Evaluation of cardinal temperatures and germination response to temperature in Safflower (Carthamus tinctorius L.) Medicinal plant

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Abstract: Understanding of the seed germination response of cultivated genotypes to low and high temperature is important in agronomical. Those genotypes that germinate in lower temperatures could be useful in temperate areas where temperature is low in germination stage whereas the genotypes tolerant to high temperatures could be sown in the areas with high temperature. Therefore, this experiment was conducted to study of the seed germination characteristics to temperature. In this experiment we used 9 genotypes of safflower crop with 7 fixed temperatures (5^0C , 15^0C , 20^0C , 25^0C , 30^0C , 32^0C and 36^0C) as factorial experiment in the growth chamber. The results showed that the effect of genotype, temperature and their interactions on germination characteristics were significant and significant reductions in the germination of safflower at temperature less than 5^0C and upper than 30^0C . The base (T_b), optimum (T_O) and maximum (T_C) temperature for germination safflower were obtained 3, 28 and 38 respectively.

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1. Introduction

Germination is a complex physiological process which is affected by temperature and water potential of the soil (Alvarado and Bradford, 2002). This process includes the events in which embryo activates from a dormant stage to a dynamic form. Germination is an important process in the final stand establishment of the crop and optimum density is achieved when the seeds are healthy and germinated completely in an appropriate rate (Albuquerque et al., 2003).

When moisture is adequate, both the rate and final fractional germination of a sample of viable seeds is controlled by temperature(Jalilian et al., 2004). Temperature is an important single factor affecting the capacity for germination by regulating dormancy, and it also critically determines the rate of progress toward completion of germination once a seed is stimulated (Bradford and still, 2002). These critical temperatures, which are commonly referred to as cardinal temperatures (minimum or basic temperature, optimum and maximum) is the range of temperature in which seeds of a particular species are able to germinate. Minimum temperature (T_b) is the lowest temperature in which a seed is able to germinate. Optimum temperature (T_o) be a temperature in which the highest percentage of the seed germinate at the shortest period of time and finally maximum temperature (T_c) is the highest temperature in which seed can germinate. Generally, cardinal temperature of a particular seed depends on environmental conditions in which it is adapted and seeds normally germinate when environmental condition for growth and development of seedling is assured (Ali et al., 2003).

As a general rule, seeds needs lower temperature in temperate environment compared with tropical conditions and wild species also need lower temperature compared with domesticated plants (Hardegree, 2006). Optimum temperature for most of the seeds is between 15 and 30 ºC and the maximum temperature is between 30 to 40 ºC. Several researchers, including Ren et al. (2005), Boroumand Rezazadeh and Koocheki (2006), Ghaderi et al. (2008) have shown that cardinal temperature for germination (i.e. T_b, T_o and T_c) depend on species. For example, measurements on weedy rice cultivars showed variations in the cardinal temperatures ranging vary significantly between genotypes (Puteh et al., 2010).

Thus, determining the temperature range at which safflower seed germinates will help to predict seedling emergence. Therefore purpose of present investigation is to evaluate of cardinal temperatures and germination response to temperature in Safflower (*Carthamus tinctorius* L.) genotypes 9.

2. Materials and Methods

The experiments were carried out factorial (F_A= variety and F_B= temperature) conducted based on CRD design with 3 replicate in Seed Laboratory of the Department of Agronomy and Plant Breeding, Gorgan University. In order to determine cardinal temperature were used 9 varieties (Fru, Nebreska 825, Nebreska10, Uot, Zarghan 279, Zhila, Varamin295, Arak2811 and DS1) of safflower (*Carthamus tinctorius* L.) seeds. Seeds exposed to a wide range of temperature as 5, 15, 20, 25, 30, 32 and 36ºC in a germinator. Before starting of the experiment, the seeds were disinfected by Sodium Hypochlorite for one minute followed by washing through distilled water. Fifty disinfected seeds were located in Petri dishes on watman paper and 10 cc of distilled water was added to each Petri dish. Petri dishes were placed in a germinator. Each temperature treatment was repeated three times. After 24 hours, germinated seeds were counted and this was continued for 14 days. At the end, the percentage and rate of germination were calculated.

