

Predicting weed emergence timings in eastern Washington using hydrothermal time models

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Hydrothermal time (degree-days) models have been used regularly to predict crop emergence based on daily calculations of soil temperature and soil moisture potential, along with species-specific environmental thresholds (Bullied et al 2012) (Figure 1). In recent years, several studies have found success in using hydrothermal models to predict emergence timing of different weedy species (Bastida et al 2021, Oreja et al 2023). While these studies provide useful insight into weed biology, they were not performed in-field, nor aimed at creating decision-support tools.

Hydrothermal time models assume that seeds begin accumulating hydrothermal time immediately upon entering the soil; however, this assumption fails in field seedbanks where entry time is unknown and duration in the seedbank is inconsistent between seeds. In 2007, Batlla and Benech-Arnold noted that summer annual seedbank dormancy fluctuated between high dormancy in the autumn/winter, and low dormancy in the spring/summer. By using an approximation of the dormancy peak (Jan 1) as a hydrothermal reset date and the starting point of calculations, the model no longer required us to know when seeds entered the soil to predict their emergence.

Two wheat-fallow studies were conducted at the Palouse Conservation Field Station near Pullman, WA in 2024 (May-Aug) and 2025 (Jan-Sep). Weather data were collected from local (WSU Ag Weather Net) and on-site (Meter Group ATMOS 41 and TEROS 21 sensors) weather stations. Each study used a randomized complete block design with two replications (7 treatment timings in 2024; 10 in 2025). Plots (5 x 10 ft²) were treated with glyphosate (16 oz ai A⁻¹) at staggered intervals (14 days apart, or 30 days apart before May) to reset weed emergence. Weed densities were measured 42 days after treatment using two 0.25 m² quadrats (Table 1).

To compute hydrothermal time on the same scale across all species, hydrothermal time was calculated starting at January 1st of the given year, using 0°C as the base temperature requirement and -1500 kPa as the base moisture potential requirement for all species. A permutation test (n = 5000) was used to compare emergence patterns of Mayweed chamomile (*Anthemis cotula*), redroot pigweed (*Amaranthus retroflexus*), common lambsquarter (*Chenopodium album*), prickly lettuce (*Lactuca serriola*), and Italian ryegrass (*Lolium perenne* subsp. *multiflorum*) across both years to evaluate model consistency ($\alpha = 0.05$). The T₁₀ and T₉₀ were calculated to represent the hydrothermal time required for the 10th and 90th emergence percentile, respectively, along with the median and mean of each species hydrothermal time requirement.

Across all species, T₁₀ ranged from 148 to 1581 hydrothermal degree-days (HDD). Mayweed chamomile had the earliest emergence distribution (T₁₀ = 148 HDD, T₉₀ = 904 HDD) (Table 3). and prickly lettuce had the latest emergence (T₁₀ = 582 HDD, T₉₀ = 1746 HDD). Common lambsquarter and Italian ryegrass similar emergence patterns (T₁₀ = 582, T₉₀ = 1192). Redroot pigweed had the shortest window of emergence (T₁₀ = 1581, T₉₀ = 1581).

We found that several species' distributions were not significantly different (Table 2), indicating that the model effectively captured the same emergence distributions in both years. Mayweed chamomile

populations were significantly different years, since the 2024 study did not effectively capture the emergence window. Common lambsquarter emergence patterns also significantly differed between years, which could be due to competition with other species.

These results suggest that a hydrothermal time model with resetting accumulations has a strong potential for developing decision-support tools for growers. By enabling more precise predictions of emergence patterns for target weed species, growers can better focus their weed management strategies on periods when weeds are actively emerging and adjust their approaches as emergence pattern change throughout the growing season. Future studies will seek to understand how these patterns shift across various sites in eastern Washington and northeastern Oregon."

References

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Figure 1. Example of hydrothermal degree-day accumulation in the soil profile. Both y-axes are scaled such that the base temperature (left axis; T_{Base}) and base water potential (right axis; Ψ_{Base}) can be represented by the same horizontal line. When both the daily average soil temperature and soil water potential are higher than their respective base levels, the difference is added to the accumulation.

