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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet

Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 3 (9): 1424-1426, 2000

Modeling the Effect of Temperature on the Germination Percentage and the Days to Germination in Some Industry Plants

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Abstract: In this study, the possibility of prediction of germination percentage and days to germination of the seeds for some industrial plants; sunflower (*Helianthus annus* L.), soybean (*Glycine max* L.), pappy (*Papaver somniferum* L.), fenugreek (*Trigonella foenum* L.), nigella (*Nigella sativa* L.) and castor oil (*Ricunus comminus* L.) by mathematical models based on temperature was investigated. For this reason, a model (*D=a-b*T+c*T2*) produced earlier for predicting the time to emergence in relation to temperature for some vegetable crops was utilised. The final structure of the model did not change for predicting the days to germination of the tried industry plants while it changed to (*D=a+b*T-c*T2*) for predicting germination percentage (GP) of the crops tried. 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 parameters. In addition, optimum temperatures (*To=b/2*c*) for seed germination in the tried crops were calculated by using the coefficients obtained from the produced regression models of the days to germination.

Key words: Modeling, industry plants, temperature, days to germination, germination percentage

Introduction

Seed germination is a complicated event including many reactions with different phases affected by temperature (Kevseroglu and Çaliskan, 1995). All growth processes within the seed are chemical reactions activated by the addition of water, subjecting to a decent temperature and oxygen presence. Therefore, the germination process requires moisture, oxygen and temperature ranges which are specific to particular crops. The higher the temperature raised 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 (Kevseroglu and Çaliskan, 1995). Water is imbibed and activates growth processes, the rate of which are very temperature dependent. Germination rate usually increases until the temperature reaches 30-35°C but imbibed seeds of some crops exhibit thermodormancy at the higher range than 30°C .

In general, most tropical and sub-tropical plants do not have dormancy problems. On the other hand, it was revealed that there was not possible to mention of a certain optimum temperature value for germination (Meyer *et al*., 1965). Optimum temperature for germination is known as a temperature value which results in the highest germination rate in a short period of time (Sagsöz, 1990). Moreover, optimum germination temperatures are not the same for all the seed species (Genvkan, 1976). In general, 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 (Kevseroglu, 1997).

In practice, the germination of seeds covers the entire process, from subjecting a resting seed to suitable conditions to cause it to develop to the stage at which the seedling produces true leaves and establishes as a young plant. Once the seed has sufficiently imbibed, the embryo inside the seed begins to produce root and stem systems, which eventually break out of the seed. Germination rate explains the minimum time that a seed needs for germinating. In growing plants from seed, germination rate is an important aspect and depends on plant species, soil moisture and especially soil temperature (Bayraktar, 1976).

Although all the factors affecting plant development are at an optimum level, obtaining higher yield depends on seed quality (Sehirali, 1989). But, if soil temperature and moisture content are not proper for seed germination, it will not be possible to obtain expected results from growing plants.

In many field crops, several studies have been carried out under field conditions to examine seed germination and emergence such as Sethi *et al.* (1985) and Sethi and Aggarwal (1986) in wheat, Cutforth *et al.* (1987) and Weaich *et al.* (1996) in corn, Arnold *et al*. (1989) and Brar *et al.* (1992) in *Sorghum halepense* L., Charles *et al.* (1991) in *Fescuta arundinacea* schreb and white clover (*Trifolium repens* L.), in *Avena fatua* and winter barley (*Hordeum sativum*) and winter wheat (*Triticum aestivum*), Forcella (1993) in velvet leaf, Prostko *et al*. (1998) in *Shorgum halepense*. In addition, although there is a marked knowledge on optimum germination temperatures for germination in some industry plant species, namely sunflower, soybean, pappy, fenugreek, nigella and castor oil, there is a lack of understanding of germination rates of above-mentioned crops under optimum and extreme temperature regimes. Thus, in the present study, it was aimed to examine the germination performance and germination duration of the seeds of these crops by adapting a mathematical model produced earlier by Uzun *et al*. (2000) to the data obtained from the present study. This kind of models have been used by many researchers to determine plant growth, development and yield in recent years.

Materials and Methods

This study was carried out in the experimental laboratory of Agricultural Faculty of Ondokuz Mayis University. The seeds of Tordillo (for sunflower), Kevir (for soybean), Mavi hashas (for pappy), Burdur orijinli (for fenugreek), Amasya orijinli (for nigella) and Anamur orijinli (for castor oil) were used as seed materials in the 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 four times for each temperature value. The seeds were placed on a moisturised filter paper (Watman No: 1) kept in glass made containers. For each replication, 100 seeds for pappy, fenugreek and nigella and 50 seeds for sunflower and soybean were used while 25 seeds were used for castor oil. 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 the seeds germinated was accepted as days to germination for each crop. In predicting the germination percentage and time to germination for tried seeds of some industry plants (as days) with different temperature regimes, a model ($D = a - b*T + c*T^2$) 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 the 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 ($Dd/Dt = -b + 2*c*T$). If the rate of variation is zero, another equation determining optimum temperature (*To*) for emergence can also be obtained. Hence, the equation turns to $To = b/2*c$. By taking into consideration these stages of the model, optimum germination temperatures for the seeds of tried crops were determined as well as obtaining standard equations predicting germination percentage and the time to germination for each crop. On the other hand, the optimum temperatures predicted by the 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 analysed by multi regression analysis method and the analysis were continued until the least sum of squares and the highest regression coefficients (r^2) were obtained. The Excel 7 package programme was used for the analysis.

