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Slopes Comparison of: Germination and Seedling Emergence Curves VS ^{60}Co Gamma Radiation Dose Sunflower Achenes

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A B S T R A C T

To determine the relationship between percentage of germination and seedling emergence in sunflower seeds, achenes were irradiated at doses of 0, 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 Gy, to establish an estimation model between both variables. Main objective was, to compare the homogeneity of slopes between germination and sprouting, of sunflower achenes irradiated with ^{60}Co gamma rays. Regression models for both cases were determined by the least squares method. Slopes in question were analyzed using the t_{cal} test for homogeneous variances. Results indicated that there is a high correlation between the slope of germination and seedling emergence curves, these being homogeneous. From this investigation it can be concluded that both slopes are homogeneous, therefore, the percentage of seedling emergence can be an estimator of the percentage of germination in achenes of sunflower, when they are irradiated with gamma of ^{60}Co.

Introduction

Germination is a physiological process that occurs mainly in botanical seeds,happens when the seed is imbibed and under suitable temperature conditions, causes in the metabolism of the seed, the beginning of hydrolysis of the endosperm and synthesis of phytoregulators such as GA_3, that break dormancy caused by abscisic acid (AA), ending with the breaking of the cover of the seedby the radicle (Suárez *et al.*, 2011, Taiz and Zeiger, 2005, Salisbury and Ross, 1994). This process is commonly confused with sprouting, due to the bad concept, that all germinated seeds sprout, which is wrong and therefore,also confused with the percentage of seedling emergence, for this reason it is important to clarify these concepts and thus,to explain patterns of behavior of plant species, when these are subjected to different factors such as: temperatures, water levels or radiation dose (Pérez *et al*., 2005). Under this trend, statistical methodology is an indispensable tool, for obtaining, analyzing and interpreting data in agricultural experimentation (Fernández *et al*., 2013). In this regard,the comparison of slopes from two curves of order one,from two factors of study, allows to know if both slopes have the same tendency, if they are homogeneous, and both present high coefficients of correlation and determination, thus theyallow both study factors to be explained, one with respect to the other (Devore, 2008, Morales and González, 2003, Zar, 1999, Steel and Torrie, 1996). So, main objective of this study was: to compare the homogeneity of slopes between variables germination and seedling emergence, in sunflower achenes irradiated with ^{60}Co gamma rays. The hypothesis was: slopes of curves of variables germination and emergence as function of increasing doses of ^{60}Co gamma rays, are homogeneous and have the same tendency, causing coefficients of correlation and determination being high and positive, thus allowing to explain one variable in terms of another.

Materials and Methods

Present research was carried out in the facilities of the Universidad Tecnológica de Tehuacán, located at 18 ° 24'51 " north latitude, 97 ° 20'00 " west longitude and 1409 meters altitude. The germplasm consisted of achenes of sunflower cv Victoria, which were irradiated in the Transelektro LGI-01 atInstituto Nacional de Investigaciones Nucleares (ININ), located at La Marquesa State of Mexico, at a dose range from 0 to 1000 Gy, with 100 Gy interval among treatments. Sowing was carried out in polystyrene trays of 200 cavities, using peat moss subjected to field capacity as a substrate. The trays with the achenes planted, were covered with a black polyethylene film and placed in a rustic greenhouse type saw roof,for better management of germination. The statistical analysis consisted of a slope comparison test between two calibration lines for the germination vs seedling emergence parameters. Regarding the obtaining of curves of degree one, a simple linear regression was performed for percentage of germination and another for sprouting, using the least squares method (Steel and Torrie, 1996). The percentage of germination, was calculated by means of the relation PG = [NSS / NGS] 100 where: PG, is the percentage of germination; NSS, number of seeds sown; NGS, number of germinated seeds. Regarding the percentage of seedling emergence, it was calculated with the equation PS = [NLP / NGS] 100 where: PS, percentage of sprouting; NSP, number of sprouted plants; NGS, number of germinated seeds (Díaz *et al*, 2018). Seed germination was evaluated 8 days and survival percentage 20 days after sowing. Once the data were obtained, we proceeded to graph to obtain the linear regression model and its respective slopes,as well as the correlation and determination coefficients. The variances of the two slopes were determined using the equation $s^2 = \frac{\sum_{i=1}^{n}(X-\bar{X})}{n-1}$ where: s^2, is the variance of the data series; $\sum_{i=1}^{n}(X_i-\bar{X})$, is the sum of the mean deviations and n-1, are the degrees of freedom (Daniel, 1991, Infante and Zárate, 1990). F_{cal} statistic was calculated using the equation $F_{cal} = \frac{S_{b_1}^2}{S_{b_2}^2}$ where: F_{cal}, is the value of the quotient between the respective variances; F_{tab}, is the tabular F value, using the Fisher tables with α = 0.05 error probability; $S_{b_1}^2$ y $S_{b_2}^2$ are the germination and sprouting variances, where $S_{b_1}^2$ the greater variance corresponding to germination, the comparison of the data between the F_{cal} and F_{tab}, was carried out out as follows:

