Use of the Weibull function to evaluate the emergence of Albizia lebbeck *(L.) Benth seedlings*

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ABSTRACT

In order to know the vigor of *Albizia lebbeck* seeds through the evaluation of seedling emergence, by means of the modified Weibull function, planting was performed under three environmental conditions and at different seed storage times. The design was completely randomized, with factorial arrangement. Variance analysis was conducted for parameters *M* (maximum cumulative emergence), *k* (emergence rate) and *Z* (delay for emergence onset) of the modified Weibull function. From the six months after the beginning of storage (44,1 %) the sudden loss of *M* percentage in the nursery (A) and slight variations in the chamber (C) were observed, as compared with A and B (crop house). The dispersal range of parameter *k* oscillated between 0,4-2,6; 0,29-1,9 and 0,5-1,4 % emergence d^{-1} for the evaluations made in A, B and C, respectively. From the analysis of *Z* it was interpreted that the time for the onset of emergence, regardless of the seeding environment, was framed between 3,0 and 7,3 days after planting. In the nursery under full sunlight, in the evaluation at 6 mos (months of storage), the best results of the biological parameters of the Weibull equation were obtained, which allowed a global analysis that indicated a high vigor degree in the *A. lebbeck* seeds, as compared with the other evaluations.

Key words: *Albizia lebbeck*, storage, emergence

INTRODUCTION

Seedling emergence is mainly related to seed germination time and rate, which is in turn conditioned by dormancy and substratum temperature, in addition to water availability and election of the seeding date (Gardarin, Dürr and Colbach, 2011).

According to Navarro, Febles and Torres (2012), vigor estimation –in its integrated and dynamic concept– constitutes the interaction of the biotic and abiotic properties which influence seeds and determine their level of activity and their performance in time, such as: the expressions of viability, dormancy, germination and emergence. For such reason, to predict seedling emergence in the field seed vigor should be considered as an essential part of quality.

The Weibull function (Weibull, 1951) was proposed by Brown and Mayer (1988) when analyzing a set of non linear, adjusted linear and logistic functions, as a data processing model for vigor comparisons based on the cumulative germination frequency. Previously, Scott, Jones and Williams (1984) concluded that the parameters contained in it partially defined the main characteristics of the germination process and the emergence. From the study conducted by Brown and Mayer (1988), in the seed field it began to be defined as modified Weibull. The properties and estimation methods for the parameters that compose the function have been studied by several authors (Aghababaei, Lai and Alamatsaz, 2010).

This non linear function is regularly used to describe the germination dynamics from the effect (on this indicator and seedling emergence) of: a) temperatures, b) stratification periods, c) pregerminative treatments, d) seed characteristics, e) the different species, cultivars and hybrids, optatively through the analysis of their parameters (Rink, Dell, Switzer and Bonner, 1979; Tanaka, 1994; Huang and Yang, 1995; Hernández and Paoloni, 1998; Cerabolini *et al*., 2004).

On the other hand, in a literature review, Gardarin *et al*. (2011) detected that the three Weibull parameters have been evaluated in 25 weed species with contrasting characteristics in the seeds.

The objective of this work was to know the vigor of *Albizia lebbeck* seeds, through the modified Weibull function, when seeding was performed under three environmental conditions and at different seed storage times.

MATERIALS AND METHODS

In March, during three consecutive years, *A. lebbeck* seeds were collected in a plantation of areas of the Experimental Station of Pastures and Forages "Indio Hatuey". Some climate variables were recorded since the moment the seeds were placed in the storehouse until the end of the storage stage (table 1); such period was 12 months in the three years of collection.

A completely randomized design was used, with factorial arrangement (3 x 8), represented by the factors seeding environment (3) and storage time (8).

In each evaluation the seeds of the same lot were divided into three portions (previous homogenization of the subsamples), in order to plant them in different environments: experimental nursery (A), with 100 % of sun exposure; nursery in crop house (B), with mesh providing 40 % shade; and germination chamber (C), under controlled light, temperature and humidity conditions.

The evaluation frequency (storage time) was 0, 2, 4, 5, 6, 7, 9 and 11 months of storage (mos), and saturation irrigation was applied.

For seeding in A and B, bags were used with a substratum composed by a mixture of Ferralitic Red soil and sheep dung completely decomposed and dry, in equal portions (1:1).

Modified Weibull function

$$F(t)=M\{1-exp\,[-k\,(t-Z)]^{c}\}$$

Where:

M: maximum value of the cumulative emergence (%).

k: estimated value of the emergence rate (% emergence d^{-1}).

Z: delay of emergence (days).

t: duration of the test.

c: determines the curve shape.

