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Effect of water and temperature on seed germination and emergence as a seed hydrothermal time model

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Abstract

The physiological process of germination depends on several environmental factors such as temperature, water potential, light, nutrients and smoke. Water and temperature are determinant factors for seed germination. Both factors can, separately or jointly, affect the germination percentage and germination rate. The effect of temperature on germination and water potential on germination canoften be described by the thermal time and hydrotime models, respectively. The germination and growth behavior of different seeds under the influence of different physical parameters have been explained by different models. Thermal-time describe effect of temperature on seed germination. The ability to germinate rapidly at low temperatures has been proposed as one of many mechanisms thatconfer a competitive advantage to this species. Previous studies of this phenomenon, however, have been limited to relativelysimple comparisons of total germinability and germination rate under selected constant-temperature treatments.Hydro-time models describe effect of water potential on seed germination as have been combined to form hydrothermal-time model that can describe seed germination patterns. Historical patterns of seedbed microclimate and predicted germination response may be useful in assessing and optimizing alternative field planting scenarios. Inclusion of weather forecasting and seedbed modeling may providereal-time management options for improving rangeland seeding success.

Key words: Hydro-time, Seed and termal-time

Seed germination

Germination and emergence are the two most important stages in the life cycle of plants that determine the efficient use of the nutrients and water resources available to plants (Gan et al., 1996). Environmental factors such as temperature, light, pH, and soil moisture are known to affect seed germination (Rizzardi et al., 2009). Temperature plays a major role in determining the periodicity of seed germination and the distribution of species (Guan et al., 2009). In the germination process, the seed's role is that of a reproductive unit; it is the thread of life that assures survival of all plant species. Furthermore, because of its role in stand establishment, seed germination remains a key to modern agriculture. Thus, especially in a world acutely aware of the delicate balance between food production and world population, a fundamental understanding of germination is essential to crop production.

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Requirements for Germination as a seed hydrothermal curve

The highest seed yield in agriculture achieved in normal condition of nutrition and environmental conditions (Shaban, 2013a,b; Beyranvand et al, 2013 and Kiani et al, 2013). Water is a basic requirement for germination. It is essential for enzyme activation, breakdown, translocation, and use of reserve storage material. In their resting state, seeds are characteristically low in moisture and relatively inactive metabolically. That is, they are in a state of quiescence. Thus, quiescent seeds are able to maintain a minimum level of metabolic activity that assures their long-term survival in the soil and during storage. Moisture availability is described in various ways. Field capacity moisture is about optimum for germination in soil; however, germination varies among species and may occur at soil moistures near the permanent wilting point. Most seeds have a critical moisture content for germination to occur. For example, this value in corn is 30%, wheat 40% and soybeans 50%. Once that critical seed moisture content is attained in the seed, sufficient water is present to initiate germination and the seed is committed to that event and can not turn back. If the internal moisture content decreases below the critical moisture content, seeds will essentially decay in the soil. Seed germination is a complex process involving many individual reactions and phases, each of which is affected by temperature. The effect on germination can be expressed in terms of cardinal temperature: that is minimium, optimum, and maximum temperatures at which germination will occur. The minimum temperature is sometimes difficult to define since germination may actually be proceeding but at such a slow rate that determination of germination is often made before actual germination is completed. The optimum temperature may be defined as the temperature giving the greatest percentage of germination in the shortest time. The maximum temperature is governed by the temperature at which denaturation of proteins essential for germination occurs. The optimum temperature for most seeds is between 15 and 30oC. The maximum temperature for most species is between 30 and 40oC. Not only does germination have cardinal temperatures, but each stage has its own cardinal temperature; therefore, the temperature response may change throughout the germination period because of the complexity of the germination process. The response to temperature depends on a number of factors, including the species, variety, growing region, quality of the seed, and duration of time from harvest. As a general rule, temperate-regions seeds require lower temperatures than do tropicalregion seeds, and wild species have lower temperature requirements than do domesticated plants. High-quality seeds are able to germinate under wider temperature ranges than low-quality seeds.

