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Evaluation of Cardinal Temperature for three Species of Medicinal Plants, Thymus Transcaspicus, Foeniculum Vulgare and Calligonum Junceum

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Abstract

In order to evaluate cardinal temperatures and optimum thermal range of germination of three medicinal plants including *Thymus transcaspicus, Foeniculum vulgare* and *Calligonumjunceum* an experiment was conducted in a Completely Randomized Design with three replications. Therefore, this experiment was conducted to study of the seed germination characteristics to temperature. The we used three medicinal plants with 9 fixed temperatures (5^0C, 10^0C, 15^0C, 20^0C, 25^0C ,30^0C, 35^0C, 40^0C and 45^0C) as factorial experiment in the growth chamber. The results showed that the effect of these crops, temperature and their interactions on germination characteristics were significant. The basic, optimum and maximum temperatures were 1.4, 29.93, and 44.66 for *Thymus transcaspicus*, 3.33, 21.35 and 42.54 for *Foeniculum vulgare* and 5.23, 33.60 and 45 for *Calligonum junceum*.

Keywords: Medicinal plants, Germination, Temperature

Introduction

Medicinal plants have been identified and used throughout human history. Plants have the ability to synthesize a wide variety of chemical compounds that are used to perform important biological functions, and to defend against attack from predators such as insects, fungi and herbivorous mammals. At least 12,000 such compounds have been isolated so far; a number estimated to be less than 10% of the total. Chemical compounds in plants mediate their effects on the human body through processes identical to those already well understood for the chemical compounds in conventional drugs; thus herbal medicines do not differ greatly from conventional drugs in terms of how they work. This enables herbal medicines to be as effective as conventional medicines, but also gives them the same potential to cause harmful side effects (Tapsell *et al*., 2006؛ Lai *et al*., 2004).

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

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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) is 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).

Since cardinal temperature is important for germination and this temperature has not been determined for medicinal plants, the purpose of present investigation is to evaluate the effect of this temperature fort hree important medicinal species including, *Thymus transcaspicus*, *Foeniculum vulgare* and *Calligonum junceum* .

Materials and Methods

The experiments were carried out factorial (F_A= Medicinal plants species and F_B= temperature) conducted based on CRD design with 3 replicate in Seed Laboratory of the Department of Agronomy and Plant Breeding, Gilan University. In order to determine cardinal temperature were used 3 Medicinal plants (*Thymus transcaspicus*, *Foeniculum vulgare* and *Calligonum junceum*) seeds. Seeds exposed to a wide range of temperature as 5^0C, 10^0C, 15^0C, 20^0C, 25^0C ,30^0C, 35^0C, 40^0C and 45^0C 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, at 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:

$1/t = (T – T_b)/\theta 1$ (1)

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

$1/t = (T_c – T)/\theta 2$ (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.

Results and Discussion

The results of analysis of variance showed that effects species , temperature and Interaction on Germination rate and percentage (1% probability level) were significant (Table 1). In Fig 1, 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^{o}C to 30^{o}C) during imbibition enhanced the germination rate and percentage for all 3 species and declined afterwards (Fig 1). By increasing temperature beyond 30 ºC, the germination percentage for all 3 species was decreased significantly and the extent of this reduction was more pronounced for *Foeniculum vulgare* species (to 30%) compared with other species (Fig1). Mean while, the maximum germination percentage of the cultivated species was observed at 30^{o}C for all the speciess (Fig 1). 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 species at different constant temperatures could be attributed to the relatively higher germination rate (Fig 1). Similarly, a lower germination percentage in 3 species was due to the lower germination rate, particularly at 30^{o}C and lower. The highest germination rate in the cultivated species was observed at 35 ^{o}C.

The results of regression relationships are shown in table 2. 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 2. The estimated germination rates, within the suboptimal and supra-optimal range of temperatures, vary between the 3 species medicinal plants. 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 2). The highest estimated germination rate was recorded for *Foeniculum vulgare*, which was 1.2

day^{-1} in the supra-optimal range. On the contrary, the lowest estimated germination rate was observed in the *Calligonum junceum* (0/01 day-1) (Table 3) .

The decline in the germination rate within the supra-optimal range for the 3 species was between 0/8 day^{-1} to 1/2 day^{-1}. Within this supra-optimal range of temperature, the *Thymus transcaspicus* was found to have the lowest estimated germination rate of 0/8 day^{-1} (Table 2)

The germination rate for the cultivated species increased linearly with the increase in the germination temperature. Meanwhile, the lowest estimated T_b for *Thymus transcaspicus* was 1/4^{o}C (Table 3). The range of the estimated T_b for the 3 species was between 1.4 – 5/23^{o}C, while the *Calligonum junceum* had the highest T_b. The T_o for the seed germination ranged from 21/35 to 33/60 for the cultivated species (Table 3). The estimated T_o for *Foeniculum vulgare* was found to be the lowest (21/35^{o}C) as compared to the 3 species, whereas the highest T_o of 33/60^{o}C was observed in the *Calligonum junceum*. The narrow range of T_c among the species was between 42/54– 45^{o}C, suggesting that 3 species seeds will not germinate above 40^{o}C.

