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*Full Length Research Paper*

# Emergence response of Persian shallot (*Allium altissimum*) to temperature

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**Temperature is one of the fundamental parameters to determine plant growth rate and production. The main aim of this study was to evaluate the emergence response of Persian shallot (*Allium altissimum*) to temperature by cardinal temperatures calculation. We used three regression models including intersected-lines, five-parameter beta and quadratic polynomial. This study was performed on ten temperature treatments including 6, 9, 12, 15, 18, 20, 22, 24, 26 and 28°C. The results showed that the highest Persian shallot emergence rate was gained under 18°C. However, increasing the temperature of growth environment sharply decreased the emergence rate of Persian shallot. In conclusion, five-parameter beta model showed highest accuracy in prediction of Persian shallot emergence response to temperature ($R^2$ =0.99**). Base temperature ($T_b$), optimum temperature ($T_o$) and maximum temperature ($T_m$) were 3.3, 17.0 and 29.5°C, respectively based on five-parameter beta model calculation.**

**Key words:** Cardinal temperatures, emergence, modeling, Persian shallot.

## INTRODUCTION

Persian shallot (*Allium altissimum*) which in Iran is called as "Mooseer" belongs to the Alliaceae family. The genus *Allium* is one of the most diverse and taxonomically difficult assemblies of the monocots (Fritsch, 1996). It is native and endemic of Iran and grows wild on the mountains (Rubatzky and Yamaguchi, 1997) quite resistant to cold and freezing stress. Persian shallot is widely used in food and medicinal industries. However, there are no any scientific documents on optimum environmental demands of this plant including temperature factor (Zammouri et al., 2008).

Emergence and germination is a complex physiological part of plant growth which would be affected by many environmental factors such as temperature, water potential, light, and nitrate nitrogen (Alvarado and Bradford, 2002). Responses of germination in seeds and emergence in bulbs to temperature can be defined in terms of cardinal temperatures, including the base or minimum ($T_{min}$), the optimum ($T_{opt}$), and the maximum ($T_{max}$) temperature (Hardegree and Winstral, 2006). Detecting the nature of the response to temperature across cardinal points is momentous for understanding the phenology, adaptation and production process of different plants under various environmental conditions (Yan and Hunt, 1999). Furthermore, estimation of cardinal temperatures plays a critical role in the growth analysis of crops (Aslam et al., 2005). Cardinal temperatures variables were characteristically allocated both a constant value, and are determined to be normally or log-normally distributed within a given plant varieties (Hardegree and Winstral, 2006). Several models have been developed to predict germination response to temperature for various species (Hardegree and Winstral, 2006). These models may also be applied to Persian shallot bulbs germination. Linear and non-linear regression models were widely used to explain cardinal temperatures (Ellis and Barrett, 1994).

Inverse of time required to complete a developmental stage is associated with the developmental rate. An inverse linear relation has been reported between the time taken to reach a given proportion of germination and the temperature during germination (Jami and Kafi, 2007). Rowse and Savage (2003) determined base

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(1.2°C) and optimum (21°C) temperatures for onion (*Allium cepa*) by two hydrothermal threshold models. Germination of the most tested *Allium* genus reached to 60 to 80% at 5°C and 90 to 100% at 11°C and 16°C (Specht and Keller, 1997). However, there is no information about the response of Persian shallot to temperature and values of cardinal temperatures across the world. The objective of this research was to determine the impact of temperature on germination response of Persian shallot using different mathematical models.

## MATERIALS AND METHODS

Persian shallot bulbs were collected in 2011 from the experimental station of Ferdowsi University of Mashhad which was located in the central part of Khorasan province of Iran. Average weight of the collected bulbs used in this study was 3.5 g. The vernalization process of the bulbs was carried out at a temperature of 4°C and dark conditions for 2 months. This was followed by vernalization treatment and shoot emergence experiments were carried out.

### Emergence test

Response of Persian shallot germination to temperature was evaluated on ten temperatures at 6, 9, 12, 15, 18, 20, 22, 24, 26 and 28°C respectively) in thermo-gradient growth chambers under dark conditions and 50% relative humidity. This study was carried out by complete randomized design (CRD) with three replications. Persian shallot bulbs (10 bulbs) were sown in the upper layer of plastic pots (upward part of bulbs was out of soil) which was filled with soil-sand-litter mixture (1:1:1). Irrigation schedule was performed by soil field capacity and was applied water treatment every two days to maintain the field capacity by pot weighting. Daily germinated bulbs counting was started 24 h after germination test and continued until the cumulative number of germinated bulbs became stable (21 days) as when 100% germination was achieved. The inverse of time required to achieve 50% germination ($T_{50}$) was determined as an index of the germination rate (Flores and Briones, 2001). Seedlings with 2 mm length of caulicle were termed "emerged".