Temperature effects

Young and Evans (1982) found that maximum germination percentages could be obtained under constant temperatures for most of the perennial grasses they studied. Hylton and Bement (1961) also found greatest germination of *Festuca octoflora* Walt. under constant 20°C than under various alternating temperature regimes. Terenti (2004) showed that the best germination (80%) in *D. eriantha* occurred at 30 and 35°C.

Water potential effects

Moisture availability imposed severe limitations on seed germination of *D. eriantha*, which has similar germination requirements that many mesophytic crops (Bonvisutto and Busso, 2007): the lower the water potential, the lower the germination percentage and the velocity of germination in this species. The lower coefficients of velocity at lower water potentials are an indication of greater germination times (Scott et al., 1984). Plants possessing seeds with exacting requirements for germination can establish more successfully than those with few restrictions (Hegarty, 1978). However, in an environment with changing moisture conditions the opportunities for germination may be reduced for seeds with specific moisture requirements. If moisture stress is low, seeds of *D. eriantha* can germinate over a wide range of temperatures; however, the more severe the water stress, the greater the reduction in germination percentage. This response presumably reflects an adaptive strategy because *D. eriantha* is generally restricted to habitats with moister conditions than those of the Phytogeographical Province of the Monte (Cano, 1988).

Storage time

Maintenance of seed quality in storage from the time of production until the seed is planted is imperative to assure its planting value. There was a marked decrease in seed viability with storage time in various seeds. This might have been partially the result of the storage conditions. The best alternative to avoid risks associated with storing seeds is to avoid storing seeds. For example, the grass seed industries in Oregon ship the seeds within a few months after harvesting. Another example includeBolivia where the wheat seed harvested in the Highlands in April is being planted in May in the Lowlands, or Colombia where rice can be produced twice a year, which decreases the storage period. However, there are times when seed growers and dealers carry over seed lots from one year to the next due to weak market, to insure an adequate supply the following year, and/or because the production system does not provide choices. Under such circumstances, the question is how to manage the seeds to maintain a high viability. If dry weather prevails during grass seed maturation and harvest, it should be allowed to harvest seeds not only with low moisture but also with high initial viability (Copeland and McDonald, 1995). This should be followed up by placing the seeds in cool and dry warehouses to lower the risks in storage (Copeland and McDonald, 1995).

Thermal-time model

Mathematical models that describe germination patterns in response to temperature (T) *have* been developed (Bradford, 2002). This model predicts that the germina-tion rate for a given seed fraction or percentage or the inverse of germination time (GRg, or $1/tg$) is linear func-tion of T above Tb. The minimum or base temperature Tb is the lowest temperature at which germination can occur. The optimum temperature To is the temperature at which germination is most rapid. This can be written as:

$1/ tg = K + m T$ or $1/ tg = m (T - Tb)$

Inverse of the slope of straight line ($1/ m$) is called ther-mal time constant $\theta T(g)$. For suboptimal temperatures (from Tb to To), germina-tion timing can be described on the basis of thermal time or heat units. That is, the T in excess of Tb multiplied by the time for a given germination percentage tg, and is a constant for that percentage (the thermal time constant, $\theta T(g)$) which can be written as:
$\theta T(g) = (T - Tb)tg$ and $GRg = 1/ tg = (T - Tb) / \theta T(g)$

This model predicts that the germination rate for a given seed fraction or percentage (GRg or $1/tg$) is linear func-tion of T above Tb. The maximum or ceiling temperature (Tc) is the highest temperature at which seeds can germinate. Similar models have been proposed to des-cribe germination rates at supra-optimal temperatures (from To to Tc). In many cases, GRg declines linearly with an increase in T between To and Tc (Hardegree, 2006). To account for this variation in Tc values, Ellis et al. (1986), Covell et al. (1986) and Hardegree (2006) propo-sed the following model:

$\theta 2 = (Tc(g) - T)tg$ or $GRg = 1/ tg = (Tc(g) - T) / \theta 2$

Where $\theta 2$ is a thermal time constant at supra-optimal T and Tc (g). The above equations are verified experimen-tally by Alvarado and Bradford (2002).

