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# A modelling approach for predicting the initial phase of Egyptian broomrape (*Phelipanche aegyptiaca*) parasitism in potato

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ABSTRACT

*Phelipanche aegyptiaca* is one of the most important parasitic weeds in some crops including potato. *P.aegyptiaca* reduces potato tuber size and can produce severe yield losses. The development of predictive models can be useful to help managers to choose the best management options and times and, thereby, improve weed control.The objective of this study was to develop a predictive thermal time model of *the P.aegyptiaca* establishment in potato using field experiment data. The relationship between the cumulative attachments of *P.aegyptiaca* and air/soil thermal time was analysed using Gompertz and Weibull functions. The Weibull soil thermal time model produced the better fit and was the more plausible one. The latter model was successfully validated under field conditions and can be used as a predictive tool contributing to optimize the timing of *P.aegyptiaca* control. According to the weibull model and soil thermal time the lag time and 50% of *P.aegyptiaca* attachments occurred in 613.75 (124.8) and 999.49 (5.98) TT respectively.



## 1. Introduction

Potato (*Solanum tuberosum* L.) is one of the world's most staple food crops in the world. Potatoes are grown in almost all over Iran, but production is focused in the western and north western provinces. The total area under potato cultivation in Iran is around 146000 ha, with a total production of 4300000 t (Anonymous, 2015). Potato is susceptible to *Phelipanche aegyptiaca* Pers.(Eizenberg and Joel, 2008), which reduces potato tuber size (Joel, 2007) and can produce severe yield losses. Parasitic behaviour of *P.aegyptiaca* not only causes serious problems for crop production, but also, because of its high seed production, produces major infestation in the soil seed bank for a long period of time. In fact, failure to contain this parasite can be disastrous. Estimated yield losses due to broomrapes can vary from 5 to 100% depending on the region and crop (Hershenhorn et al., 2009; Sauerborn, 1991).

Direct connection to the host, its long life underground, producing many small seeds and high dormancy make *P. Aegyptiaca* difficult to control. Several methods have been proposed for broomrape control in the field (e.g., alternating planting dates, chemical control, soil solarization, trap crops, etc.) (Eizenberg et al., 2012; Goldwasser et al., 2001; Mauro et al., 2015). However, chemical control has been found to be the most promising cost-effective solution for broomrape (Eizenberg et al., 2012). At early emergence time, broomrape is more sensitive to herbicide like sulfonylurea in tomato and imazapic in sunflower (Aly et al., 2001; Hershenhorn et al., 2009) but the herbicide's effectiveness is conditioned by the timing of its application (Haidar and Shdeed, 2015). Any effective weed control program relies heavily on well-timed herbicide applications. Herbicides should be applied during the initial state of the parasite development. Therefore, farmers need to know about timing of broomrape's attachment adequately. In this context, the development of predictive models can be a useful tool for helping managers to anticipate the best management options and times and, thereby, improve broomrape control (Yousefi et al., 2014; Zambrano-Navea et al., 2013). Important advances have been made in recent years in the development of predictive field weed seedling models based on thermal time with successful results (Forcella et al., 2000; Gonzalez-Andujar et al., 2016). Thermal time, which is the accumulation of heat units over

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time, commonly referred to as growing degree days, is perhaps the variable that best describes seedling emergence patterns in multiple weed species (Harvey and Forcella, 1993; Royo-Esnal et al., 2010; Yousefi et al., 2014). Several types of nonlinear regression models (e.g. Logistic, Weibull, etc.) have been used to predict weed emergence or germination by thermal time (Gonzalez-Andujar et al., 2016; Izquierdo et al., 2009; Alvarado and Bradford, 2002). For instance, Yousefi et al. (2014) fitted a Gompertz models based on thermal time to predict the emergence of *Avena fatua* and *Polyognum aviculare* in garlic. The models validation performed well in predicting the seedling emergence of both species. A few studies have set up predictive models for broomrapes attachment based on thermal time in different crops (e.g. Eizenberg et al., 2012). Ephrath et al. (2012) used a logistic model for detection of the initial parasitism phase of *P. aegyptiaca* in tomato. A similar model was proposed by Eizenberg et al. (2005) to predict the parasitism of *Orobanche minor* in red clover.

To the best of our knowledge, no model is available in potato that predicts the timing of *P.aegyptiaca* attachment. Therefore, the objective of this study was to develop and validate a thermal time model of *P.aegyptiac a*attachment in potato that could help producers in the decision-making process to determine when to implement control practices and maximize the control of this species.