The values of M, k and Z were obtained from the data recorded during the 21 days of the seedling emergence test.

Variance analysis was performed for M, k and Z, according to the simple classification model with factorial arrangement (3 x 8). The data were transformed according to Arcsin $\sqrt{\%}$ + 0,375. Duncan's (1955) multiple comparison test was used for a significance level of P<0,05. The statistical pack used was InfoStat version 1.0 (Rienzo *et al*., 2001).

RESULTS AND DISCUSSION

Fig. 1 shows the highly significant interaction (P<0,001) between the factors seeding environment and storage time, which was found in the biological response of the maximum cumulative emergence (parameter M).

Table 1. Correspondence among evaluations, time of the year and climate variables.

Evaluation (mos)	Time of the year	Maximum T (ºC)	Minimum T (ºC)	Soil T (ºC)	Maximum RH (%)	Minimum RH (%)	Cumulative rainfall (mm)
0	March	30,62	14,59	32,82	95,57	49,00	62,20
2	May	34,80	19,99	34,51	95,81	56,43	205,80
4	July	33,54	21,82	35,81	96,33	57,48	114,50
5	August	60,06	22,07	31,30	96,95	63,43	163,10
6	September	32,59	21,50	33,35	97,19	63,71	79,80
7	October	29,85	19,39	33,60	96,62	61,95	49,70
9	December	26,55	13,75	26,97	95,71	55,62	10,00
11	February	30,12	16,16	31,25	97,00	46,14	3,30

T: temperature, RH: relative humidity

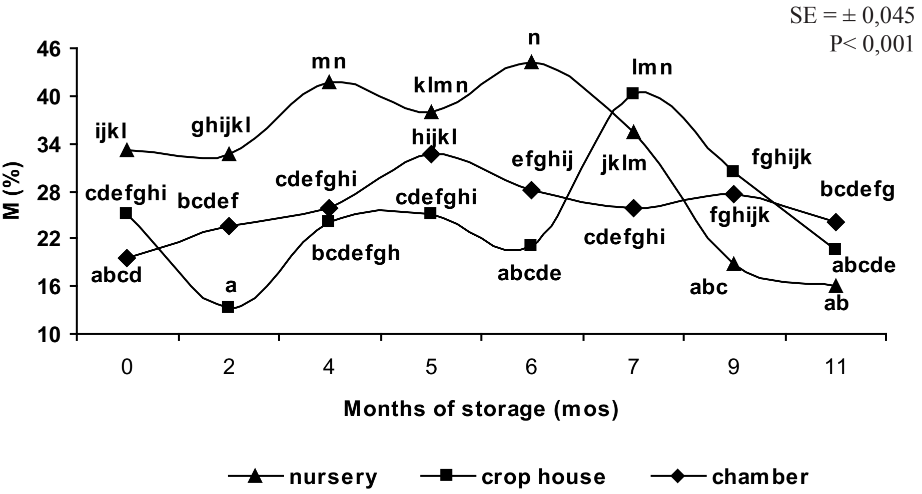

Fig. 1 Maximum cumulative emergence (*M*) for the seeding environments in each storage time.

The highest *M* value was 44,1 % and it was reached in environment *A* (nursery under full sunlight), when seeds with 6 mos were planted. It differed from the others, except in the evaluations at 7 mos (40,1 %) in B (crop house environment) and at 4 (41,8 %) and 5 mos (37,8 %), both recorded in A. The last one did not show significant differences with regards to the seeding performed in the nursery at 0, 2 and 7 mos, or at 9 and 5 mos in the crop house and the germination chamber, respectively.

It can also be observed that the highest *M* values were recorded in A from 0 to 6 mos, while since 7 and until 9 mos they corresponded to B. At the end of the study (11 mos) planting in C showed the highest value for M, although without differing from the other two.

Two situations occurred that deserve special attention. The first one is the sudden loss of the *M* percentage observed in A, since 6 mos (44,1 %); this could be related to the storage time, which caused significant differences from here with regards to 7 (35,5 %), 9 (18,9 %) and 11 mos (16,0 %). The climate conditions could have influenced, because the evaluation at 6 mos and the next ones coincided with the months in which the climate indicators varied with regards to the period after 6 mos (October–February). The second situation is related to the slight variations of the cumulative emergence percentage that appeared in C, as compared with A and B, because M oscillated between 19,5 and 32,7 %, both recorded at 0 and 5 mos, respectively.

This performance may indicate that the prevailing environmental conditions in the nursery under full sunlight (A) could have been related to the germination process and, thus, to seedling emergence. In addition, Bewley and Black (1982) stated that, in nature, daily thermal fluctuations (typical of tropical, subtropical and Mediterranean climates) cause the progressive weakening of hard impermeable seed coats, induce germination and promote in a limited time the highest probability of favoring emergence.

