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Modeling the Effect of Temperature on the Days to Germination in Seeds of Flue-cured and Oriental Tobacco (*Nicotiana tabacum* L.)

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Abstract: In this research, the possibility of prediction of days to germination of seeds for Flue-cured and Oriental tobacco (*Nicotiana tabacum* L.) by mathematical models based on temperature was investigated. A model, ($D = \alpha - (b\times T)+(c\times T^2)$ was used that previously predicted the time to emergence in relation to temperature for some vegetable crops and was unchanged when applied to both tobaccos. It was found that the new mathematical models obtained after adapting the present data to the above mentioned model could be used safely in terms of the studied parameter. In addition to determining optimum ($T_0 = -b / 2\times c$) seed germination temperature, days to germination was calculated by using coefficients obtained from the regression models. Considering the marked interest by many researchers in modeling plant growth and development in recent years, the equations produced in this study may be helpful in this field. Models which predict days to germination or optimum temperatures could be used for adjusting a proper time for seed sowing according to different regions and utilizing the growing season of these regions more productively.

Key words: Flue-cured and Oriental tobacco, temperature, modeling, days to germination

INTRODUCTION

The tobacco (*Nicotiana tabacum* L.) plant is native to the New World and was smoked, chewed and snuffed by native peoples at least one thousand years before Columbus landed here (Marcotrigiano, 1986). It belongs to the nightshade family, which also includes potatoes, tomatoes, eggplant and red peppers. Today it is an important cash crop throughout different production areas of the world. Planted area has reached 3.931.715 ha and resulted in 6.376.369 ton production in worldwide during 2005 (Anonymous, 2006). Also, tobacco ranks in the top five crops for hectares planted and total cash receipts generated in Turkey (Kevseroğlu, 2000). These figures clearly demonstrate the importance of tobacco, as well as the potential economic benefits possibly realized from productivity increases.

All growth processes within the seed are chemical reactions activated by the addition of water, favorable temperature and oxygen presence. Therefore, the germination process requires moisture, oxygen and temperature ranges which are specific to the particular seed type. The higher the temperature is raised the faster the rate of chemical reaction. However, there are biological limitations to how high the temperature can be raised. The upper limit of high temperature tolerance varies with plant species (Flores and Briones, 2001). Germination rate usually increases until the temperature reaches 30-35°C. At higher temperatures imbibed seeds of some plant species exhibit thermo dormancy (Villalobos and Pelaez, 2001). Generally, optimum temperatures are preferred for both seed germination and plant growth. Therefore, it will be useful to know minimum, optimum and maximum temperatures required for plant growth and development (Arechiga and Carlos, 2000).

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Several studies have been carried out to examine the effect of temperature on seed laboratory germination and field emergence for several plant species such as *Raphanus sativus* (Nomura *et al*., 2001), *Hibiscus esculentus* (Demir, 2001), *Triticum aestivum* (Seefeldt *et al*., 2002) and *Prunus persica* (Malcolm *et al*., 2003). Although there is a marked knowledge of optimum germination temperature for tobacco (Kathleen, 1998; Ray *et al*., 1999; Peter *et al*., 2004), there is a lack of understanding of germination rates of this species under optimum and extreme temperature regimes. The following study examines seed germination performance and germination duration of Flue-cured and Oriental tobaccos by adapting a mathematical model developed by Uzun *et al*. (2000) to predict the time elapsing from seed sowing to emergence for some vegetable crops.

MATERIALS AND METHODS

The seeds of Virginia-15 (for Flue-cured tobacco) and Bafra (for Oriental tobacco) cultivars were used as seed material in this study.

The study was performed in germination cabin adjusted to 0, 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50°C, respectively and repeated three times for each temperature value. The seeds were placed on moisturized filter paper (Watman No: 1) kept in glass made containers. For each replication, 100 seeds of both tobaccos were used. The seeds left for germination were observed every day and germinated seeds were also counted according to different temperatures. The time at which 50% of seeds germinated was accepted as days to germination for each kind of tobacco. In predicting the time to germination for seeds of both tobaccos (as days) with different temperature regimes, a model ($Dd/dt = -b+(2\times c\times T)$) produced by Uzun *et al*. (2000) in order to predict the time elapsing from seed sowing to emergence for some vegetable crops was adapted to data obtained from the present study by carrying out multi regression analysis. In the above model; D represents the time elapsing from seed sowing to emergence as days and T represents mean temperature (°C).

