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TEMPERATURE - GERMINATION RESPONSES OF SUNFLOWER (*Helianthus annuus* L.) GENOTYPES

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SUMMARY

Seed germination of six sunflower (*Helianthus annuus* L.) hybrids was investigated across a range of eleven constant temperatures between 5°C and 45°C. Large temperature differences in germination rate 1/t (d^{-1}), cardinal temperature (°C) and thermal time θ (°cd) were observed among hybrids. Base temperatures (Tb) varied between 3.3°C and 6.7°C whereas maximum germination temperatures (Tm) varied between 41.7°C and 48.9°C. Final germination fraction was attained at 15°C - 25°C whereas the maximum rate of germination was attained at 30.4°C - 35.6°C. The maximum germination rate of hybrid USDA 894, the cultivar with the slowest germination rate, was only 50% of that of hybrid EX 47. The low Tb and high Tm of sunflower appear to be one of the factors which explain the successful adaptation of sunflower to a wide range of temperature. These findings are discussed in relation to the origin of the crop and its wide adaptations in diverse habitats and climatic zones.

Key words: sunflower, seed germination, cultivars, temperature response, genetic variability

INTRODUCTION

Sudan's sunflower (*Helianthus annuus* L.) hectarage increased from 17000 ha during the 1986-87 growing season to over 125000 ha during the 1989-90 growing season. Hybrid seed for commercial production is imported annually from temperate regions and the sowing of sunflower usually commences during July after the advent of rains, when soil surface temperatures have decreased to approximately 35°C. In the semiarid tropics soil surface temperatures >60°C can be experienced during the summer before the onset of the rainy season (Peacock, 1982). The problem in sunflower production is stand establishment. Poor germination and seedling establishment of crops in these regions has been attributed to loss of seed viability

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during inhibition caused by high temperatures (Garcia-Huidobro *et al.*, 1982; Peacock, 1982).

Genetic variability and tolerance for germination at high temperatures has been established for several crops of tropical origin. These include sorghum (*Sorghum bicolor* (L.) Moench) Wilson *et al.*, 1982; pearl millet (*Pennisetum glaucum* (L.) R.Br.) and peanuts (*Arachis hypogaea* L.) Mohamed *et al.*, 1988. Although sunflowers are of temperate origin (Carter, 1978), they germinate and grow successfully across a wide range of climatic environments including hot tropical climates like Sudan (Khalifa, 1981; 1984; Amir and Khalifa, 1991). This wide adaptation of sunflower to diverse climates has been attributed to morphological, physiological and economic factors (Carter, 1978). However, precise quantification of the characters which are responsible for that adaptation are meagre for sunflower. The objectives of this study were to evaluate genetic variability in germination temperature among sunflower genotypes and to identify characters that are responsible for high temperature tolerance.

MATERIALS AND METHODS

The germination response of six sunflower hybirds: USDA 894, Sunwheat 101, Ex 47, HV, HO and HL to different constant temperatures were evaluated in laboratory studies. Pertinent information about the six hybrids utilized in this study is presented in Table 1. The hybrids have different maturities and are derived from diverse crosses. USDA 894 typifies the cultivar commercially grown in North Dakota, while Sunwheat 101 is an early maturing dwarf hybrid and EX 47 is an early maturing semidwarf hybrid. HV is a genotype selected for evaluation because of its reported high level of seedling vigor, whereas HO and HL are near isogenics having high oleic and linoleic oil contents, respectively.

