Seed Germination App Version 1.0

Interactive data analysis platform for germination analysis

Germination Indexes

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Table of Contents

Germination Indexes

1. Final germination percentage (FGP) or Germinability (G)

According to L. G. Labouriau (1983), germinability is the percentage of seeds in which the germination process comes to the end in the experimental conditions by the intraseminal growth, resulting in the protrusion (or emergence) of a living embryo.

$$FGP = G = \left(\frac{\sum_{i=1}^{k} n1}{N}\right)100$$

(*in percentage; expressed in the program as FGP*)

Where: n_i: number of germinated seed in the i^{th} time; N: total number of seed in each experimental unit.

The higher the FGP value, the greater the germination of a seed population. Scott et al. (1984)

2. Mean germination Time (MGT)

The mean germination time was proposed by Haberlandt in 1875 (L. G. Labouriau 1983) and used by Czabator (1962) as mean length of incubation time (see Ranal and Santana (2006) for other details). It is calculated as the weighted mean of the germination time (hour, day or other time unit). The number of germinated seeds at the intervals established for the data collection is used as weight (Ranal and Santana 2006).

$$\bar{t} = \frac{\sum_{i=1}^{k} n_i t_i}{\sum_{i=1}^{k} n_i},$$

(*in hour, day or other time unit; expressed in the program as MGT*)

Where t_i: time from the start of the experiment to the i^{th} observation (day for the example); n_i: number of seeds germinated in the i^{th} time (not the accumulated number, but the number correspondent to the i^{th} observation), and k: last time of germination.

MGT is an accurate measure of the time taken for a lot to germinate, but does not correlate this well with the time spread or uniformity of germination. It focusses instead on the day when most germination events occurred. The lower the MGT, the faster a population of seeds has germinated.

The lower the MGT, the faster a population of seeds has germinated. Orchard (1977)

3. Standard deviation of the germination time (SDG)

$$S_t = \sqrt{\left\{\frac{\{\sum_{i=1}^{k} ni(ti - \bar{t})^2\}}{\sum_{i=1}^{k} ni - 1}\right\}}$$

(*in the same time unit of the mean germination time; expressed in the program as SDG*)

Where $\bar{t}_i$ time from the start of the experiment to the i^{th} observation (hour, day or other time unit); n_i : number of germinated seeds in the i^{th} time (not the accumulated number) and k: the last time of observation.

4. Variance of germination time (VGT)

$$\bar{t} = \frac{\sum_{i=1}^{k} n_i(t_i - \bar{t})^2}{\sum_{i=1}^{k} n_i - 1}$$

(*in the same time; expressed in the program as VGT*)

Where $\bar{t}$: mean germination time; t_i: time between the start of the experiment and the i^{th} observation (day for the example); n_i: number of seeds germinated in the i^{th} time, and k: last time of germination.

5. Coefficient of variation of the germination time (CVT)

$$CV_t = (\frac{S_t}{\bar{t}})100$$

(*in the same time unit of the mean germination time; expressed in the program as CVT*)

Where s_t: standard deviation of the germination time and t: mean germination time.

6.Mean germination rate (MGR)

The mean germination rate is defined as the reciprocal of the mean germination time, since the mean germination rate increases and decreases with $\frac{1}{\bar{t}^{1}}$, not with $\bar{t}$ (L. G. Labouriau 1983b).

$$\bar{v} = \frac{1}{\bar{t}}$$

(*in hours*$^{-1}$, *day*$^{-1}$ *or other reciprocal time unit, expressed in the program as MGR*)

7. Germination speed (GSP)

$$GSP = (\frac{1}{\bar{t}})100$$

(*in percentage, expressed in the program as MGR*)

8. Germination rate index (GRI)

$$GRI = G_1/1 + G_2/2 + ... + G_i/i$$

(*in percentage/day, expressed in the program as GRI*)

Where G_1 is the germination percentage on day 1, G_2 is the germination parentage at day 2; and so on.

GRI calculations merely show the percentage of germination per day, so the higher the percentage and the shorter the duration, the higher the GRI. This parameter lacks any correlation with the 'high' and 'low' germination days as it spreads the percentage evenly across the time spread Ranal *et al*. (2009).

The GRI reflects the percentage of germination on each day of the germination period. Higher GRI values indicate higher and faster germination. Esechi (1994) after modification.

9. Germination Index (GI)

$$GI = (10\times n_1) + (9\times n_2) + \cdot\cdot\cdot + (1\times n_{10})$$

(*expressed in the program as GI*)

Where n_1, n_2 . . . n_{10} = No. of germinated seeds on the first, second and subsequent days until the 10th day; 10, 9 . . . and 1 are weights given to the number of germinated seeds on the first, second and subsequent days, respectively.

The **GI** appears to be the most comprehensive measurement parameter combining both germination percentage and speed (spread, duration and ‘high/low’ events). It magnifies the variation among seed lots in this regard with an easily compared numerical measurement Ranal *et al*. (2009).

In the GI, maximum weight is given to the seeds germinated on the first day and less to those germinated later on. The lowest weight would be for seeds germinated on the 10th day. Therefore, the GI emphasizes on both the percentage of germination and its speed. A higher GI value denotes a higher percentage and rate of germination (Bench Arnold et al. 1991)

10. Synchrony of germination process (SYN)

This index was proposed by Primack (1985) to assess the degree of overlapping of flowering among individuals in a population and Ranal and Santana (2006) adopted it for seed germination. The synchrony of germination of one seed with another assumed Z=1 when the germination of all seeds occur at the same time and Z=0 when at least two seeds can germinate, one at each time.

$$Z = \frac{\sum_{i=1}^{k} C_{n_i,2}}{C_{\sum n_i,2}}$$

(*a dimensional measurement; expressed in the program as SYN*);

$$being\ C_{n_i,2} = \frac{n_i(n_i-1)}{2};\ N = \frac{\sum n_i(\sum n_i - 1)}{2}$$

Where $C_{n_i,2}$: combination of the seeds germinated in the i^{th} time, two by two, and n_i: number of seeds germinated in the i^{th} time.

11. Uncertainty of the germination process (UNC)

This measurement is an adaptation of the Shannon index and measures the degree of uncertainty associated to the distribution of the relative frequency of germination (Labouriau and Valadares 1976). Low values indicate more synchronized germination (Ranal and Santana 2006).

$$U = -\sum_{i=1}^{k} f_i \log_2 f_i$$

(*in bit; expressed in the program as UNC*); being $f_i = \frac{n_i}{\sum_{i=1}^{k} n_1}$

Where f_i: relative frequency of germination; n_i: number of seeds germinated on the i^{th} time, and k: last day of observation.

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