Rate of germination was determined by the following formula:

$$Rs = \sum_{i=1}^{n} \frac{Si}{Di}$$

Where Rs is rate of germination, Si: number of germinated seed/day and Di: number of days seeds were monitored. The reciprocals of the time to germination were plotted to estimate the optimum temperature, which the rate of germination was maximum (T_o). The rates of germination were also subjected to the linear regression analysis to describe cumulative germination response of temperature (SAS Institute, 2005). The cumulative percentage germination (CGP), obtained from the germination tests at different temperatures, were used to calculate the cardinal temperatures. Intersected-line models were used as proposed by Garcia-Huidobro et al. (1982). The equation used to describe the rates of germination between base and up to optimum temperatures is as follows:

$$1/t = (T - T_b)/\theta 1 \quad (1)$$

In order to describe the germination responses above T_o, but below the maximum temperature (T_c), equation (2) was used:

$$1/t = (T_c - T)/\theta 2 \quad (2)$$

Cardinal temperatures is the temperature, while T_b, T_o and T_c are the base, optimum and maximum temperatures, respectively. These models predict the germination rate for a given seed fraction (sub-optimal and supra-optimal range) in a linear function of temperature. The intercepts of the fitted linear regression lines on the temperature axes were used to estimate T_b and T_o. T_o, was calculated as the intercept of suboptimal and supra-optimal temperature function (Hardegree, 2006).

All the collected data were subjected to the analysis of variance using the Statistical Analysis System (SAS) Software, version 9.1. When ANOVA indicated a significant effect, the least significant difference (LSD) was performed to determine significant differences among the means of the treatments.

3. Results and Discussion

The results of analysis of variance showed that effects genotypes, temperature and Interaction on Germination rate and percentage (1% probability level) were significant (Table 1). In table 2, the mean compare of germination rate and percentage are presented. As it is shown, temperature has a pronounced effect on rate and percentage of germination. The increase in the temperature (i.e. from 5°C to 30°C) during imbibition enhanced the germination rate and percentage for all 9 genotypes and declined afterwards (Table 2). By increasing temperature beyond 30 ºC, the germination percentage for all safflower genotypes was decreased significantly and the extent of this reduction was more pronounced for Uot genotype (to 50%) compared with other genotypes (Table 3). Meanwhile, the maximum germination percentage of the cultivated variety was observed at 25°C for all the genotypes (Table 2). These findings have also been confirmed elsewhere (Ali et al., 2003). Alvarado and Bradford found that with increasing temperature up to optimum level, rate of germination was increased and declined thereafter (Alvarado and Bradford, 2002). The higher germination percentage in the cultivated variety at different constant

Temperatures (10-30°C) could be attributed to the relatively higher germination rate (Table 3). Similarly, a lower germination percentage in safflower genotypes was due to the lower germination rate, particularly at 25°C and lower. The highest germination rate in the cultivated variety was observed at 25 °C.

The results of regression relationships are shown in table 4. The influence of temperature on Germination rate was described by a segmented function. Germination rate was strongly correlated with temperature as it is described by two liner relationships: one below and other above optimum temperature.

The results of regression relationships are shown in table 4. The estimated germination rates, within the suboptimal and supra-optimal range of temperatures, vary between the safflower genotypes. All the germination rates, which were calculated

from the estimated germination time course, showed a significant correlation with temperature at both the sub-optimal and supra-optimal ranges of temperatures (Table 4). The highest estimated germination rate was recorded for Nebreska 825, which was 0.246 day^{-1} in the supra-optimal range. On the contrary, the lowest estimated germination rate was observed in the Varamin295 genotype (0/0363 day-1).

The decline in the germination rate within the supra-optimal range for the safflower genotypes was between -0/0203 day^{-1} to -0/0709 day^{-1}. Within this supra-optimal range of temperature, the Varamin295 genotype was found to have the lowest estimated germination rate of -0/0203 day^{-1}.

The germination rate for the cultivated varietys increased linearly with the increase in the germination temperature. Meanwhile, the lowest estimated T_b for Fru was 2.47°C (Table 5). The range of the estimated T_b for the safflower genotypes was between 2/47 – 3/50°C, while the Nebreska 825 had the highest Tb. The T_o for the seed germination ranged from 25/78 to 31/44 for the cultivated varietys (Table 5). The estimated T_o for Varamin295 was found to be the lowest (25.78°C) as compared to the other genotypes, whereas the highest T_o of 31.44°C was observed in the Zhila variety. The narrow range of T_c among the two varieties was between 37/10–38/60°C, suggesting that safflower seed will not germinate above 39°C.

The results of the present study confirm that, in the absence of other limiting factors (water, oxygen and light), the germination of safflower seed influenced by temperature. This observation is consistent with past work on warm season grasses (Madakadze et al., 2001), pea (Sincik et al., 2004) and rangeland grass species (Hardegree, 2006). Tabrizi et al. found that with increasing temperature from 5 to 15ºC, seed germination of *Plantago ovata* was increased and there was a declining trend afterwards (Tabrizi et al., 2004). This was also the case for *Medicago sativa*, *Cucurbita pepo*, *Borago officinalis* and *Nigella sativa* but the highest percentage of germination occurred at 25, 37.7, 39.9, and 35ºC (Mahmoodi et al., 2008؛ Ghaderi et al., 2008). Koocheki and Zarif also found that the maximum percentage of germination for some forage species was at 15ºC and by increasing or decreasing temperature beyond this level percentage of germination was decreased significantly and the lowest value was obtained at 5ºC which was 72 percent lower than the value obtained for 15ºC (Koocheki and Zarif Ketabi, 1996).

