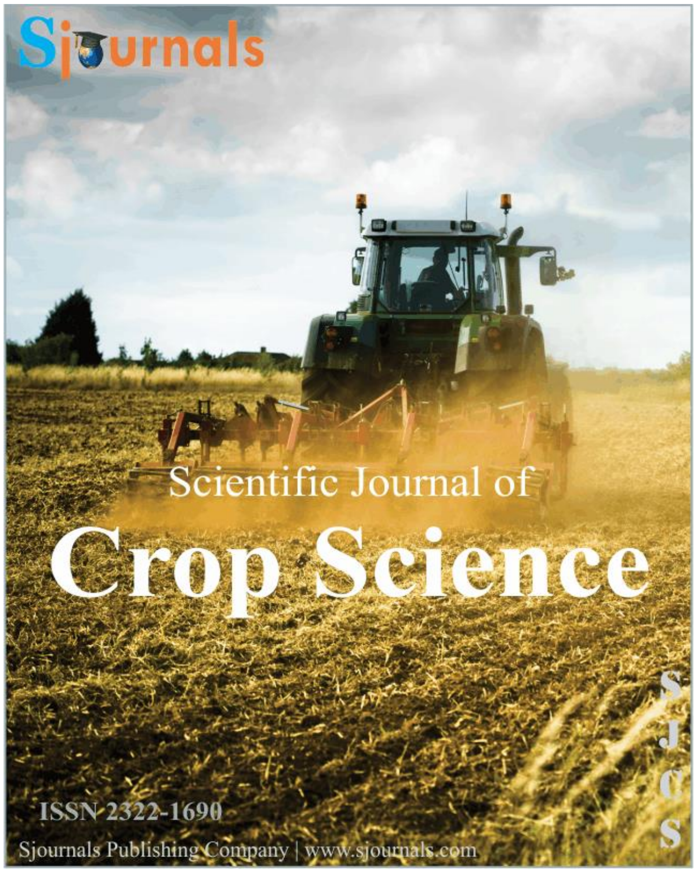
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Original article

Modeling the seed emergence rate of two plant species cultivars in field conditions

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ABSTRACT

The plant's vital cycle begins with seed germination in the soil. The length and seed rate emergence depends on the temperature, moisture and oxygen of soil and the quality of the seedbed. In irrigation conditions, temperature is one of the most influential factors on the emergence stage. In order to determine the seed emergence rate of safflower and soybean cultivars, planting dates of these cultivars during different years in research fields of Isfahan province were used. To determine the emergence rate the length of emergence period inversed. Emergence rate considered as dependent variable and thermal factors were used as independent variables in the stepwise regression. With increasing temperature, the length of the emergence period decreased. The coefficients of determination for determining the rate of emergence stage for safflower cultivars namely Arak, Sofeh and Goldasht, were 75.99, 69.75 and 76.07 percent respectively, and for soybean cultivars namely Hack, Williams and Steel, were 63, 70.4 and 70.2 percent respectively. Based on the results, the contribution of heat parameters to determining the seed emergence rate of different cultivars is not constant.

1. Introduction

Germination is a critical stage in the life cycle of plants. It often controls population dynamics, and depends on temperature strictly (Keller and Kollmann, 1999). All growth processes within the seed are chemical reactions activated by the addition of water, decent temperature and oxygen presence. Therefore, the germination process requires moisture, oxygen and temperature ranges which are specific to particular crops (Cirak et al., 2004a). The higher the temperature raise the faster will be the rate of chemical reactions. But, there are biological limitations as to how the temperature can be raised. The upper limit of rising temperature varies with plant species (Flores and Briones, 2001). Water is imbibed and activates growth processes, the rate of which depends on temperature. Germination rate usually increase until the temperature reaches 30-35 ˚C. But imbibed seeds of some plant species exhibit thermo dormancy at the higher temperature (Villalobos et al., 2001). On the other hand, it was revealed that there was not possible to mention of a certain optimum temperature value for germination (Arechiga and Carlos, 2000). Optimum temperature for germination is known as a temperature value which results in the highest germination rate in a short period of time (Hakansson et al., 2002). Moreover, optimum germination temperatures are not the same for all the seed species. Generally, optimum temperatures are preferred for both seed germination and plant growth (Cirak et al., 2004b). Therefore, it will be useful to know minimum, optimum and maximum temperatures required for plant growth and development (Arechiga and Carlos, 2000). Also the length and seed emergence rate depends on the temperature, moisture and soil oxygen and the quality of the seed bed. Each plant has a minimum, a maximum and a suitable temperature for emergence and growth. The soil temperature is up to a depth of 20 to 30 centimeters with the daily air temperature is on equilibrium. But the relationship between air temperature and soil temperature is not simple, and it affects the color, texture, moisture, soil cover, and tilt and gravity of ground surface. In addition, the daily average of air temperature is constantly changing, so the use of other relationships is necessary (Khajehpour, 1997).