## 2. Material and methods

### 2.1. Experimental site

Three experimental plots (25 × 6 m) were established in 2014 and 2015 at the Agricultural Research Station of Bu-Ali Sina University located in Hamedan, Iran (35°1′N, 48°31′E, elevation 1690 m a.s.l.). The annual mean temperature and precipitation were11.3 °C and 384 mm, respectively. The soil type was clay loam with pH 7.7, and 1.4% organic matter. The experimental plots were artificially inoculated with the soil infested by the *P.aegyptiaca* seeds. The infested soils were spread by hand and mechanically incorporated into the field by a disk plough in 10 cm depth. Seeds were collected by collecting soil surface in a cucumber field strongly contaminated with *P.aegyptiaca* in 2013. Average of 1 kg soil that naturally was contaminated to *P.aegyptiaca* seeds overspread in 1 $m^3$ soil of fields. In each experimental plot, potato (var. Ramos) tubers were sown into 22 cm-high ridges spaced 75 cm apart in at a 10 cm depth. Irrigation was done weekly and other weeds removed by hand weeding.

### 2.2. Data collection

Sampling started 10 days after the potatoes emerged. Every week during two months, potato plants were carefully hand harvested from 50 cm-long rows in four random samples in each experiment, roots were washed and *P.aegyptiaca* infestation was measured by counting the smallest visible attachments (1 mm–2 cm) on every potato plant (Eizenberg et al., 2005). Temperature sensors connected to a data logger were placed at 20 cm up the soil (air temperature) and at 7 cm soil depth. The data logger device was hand making with two sensors, in the soil and the air (Microprocessor: ATMEGA32, Thermal sensor: DS1820, The interface storage system: FAT SYSTEM). Data was hourly recorded. Microclimatological data (air temperature and rainfall) for experimental location is summarize in Table 1.

### 2.3. Data analysis

Cumulative thermal time (TT) was calculated for each sampling date starting from potato sowing by the following equation:

$$TT = \sum_{i=1}^{n} (T_{mean} - T_{base}) \tag{1}$$

where $n$ is the day number, $T_{mean}$ represents the daily mean (soil or air) temperature in°C, and $T_{base}$ is the minimum temperature at which *P.aegyptiaca* start infestation. Base temperature for *P.aegyptiaca* ($T_{base}$) was set at 4.9 °C (Ephrath et al., 2012; Kebreab and Murdoch, 1999). TT was used as the explicative variable to describe cumulative percentage of *P.aegyptiaca* attachment (Y) using two nonlinear models widely used in the literature (Gonzalez-Andujar et al., 2016): Gompertz and Weibull. The Gompertz equation is:

$$y = a{*}\exp\left(-\exp\left(-\frac{TT - TT36}{b}\right)\right) \tag{2}$$

where y is the percent of attachment, $a$ is the maximum accumulated attachments in percentage, TT is the cumulative thermal-time calculated with soil or air temperature, $b$ is the rate of increase of attachments, $TT_{36}$ represents TT where the attachment percent of 36.6% of maximal attachments, and $c$ is a shape parameter that determines the skewness and kurtosis of the distribution. Also $TT_{10}$, $TT_{20}$, and $TT_{50}$ were estimated.

The Weibull equation is:

$$y = a * \left(1 - \exp\left(-\left[\left(TT - TT50 + b{*}\ln(2)^{\frac{1}{c}}\right)\Big/ b\right)\right]^{c}\right)\right) \tag{3}$$

where Y is the percent of attachment with TT calculated for soil or air temperature, $a$ is the maximum accumulated attachments in percentage, $b$ is the lag phase for initiation of attachment, TT50 is amount of TT for 50% of attachments and $c$ is a shape parameter that determines the skewness and kurtosis of the distribution. Also $TT_{10}$, $TT_{20}$, and $TT_{36}$ were estimated.

A correcting coefficient (CC) for parameters estimated for attachment vs. air temperature calculated as follows:

$$CC = \frac{P_s}{P_a} \tag{4}$$

**Table 1**
Microclimatological data for experimental location.

| Month | Max temperature (°C) | | Ave temperature (°C) | | Min temperature (°C) | | Rainfall (mm) | |
|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| May | 24.72 | 26.89 | 16.68 | 18.65 | 7.87 | 8.91 | 0.88 | 0.13 |
| June | 31.41 | 34.25 | 22.94 | 24.27 | 12.20 | 12.27 | 0.01 | 0.00 |
| July | 35.31 | 35.84 | 26.65 | 27.15 | 15.97 | 16.69 | 0.01 | 0.13 |
| August | 35.31 | 35.31 | 25.77 | 25.70 | 14.68 | 14.02 | 0.01 | 21.50 |
| September | 30.71 | 29.32 | 20.95 | 19.58 | 9.99 | 10.13 | 0.00 | 1.39 |
| October | 21.16 | 24.57 | 12.37 | 15.68 | 4.54 | 7.47 | 1.01 | 2.25 |