Table 1: Genetic diversity, maturity, moisture content (%) and mean seed weight (mg) of six sunflower hybrids

Hybrid	Maturity	Type of cross	Moisture ($g\ kg^{-1}$)	Seed dry weight ($mg\ seed^{-1}$)
USDA 894	medium	single cross	54	49.4
Sunwheat 101	early	single cross	57	43.8
EX 47	early	single cross	67	67.6
HV	medium	single cross	50	58.8
HO	medium	single cross	67	61.9
HL	medium	single cross	57	56.2

Within cultivars seeds were selected as much as possible for uniformity in size and shape, although some differences in seed size among cultivars were still apparent (Table 1). Seed of the hybrids were germinated across a range of eleven constant temperatures ranging from 5°C to 45°C. Germination was conducted in normal (9 cm diam) petri-dishes, lined with Whatman No.1 filter paper and placed in either a

Model 655F Fisher Scientific Isotemp Oven for temperature treatments: 25°C, 30°C, 35°C, 37°C, 40°C, 42°C and 45°C, or in a Model SG3OSS seed germinator from the Hoffman Manufacturing Company (International Agric. Supply, 30392 Walnut Dr. S.W., Albany, Oregon, 97321), for temperature treatments: 5°C, 10°C, 15°C, and 20°C. Each germination unit was set at the desired temperature. Temperatures were continuously recorded during the entire experiment. Distilled water to maintain the paper at the saturation level was added when deemed necessary. Each petri-dish contained 10 seed and was regarded as a replication. Each petri-dish in a temperature treatment consisted of four replications cultivar^{-1} in a randomized design. Germination counts were made three times daily and seedlings were considered germinated when the radicle was 10 mm long.

RESULTS

The time course of germination of hybrid EX 47 at temperatures ranging between 5°C and 42°C which was typical of all hybrids is presented in Figure l.

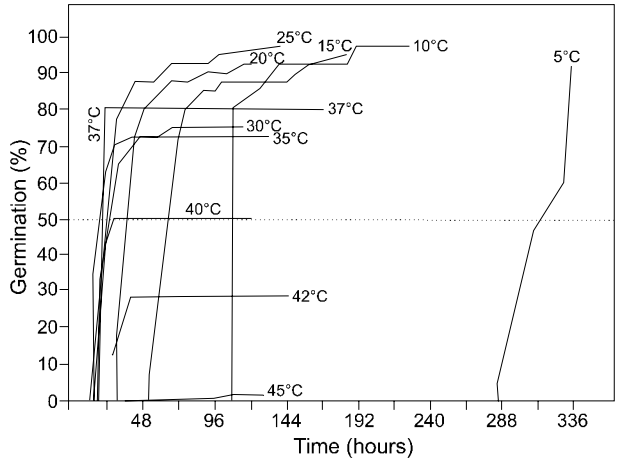

Figure 1: Germination (%) vs time for sunflower hybrid EX 47

Evidence of germination was observed in this cultivar 7 hours after the experiment was initiated. The earliest successful completion of germination (the radicle reached 10 mm in length) of this cultivar occurred in 17 h at 35°C, 37°C and 40°C. The earliest recorded germination at 5°C occurred 286 h (approximately 12 days) after sowing. Other hybrids displayed a similar time course of germination as is related to time and temperature, despite variations among hybrids relative to the initiation and magnitude of germination.

The maximum germination (GM) at each temperature for the six hybrids is presented in Figure 2. Genotypic variations were evident. USDA 894, the slowest germinating hybrid, had GM at 15°C. Maximum germination of the other hybrids decreased after 25°C reaching or approaching zero between 40°C and 45°C. The lin-

ear regression between germination rate 1/t (d^{-1}) and temperature T (°C) for the six sunflower cultivars is given in Table 2.

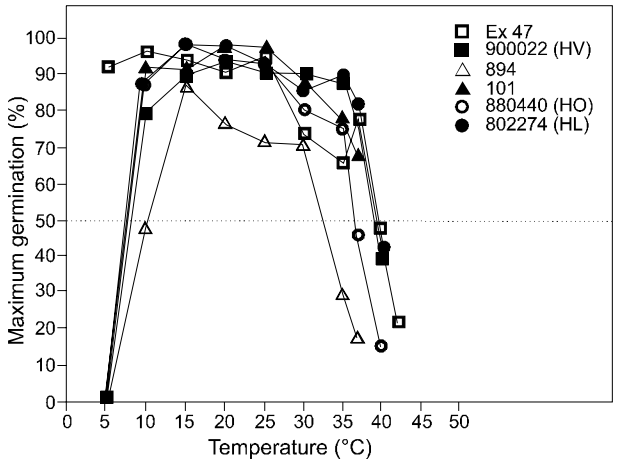

Figure 2: Maximum germination (%) of six sunflower hybrids vs temperature

Table 2: Linear regressions of germination rate 1/t (d^{-1}) on temperature T (°C) for six sunflower hybrids