Hydro-time model

Gummerson (1986) and Bradford (2002) proposed the hydro time concept. When a seed is dried from fully hydrated state, there must be some point at which it will no longer be able to germinate. Ψb is the base or thres-hold parameter that will just prevent germination of fraction g of the seed population. Gummerson (1986) and Bradford (2002) showed that if GRg values were plotted as a function of Ψ, the resulting curves were essentially linear and parallel. According to hydro-time model, germination rate is linearly related to water potential. θH is hydro time constant and can be written as:

$$\theta H = (\Psi - \Psi b) \times tg$$

From Equation 5, tg is inversely related to the difference between the Ψ and Ψb value of that seed.

Hydro-thermal model

The timing of germination is critical, as the likelihood of seedling survival is dependent upon the subsequent availability of adequate water, temperature, light and nutrients to support plant growth. Many factors contribute to the timing and success of weed emergence, but seed dormancy ‘‘is the most important of a series of components and processes that affect seedling emergence’’ (Forcella et al. 2000). The hydrothermaltime concept (Bradford 1995; Gummerson 1986) will be advocated as a unifying model to describe the patterns of potential germinability that occur as seed populations enter and leave environmentally induced dormant or inhibited states. The hydrothermal time model proposes that seed germination rates are proportional to the amount by which temperature (T) and water potential (c) exceed base or threshold values for these environmental factors. Hydrothermal time models have considerable potential for characterizing and quantifying the effects of the thermal and hydric environment on seed dormancy and subsequent germination and seedling emergence. The conceptual and mathematical basis of the hydrothermal time model will be described, some applications in characterizing seed dormancy and germination behavior will be examined, and directions for future development will be discussed. Temperature is the primary environmental signal regulating both dormancy and germination (Roberts 1988). With respect to dormancy, seasonal changes in temperature are a major determinant of the loss of primary dormancy and of the cycling of secondary dormancy (Hilhorst 1998). A second role for temperature is to determine the rate of progress toward completion of germination once a non-dormant seed is stimulated to germinate. That is, the germination rate for a given seed fraction (GRg) is often a linear function of temperature between Tb and To (Bierhuizen and Wagenvoort 1974;.) The thermal time model can account for alternating or variable temperatures by summing the thermal times accumulated at each T (Ellis and Barrett 1994). Thermal-time and hydro-time models as described above have been combined to form hydrothermal-time model that can describe seed germination patterns. Combining hydrotime equations and termaltime equation, a hydrothermal time constant θHT for sub-optimal temperature T can be defined (Bradford, 2002; Grundy et al., 2000):

$$\theta HT = (\Psi - \Psi b)\ (T - Tb)\ tg$$

This hydrothermal model has worked well to describe germination time courses (Bradford, 2002).

Conclusion

A wide range of diversity in the temperature influences on the germination capacity of many species, which might be related to different strategies adopted by these species as a consequence of the heterogeneity of habitats and climatic seasonality intrinsic to their ecosystems. Hydrotime analysis can provide several indices of seed quality relating to stress tolerance, speed and uniformity of germination. application of the hydrotime model can also feed back into breeding and selection programs to identify lines having improved seed performance and stress tolerance. The hydrothermal time model to describe germination timing and percentage across all T and Ψ at which germination can occur. This comprehensive, physiologically based model accounts for all three of the cardinal temperatures for seed germination. The parameters of the model can be used to quantitatively characterize and compare the physiological status of seed populations under different environmental conditions or having different genetic backgrounds. In addition, the model targets the processes by which seed water potential thresholds are determined for further biochemical and molecular investigation.

REFERENCES

Baskin JM, Baskin CC (2004). A classification system for seed dormancy. Seed Sci. Res.14:1–16.

Beyranvand, H., Farnia, A., Nakhjavan, SH. and Shaban, M. (2013). Response of yield and yield components of maize (Zea mayz L.) to different bio fertilizers. International journal of Advanced Biological and Biomedical Research. Volume 1, Issue 9: 1068-1077.

