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Original Article

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QUANTIFICATION OF GERMINATION RESPONSE OF MILLET (*PANICUM MILIACEUM* L.) SEEDS TO WATER POTENTIAL AND PRIMING USING HYDROTIME MODEL

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ABSTRACT. Seed germination is a complex biological process that is influenced by different environmental physical factors including temperature, water potential, salinity, pH and light, as well as intrinsic genetic factors. In such environments, the water needed for germination is available for only a short time, and consequently, successful crop establishment depends not only on rapid and uniform germination of the seedlot, but also on its ability to germinate under low water availability. All of these attributes can be analyzed through the hydrotime model (HT). Millet (*Panicum miliaceum* L.) is cultivated in arid and semi-arid regions of Iran. Therefore, in this study, using the hydrotime modeling approach, germination response of millet to priming (water and gibberellin 50 ppm at 15°C for 24 h) and water potential (0, -0.3, -0.6, -0.9, and -1.2 Mpa) was studied. Hydrotime (HT) model were fitted to cumulative germination of seeds and recorded in germination tests carried out at different water potentials (0, -0.3, -0.6, -0.9 and -1.2 MPa) and priming treatments (control, hydropriming and hormone priming). Results showed that, germination of millet decreased significantly with reduction of osmotic potential. Results indicated that the hydrotime constant (θH) for control, hydropriming and hormone priming were 0.89, 0.79 and 0.67 MPa d, the water potential (Ψb(50)) for control, hydropriming and hormone priming were -0.89, -0.94 and -1.11 MPa, respectively. Results indicated that the use of hydrotime model in germination prediction could be useful to provide more accurate estimates for the

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timing of sowing and management of millet.

Keywords: base temperature; base water potential; germination prediction; hydrotime; *Panicum miliaceum* L.

INTRODUCTION

Seed germination is a complex biological process that is influenced by different environmental physical factors, including temperature, water potential, salinity, pH and light, as well as intrinsic genetic factors (Ansari *et al.,* 2016; Torresen *et al.,* 2017). The ability to predict the timing of seed germination and seedling emergence using soil temperature and water potential could enhance effectiveness of seedling management (Leblanc *et al.,* 2004; Ansari *et al.,* 2016). Temporal patterns for seed germination have been successfully predicted in different plant species using thermal time, hydrotime and hydrothermal time models (Masin *et al.,* 2010; Zambrano-Navea *et al.,* 2013; Mesgaran *et al.,* 2013).

Hydrotime model describe seed germination responses to water potential (García *et al.,* 2013; Zambrano-Navea *et al.,* 2013). The significance of hydrotime modeling was first proposed by Gummerson (1986) and afterwards developed by Bradford (1990, 1995). Hydrotime models are threshold models that simultaneously describe germination percentage and rate in a seed population (Gummerson, 1986; Bradford, 1995, 2002; Finch-Savage, 2004) using biologically informative parameters, such as water potential ($\Psi b(g)$), hydrotime constant (θHT), and standard deviation of the base water potential ($\sigma\Psi b$), which are characteristic for a seed population (Meyer and Allen, 2009). Hydrotime model describes seed germination responses to water potential changes using the following function (Gummerson, 1986; Bradford, 1990):

$$\theta H=(\psi-\psi b(g))\times tg \quad \textit{(Eqn 1)}$$

where, θH is the hydrotime (MPa h), the seeds require for germination, ψ the actual water potential of the germination medium (MPa), $\psi b(g)$ the theoretical threshold or base water potential that will just prevent germination of fraction g, and tg is the germination time (h) of the corresponding fraction g. The model assumes that ψb varies among fractions of a seed population following a normal distribution with its mean, $\psi b(50)$, and standard deviation, $\sigma\psi b$, and θH is considered constant for a seed population (Bradford, 1990). The assumptions allow the germination time-course curve for a seed population to be characterized by the following probit equation:

$$Probit(g)=(\psi-\theta H/tg)-\psi b(50)/\sigma\psi b \quad \textit{(Eqn 2)}$$

The parameters of the model have proven to have a physiological basis and an ecological significance (Bradford, 2002); therefore, these modelling approaches have been successful in prediction of field seedling emergence (Roman *et al.,* 2000).

Millets are a group of highly variable small-seeded grasses, widely grown around the world as cereal crops or grains for fodder and human food. Millets are important crops in the semi-arid tropics of Asia and Africa (especially in India, Mali, Nigeria, and Niger) with 97% of millet production in developing countries. The crop is favored due to its productivity and short growing season under dry, high-temperature conditions.

Millet (*Panicum miliaceum* L.) is cultivated in arid and semi-arid regions of Iran. The purpose of this research was to predicting seed germination of millet using hydrotime model.