Furthermore, the rate of variation in seedling emergence can be obtained from derivative of the above equation ($Dd/dt = - b+(2\times c\times T)$. If the rate of variation is zero, another equation determining optimum temperature (T_0) for emergence can also be obtained. Hence, the equation turns to $T_0 = -b/2\times c$. by taking into consideration these stages of the model, optimum germination temperatures for the seeds of both tobaccos were determined as well as obtaining standard equations predicting the time to germination for each. On the other hand the optimum temperatures predicted by evaluated equations from the present study were compared with those reported in the literature.

For model evaluation, the data obtained from the present study were analyzed by multi regression analysis method and the analysis were continued until the least sum of squares and the highest regression coefficient (r^2) were obtained. The Excel 2003 package program was used for the analysis.

RESULTS AND DISCUSSION

The coefficients, their standard errors and degree of significance derived by applying the data obtained here to the model described in the section of materials and methods are shown in Table 1. In

Table 1: The coefficients, their standard errors and r^2 values of the new produced equations predicting the days to germinationD = α- ($b\times T$)+($c\times T^2$) based on mean temperature for Flue-cured and Oriental tobacco seeds

Kinds of tobacco	Multiple regression coefficients (a, b, c) and standard errors for model equation					
	a	b	c	r^2	T_0(°C) Predicted by the models	T_0(°C) Reported by literatures
Oriental	0.61±0.25*	-0.05±0.002*	0.0014±0.0004 *	0.96*	18.75	2-20
Flue-cured	0.1±0.017*	-0.005±0.001*	0.0002*±2.88E^{-05}*	0.99***	13.01	

*, **, ***: Significant at the level of $p<0.05$, 0.01 and 0.001, respectively, D: Days to germination, T: Temperature, a, b and c: Coefficients

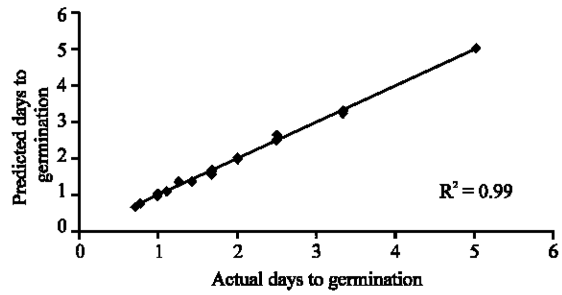

Fig. 1: Relationship between actual and predicted days to germination for Flue-cured and Oriental tobacco seeds

determining the adapted models for each kind of tobacco, analysis were carried out until the lowest standard errors of independent variables namely T and T^2 values and the highest r^2 (regression coefficients) values of the equations were obtained. It was found that the model adapted to the data obtained from the present study did not show any structural change in terms of predicting the days to germination for the seeds of both Flue-cured and Oriental tobacco and the regression coefficients of the new produced equations for days to germination were 0.99 for Flue-cured tobacco and 0.96 for Oriental tobacco. At this stage, we can say that very reliable equations have been obtained for predicting the days to germination as affected by temperature. Similar seed germination models were developed for *Eucalyptus delegatensis* (Battaglia, 1997), *Orobanche aegyptiaca* (Murdoch and Kebreab, 1999), *Nigella sativa* (Kevseroğlu *et al*., 2000), *Triticum aestivum* (Jame and Cutforth, 2004) and *Hypericum* sp. (Çırak *et al*., 2006).

The relationship between actual and predicted days to germination by the new produced equations was also investigated in order to find out their prediction performances (Fig. 1). The coefficient of the solid line was 0.99 for days to germination.

It might be possible to determine optimum temperatures (T_0) for germination by using the coefficients of independent variables (b and c) obtained from the equations belonging to the days to germination for each kind of tobacco. The optimum germination temperature of tobacco seeds was reported as 12-20°C (Kathleen, 1998; Ray *et al*., 1999; Peter *et al*., 2004). As seen in Table 1, it was found that optimum temperature for germination of Flue-cured and oriental tobaccos was 13 and 19°C, respectively. The only disadvantage of this kind of comparison was the fact that it was not possible to find a single optimum temperature in the literature for each species.

CONCLUSIONS

With the increasing interest by many researchers in modelling plant growth and development in recent years, the equations produced in this study may be helpful in this field. Models which predict days to germination or optimum temperatures could be used for adjusting a proper time for seed sowing according to different regions and utilizing the growing season of these regions more productively. The broad temperature limits (0 to 50°C) used in the present study and the high values for regression coefficients also enables us to use these models safely.

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