### Statistical analysis and model evaluation

In order to compare the temperature impacts on Persian shallot emergence, analysis of variance (ANOVA) was performed as standard procedure for complete randomized design. Before statistical analysis, a normality test was performed for all data and data were transformed (arcsin √ %) (Jami and Kafi, 2007). The t-test was used to find significant differences among treatments. Determination of cardinal temperatures was performed by three regression models between inverse of time span to 50% emergence and various temperatures.

#### *Intersected-lines model*

Intersected lines models were fitted to the data of the reciprocals of time to 50% of germination of various temperatures using the following equations (Jami and Kafi, 2007):

$$f = if(T < T_o, region\ 1\ (T), region\ 2\ (T)) \quad (1)$$

$$Region\ 1(T) = b\ (T - T_b) \quad (2)$$

$$Region\ 2(T) = c\ (T_m - T) \quad (3)$$

Where $T$ is temperature treatment, $T_b$, $T_{opt}$, and $T_{max}$ are base, optimum and maximum temperatures.

#### *Five-parameter beta model*

Five-parameter beta model was provided to quantify the relationship across the development rate and temperatures. The beta function was widely utilized to provide a flexible family of non-symmetric, unimodel probability density functions with fixed end points which set aside points of inflexion on the other side of the model (Yin et al., 1995). Beta function is defined as:

$$Development\ rate = \exp(\mu)\ (T - T_b)^{\alpha}(T_c - T)^{\beta} \quad (4)$$

$$T_o = (\alpha T_m + \beta T_b)/(\alpha + \beta) \quad (5)$$

Where $T$, $T_b$, $T_c$, $T_o$, and $T_m$ are treatment, base, ceiling, optimum and maximum temperatures. In addition, $\mu$, $\alpha$, and $\beta$ are model parameters.

#### *Quadratic polynomial model*

A quadratic polynomial equation which was used to determine the cardinal temperatures described as:

$$f = a + bT + cT^2 \quad (6)$$

$$T_o = b + 2cT \quad (7)$$

Where $T$ is temperature, a, b and c are model constants.

## RESULTS AND DISCUSSION

### Emergence test

Emergence rate of Persian shallot was significantly affected by various temperature treatments ($P$ > 0.05) (Figure 1). Highest number of days to emergence (2.1 days) of bulbs was obtained under a temperature of 18°C (Figure 1). However, the rising of the temperature gradually increased the time required for the Persian shallot germination process. Moreover, the lowest germination rate (15 days) was gained under the treatment of a temperature of 28°C (Figure 1).

Persian shallot is a cold resistance plant which originated from the mountainous parts of Khorasan province and is able to cope with cold harsh environments. Some unpublished reports have showed that Persian shallot might be resistant to temperatures down to about -25°C. Therefore, increasing the temperature remarkably declines the germination rate.

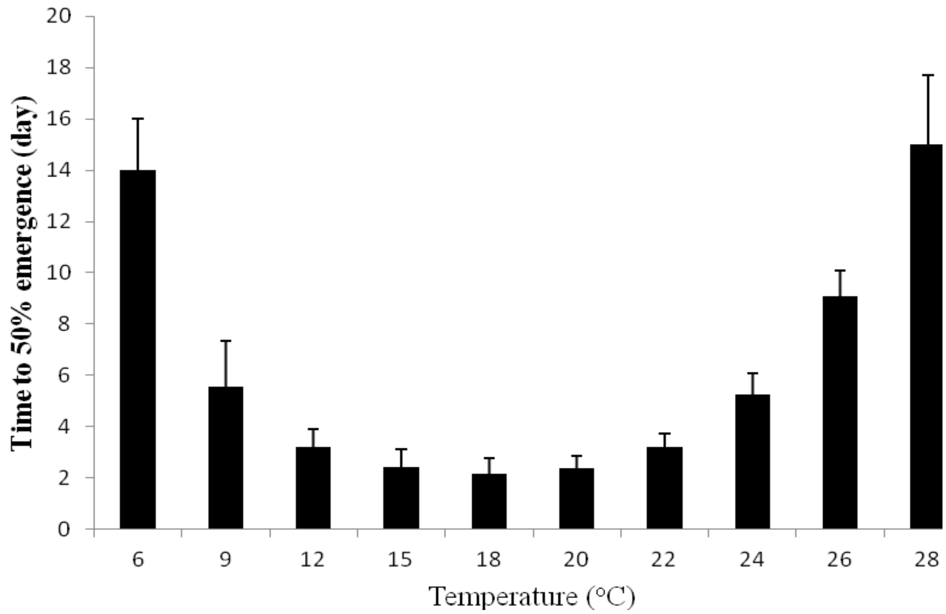


**Figure 1.** Temperature response of time taken to achieve 50% germination of Persian shallot (Error bars represent standard error of means for each temperature).

