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Modelling the Effect of Temperature on the Germination Power in Some Legume Crops

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Abstract: This study was conducted to research, the possibility of prediction of germination powers of the seeds for some legume crops, namely green bean (Öz Ayşe 16, Dade, Tina and 4F-89 Cv.), red podded bean (Gitan and Sırık 97 Cv.), pea (Yaprak and Progres No:9 Cv.), cowpea (izmir orij. population and karagoz Cv.) and broad bean (Amasya orij. population Cv.) by mathematical models based on temperature. Therefore, a model ($D=a-b*T+c*T^2$) produced earlier for predicting the time to emergence in relation to temperature for some vegetable crops was utilized. This model changed to ($D=a+b*T- c*T^2$) for germination power of the legume crops tried. The prediction performance of this model with respect to the data used was highly acceptable. Values of regression coefficients (R^2) varied from 0.89 to 0.98 depending on the species. It was found that the new mathematical models obtained after adapting the present data to the above mentioned model could be used safely in predicting germination power for some legume crops. In addition, optimum temperatures ($To=b/2*c$) for seed germination power were calculated by using the coefficients obtained from the produced regression models.

Key words: Germination power, modelling, temperature, legume crops

INTRODUCTION

Seeds is the primary and essential starting point for a wide range of horticultural crops, including the majority of vegetables, field crops and many annual and biennial ornamentals. Although all the factors affecting plant growth and development are at an optimum level, obtaining higher yield by the way vigour plant growing depends on seed quality[1,2]. Seed quality embraces several factors, for example, potential germination (including vigour), genetical quality, mechanical purity (including free from undesirable seeds and weeds, noxious species or other crop species), uniform germination in short period and free from seed transmitted pathogens and pests[3,4]. The seed quality is affected by many factors as ecologically and genetically[5]. Besides ecological factors, some seed characters are effective in legume crops growing in order to obtain a desirable yield and quality.

After sowing, uniform germination and seedling emergence are expect to the farmers. However, it has been determined that snap bean producers in Turkey have some problems due to the low germination and field emergence rates for some cultivars[6,7].

Germination experiments at laboratory conditions are carried out in order to determine the favorable characteristics of the seeds before sowing. Since germination power is very important for about earliness in the plant growing and it can differ according to species, soil structures, sowing methods and especially temperature, soil moisture ratios, age of seeds, seeds hormon contents and storage conditions (temperature and humudity)[8-10].

Moisture, oxygen and temperature ranges which are specific to particular crops primary requirements of germination process (Some seeds are need of light for favorable germination rate also). Seed germination is a complicated event including many reactions with different phases affected by temperature[11-13]. The temperature requirement of vegetable seeds for germination varies according to species. Some vegetable seeds germinate above a temperature tresh-hold of 0°C, some of the others can only begin to germinate at temperatures above 8 to 10°C as summer vegetable crops[14]. Minimum, optimum and maximum germination temperatures for winter vegetable crops are 0-4, 10-20 and 35-40°C respectively. However, minimum, optimum and maximum germination temperatures for summer vegetable crops are 10-16, 20-30 and 40-45°C[15]. The higher temperature raised the faster will be the rate of chemical reactions in seed germination[1]. Germination power can be different between species and also varieties[1]. Seed testa is also effective on the germination power of seeds beside temperature. A highly significant negative correlation (r = -0.7218**) between

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seed coat rate and germination power in different cow pea genotypes were determined[16]. A thick testa is a negative effect for imbibition during germination. It was notified that in dwarf types of snap bean, colourfull seeds had higher germination and emergence rate than the white seeds[17]. In another research, it was found that there was a significant and negative relationship (r^2 = -0.7719*) between testa rate and germination power in coloured cultivars[18].

Legume vegetable species show differences for temperature requirement during the germination. Green bean, red podded bean and cow pea seeds do not prefer low temperatures during germination. The snap bean seeds could be damaged due to heavy rain if they are sown in cool season and emergence problem in field is encountered. This situation are also clear for white colour seeds[19]. Şehirali[1] stated that germination rate of bean decreased at 10 and 18-20°C was optimum. He also found that there was not any growth activity in bean seeds at over 35°C.