MATERIAL AND METHODS

This study was conducted in the Faculty, Agricultural and Natural Resources Research Center of Yazd, Iran.

Germination protocol

Twenty five seeds of millet were placed evenly in a Petri dish (9 cm diam.) containing two pieces of No.1 filter paper. The filter paper was moistened with 5 ml deionized water (pH= 6) and other test solution. The Petri dishes were placed in an incubator at 25°C under constant darkness for 14 days. The number of seeds that germinated was determined after 14 days.

Effect of osmotic potential

Millet seeds were germinated in various polyethylene glycol (PEG 600) solutions to obtain water potentials of 0, -0.3, -0.6, -0.9, and -1.2 Mpa (Michel and Kafman). Other environmental conditions were the same as previously stated in the germination protocol.

Priming

Seeds of were pretreated with water and gibberellin 50 ppm at 15°C for 24 h. Millet seeds were exposure in 20 cm glass Petri dishes containing 15 ml solution. The imbibed seeds were then washed four times with tap water and dried on filter paper at 15±1°C for 24 h (Ansari and Sharif-Zadeh, 2012).

Statistical analysis

A randomized complete block design with three replications was used in this experiment. Data analyses to determine the values of the hydrotime model parameters; $\psi b(50)$, θH, and $\sigma\psi b$ were conducted using repeated probit regression analysis as described previously *(Eqn 2)* by Bradford (1990, 1995).

RESULTS

Results indicated that germination of Millet decreased significantly with reduction of osmotic potential (data not showed).

Results showed that, the hydrotime constant (θH) for control, hydropriming and hormone priming were 0.89, 0.79 and 0.67 MPa d (*Table 1*).

In most cases, the model fitted the experimental data well with R^2 values ranging from 0.77 to 0.85 (*Figs. 1* and *2*). Cumulative germination percentage at different osmotic potentials (Mpa) versus normalized for millet seeds is presented in *Fig 3.* Results showed that the water potential ($\Psi b(50)$) for control, hydropriming and hormone priming were -0.89, -0.94 and -1.11 MPa, respectively (*Table 1* and *Fig 4*).

In general, water potential influenced germination rate and final germination percentage in millet. The HT model analysis revealed that, for priming, the θH constant had been reduced. The uniformity of germination (described by σψ(b)) was not greatly improved by the priming treatments. These results showed that the hormone priming should have better performance than the hydropriming and hormone priming and hydropriming should have better performance than the control.

Table 1 - Estimated parameters of hydrotime model for millet. θH, Ψb(50) and σΨb(50) indicate, respectively, hydrotime constant, mean base water potential and its standard deviation in millet population

Treatment	θH	Ψb(50)	σ Ψb(50)	R2
Control	0.89(0.04)	-0.89(0.02)	0.31(0.01)	0.85
Hydropriming	0.79(0.03)	-0.94(0.01)	0.34(0.01)	0.82
Hormone priming	0.67(0.05)	-1.11(0.02)	0.39(0.01)	0.79

Numbers in parentheses represent standard error.

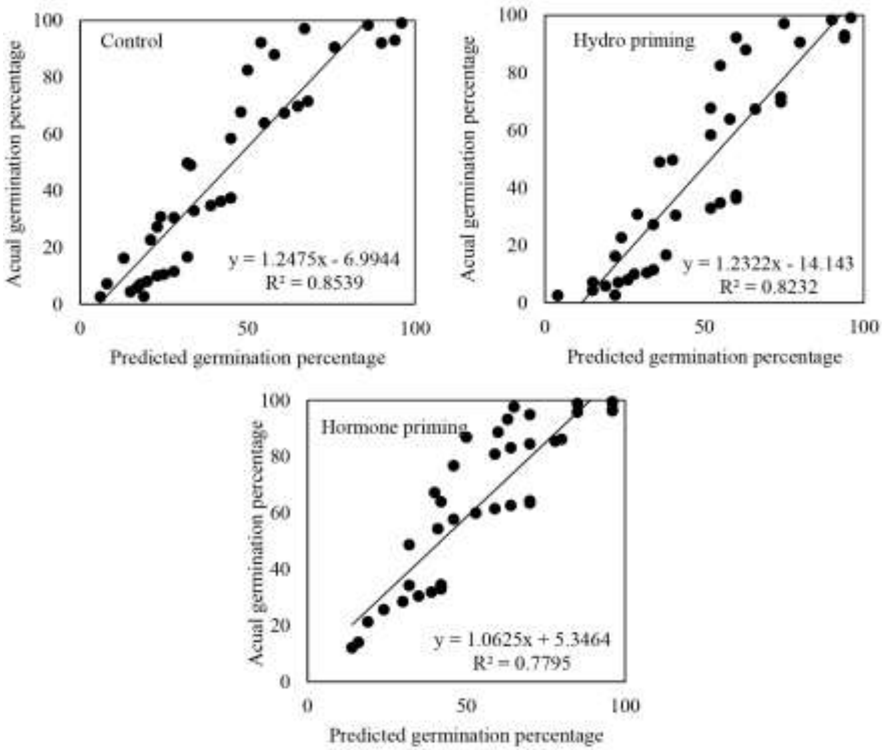

Figure 1 - Injective function of observed germination percentage values *versus* predicted values from hydrotime model in different temperatures for millet

