowered, final germination decreased and seeds failed to germinate at 8 °C. (Table 2). The cottonseed appeared to germinate within a range of temperatures. The results revealed that upper limit seed germination (45.17%) was found in cotton variety MAY 344 and the lower seed germination (16.17%) was recorded in variety CANDIA. The interaction indicated that both genotypes under the study had the maximum germination percentage at 20 °C the highest germination percentage (91.33%) was recorded in MAY 344 and the lowest (41.33%) in CANDIA (Table 2).

Mean germination time ranged from 0 to six days, with significant ($P \leq 0.01$) different between temperature regimes (Table 1). In the temperature gradient experiment of 36 °C, which rapidly initiated germination, the seeds took one day to germinate (Table 2). The seeds at 16 °C took longer; that is, it took them six days from the start of the treatment (Table 2). At 8 °C, the seeds needed the most extended period to initiate germination (Table 2). The results revealed with no significant ($P \leq 0.05$) different between genotypes and interaction on mean germination time (Table 1). Cottonseeds failed to germinate at 8 °C; they took few days (1.95 day) to germinated at 36 °C (Table 2). At 16 °C and 28 °C, the MAY 344 and CANDIA seeds germinated slowly, taking 8.48 and 5.59 6 days in MAY 344, and 5.33 and 6.24 days in CANDIA (Table 2).

Table 1: Analysis of Variance (F Values) for effects of genotype, temperature and genotype x temperature interaction on germination parameters of cottonseeds.

Source of Variation	d.f.	Germination Parameters		
		Germinability (%)	Germination Time (days)	Emergence Rate Index (% d^{-1})
Genotype	1	294,13**	0.068ns	124,12**
Temperature	7	57,66**	15,36**	40,37**
Genotype x Temperature	7	12,98**	1,76ns	13,88**

Table 2: Effects of temperature, genotype and genotype x temperature interaction on germination parameters of cottonseeds.

		Germination Percentage (%)	Germination Time (days)	Emergence Rate Index (% d^{-1})
Genotypes				
May-344		45.17a	4.06	1.89a
Candia		16.17b	3.94	0.58b
Temperatures (^{0}C)				
8		0.00f	0.00f	0.00d
12		1.67f	3.00de	0.02d
16		29.67d	6.91a	0.68cd
20		66.33a	5.00bc	2.77a
24		57.00b	5.43abc	2.02ab
28		36.33cd	5.91ab	1.27bc
32		42.67c	3.83cd	2.37a
36		11.67e	1.93e	0.75cd
Genotype x Temperature Interactions				
8	MAY-344	0.00f	0.00	0.00e
	CANDIA	0.00f	0.00	0.00e
12	MAY-344	2.00f	3.60	0.02e
	CANDIA	1.34f	2.40	0.02e
16	MAY-344	47.33c	8.48	1.06cde
	CANDIA	12.01ef	5.33	0.31e
20	MAY-344	91.33a	4.12	4.12a
	CANDIA	41.33cd	5.89	1.42cd
24	MAY-344	85.34a	5.65	3.09b
	CANDIA	28.67de	5.20	0.96cde
28	MAY-344	53.33bc	5.59	1.90c
	CANDIA	19.34ef	6.24	0.63de
32	MAY-344	67.33b	3.17	3.98a
	CANDIA	17.99ef	4.49	0.76de
36	MAY-344	14.67ef	1.91	0.97cde
	CANDIA	8.67ef	1.95	0.53de

Values with different letters in the same column for each main effect are statistically different at $p \leq 0.05$. The emergence rate index was significantly ($P \leq 0.01$) different at each level of temperature (Table 1). The results showed that, maximum speed was observed at a temperature pattern of 20 °C, followed by 32 °C, 24 °C, 28 °C, 36 °C and minimum at 16 °C and 12 °C (Table 2). On overall analysis, MAY 344 showed the maximum speed of germination, while CANDIA germinated with the slowest speed (Table 2). The interaction between temperature and genotype was also significant ($P \leq 0.01$) for the emergence rate index (Table 1). The interaction indicated that MAY 344 had the fastest germination speed at 20 °C, 32 °C and 24 °C temperature levels, while the genotype CANDIA showed maximum speed at 20 °C, 24 °C and 32 °C. At 8 °C, all genotypes did not show speed of germination (Table 2).