The results of the present study confirm that, in the absence of other limiting factors (water, oxygen and light), the germination of 3 species of medicinal plants seeds 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 influenced by temperature is the rate of germination. The extreme temperature values had a greater deleterious effect on germination percentage. In addition, the result have shown that, for all rice 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 3 species of medicinal plants seeds germination. This difference were significant between 3 species of medicinal plants cardinal temperature and components of germination.

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

S.O.V	DF	Germination percentage	Germonation rate
Temperature	8	8806/74**	0/5689**
species	2	165/05**	0/1254**
Interaction	16	69/45**	0/0653**
Error	54	19/60	0/0975

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

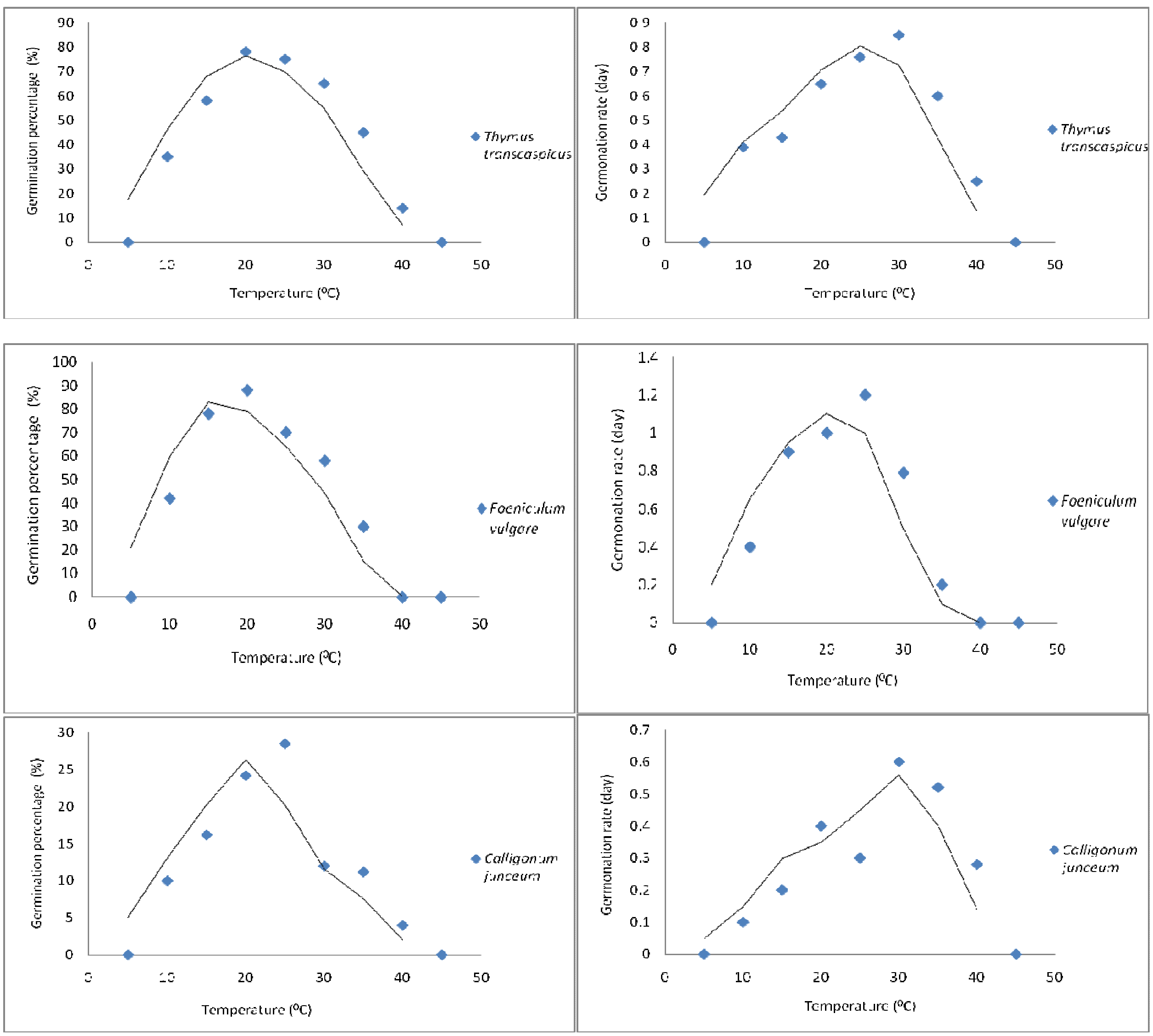

Fig 1. Effect of temperature on Germination percentage and rate in 3 species of Medicinal plants.

Table 2. Equations of linear regression 3 species of Medicinal plants sub-optimal and supra-optimal temperatures

Species	Sub-optimal temperature	R^2	Supra-optimal temperature	R^2
Thymus transcaspicus	y = 0.031x - 0.044	0.92	y = -0.06x + 2.683	0.99
Foeniculum vulgare	y = 0.06x - 0.200	0.93	y = -0.051x + 2.175	0.78
Calligonum junceum	y = 0.021x - 0.113	0.88	y = -0.052x + 2.346	0.99

Table 3. Cardinal temperatures for 3 species of Medicinal plants.

Species	T_b (minimum)	T_o (optimum)	T_c (maximum)
Thymus transcaspicus	1.41	22.93	44.66
Foeniculum vulgare	3.33	21.35	42.54
Calligonum junceum	5.23	33.60	45

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