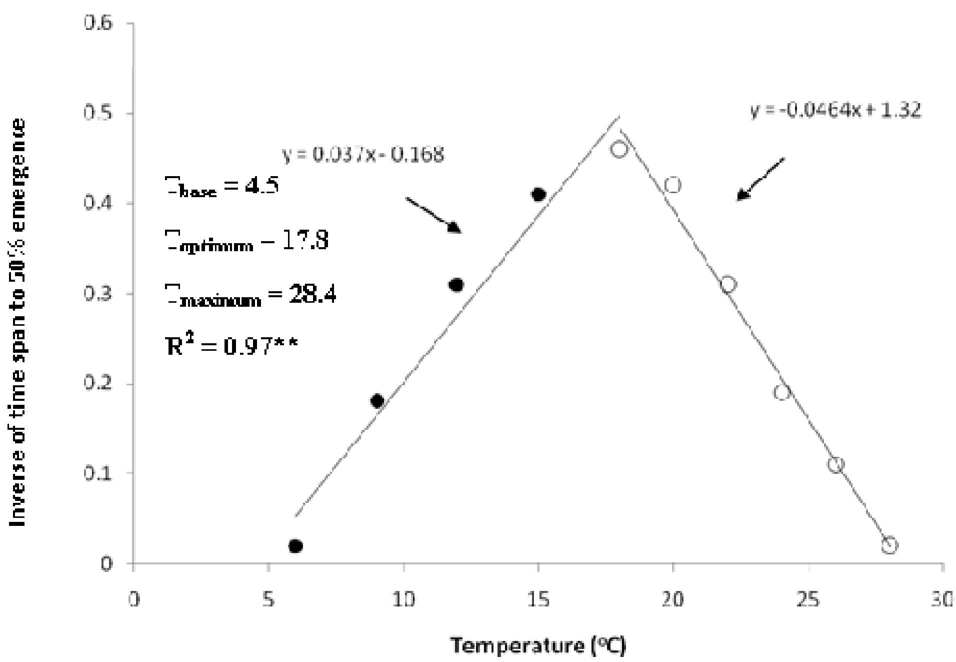


**Figure 2.** Intersected-lines model for Persian shallot germination rate index (inverse time taken to achieve 50% germination) in response to temperature.

## Modeling

Intersected-lines, five-parameter Beta and quadratic polynomial models were fitted to data collected for Persian shallot. Figure 1 shows the structure of intersected-lines for different temperature treatments. Based on this model estimation, $T_b$, $T_{opt}$, and $T_{max}$ of Persian shallot are 4.5, 17.8, and 28.4°C, respectively (Figure 1).

Five-parameters Beta model indicated highest significant ($P$ > 0.01) correlation across observed and simulated values of emergence rate (Figure 2). Estimated