Cultivar	Regression of 1/t on T where T<To	r^2	Regression of 1/t on T where T>To	r^2
USDA 894	1/t=-0.09980+0.02032T	0.80	1/t=2.224-0.05331T	0.86
Sunwheat 101	1/t=-0.1368+0.02614T	0.98	1/t=2.992 -0.06184T	0.94
EX 47	1/t=-0.1457+0.03885T	0.98	1/t=4.369 -0.08952T	0.98
HV	1/t=-0.2194+0.03263T	0.98	1/t=3.627 -0.07805T	0.99
HO	1/t=-0.09698+0.02930T	0.97	1/t=2.422-0.04953T	0.76
HL	1/t=-0.1713+0.03095T	0.98	1/t=5.134-0.1208T	0.95

The r^2 values ranged between 0.76 and 0.99. Optimum germination temperature To (°C) was calculated at the intersect of the regressions when T<To and T>To. Thermal time, θ (°cd), on both sides of To was calculated as the reciprocal of the slope. The two straight lines which describe the relationship between the rate of germination and temperature, below and above To can be expressed as:

below To, $1/t=(T-Tb)/\theta_1$

above To, $1/t=(Tm-T)/\theta_2$

t≅Time, T≅Temperature, Tb≅Base temperature,

Tm≅Maximum temperature, To≅Optimum temperature

Hybrids EX 47 and USDA 894 exhibited the most rapid and slowest germination rate, respectively, of the material evaluated. Although hybrid EX 47 exhibited a higher rate of germination than the other hybrids at most temperatures (Figure 3), it could not withstand extended exposure to supra-optimal temperatures (37°C - 42°C) as discoloration of the root and death occurred shortly after radicle protru-

sion. Hybrid HO, the high oleic hybrid, was the least responsive to changes in temperature on both sides of To as shown by its low θ_1/θ_2 ratio (Table 3). In contrast HL had the highest relative responsiveness to change in temperature on both sides of To as it had the highest θ_1/θ_2 ratio.

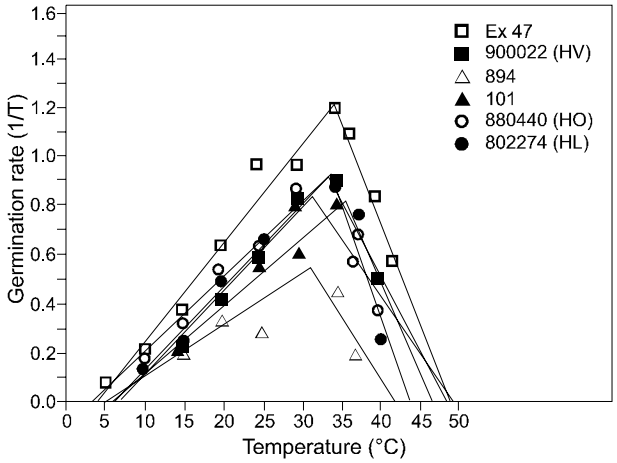

Figure 3: Rate of germination of six sunflower hybrids vs temperature

Optimum and maximum temperatures were calculated from the 1/t - T relationship for every hybrid when 1/t was zero at both sides of To. The lowest Tb values at 3.3°C and 3.8°C were exhibited by HO and EX 47, respectively, while the highest Tm values of 48.9°C and 48.8°C, respectively, were obtained with the same two hybrids (Table 3). EX 47 was the earliest hybrid below To as indicated by the low thermal time (°cd) requirement (Table 3) and second to HL on supra-optimal temperatures which had the lowest θ_2 at 8.3°cd. The thermal time (°cd) required for germination to 50% level below To was always higher than that above To for all hybrids. Variations among hybrids in thermal time requirement (°cd) were evident at both sides of To.