Several studies have been carried out to examine the effect of temperature on seed germination and emergence for some plant species under field or laboratory conditions such as Zadeh and Alistair (2001) in *Cenchrus ciliaris*, Norman et al., (2001) in *Raphanus sativus*, Vilalobos and Pelaez (2001) in *Prosopis caldenia*, Delgado et al. (2001) in *Cistus ladanifer*, Demir (2001) in *Hibiscus esculentus*, Seefeldr et al. (2002) in *Triticum aesstivum*, Huang et al. (2003) in *Haloxylon ammodedron*, Malcolm et al. (2003) in *Prunus persica*, Barrera and Nobel (2003) in *Stenocereus queretaroensis*. Klips and Penalosa (2003) in *Lythrum salicaria*, Markus (2004) in *Bidens cernua* and *Bidens tripartite*, Manfred et al. (2004) in *Brachycome Mueller*, Nomizu et al. (2004) in *Hepatica nobilis*, Wang et al. (2004) in *Eurtia lanata*.

At first, it's best to consider development as not just a general process, but as a variable of day-to-day. Because this daily development rate is not directly measurable, it would be better to determine the mean total development at short intervals. It seems that during this short time the process of development has very good harmony. In this case, the development rate is the inverse length of this period (Robertson, 1983). The purpose of this study was to estimate the emergence rate of soybean and safflower cultivars in field conditions by determining the equations based on temperature and also the effect of this climatic element on the length of the emergence of these cultivars for their cultivation.

2. Materials and methods

2.1. Safflower

In order to determine the rate of emergence of three safflower cultivars namely Arak, Sofeh and Goldasht, and also to evaluate the effect of developmental rate of this stage to temperature variations, planting dates of these cultivars were carried out during five years at Kabootar-Abad Agricultural Research Station in Isfahan These cultivars were cultivated in different planting dates during different years (2003-2009). The range of planting dates from March 15 to July 31 was about 15 days apart. Each planting date cultivated at least in three replications and maximum in six replications. Kabootar-Abad station (32° 30'N, 51° 49'E and 1541 meters) is located at 30 km southeast of Isfahan. According to the classification of the coupon this station has the dry climate with hot and dry summer. The mean annual rainfall and annual temperatures in this station are 122 mm and 16.1 °C, respectively. Agriculture practices were performed according to common safflower experiments. In these experiments, after removing the first and fourth lines from each of sub plot and half a meter from the beginning and the end of the second and third lines of each plot the remaining formed statistical population of the experiment. The emergence stage was, when the cotyledons leaves revealed in 90% of the planting points.

2.2. Soybean

This study was carried out on soybean cultivars (Steele, Hack and Williams) in different years, planting dates and research fields. Khatoon Abad (32° 40' N, 51° 48'E, 1555 m), Kholeanjan (32 23' N, 51 34 W, 1651 m), Qahdirjan (32° 34 N, 51° 30' W and 1680 m), and Kabotarabad (32° 30' N, 51° 49' W and 1541 m) were research fields. Soybean cultivars namely Steele, Hack and Williams belong to maturity group of 1, 2 and 3 respectively, and all of them with indeterminate growth habit cultivated in nine planting dates during 1994-1997. The range of planting dates was from early May to late July in different years. Each region and year were considered as an independent experiment. Each experiment was based on two factors of agricultural experiment design, so that planting dates were considered as the main factors and cultivars were considered as sub factors. Agriculture practices were performed according to common soybean experiments. During the growth of plants, the dates of the RE stage (emergence) were recorded according to the method of Fehr et al. (Fehr, 1971).