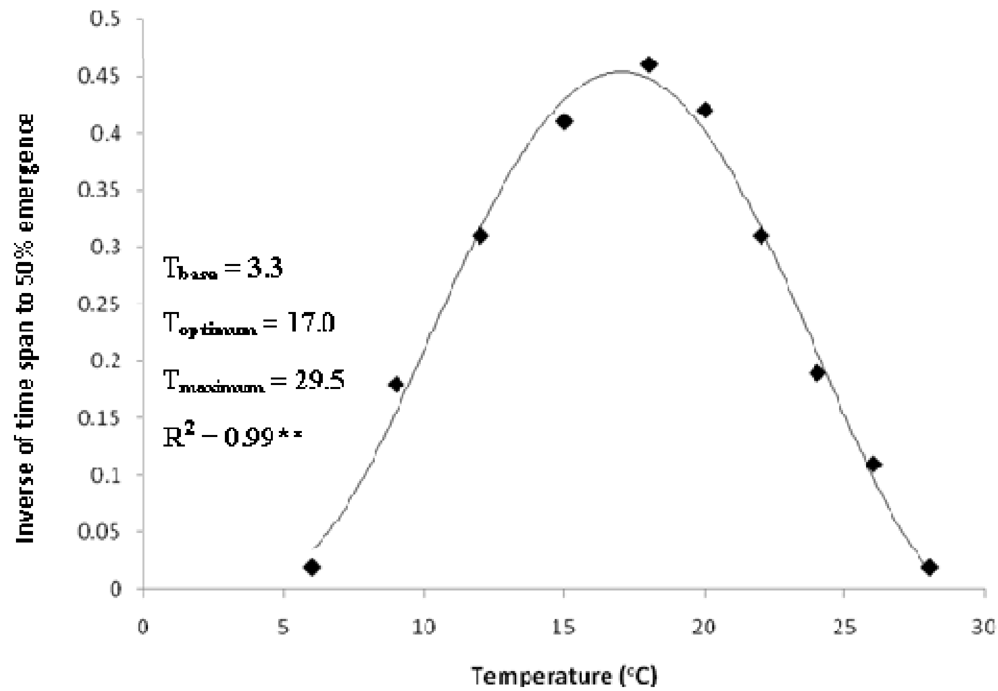


**Figure 3.** Five-parameters Beta model for Persian shallot germination rate index (inverse time taken to achieve 50% germination) in response to temperature.

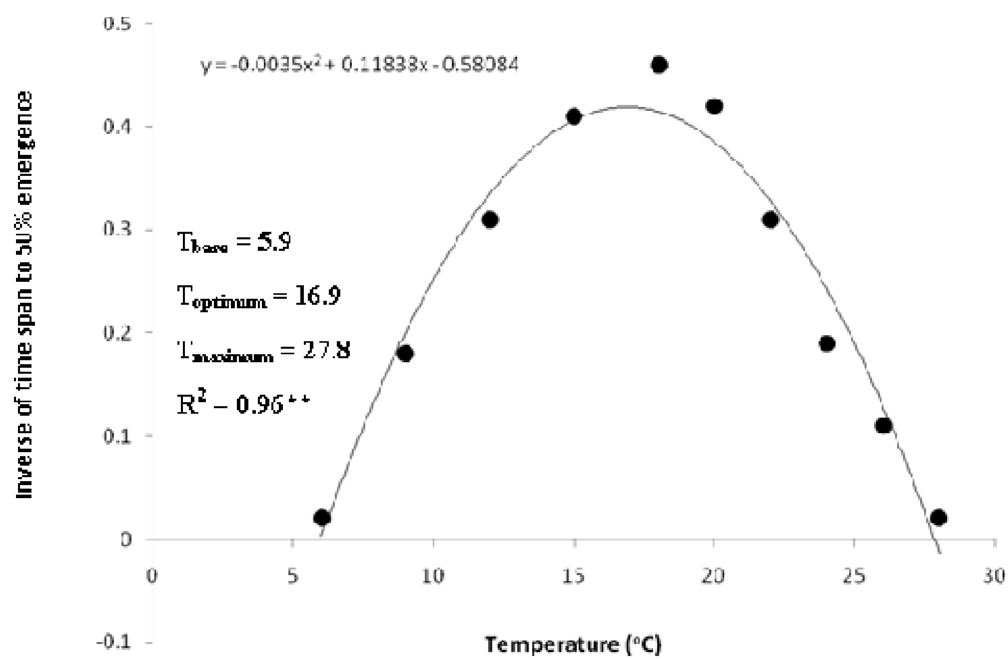


**Figure 4.** Quadratic polynomial model for Persian shallot germination rate index (inverse time taken to achieve 50% germination) in response to temperature.

values of the base, optimum and maximum temperatures were 3.3, 17 and 29.5°C in five-parameter Beta model (Figure 3).

Quadratic polynomial model represented the lowest accuracy in prediction of emergence response of bulbs to temperature across all study models; however, it was significant (Figure 4). This model estimated highest value for base temperature (5.9°C) and lowest value for optimum temperature (16.9℃) across all study models (Figure 4). In general, there were no noticeable differences across all study functions in the estimation of the cardinal temperatures of Persian shallot. Maximum and minimum temperatures of most winter crops such as winter wheat are between 4.6 to 30℃ (Porter and Gawith, 1999) and 4.2 to 31℃ for canola (Singh et al., 2008). Streck (2003) found out that the cardinal temperatures for (*Allium cepa* L.) venalization was about 0, 10, and 16℃ respectively.

## Conclusion

The estimated base temperature for Persian shallot bulbs emergence likely fluctuates between 3.3 and 5.9℃ across all study models. In addition, the maximum temperature for bulb emergence was predicted between 27.8 and 29.4℃, and the optimum temperature for Persian shallot emergence assortments is from 16.9 to 17.8℃ with a mean value of 17.3℃. Emergence rate declined below 12℃, and beyond 22℃. In conclusion, five-parameter Beta model indicated highest accurate-ness in prediction of Persian shallot emergence response to temperature. Persian shallot is a cold-season crop that should not be cultivated until the soil attains a temperature of 5℃.

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