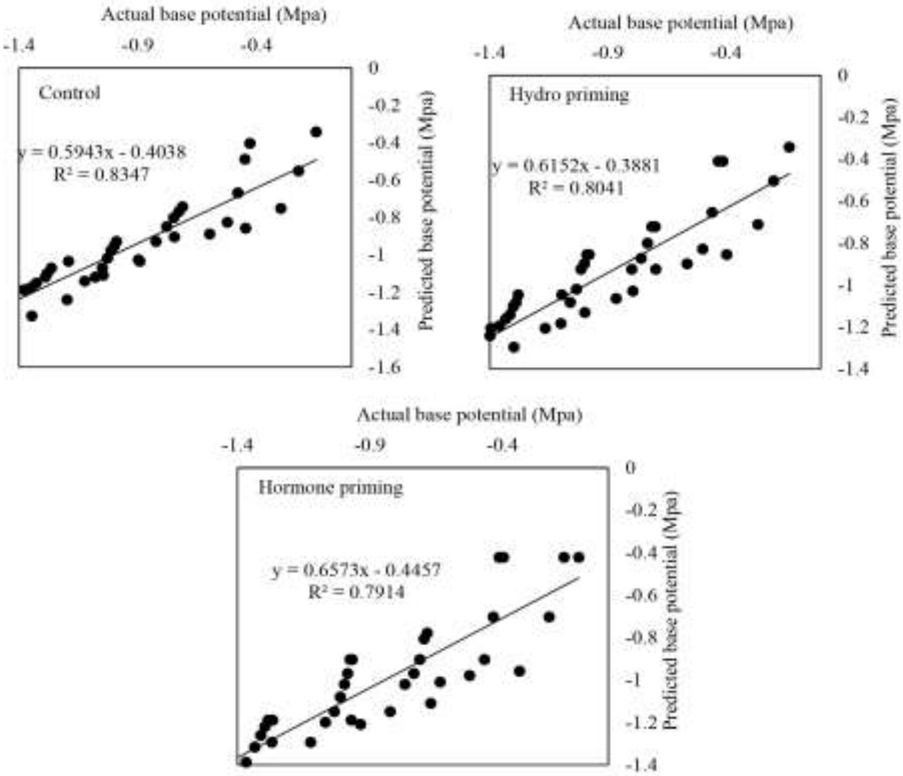

Figure 2 - Predicted base water potential values from hydrotime model *versus* observed values (MPa) for millet

Germination is basic processes in the survival and success of a plant (Bradford, 2002; Ansari *et al.,* 2012) and the ability to predict germination could enhance crop management.

In fact, this distribution has been almost exclusively assumed so far in hydrothermal models (Gummerson, 1986; Bradford, 1990). Nevertheless, it has been recently shown that alternative functions that allow for a right skewed distribution of Ψb(g), such as the log-logistic, inverse normal or lognormal distributions, depending on the species, can provide a more accurate fit to germination data (Mesgaran *et al.,* 2013). Karlsson and Milberg (2007) found a good fit for *C. bonariensis* germination data with the logistic function, the possibility remains that alternative functions might give better fit. Although, various researchers have estimated hydrotime constant, mean base water potential and standard deviation for different plant seed species using hydrotime model with the normal function (Mesgaran *et al.,* 2013; Huarte, 2006). Windauer *et al.* (2007) indicated that priming reduced θH and increases Ψb(50).