In this regard, Fairbrother (1991) sustained that thermal fluctuations under natural conditions cause the expansion and contraction of seed coat tissues, which brings about fractures that favor the entrance of the necessary water for germination.

It is possible that the inability shown by the seeds in C to express the highest emergence potential of the species and, in turn, attenuate or cancel the dormant state, is due to the presence of standardized and more stable conditions in time, because seeds are known to show germination-regulating enzymatic mechanisms (Nonagaki, 2006) which are triggered only when thermal changes occur in their environment (Johnston, Olivares, Henríquez and Fernández, 1997). These daily temperature variations not only allow to know the best season for germination and emergence, but also to detect the depth where they are and perform both processes successfully (Baskin and Baskin, 1998).

It should be remembered that in the chamber (C) there were controlled conditions (light, temperature and humidity), which is also related to the fact that the fluctuations of emergence percentage in that seeding environment were discreet as compared with the performance in A and B.

Such deductions reaffirm that the existing relation between the dormant state and its elimination under certain environmental conditions also constitutes a more perceptible response to the environment. This allows germination, emergence and, thus, the establishment of the new plant only when the conditions are propitious for the species (Bewley and Black, 1994; Khurana and Singh, 2001).

On the other hand, the parameter *k*, which corresponds to the emergence rate showed significant interaction (P<0,001) for the conducted evaluations (fig. 2). The highest values (2,3 % emergence d^{-1}) was recorded at 6 mos in A, without significant differences with regards to the evaluations at 4 mos (2,1 % emergence d^{-1}) in A and at 7 mos (1,9 % emergence d^{-1}) in B. Both values did not differ from the seeding at 5 mos in A (1,8 % emergence d^{-1}).

The emergence rate showed a dispersal range which varied between 0,4-2,6; 0,29-1,9 and 0,5-1,4 % emergence d^{-1} for the evaluations performed in the nursery (A), the crop house (B) and the chamber (C), respectively.

When analyzing as a whole the performance of *M* and *k*, it can be observed not only that the highest cumulative emergence values were obtained in the nursery under full sunlight during the interval 0-6 mos, but also that the seedling emergence was faster, which was obviously shown in higher emergence uniformity.

The delay of seeds in emergence, represented by the value *Z* (fig. 3), had significant interaction (P<0,001). In this parameter the lowest values expressed the best performance, because as *Z* decreased the time required for the seedlings to emerge was reduced and, obviously, early emergence is always advantageous for the success of a plantation's establishment.

From the analysis of the curves represented by *Z* it is interpreted that seedling emergence started earlier (3 days) when the seeds were planted at 2 mos in A, although this value did not differ statistically from the records in all the evaluations, except in the seeding in B at 2, 9 and 11 mos (14,3; 10,5 and 8,3 days, respectively), as well as at 11 mos (7,7 days) in C. It is then appreciated that the time for the start of emergence, without distinction of the seeding environment, was framed between 3,0 and 7,3 days after planting, which allows to state that all the seeding performed in A was considered within the above-mentioned time interval.

The worst *Z* value (14,3 days) was obtained at 2 mos in B, followed by the one reached at 10,5 days also in B, but at 9 mos. This performance is not in correspondence with that of other species with epigeal germination, orthodox seeds and representatives of the Mimosaceae subfamily. Nevertheless, it is close to that of Prosopis tamarugo, a tree legume which took between 5 and 10 days to start germination (CATIE, 2000) without previous application of pregerminative treatments.

When making an integrating analysis –having the results of figures 1, 2 and 3 (described in the previous paragraphs– and in correspondence with Czabator (1962), who proved that the germination

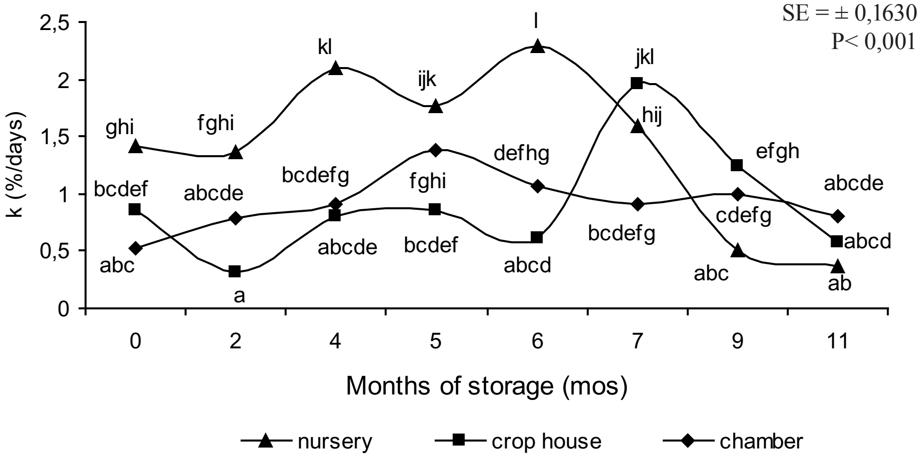

Fig. 2. Emergence rate (*k*) for the seeding environments in each storage time.

