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Short communication

Hydrotime model analysis of *Trachyspermum ammi* (L.) Sprague seed germination

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ABSTRACT

Trachyspermum ammi (L.) Sprague (Apiaceae) is an annual herb that is known medicinal plant. Information about germination of *T. ammi* is scarce. The aims of this study were (1) to develop a general hydrotime model to predict seed germination of *T. ammi* and (2) to evaluate seed germination of *T. ammi* using hydrotime parameters. Seeds of 20 *T. ammi* ecotypes were germinated at five water potentials: 0, −0.1, −0.2, −0.3, and −0.4 MPa. Quantification of seed germination was conducted in relation to water potential using the hydrotime model for each of the 20 ecotypes. The ecotypes differed for estimated values of hydrotime (θ_H), base water potential ($\psi_b(50)$) and $\sigma_{\psi b}$. The average θ_H was 13.6 MPa-h. The ψb(50) varied from −0.32 to −0.12 MPa, with an average of −0.21 MPa. Average $\sigma_{\psi b}$ was 0.18 and it varied from 0.13 to 0.31. A general model was fitted to all germination data for the 20 ecotypes and 5 levels of water potentials based on an average of θ_H, $\psi_b(50)$, and $\sigma_{\psi b}$. The general model predictions agreed closely with observed germination. High ψb(50) and low θ_H values were associated with a rapid germination rate under wet conditions but inhibited germinating at reduced water potentials. Low θ_H values are contributed by rapid germination and high ψb(50) is showing that germination in dry condition would not be done. These lead to a good establishment of *T. ammi* by rapid germination after rainfall and resulted to take advantage of the short wet periods in arid and semiarid environments.

1. Introduction

Trachyspermum ammi (L.) Sprague (Apiaceae) is an annual herb that is known a medicinal plant. *T. ammi* is probably native to arid and semiarid regions of India, Pakistan, Afghanistan, Iran and Egypt (Sadat-Noori et al., 2015). *T. ammi* is an annual plant with more than 90 cm tall and its stem has many branches. The inflorescence is compound umbel same as some other Apiaceae family and it contains 16 umbels and each one has up to 16 flowers. The form of leaves is spinnate and lower leaves are bigger and have long petioles. Fruits of *T. ammi* are grayish brown, ovoid, and have two mericarps with prominent ridges and they are 2 mm in long and 1.7 mm in wide (Asif et al., 2014). The monoterpene, thymol is the main component in the essential oil of raw *T. ammi* seeds and its flavour is aromatic similar to thyme (Rao et al., 2015). The essential oil of *T. ammi* (2.5–5% in the dried fruit) is dominated by thymol at 35–60%. This is similar to the thymol content of common thyme (*Thymus vulgaris* L.) which contains 20–54% thymol (Sadat-Noori et al., 2015). Thymol is a strong germicide,antispasmodic and fungicide agent. The *T. ammi* essential oil exhibited nematicidal, scolicidal, antitermitic, antibacterial, antifungal, and antioxidant effects (Vitali et al., 2016). The non-thymol fraction of essential oil contains *p*-cymene, *y*-terpinene, α-pinene, β-pinene, and other minor components (Zarshenas et al., 2014).

Seedling emergence probably is the single most important phenological event that influences the success of an annual plant. The time of seedling emergence determines whether a plant competes successfully with weeds, is consumed by herbivores, infected with diseases, and the phenological stages (Forcella et al., 2000). Models are helpfully tools to predict timing of emergence and to use in crop managements. Thermal time, hydrotime and hydrothermal time models are the most important models that are used to predict seed germination and emergence. Thermal time is a good predictive model at the non-limiting conditions of soil moisture. However in warm and frequently dry environments hydrothermal conditions could have a crucial role in the germination dynamics of annuals (Soltani et al., 2016). Gummerson (1986) showed that if germination rate values were plotted as a function of water potential (ψ), the resulting curves were essentially linear and parallel, having a common slope and intercepting the ψ axis at different threshold or base ψ (ψ_b) values. Since the slopes were the same, the total hydrotime (MPa-hours or MPa-days) to radicle emergence was the