Table 3: Cardinal temperatures (°C) and thermal time (θ_1 and θ_2) for germination of six sunflower hybrids

Cultivars	Tb	To	Tm	θ_1	θ_2	θ_1/θ_2
USDA 894	4.3	30.4	41.7	49.2	18.8	2.62
Sunwheat 101	5.2	35.6	48.4	38.3	16.2	2.36
EX 47	3.8	35.2	48.8	25.7	11.2	2.29
HV	6.7	34.8	46.5	30.6	12.8	2.39
HO	3.3	32.0	48.9	34.1	20.2	1.69
HL	5.5	35.0	42.5	32.3	8.3	3.89

DISCUSSION

As indicated previously, the protruding radicle was first visible seven hours after sowing in EX 47 at 25°C and the earliest successful germination (1.0 cm radicle) was attained 17 h after sowing in 35°C, 37°C, and 40°C constant temperatures. Base temperatures obtained in this study ranged between 3.3°C and 6.7°C whereas maximum temperatures (Tm) ranged between 41.7°C and 48.9°C. The base temperatures (Tb) recorded in this study are in accord with the 4.0°C reported by Carter (1978) and the 6.0°C reported by Rollier and Burghart (1974) for sunflower. However, information on the maximum temperature for germination of sunflower is not available. Mayer and Poljacoff-Mayber (1982) reported temperature ranges in which germination occurs for different seeds, and it is apparent that when seeds have low minimum temperatures (*i.e.*, low base temperature, Tb) in the range of 0°C - 5.0°C, they also have low maximum temperatures (Tm) in the range of 30.0°C - 40.0°C, examples given are: *Triticum aestivum* L., *Hordeum sativum*, *Secale cereale* L., *Avena sativa* L., *Fagopyrum esculentum* L., *Convolvulus arvensis* L., *Lepidium draba* L. and *Delphinium* (annual). When seeds have high minimum temperatures in the range of 8.0°C - 19.0°C, they also have high maximum temperatures in the range of 40.0°C - 50.0°C; for example *Zea mays* L., *Oryza sativa* L. and *Cucumis melo* L. However, the authors cited two species namely, *Solanium carolinense* and *Nicotiana tabacum*, with high minimum temperatures of 20.0°C and 10.0°C and low maximum temperatures of 35.0°C - 40.0°C and 30.0°C. The low Tb and high Tm of sunflower appear to be one of the factors which explain the successful adaptation of sunflower to a wide range of temperature (Khalifa, 1981; 1984).

The differences in cardinal temperatures shown for sunflower in this study could indicate the diverse genetic heritage of the crop. The annual sunflower is probably the most diverse species of sunflower in North America geographically, morphologically and habitatwise (Rogers, Thompson and Seiler, 1982) and Carter (1978) who reported that the southwest US rendered the most extensively documented account of sunflower. *H.annuus* sp. extend across a wide area of USA into eastern Canada. This wide geographic, morphological and habitatwise diversity of sunflower extending from very hot areas in the southwest US into very cold areas in eastern Canada, might have developed the unique characteristics of sunflower tolerance to both high and low temperature and accounted for the wide adaptation of the crop. This is in accord with Carter (1978) who reported that tolerance to both low and high temperatures contributes to sunflower's adaptation in different environments.