Yes: $F_{cal}<F_{tab}$; the variances are homogeneous.

Yes: $F_{cal}> F_{tab}$; the variances are heterogeneous.

To determine if the slopes are statistically equal, the tcal test for homogeneous variances was applied, using the equation $t_{cal} = \frac{|b_1 - b_2|}{\sqrt{S^2_{b_1} - S^2_{b_2}}}$ where: t_{cal}, is the value of t calculated; t_{tab}, is the tabular t value, using the Student t tables at a level of significance α = 0.05 error probability with (n_1 + n_{2-2}) degrees of freedom. Once the data was obtained, the comparison between t_{cal} and t_{tab} was made:

Yes: $t_{cal} < t_{tab}$; the slopes are similar.

Yes: $t_{cal} > t_{tab}$; the slopes are different (Zar, 1999).

To obtain the correction coefficient between germination and percentage of seedling emergence, the regression line by least squares was obtained, between germination vs seedling emergence, this being the slope of the mathematical model of regression, with no ordinate to originwithout ordering the origin.

Results and Discussion

Figure 1 shows the regression equations for germination percentage and seedling emergence percentage. It can be seen that both factors were adjusted to linear decreasing models, with highly significant coefficients of determination 0.96, respectively.For germination the slope -0.1094 indicates that for each 1.0 Gy irradiation of ^{60}Co, the germination decreases in 0.1094%. Regarding the percentage of seedling emergence, the slope of the model yielded a value of -0.1125 that is 2.83% more than germination.These results, differ from those reported by Estrada *et al*., (2011), who worked with geophytic plants such as *Polianthes spp*, irradiating bulbs with ^{60}Co gamma, finding that the budding mathematical models conform to quadratic curves, difference that is attributed to the different genotypes studied.Regarding linear models obtained in sunflower, from the biological point of view, it can not be possible, since there should not be a greater number of live plants than germinated plants, so it is important to make the adjustment model between germination and seedling emergence.The germination of plant species, when subjected to ionizing irradiation, is a fact that has been studied extensively, as shown by the study by Hernández *et al*., (2017),who report the effect of ^{60}Co gamma rays on the decrease in the survival percentage of Laelia autumnalis protocormos, coinciding with this study.On the other hand, Martirena *et al*., (2015), mention that the germination, is not affected up to 400 Gy in seeds of *Phaseolus vulgaris* cv. Ica Pijao, under in vitro conditions.This difference may be due to the different species used in each study.

The homogeneity of slopes is presented in Table 1, it can be seen that the highest variance corresponded to 1,201.21% sprouting. In relation to the coefficient of determination, in both cases presented the same value 0.96 which indicated that the sprouting of sunflower seedlings from irradiated aquenios, is explained in 96%, by germination. Fisher's test showed that the variances between slopes are homogeneous, because the value of F_{tab} 3,44, turned out to be higher than the calculated value 1,02 which shows that both mathematical models show the same trend.Test showed that both slopes are similar, being able to demonstrate that the seedling emergence of sunflower seedlings can be explained by germination, when ^{60}Co gamma rays are applied, a fact that can be seen in the germination vs sprouting chart, where values of each factor decrease, as the radiation dose increases in the range of 100 to 900 Gy.