While Şehirali[15] and Günay[20] found that the minimum, optimum and maximum temperatures were 5-6, 30 and 35°C for germination of pea seeds respectively, Lorenz and Maynard[21] found them as 5, 26 and 30°C respectively. It was determined that soil temperature must be between 4 and 18°C for a normal germination of pea seeds[7]. Vural *et al.*[22] stated that the minimum and optimum temperatures for germination of cowpea seeds were 8-10 and 20-25°C, respectively.

Studies on broad bean germination showed that there were a great variation between temperature regimes. The minimum, optimum and maximum germination temperatures for broad bean seeds were 3, 20-25 and 30-35°C, respectively[23,24]. On the other hand, Abd-el Hamit[25] found that 18°C was an optimum temperature for the germination of broad bean seeds. Skjelvag[26] showed that the germination rate and time elapsing from sowing to emergence increased linearly in a controlled temperatures between 12-21°C.

The models have been used by many researchers to determine plant growth, development and yield in recent years[27]. Plant development includes the durations from seed sowing to preceeding to reproductive stage and from this stage to maturity. Especially, temperature and light have an important effect on plant developmental phases[28,29]. The time elapsing from seed sowing to seedling emergence can be regarded as a parameter to the development of plants[20,30]. The changes in the seed quality affect especially field emergence and seedling periods[31].

In this research, the relationships between temperature and germination of legume vegetables such as green bean, red podded bean, pea, cowpea and broad bean were investigated at 15 different temperature regimes (5-40°C). Findings from this study has been used to determine germination power by means of the mathematical model produced earlier by Uzun *et al.*[14]. On the other hand, the optimum temperatures for germination of the tried crops were also determined.

MATERIALS AND METHODS

This research was carried out in the laboratory of The Profession High School of Bafra of Ondokuz Mayıs University in 2002 year.

Green bean (Oz Ayşe 16, Dade, Tina and 4F-89 Cv.), red podded bean (Gitan and Sırık 97 Cv.), pea (Yaprak and Progres No:9 Cv.), cowpea (izmir orij. population and karagoz Cv.) and broad bean (Amasya orij. population) seeds were used. Seed germination experiments were carried out in growth chamber cabinet. The seeds were placed between moistured filter papers (Watman No:1) according to Between Paper (BP) technique[1], kept in petri dishes as 100 seeds for each replication. The study was performed in growth chamber cabinet adjusted to 5, 8, 10, 13, 15, 18, 20, 23, 25, 28, 30, 33, 35, 38 and 40°C respectively. Each treatment was repeated four times for each temperature value. The seeds having radicle 1 cm long for the criteria of the seed germination[32] were left every day and also counted according to different temperatures.

The evaluation of germination results were analysed according to the International Seed Testing Association (ISTA) for determining germination power rate (%) for each temperature value[16,33].

In predicting the germination power for tried seeds of some legume crops (as percentage) with different temperature regimes, a model ($D = a-b*T+c*T^2$) produced by Uzun *et al.*[14] in order to predict the time elapsing from sowing to emergence for some vegetable crops was adapted to the data obtained from the present study by carrying out multi regression analysis. In this model;

$$D = a-b*T+c*T^2$$

Where:

D: The time elapsing from seed sowing to emergence as days
T: Mean temperature (°C)
a, b, c are coefficients of the parameters

These stages of the model by taking into consideration, optimum germination for the seeds of tried crops were determined as well as obtaining standard equation predicting germination power for each crop. Hence the equation changed to To = b/2*c.

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 7.0 package programme was used for the analysis.

RESULTS AND DISCUSSION

In determining the adapted models for each tried species, multi regression analysis were carried out until the lowest standard errors of independent variables, namely T and T^2 values and the highest r (regression coefficients) values of the equations were obtained.