Results and Discussion

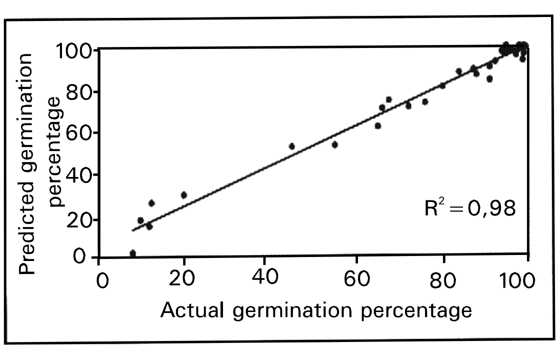
The coefficients, their standard errors and degree of significance derived by applying the data obtained here to the model described in the section of material and methods are given in Table 1. In determining the adapted models for each tried crop, analysis were carried out until the lowest standard errors of independent variables namely T and T^2 values and the highest r^2 (regression coefficients) values of the equations were obtained. After following the modeling procedure, it was

Table 1: The coefficients, their standard errors and r^2 values of the new produced equations predicting the days to germination ($D = a - b*T + c*T^2$) and germination percentage ($GP = a + b*T - c*T^2$) based on mean temperature for some industry plants

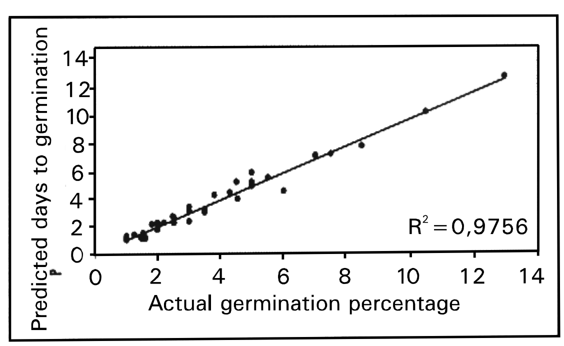
Plant species and Standard Errors (SE)	Coefficients (for germination percentage, GP) a	B	c	R^2
Sunflower (SE)	26.21±5.66**	8.11±0.50 ***	-0.21±0.009***	0.99***
Soybean (SE)	43.92±15.38*	7.14±1.35**	-0.19±0.026**	O97***
Pappy (SE)	80.27±2.88***	2.38±0.37**	-0.006±0.01**	0.93**
Fenugreek (SE)	83.24±8.78***	2.32±0.80*	-0.091±0.015***	0.97***
Nigella (SE)	43.71±5.81**	7.62±0.63**	-0.026±0.015**	0.99***
Castor oil (SE)	-323.03± 55.85*	30.91±3.87**	-0.562±0.06**	0.98**

Plant species and Standard Errors (SE)	Coefficients (for days to germination) a	B	c	R^2	To (°C) Predicted by the models	To (°C) Reported in literature
Sunflower (SE)	8.81 0.60***	-0.47 0.053***	0.007 0.001***	0.98***	33.5	20-30
Soybean (SE)	11.49 0.73***	-0.79 0.064***	0.015 0.001***	0.97***	26.3	20-30
Pappy (SE)	20.48 0.78***	-1.75 0.088***	0.039 0.002***	0.99***	22.4	20
Fenugreek (SE)	11.29 0.60***	-0.93 0.06***	0.021 0.001***	0.98***	22.1	20
Nigella (SE)	23.97 1.61***	-1.72 0.154***	0.034 0.003***	0.98***	25.3	20
Castor oil (SE)	22.08 1.39***	-1.327 0.096**	0.0218 0.001**	0.99**	30.4	20-30

*, **, *** : Significant at the level of $p < 0.05, 0.01, 0.001$ respectively



(a)



(b)

Fig. 1: Relationships between actual and predicted germination percentage (a) and actual and predicted days to germination (b) for all the plant species tried

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 tried industry plants while it changed from $D = a - b*T + c*T^2$ to $D = a + b*T - c*T^2$ in terms of predicting the germination percentage (GP) (Table 1).

As seen in Table 1, the regression coefficients (r^2) of the new produced equations for germination percentage in the tried plant species changed between 0.93 (in pappy) and 0.99 (in sunflower) as a result of model adaptation.