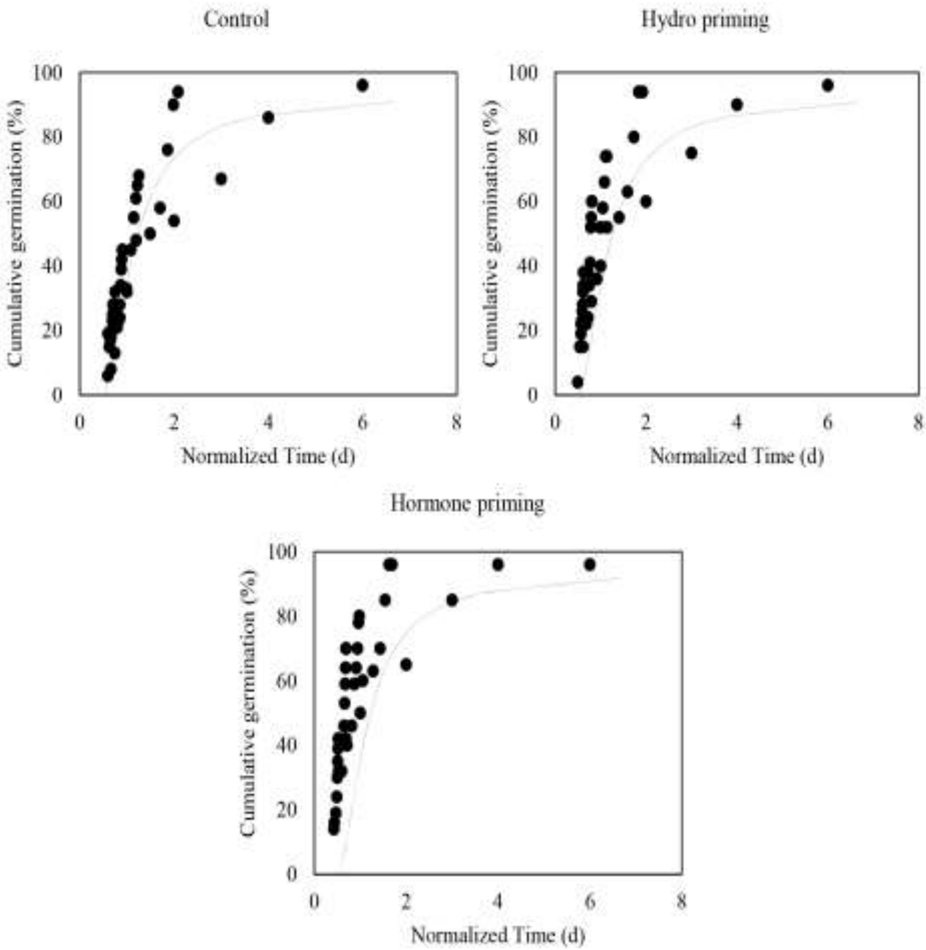

Figure 3 - Cumulative germination percentage at different osmotic potentials (Mpa) *versus* normalized for millet

In contrast, these data shown that germination of millet (using priming) remains high under osmotic potential conditions and may have a competitive advantage over against other plant and weed species under drought stress conditions.

This relatively simple model can describe and quantify the germination behavior of seeds across a wide array of environmental conditions, and can be used as an input for more general models of seed germination and seedling emergence in the field. Therefore, these models can be used to predict germination for better determination of sowing timing.

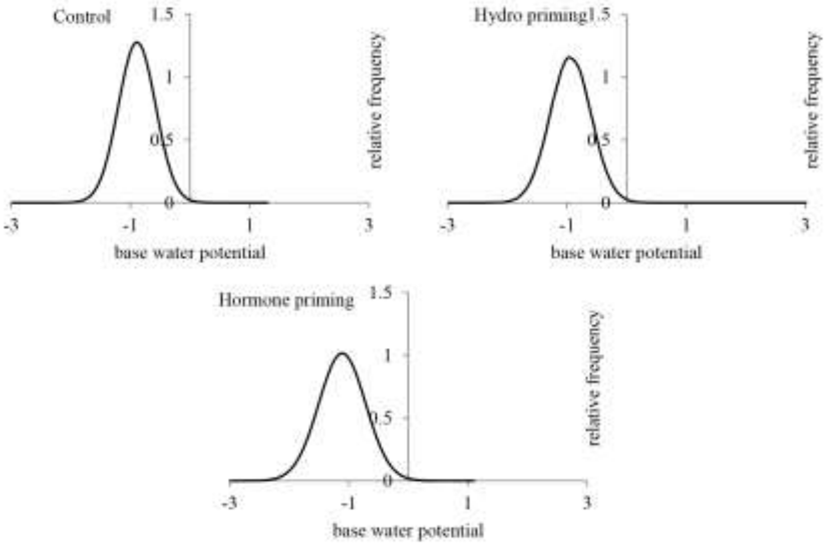

Figure 4 - Normal distribution of base water potential (MPa) for millet

CONCLUSION

Germination percentage and germination rate could occur under a wide potential osmotic, although it is concentrated in the hormonepriming. Results showed that hydrotime model is suited to predicting seed germination of millet seeds. In addition, the information gathered with this work allows us to build mathematical models to predict germination of millet (control and priming) in the field under various environments.

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