DISCUSSION

Temperature is critical for regulating plant growth and development. The percentage of the cottonseed germination potential increases linearly as the temperature rises and then decreases linearly until reaching the optimal level, followed by a reduction beyond that level (Raphael et al., 2017). The germination percentage was highest at 20 °C in both of the cotton genotypes. The result was similar with previous findings (Wanjura and Buxton, 1972; Smith and Varvil, 1984). At 24 °C, all the genotypes were statistically on par with the 20 °C temperature; however, numerically, a slight reduction was observed. As the temperature exceeded 24 °C, a significant reduction in germination percentage was recorded for the genotypes and reached a minimum level at 36 °C. In a similar observation to this research, Sharma et al., (2022) observed highest germination percentage at 20 °C in most of the wheat genotypes. In addition, working with rapeseed in Hungary, Haj Sghaier et al., (2022) noted an increase germination percentage at 20 °C. A temperature above or below the optimum caused the germination potential to drop (Ikram, et al., 2022; Burke and Wanjura, 2010). High temperatures of 36 °C greatly hindered seed germination and subsequent emergence owing to the inhibitory impact of high temperatures. The inhibition of seed germination has been well documented in response to high temperature which often occurs through the induction of Abscisic acid (ABA) (Toh et al., 2008). Moreover, high temperature during germination causes cell and embryo death and strictly prohibits the normal germination process or sometimes proved to be lethal in many plant species (Iloh et al., 2014; Kumar et al., 2011).

There were some notable genotypic differences in the germination percentage at different temperature levels. The genotypes MAY 344 was on par germination across the temperatures. This genotypic variability might be due to the genetic potentiality of different genotypes to withstand temperature fluctuations. However, the response of genotypes towards the early heat stress shows any clear relationship with their characteristic breeding nature to cope with terminal heat stress. The similar results were reported by the previous findings (Chu et al. 2016; Fernando and Aníbal, 2018).

The speed of germination followed a different pattern as compared to the germination percentage. The germination speed increased with the rise in temperature, and it was significantly higher at 32 °C than 20 °C, but it reduced at higher temperature, i.e., 36 °C. On increases in temperature up to 36 °C led to the most rapid and complete germination of seeds after one day of incubation (Table 2). Germination was sluggish when the temperature was reduced to 12 °C. However, low temperatures of 12 °C or below caused delayed germination, so that the process required a longer time. Metabolic reactions and enzyme activity cause variation in the germination time during the germination process. Indeed, lower temperatures cause seeds to have a slower metabolism, resulting in slower growth, whereas higher temperatures attribute to have a higher rate of seed reserve mobilization, dissipating the seed energy required for growth (Cassaro-Silva et al., 2001;de Oliveira et al., 2013). Working with maize, Khaeim et al., (2022) revealed that germination at ≤15 °C required a longer time to reach the standard measurement point of germination. In another studies, resulted an increase of germination rate in cotton seeds at higher temperatures (Raphael et al., 2017, Francisco and James, 2011).

CONCLUSION

The findings of this study highlighted the critical factor affecting cottonseed germination and established the optimal range for successful germination. The optimal temperature for cottonseeds germination was within a more comprehensive range from 20 °C to 24 °C. Maximum germination speed was obtained at 36 °C. Genotypic variability was observed in the response towards heat stress given during the germination stage. These findings have the potential to optimize the sowing time in different agroclimatic regions and breeding programs for the development of modern cotton cultivars tolerant to early heat stress.

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