For both two species, the correlation coefficients between meteorological variables and their emergence period were calculated. Inverse length of each developmental stage (1 / N) as a function variable and thermal parameters, were used as independent variables in the step wise regression of SAS software. Independent variables used for planting to emergence stage include mean minimum (Tmin), mean maximum (Tmax), average mean values (Tmean), the difference between the mean of the maxima to the minimum (Tmax-Tmin), and also the squares, cubes and fourth strengths of heat variables. The mentioned thermal variables were considered as independent variables in step wise regression equations. The regression stage was chosen as the appropriate model that the regression coefficient and its partial R2 were significant at least at 5% probability level and had the maximum total detection coefficient.

3. Results and discussion

3.1. Safflower

The period from planting to emergence for Arak cultivar varied from 5 to 20 days and for Sofea and Gholdasht cultivars varied from 4 to 20 days during the experiments. The average length of period for Arak, Sofea and Goldasht cultivars was 10.6, 9.1 and 9.2 days respectively. The development rate varied from 0.05 to 0.25 during the planting to emergence of the cultivars and the mean was 0.11. These differences show necessitate of independent evaluation for each cultivars. In all cultivars, the length of the period decreased with delay in planting and as a result of increasing temperature. The correlation coefficients also confirm this (Table 1).

Table 1
Correlation coefficients of safflower cultivars for planting to germination stage with meteorological variables.

	Temperature		
	Maximum mean	**Minimum mean**	**Mean average**
Arak			
Minimum mean	**0.781		
Mean average	**0.927	**0.941	
Period mean	**-0.729	**-0.352	**-0.550
Sofeh			
Minimum mean	**0.977		
Mean average	**0.995	**0.993	
Period mean	**-0.887	**-0.90	**-0.899
Goldasht			
Minimum mean	**0.977		
Mean average	**0.995	**0.993	
Period mean	**-0.881	**-0.897	**-0.899

**: Significant at 1% probability

The results of stepwise regression for the rate of development of Arak, Sofeah and Goldasht cultivars are shown in Table 2. For Arak, the minimum temperature was the only variable that entered the model and explained 69.75% of the variations in the rate of development of this period (Model 1).

Model 1: $1/N= 0.03958712+0.00700082T_{min}$ $R^2=75.69\%$

For Sofeah, the mean temperature was the only variable that entered the model and expressed 69.75% of the variation of this period (Model 2).

Model 2: $1/N=-0.0104729+0.00697526T_{mean}$ $R^2=75.69\%$

Like the Sofeah cultivar, the mean temperature was the only variable that entered the Goldasht model and interpreted 76.88% of the variation in the rate of emergence of this period (Model 3).

Model 3: $1/N=-0.01082834+0.00655551T_{mean}$ $R^2=76.08\%$

These variables seem to explain the significant changes in soil temperature. In addition of air temperature, factors such as texture, color, gradient, soil moisture, irrigation intervals, seeding depth and seed bedding characteristics affect soil temperature. Therefore, the accurate estimation of the planting date to the emergence requires a direct measurement of soil temperature, which is difficult to do in the farmers' farm. It should be noted that the difference between the input variables to the model indicates that although the soil temperature and the resulting emergence rate are influenced by the thermal variables, but part of the reason for the input of a variable to the model is related to the variance of the variables and the correlation between them (Table 1).

Table 2
Summary of stepwise regression for estimating of development rate of planting to germination stage of safflower cultivars.

[1]Variable	R^2 Determination coefficient of model (R^2)	R^2 Partial determining coefficient (P.R^2)	Regression coefficient
Arak cultivar			
Intercept	_	_	0.03958712
T_{min}	**0.7569	0.7569	0.00700082
Sofeh cultivar			
Intercept	_	_	0.0104729–
T_{mean}	**0.7569	*0.7569	0.00647526
Goldasht cultivar			
Intercept	_	_	0.01082834–
T_{mean}	**0.7607	0.7607	0.00655551

1. T_{min}, T_{mean} are minimum and mean average respectively

3.2. Soybean

During the years and dates of planting, the length of the planting period until the emergence for HacK was varied from 3 to 15 days, for Williams from 3 to 14 days and for Still 5 to 7 days during the experiment period. The average length of period for the mentioned cultivars was 8.3, 8.8 and 6.8 days respectively. These differences necessitate an independent evaluation for each cultivar. In all three cultivars, the length of the period decreased with delay in planting and as a result of the general increase in temperature. The low variation of the length of the period in the still due to the fact that this cultivar was not considered in the early planting dates during the years 1994-1998. In Hack and Williams cultivars, thermal variables showed a negative correlation (Table 3). Which suggests a positive effect of increasing the temperature of the air and hence the temperature of the soil on the rate of emergence.