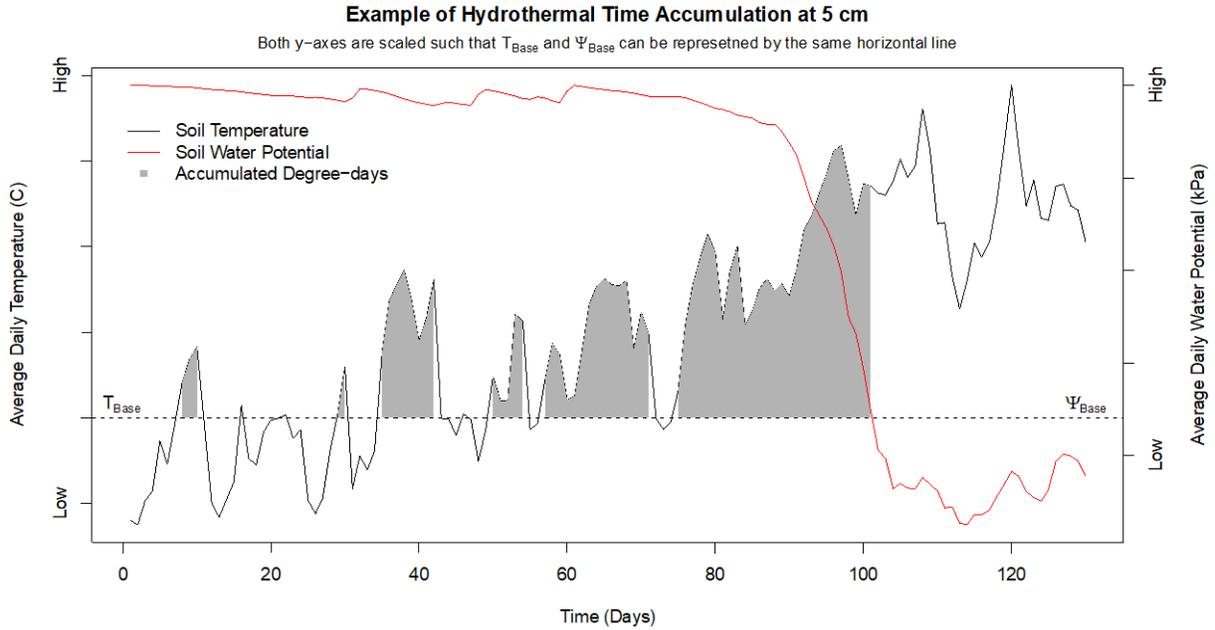


Figure 2. Plot of the accumulation of hydrothermal degree-days from January 2025 through September 2025. As an example, the T_{10} , median, mean, and T_{90} for Italian ryegrass (*Lolium perenne* subsp. *multiflorum*) emergence were calculated and are also show in the figure, as well as the corresponding calendar dates.

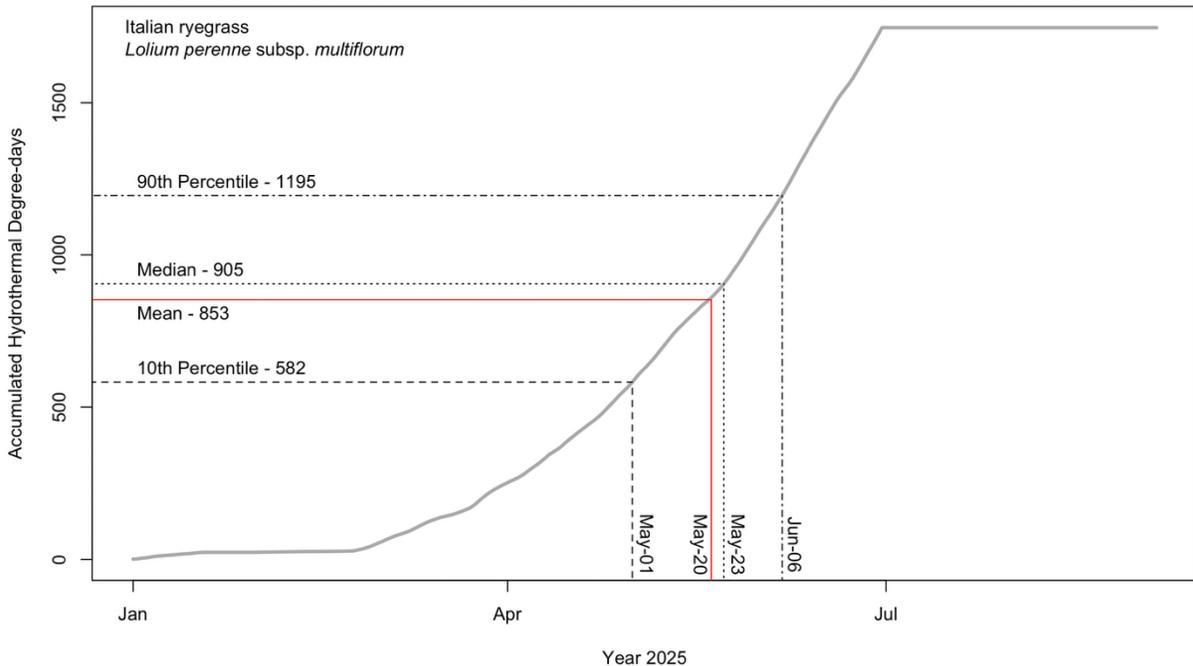


Table 1. Treatment and rating dates from the 2024 and 2025 studies on summer annual weed emergence near Pullman, WA. Treatments were applied 6 weeks prior to ratings.

Dates			
2024		2025	
Treatment	Rating	Treatment	Rating
-	-	12-09 (2024)	1-29
-	-	1-16	3-19
4-02	5-20	3-19	5-01
4-19	6-06	4-02	5-23
5-03	6-18	4-18	6-06
5-20	7-02	5-01	6-23
6-06	7-15	5-23	7-11
6-18	7-30	6-06	7-30
7-02	8-12	6-23	8-21
-	-	7-11	9-04

Table 2. The p-values between the emergence distributions of the 2024 and 2025 populations for five weed species near Pullman, WA, along with the 10th percentiles, medians, means, and 90th percentiles of the respective 2025 populations' emergences.

Scientific Name	Common Name	P-value	2025 Population Statistics			
			T ₁₀	Median	Mean	T ₉₀
— hydrothermal degree-days —						
<i>Anthemis cotula</i>	Mayweed chamomile	0.04*	148	582	693	905
<i>Amaranthus retroflexus</i>	Redroot pigweed	0.41	1581	1581	1546	1581
<i>Chenopodium album</i>	Common lambsquarters	0.02*	582	905	1005	1195
<i>Lactuca serriola</i>	Prickly lettuce	0.32	582	905	977	1746
<i>Lolium perenne</i> subsp. <i>multiflorum</i>	Italian ryegrass	0.30	582	905	867	1195