Another aspect of seed germination that might influence by temperature is the rate of germination. The extreme temperature values had a greater deleterious effect on germination percentage. In addition, the result has shown that, for all safflower genotypes studied here, GR was increased linearly to optimum temperature and then decreased. Similar linear relationships between GR and temperature have been observed by Kamkar et al. (2006) in millet and Jami Al-Ahmadi and Kafi (2007) in kochia and Berti and Jonhnson (2008) in cuphea.
Based on the results of the present study, it can be concluded that when the soil temperature of a location known, the cardinal temperature and thermal time could be useful guidance to those considering introduction of this species in a new area or in selecting the sowing time. Moreover, the cardinal temperature derived for seed germination rate could be used for prediction of subsequent development stages of growth (Freeman, 2005). However, more works are needed to clarify this point.

Conclusion

In conclusion, can conclude that effect of temperature were significant for all components of safflower seed germination. This difference was significant between genotypes of safflower in cardinal temperature and components of germination. From this genetic diversity can used in breeding and screening for increase of primary vigor and tolerance of plants and genotypes to different temperature degrees.

Table 1. Results analysis of variance effect temperature and genotypes on Germination rate and percentage.

S.O.V	DF	Germination percentage	Germonation rate
Temperature	6	9768/79**	4/122**
Genotypes	8	2464/31**	0/345**
Interaction	48	367/644**	0/0877**
Error	126	46/97	0/0146

ns, *and **: Not significant, significant at the 5% and 1% probability levels, respectively

Table 2. Mean compare of effect temperature in Safflower different genotypes

Temperature	Germination percentage (%)	Germonation rate (day)
5^0C	39/1f	0/118f
15^0C	80/5c	0/473e
20^0C	89/88b	0/816c
25^0C	93/85a	1/107a
30^0C	88/02b	0/964b
32^0C	69/58d	0/914b
36^0C	56/83e	0/664d

Table 3. Effect of temperature and genotypes on Germination percentage

	Temperature						
Genotypes	5^0C	15^0C	20^0C	25^0C	30^0C	32^0C	36^0C
Fru	63/33	94	94	94/66	89/33	64/66	55/33
Nebreska 825	34	87/3	96/7	98/7	98	84	85/3
Nebreska10	35/3	86/7	96/7	97/3	94/7	76	81/3
Uot	24/67	72/3	85/33	98/67	95/33	74/67	48/67
Zarghan 279	44/6	88/6	95/3	95/3	81/3	79/3	74
Zhila	36	73/3	80/6	82/7	78/7	62	35/3
Varamin295	16	62/7	76	82/7	71/3	39	25/3
Arak2811	58	72	94	98/7	95	76	55
DS1	40	88	90/3	96	88/6	70/66	51/3

Table 4. Equations of linear regression of 9 Safflower varieties sub-optimal and supra-optimal temperatures

genotypes	Sub-optimal temperature	R^2	Supra-optimal temperature	R^2
Fru	y= -0/044X + 0/0109	0/89	y= 0/113X + 4/35	0/80
Nebreska 825	y= -0/0709 X - 0/227	0/86	y= -0/246X + 9/32	0/94
Nebreska10	y= -0/0283 X - 0/0991	0/73	y= -0/084 X + 3/24	0/76
Uot	y= -0/0219 X + 0/0622	0/81	y= 0/106 X + 3/95	0/76
Zarghan 279	y= -0/0214 X + 0/0698	0/76	y= /0906X + 3/31	0/70
Zhila	y= -0/0361 X + 0/0992	0/77	y= - 0/172 X + 6/64	0/77
Varamin295	y= -0/0203 X + 0/0630	0/64	y= 0/0363 X - 1/38	0/51
Arak2811	y= -0/0285 X + 0/0758	0/78	y= 0/0986 X + 3/77	0/76
DS1	y= -0/0316 X - 0/0757	0/83	y= -0/0865 X + 3/21	0/80

Table 5. Cardinal temperatures for Safflower different genotypes

genotypes	T_b (minimum)	T_o (optimum)	T_c (maximum)
Fru	2/47	27/63	38/49
Nebreska 825	3/20	28/77	37/88
Nebreska10	3/50	28/03	38/57
Uot	2/84	30/61	37/26
Zarghan 279	3/26	28/93	37/53
Zhila	2/74	31/44	38/60
Varamin295	3/1	25/78	38/01
Arak2811	2/65	29/08	38/23
DS1	2/39	26/56	37/10

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