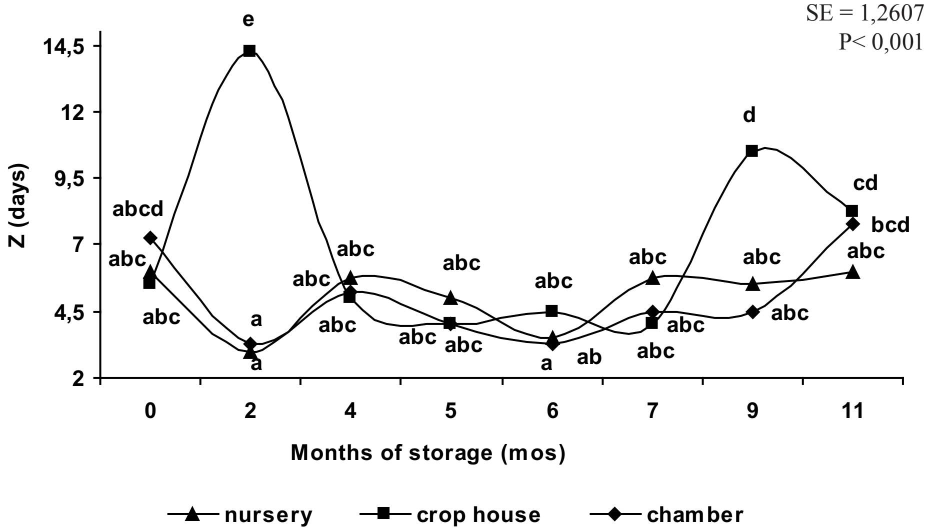

Fig. 3. Delay for the start of emergence (*Z*) for the seeding environments in each storage time.

rate is positively related to the fast emergence in the field and to seedling development, it may be considered that although a categorically defined performance was not observed, the nursery under full sunlight is the seeding environment where vigor is best expressed, for which a more evident and earlier emergence is obtained.

On the other hand, all seems to indicate that the chamber conditions are not the most propitious for a better and more real expression of vigor. In this sense, it is opportune to emphasize that the international regulations of ISTA (1999) and AOSA (1992) did not show the specifications in A. lebbeck for the test under controlled conditions, or in other tree species from the tropic or arid zones. The chamber conditions in this trial were adapted according to the regulations for other legume trees.

The group of interactions found throughout the experiment, whose biological explanations are, sometimes, complex and difficult to interpret, must be mentioned. In addition, they were caused by the relations created between the planting conditions (considered external factors) and the storage times which were deemed as internal factors.

The above-explained elements coincide with the report by Marcos Filho (2011), who stated that the influence of the physiological potential which is focused on the crop establishment and the initial development of plants is sufficient reason to justify the election of high-vigor lots. The preference for the frequent utilization of any of the vigor tests in quality control programs should rely on methods accessible for the analysts, which allow the relatively fast attainment of results associated to seedling emergence in the field.

Regarding the mathematical function, Barabadi (2013) considered that Weibull probability graphics offer the basis for the reliability analysis. Likewise, Manso, Pardos, Keyes and Calama (2012), when studying natural regeneration patterns in managed stands of *Pinus pinea* L., concluded that the Weibull model showed the best adjustment to predict the seed dispersal pattern, which allowed to modify silvicultural practices in the northern region of Spain. Other results show the usefulness of such model for soil studies in the seedbank, in addition to its suitability to describe distributions of seed size and number (Casco, Dias and Dias, 2008).

CONCLUSIONS

Using the Weibull function the performance of the emergence of *A. lebbeck* seedlings was evaluated. In addition, the bases were established for the estimation of seed vigor through the integrating analysis of the three parameters of the modified function. The global analysis of the biological parameters, evaluated under three seeding conditions and at different seed storage times, indicated a high vigor degree when the seeds were planted in the nursery under full sunlight at 6 mos. This means that the seeds at this time not only germinate faster, but they also have higher emergence, which is advantageous for the establishment of *A. lebbeck* seedlings under field conditions.

Received: December 21, 2011
Accepted: February 6, 2013