This result showed that the effect of temperature on germination percentage was much more important than the other possible effective parameters since 93 to 99 % of the variation in germination percentage was explained by temperature depending on the plant species.

After model adaptation processes, it was also found that the regression coefficients (r^2) of the new produced equations for days to germination in the tried plant species changed between 0.97 (in soybean) and 0.99 (in pappy and castor oil). The regression coefficient of the equations belonging to the other species (sunflower, fenugreek and nigella) was found to be 0.98. At this stage, we can say that very reliable equations have been obtained for predicting the days to germination as affected by temperature.

The relationship between actual germination percentage and predicted germination percentage by the new produced equations was also investigated in order to find out their prediction performances (Fig. 1a) as well as comparing actual and predicted days to germination (Fig. 1b).

As seen in Fig. 1a and b, the coefficients of the solid lines were 0.98 for germination percentage and 0.97 for days to germination respectively.

On the other hand, as explained in the section of Material and Methods, it would be possible to determine optimum temperatures (To) for germination by using the coefficients of independent variables (b and c) obtained from the equations belonging to the days to germination for each species. As seen in Table 1, it was found that optimum temperatures for germination predicted by the current equations were in general in the limit of those reported in the literature. But the only disadvantage of this comparison was the fact that it was not possible to find a single optimum temperature in the literature for each crop.

To conclude, considering that there have been a marked interest by many workers in modelling plant growth and development in recent years, the equations produced in the present study may be used in this field. This kind of models such as those predicting days to germination or optimum temperatures could be used for adjusting a proper time for seed sowing according to different regions and utilising the vegetation period of these regions more productively. The temperature limits (0 to 50°C) used in the present study also enable us to use these models safely.

References

Arnold, R.L.B., C.M. Ghersa, R.A. Sanchez and P. Insausti, 1989. A mathematical model to predict *Sorghum halepense* (L.) Pers. Seedling emergence in relation to soil temperature. Weed Res., 30: 91-99.

Bayraktar, K., 1976. *Sebze yetistirme* Cilt-III. Sebzelerde Tohum Üretimi. Ege Universitesi Ziraat Fakultesi Yayinlari, Ege Universitesi Matbaasi, Bornova, Izmir.

Brar, G.S., J.L. Steiner, P.W. Unger and S.S. Prihar, 1992. Modeling sorghum seedling establishment from soil wetness and temperature of drying seed zones. Agron. J., 84: 905-910.

Charles, G.W., G.J. Blair and A.C. Andrews, 1991. The effect of soil temperature, sowing depth and soil bulk density on the seedling emergence of tall fescue (*Festuca arundinacea* Schreb.) and white clover (*Trifolium repens* L.). Aust. J. Agric. Res., 42: 1261-1269.

Cutforth, H.W., C.F. Shaykewich and C.M. Cho, 1987. A model to estimate the time to emergence for corn under field conditions. Can. J. Soil Sci., 67: 659-665.

Forcella, F., 1993. Seedling emergence model for velvetleaf. Agron. J., 85: 929-933.

Genvkan, M.S., 1976. Tohumluk. Ziraat Fak. Oitesi Yayinlari, No. 253. Ege Universitesi, Matbaasi, Bornova, Izmir.

Kevseroglu, K. and O. Caliskan, 1995. Farkli sicaklik derecelerinin bazi endustri bitkileri tohumlarinin cimlenmesine etkisi. OMUZF Dergisi, 10: 23-31.

Kevseroglu, K., 1997. Bitki ekolojisi ders notlari. OMUBMYO Bafra-Samsun.

Meyer, B.S., D.B. Anderson and R.H. Bohning, 1965. Introduction to Plant Physiology. Wiley, London, pp: 516.

Prostko, E.P., H.I. Wu and J.M. Chandler, 1998. Modeling seedling johnsongrass (*Sorghum halepense*) emergence as influenced by temperature and burial depth. Weed Sci., 46: 549-554.

Sagsoz, S., 1990. Tohumluk Bilimi. AU Zir. Fak. Yay. No. 302, Ders Kitabi, Erzurum, pp: 270.

Sehirali, 1989. Tohumluk ve Teknolojisi. A.O. Basimevi, Ankara, Pages: 330.

Sethi, A.S. and G.C. Aggarwal, 1986. A dynamic model to predict wheat emergence from soil moisture and temperature. Proc. Indian Natl. Sci. Acad., B52: 495-498.

Sethi, A.S., R.P. Mor and G.C. Aggarwal, 1985. A model to predict wheat emergence from soil temperature and soil moisture. Proc. Indian Natl. Sci. Acad., B51: 117-122.

Uzun, S., D. Marangoz and F. Ozkaraman, 2000. Modeling the time elapsing from seed sowing to emergence in some vegetable crops. Pak. J. Biol. Sci., (In Press).

Weaich, K., K.L. Bristow and A. Cass, 1996. Simulating maize emergence using soil and climate data. Agron. J., 88: 667-674.