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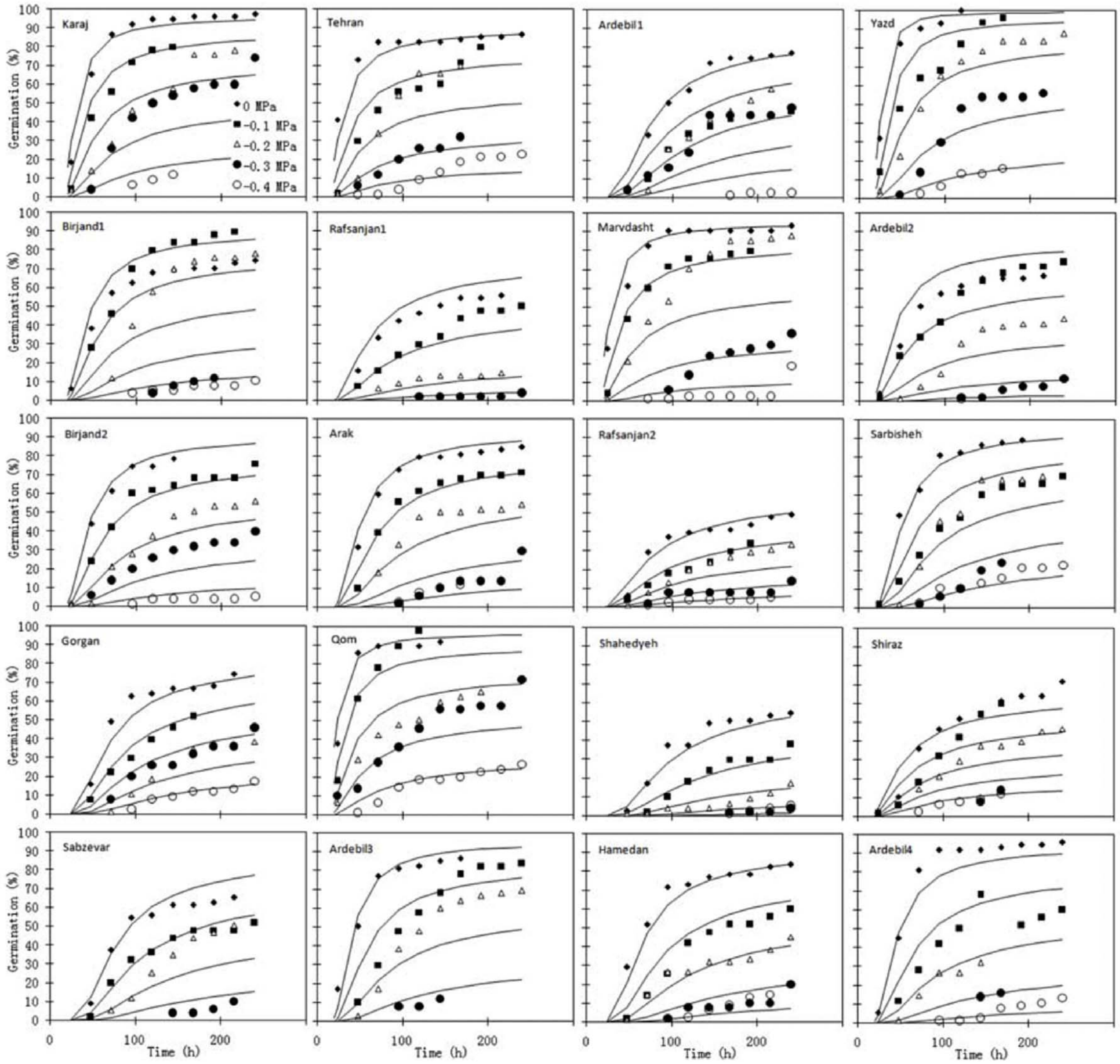

Fig. 1. Germination time courses of 20 *Trachyspermum ammi* ecotypes. Symbols indicate interpolations of observed germination data and lines germination time courses predicted by the hydrotime model based on parameter estimates in Table 1.

same for all seeds in the population, but individual seeds varied in their threshold $\psi_b(g)$ at which radicle emergence would be prevented (Bradford, 2002). Thus, hydrotime model has three parameters: (1) the hydrotime constant, θ_H (MPa-hours or MPa days), (2) the base water potential, ψb(g) (MPa), and (3) the standard deviation of the ψb (g) ($\sigma_{\psi b}$). It is indicated that different seed lots or genotypes have different hydrotime constant and ψ_b (Soltani and Farzaneh, 2014; Farzaneh and Soltani, 2011). Therefore, it is necessary to determine the parameters for different genotypes or seed lots to construct a general model to prediction seed germination or seedling emergence. However, most previous models are constructed based on limited data to a few genotypes and such models cannot be general. The aims of this study were (1) to develop a general hydrotime model to predict seed germination of *T. ammi* and (2) to evaluate of seed germination of *T. ammi* using hydrotime parameters. The model parameters can be used to seedling emergence models of *T. ammi*.

2. Material and methods

2.1. Laboratory experiment

Seeds of 20 *T. ammi* ecotypes were obtained from the Gene Bank of Natural Resources, Research Institute of Forests and Rangelands (RIFR), Iran. The seeds were produced in the growing season 2014 in Tehran, Iran and harvested during July 2014. After harvesting seeds were kept in the laboratory and in the dark condition until the experiment start. The experiment was started at September 2014. Three replicates of 25 seeds for each ecotype were germinated in 150 mm-diameter Petri dishes on filter paper at 25 °C at each of five water potentials: 0, −0.1, −0.2, −0.3, and −0.4 MPa. Water potentials were maintained with solutions of polyethylene glycol 6000 prepared according to Michel and Kaufmann (1973). Before seed placement, the filter papers were soaked in the PEG solution for 24 h. Seeds were observed twice daily and considered germinated when the radicle was ≥2 mm long.

2.2. Statistical analysis

Data were subjected to analysis of variance (ANOVA) to examine the effect of ecotype and water potential and their interaction on germination rate and percentage. ANOVA was performed using the GLM procedure of the Statistical Analysis System (SAS Institute Inc., Cary, NC, USA, 2011). Hydrotime model was applied to investigate the effect of decreasing water potential for each ecotype separately, because the treatment levels were quantities (numbers), i.e. not qualities such as in studies that compare cultivars.

Modeling of seed germination was conducted using the hydrotime