Bierhuizen, J. F. and W. A. Wagenvoort. 1974. Some aspects of seed germination in vegetables. I. The determination and application of heat sums and minimum temperature for germination. Scientia Hortic. 2: 213–219.

Bradford KJ (2002). Applications of hydrothermal time to quantifying and modeling seed germination and dormancy, Weed Sci. 50:248–260.

Bradford, K. J. (1995). Water relations in seed germination. Pages 351–396 in J. Kigel and G. Galili, eds. Seed Development and Germination. New York, Marcel Dekker, Inc.

Covell S, Ellis RH, Roberts EH, Summerfield RJ (1986). The influence of temperature on seed germination rate in grain legumes. I. A comparison of chickpea, lentil, soybean, and cowpea at constant temperatures. J. Exp. Bot. 37: 705–715.

Ellis RH, Covell S, Roberts EH, Summerfield RJ (1986). The influence of temperature on seed germination rate in grain legumes. II. Intraspecific variation in chickpea (*Cicer arietinum* L.) at constant temperatures. J. Exp. Bot. 37:1503-1515.

Ellis, R. H. and S. Barrett. (1994). Alternating temperatures and the rate of seed germination in lentil. Ann. Bot. 74:519–524.

Forcella, F., R. L. Benech-Arnold, R. Sa´nchez, and C. M. Ghersa. (2000). Modeling seedling emergence. Field Crops Res. 67:123–139.

GAN, Y. (1996). Evaluation of select nonlinear regression models in quantifying seedling emergence rate of spring wheat. Crop Sci., v. 36, n. 1, p. 165-168.

Grundy AC, Phelps K, Reader RJ, Burston S. (2000). Modelling the germination of Stellaria media using the concept of hydrothermal time. New Phytol. 148:433–444.

GUAN, B. (2009). Germination responses of Medicago ruthenica seeds to salinity, alkalinity, and temperature. J. Arid Environ., v. 73, n. 1, p. 135-138.

Guillermo RC, Diego B, Mario RS, Gustavo O. (2009). Germination parameterization and development of an after-ripening thermal-time model for primary dormancy release of *Lithospermum arvense* seeds. Annals Bot.103:1291–1301.

Gummerson, R. J. (1986). The effect of constant temperatures and osmotic potential on the germination of sugar beet. J. Exp. Bot. 37:729–741.

Hardegree SP (2006). Predicting germination response to temperature. I. Cardinal-temperature models and sub-population specific regression. Annals Bot. 97:1115–1125.

Hilhorst, H. W. M. 1998. The regulation of secondary dormancy. The membrane hypothesis revisited. Seed Sci. Res. 8:77–90.

Kiani, M, Farnia, A.,and Shaban, M. (2013). Changes of seed yield, seed protein and seed oil in rapeseed (*Brassica napus* L.) under application of different bio fertilizers. International journal of Advanced Biological and Biomedical Research. Volume 1, Issue 10: 1170-1178.

RIZZARDI, M. A. et al. Effect of cardinal temperature and water potential on morning glory (Ipomoea triloba) seed germination. Planta Daninha, v. 27, n. 1, p. 13-21, 2009.

Roberts, E. H. 1988. Temperature and seed germination. Pages 109–132 *in* S. P. Long and F. I. Woodward, eds. Plants and Temperature. Cambridge, U.K: Society for Experimental Biology.

Shaban, M. (2013a). Application of seed equilibrium moisture curves in agro physics. International journal of Advanced Biological and Biomedical Research. Volume 1, Issue 9: 885-898.

Shaban, M. (2013b). Biochemical aspects of protein changes in seed physiology and germination. International journal of Advanced Biological and Biomedical Research. Volume 1, Issue 8: 885-898.

Wei Y, Bai Y, Henderson DC. (2009). Critical conditions for successful regeneration of an endangered annual plant *Cryptantha minima*: A modeling approach. J. Arid. Environ. 73:872-875.