According to figure 1 B, the correction factor to determine the seedling emergence percentage of sunflower seedlings, with respect to germination was 0.9685, since the model does not present an ordinate to origin, being the linear adjustment model with a highly significant coefficient of determination 0.99, resulting in an excellent adjustment model.This methodology is of great importance that can have applications, in the determination of the LD_{50} for germination and sprouting of seedlings, in genetic improvement programs where the creation of new varieties is used, through the use of ionizing radiations such as ^{60}Co gamma rays.

Figure.1A, mathematical models for germination and seedling emergence, of sunflower achenes irradiated with ^{60}Co gamma rays. B, correction coefficient for seedling emergence percentage with respect to germination, in sunflower cv. Victory. Universidad Tecnologica de Tehuacan. 2018. **; *; n.s, significant at 0.01; 0.05 and not significant

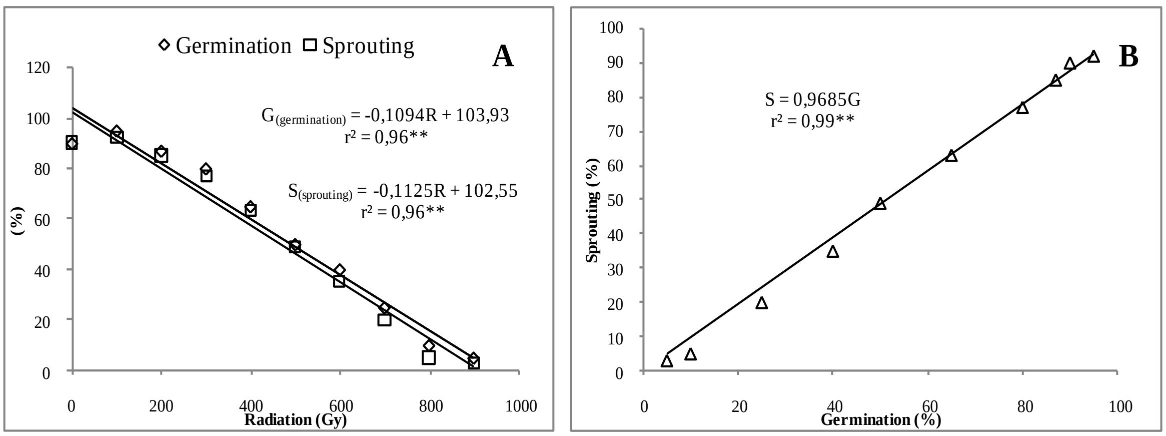

Table.1 Fisher's test and Student's t test to determine the homogeneity of slopes: germination vs seedling emergence, in achenes of sunflower (*Helianthus annuus* L.) cv. Victoria, irradiated with ^{60}Co gamma. 2018

Factor	b_n	S^2	r	r^2	d.f	F_{cal}	F_{tab}	t_{cal}	t_{tab}
Germination	-0,1094	1,138.67	0.97	0.96	8	1,02	3,44	0,00458	2,1009
Seedling emergence	-0,1125	1,201.21	0.97	0.96	8				
yes:	$F_{cal} < F_{tab}$; the variances are homogeneous.								
yes:	$F_{cal} > F_{tab}$; the variances are heterogeneous.								
yes:	$t_{cal} < t_{tab}$; the slopes are similar.								
yes:	$t_{cal} > t_{tab}$; the slopes are different.								

α = 0.05; b_n, slope of the regression model; S^2, variance; r, correlation coefficient; r^2, coefficient of determination; d.f, degrees of freedom.

It is concluded, when carrying out research of irradiation with gamma of ^{60}Co, to determine the percentage of germination and sprouting, it is necessary to carry out a slope homogenization test, to obtain the adjustment coefficient between germination and seedling emergence.

With the adjustment coefficient, is possible to estimate the percentage of germination, based on the sprouting data.

Assessment of germination based on, great importance, for the researcher, when studies of mutagenesis are carried out, to generate the radiosensitivity curves and to determine the LD_{50}.

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