After following the modelling procedure, it was found that the model adapted to the data obtained from the present study showed that the model changed from D = a-b*T+c*T^2 to D = a+b*T-c*T^2 (Table 1) for the tried legume crops to determine germination power values.

As seen in Table 1, the regression coefficients (r^2) of the new produced equations for germination power in some legume species changed between 0.89 (green bean) and 0.98 (broad bean) as a result of model adaptation. In addition to the results, the regression coefficients changed in each plant varieties for germination power, 0.89 (Dade and Tina Cv.) – 0.92 (Öz Ayşe 16 Cv.) - 0.94 (4F-89 Cv.) in the green bean, 0.90 (Gitan and Sırık 97 Cv.) in the red podded bean, 0.95 (Yaprak Cv.) – 0.97 (Progres No:9) in the pea, 0.89 (Karagöz Cv.) – 0.94 (Izmir orig. pop.) in the cowpea and 0.98 in Amasya originated broad bean (Table 1).

The results showed that the effect of temperature on germination power was much more important than the other possible effective parameters since 89 to 98% of the variation in germination power was explained by temperature depending on the plant species and varieties.

The regression coefficients of the equations belonging to the other species was found generally high. We can say that very reliable equations have been obtained in the present study for predicting germination power (%) as affected by temperature. On the other hand, as explained in the section of material and methods, it would be possible to determine optimal temperatures (°C) for germination power by using the coefficients of independent variables (b and c) obtained from the equations belonging to the germination power for tried legume crops (Table 1).

High temperatures had a negative effect on the germination power. Optimum temperature requirement of green bean varieties were found between 22.1–25.2°C. These values were similar as for red podded bean but were lower then cowpea varieties (Table 1). Broad bean seeds germinated 15.1°C and these germination value were found lower to be compared to other legumes crops. It was determined that both germination period derived with higher temperatures and germination power decreased at the same conditions.

This kind of models have been used by many researchers to determine plant growth, development and yield recent years. In some plant species, many models were found to be useful for predicting germination speed, germination power and germination period or field emergence speed, emergence power and field emergence period by some researchers in Turkey[13,14]. These 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.

Table 1: The coefficients, their standard errors and R^2 values of the new produced equations predicting germination power (D= a+b*T-c*T^2) for some legumes vegetable crops

		Co-efficients				
Species	Varieties	a	b	c	R^2	Predicted optimum temperature (°C)
	ÖzAyşe 16 (10-35 °C)	+30.44 (9.80)**	6.54 (0.94)***	0.16 (0.02)***	0.92***	20.8
Green bean	Dade (1035 °C)	-136.9 (26.8)***	19.9 (2.57)***	0.45 (0.05)***	0.89***	22.1
	Tina (10-40 °C)	-95.95 (18.58)***	14.1 (1.6)***	0.28 (0.03)***	0.89***	25.2
	4F-89 (13-40 °C)	-48.4 (21.1)*	13.18 (1.7)***	0.28 (0.03)***	0.94***	23.5
Red podded bean	Gitan (13-38 °C)	-66.85 (27.1)***	13.42 (2.18)***	0.28 (0.04)**	0.90***	23.9
	Sırık (10-40 °C)	-97-69.05 (19.55)**	14.32 (1.69)***	0.29 (0.03)***	0.90***	24.6
Pea	Yaprak (5-35 °C)	+32.4 (3.35)***	4.58 (0.37)***	0.12 (0.009)***	0.95***	19.1
	Progres No:9 (5-35 °C)	+70.35 (3.13)***	3.65 (0.35)***	0.10 (0.008)***	0.97***	18.3
Cowpea	Izmir Orij.population (5-40 °C)	-84.29 (12.27)***	14.04 (1.13)***	0.26 (0.02)***	0.94***	27.0
	Karagöz (5-40 °C)	-83.14 (21.31)***	13.07 (1.72)***	0.25 (0.03)***	0.89***	26.1
Broad bean	Amasya Orij.population (5-33 °C)	-43.3 (6.5)***	7.55 (0.73)***	0.25 (0.017)***	0.98***	15.1

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

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