Table 3
Correlation coefficients of soybean cultivars for planting to germination stage with meteorological variables.

	Temperature		
	Maximum mean	**Minimum mean**	**Mean average**
Hack			
Minimum mean	**0.805		
Mean average	**0.940	**0.939	
Period mean	**-0.770	**-0.412	**-0.604
Williams			
Minimum mean	**0.772		
Mean average	**0.934	**0.928	
Period mean	**-0.745	**-0.357	**-0.574
Steel			
Minimum mean	**0.745		
Mean average	**0.872	**0.962	
Period mean	0.099	**0.480	**0.384

**: Significant at 1% probability

Table 4
Summary of stepwise regression for estimating of development rate of planting to germination stage of soybean cultivars.

[1]Variable	R^2 Determination coefficient of model (R^2)	R^2 Partial determining coefficient(P.R^2)	Regression coefficient
Steel			
Intercept	_	_	-0.2082
$(T_{max}-T_{min})^2$	*0.349	0.349	0.0012
$_{mean}{}^{3}$ T	*0.702	0.353	$10^{-5}\times2$
Hack			
Intercept	_	_	0.6310
T_{max}	*0.373	0.373	0.1233-
$(T_{max}-T_{min})^2$	*0.57	0.197	0.1380
T_{min}	*0.63	0.06	0.005
Williams			
Intercept	_	_	1.0895
T_{max}	*0.323	0.323	0.1763-
$(T_{max}-T_{min})^2$	*0.583	0.260	0.0067
T_{min}	*0.704	0.121	0.01881

1., Tmin $T_{max,}$, Tmean are minimum mean maximum mean and mean average respectively.

The results of step wise regression analysis for the estimation of the emergence rate for the different soybean cultivars are shown in Table 4. The maximum temperature was the first variable introduced into the Hack cultivar model and alone justifies about 37% of the variation. After maximum temperature, the maximum temperature difference from the minimum entered the model, with 19.7% alone and with the variable The previous model accuracy was 57%. After these two variables, the minimum temperature was the last variable that entered the model significantly and alone interpreted 6% of the variation and with the other two variables, 63% of the variations of this period for the Hack explained (Model 4).

Model 4: $1/N=0.6310-0.1233T_{max}+0.1380(T_{max}-T_{min})^2+0.0050T_{min}$ $R^2=63\%$

Like the Hock variety, variables entered into the Williams variety model were the maximum temperature, the maximum temperature difference with minimum and minimum temperatures, respectively, 32.3, 26 and 12.1 percent of the variations in the rate of emergence of Williams cultivar, and in general the accuracy of the model was 70.4% (Model 5).

Model 5: $1/N=1.0895-0.1763T_{max}+0.0067(T_{max}-T_{min})^2+0.1881T_{min}$ $R^2=70.4\%$

Due to the maximum temperature entry in these models, a high temperature contribution to determining the soil temperature can be mentioned. During the period of planting to the emergence of the steel variety, the variables of the square difference of the mean of maximum from the minimum and the cubic average of the minimum daily temperature were introduced into the model which justified 34.9 and 35.3 of the variations of this period and justified the coefficient of detection of the model 70.2% (Model 6).

Model 6: $1/N=-0.2082+0.0012(T_{max}-T_{min})^2+0.00000T^3_{min}$ R2=70.2%

The difference between safflower and soybean cultivars in terms of length and rate of planting to emergence stage show necessitates an independent evaluation for each cultivar. The planting stage to the emergence of the cultivars showed different reactions to temperature changes due to planting delays, so that the input variables in the equations did not constant. Therefore, it can be concluded that the contribution of thermal parameters is not constant over the course of the period, due to the climatic, soil, and agronomic elements, the interactions of these factors with each other and with the genotype of the plant. Part of the reason for entering a variable into a model may be related to the variance of the variables and the correlation between them, and there are always no physiological reasons for this issue. High coefficients of explanation and evaluation of planting to emergence models indicate the adequacy of models to estimate the rate of development of this stage using temperature variables. Considering seed germination in soil and effect of color, texture, moisture and soil cover, and the rate and direction of gradient on soil temperature, it can be concluded that a more accurate and accurate estimation of the planting to the emergence of the seeds requires direct measurement of soil temperature. Separating the regions of the country into homogeneous regions of temperature can increase the accuracy of estimation of developmental models. Such a study requires access to sufficient phonological information in each climatic region.

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