The final germination fraction of sunflower in this study was attained between 15.0°C and 25.0°C whereas the optimum rate of germination was between 30.4°C and 35.6°C. This would suggest that while increasing temperatures up to 35.6°C increases germination rates, final germination fraction is attained in the range of 15.0°C - 25.0°C. This is in accord with Owens and Call (1985) on the effects of temperature on germination of *Helianthus maximiliani* cultivar Aztec and *Simsia calva* cultivar “PMT - 856”. On the evidence made available in this study, sunflower

could germinate within the range of temperatures reported for tropical crops; millet (Garcia-Huidobro, Monteith and Squire, 1982; Khalifa and Ong, 1990) and groundnut (Mohamed, Clark and Ong, 1988). Although sunflower is a C3 crop, however, the germination rates reported in this study are comparable to those reported for millet (Khalifa and Ong, 1990) which is a C4 crop. Early spring sowing of sunflower in temperate regions increases yield and oil percentage (Carter, 1978). A hybrid with a low Tb for germination would tolerate cool temperatures and could be suitable for early sowings in spring. On the other hand, a cultivar with a high Tb and a high Tm for germination would be expected to tolerate high temperatures during early sowing before the advent of effective rains in the semiarid tropics. EX 47 with a low Tb of 3.8°C for germination and a high Tm of 48.8°C is expected to tolerate both temperature extremes during germination. HO and HL are near isogenic high oleic and high linoleic oil seed sunflower hybrids, respectively. HO appears to be relatively insensitive to change in temperature as is shown in its low thermal time requirement ratio (θ_1/θ_2).

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GERMINACION COMO REACCION A LA TEMPERATURA EN LOS GENOTIPOS DEL GIRASOL (*Helianthus annuus* L.)

RESUMEN

La germinacion de semillas de los hibridos de girasol (*Helianthus annuus* L.) fue investigada con 11 temperaturas constantes que variaban de 5°C a 45°C. Los hibridos se diferenciaban considerablemente en cuanto a la dinamica de germinacion 1/t (d^{-1}), temperatura basica (°C) y al tiempo termico θ (°cd) con temperaturas diferentes. Las temperaturas iniciales (Tb) variaban entre 3.3°C y 6.7°C, y las temperaturas maximas de germinacion (Tm) entre 41.7°C y 48.9°C. La fraccion ultima de semilla germino a las temperaturas de 15°C a 25°C, mientras la mas alta dinamica de germinacion fue alcanzada a las temperaturas de 30.4°C a 35.6°C. La dinamica maxima de germinacion del hibrido USDA 894, que tenia la germinacion mas lenta, era apenas de 50% de la dinamica que tenia el hibrido EX 47. Parece que los valores bajos de Tb y los valores altos son los factores que explican la grande adaptabilidad del girasol a la escala extensa de temperatura. Estas observaciones fueron tratadas en cuanto a la origen del cultivo y a su grande adaptabilidad a las condiciones diferentes del medio y las varias zonas climaticas.

GERMINATION - RÉACTION À LA TEMPÉRATURE DANS LES GÉNOTYPES DE TOURNESOL (*Helianthus annuus* L.)

RÉSUMÉ

La germination des graines de six hybrides de tournesol (*Helianthus annuus* L.) a été étudiée sur une échelle de onze températures constantes de 5°C à 45°C. Les hybrides ont montré de grandes différences pour ce qui concerne la dynamique de germination 1/t (d^{-1}), la température de base (°C) et le temps thermique θ (°cd) à différentes températures. Les températures de base (Tb) variaient entre 3.3°C - 6.7°C alors que les températures maximales de germination (Tm) variaient entre 41.7°C et 48.9°C. La fraction finale de la germination a été atteinte à 15°C - 25°C alors que la plus grande dynamique de germination a été atteinte à 30.4°C - 35.6°C. La dynamique maximale de germination de l'hybride USDA 894, qui a montré la germination la plus lente, a été d'à peine 50% de la dynamique de germination de l'hybride EX 47. Il semble que les valeurs peu élevées Tb et les valeurs élevées Tm soient les facteurs qui expliquent la capacité d'adaptation du tournesol à une grande échelle de températures. Ces résultats sont discutés en rapport avec l'origine de la plante et ses adaptations multiples aux divers habitats et zones climatiques.