

Estimation of cardinal temperatures for germination among *Turgenia litifolia* (L.) Hoffm and *Datura stramonium* L seeds.

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Estimation of cardinal temperatures for germination among *Turgenia litifolia*

(L.) Hoffm and *Datura stramonium* L seeds.

Running head: Cardinal temperatures for weed germination seeds

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Abstract

Modeling is necessary to better understanding of weed management. For this aim, *Turgenia litifolia* (L.) Hoffm and *Datura stramonium* L. as two important and problematic weeds germination in wheat and corn fields were compared under temperatures of 0, 5, 10, 15, 20, 25, 30 and 35°C in the germinator, controlled condition included the lighting (12.12 hours and the relative humidity with 30% as of two separate designs in completely randomized design with four replications in the Faculty of Agriculture of Ilam University. Two experiments were carried out twice, the data of the experiments were pooled for analysis, as there was no time-by treatment interaction. Four models, segmented, dent-like, beta and modified beta were used to describe germination changes with respect to temperature. The results showed that four models were significant for *T. litifolia* germination, and all models were significant on *D. stramonium* except the beta model. In *T. litifolia*, suitable germination models were dent-like and beta models. According to dent-like model, base temperature of *T. litifolia*; was Zero, the first optimum temperature; 15 degrees, optimal second; 29.5 degrees and maximum germination was estimated at 35 degrees. The suitable model for *D. stramonium* germination was also the segmented model. According the segmented model, the base temperature, optimum temperature and maximum germination were estimated to be zero, 29.7 and 35°C, respectively. Generally, experiment results showing that, for *T. litifolia* weed management in wheat field, appropriate time for herbicide application is in the range of 15.5-29°C and the appropriate time for *D. stramonium* management in corn field is mechanical, herbicide application or integrated weed management at time it is 29.7 degrees.

Keywords: Modeling, Predictive Models, Cardinal temperatures, Weed Management

Introduction

Seed germination is one of the critical steps that ensure seedling establishment and successful determination of plant growth and development in its life later stages (Almansouri et al. 2001). For germination, every plant urgently needs environmental conditions specific range of (Lu et al. 2006). Temperature is one of the first factors affecting the rate and percentage of seed germination (Kamkar et al. 2012), watering process and seeds biochemical changes, regulate germination are directly affected by temperature. So, most species require a suitable temperature for germination (Guo et al. 2020). Germination response to temperature can be identified through the germination rate, which characterized by three temperature thresholds including basal, optimum and maximum temperatures (Sampayo-Maldano et al. 2019). Base, minimum, maximum and germination temperature are referred to as cardinal temperature (Hosseini et al. 2017). Cardinal temperature varies between species, and even within a species as a factor related to plant adaptation (Ruiz-corral 2002). Having information such as germination characteristics can be effective in determining the time period with the most impact on weed control (Ghorbani et al. 1999; Guo and Al-Khatib 2003; Sellers et al 2003). Germination pattern understanding and emergence of weed species can provide comprehensive information for the development of management strategies in the future (Chauhan et al. 2006). in weed science and their management models are important, and can be used to better understand and select more efficient management methods (Bagavathiannan et al. 2020). Response of plants to temperature, segmented, dent-like and beta models can be used to modeling the germination (Soltani and Sinclair 2012).

Cardaria draba and *Hordeum murinum* calculated, using a segmented and dent-like model, cardinal weed temperatures of barley, (Hosseini et al. 2017). In study on *Chenopodium album*

(Lambsquarters), founded that the basal and optimum temperatures for leaf emergence and stem growth were similar (Huang et al., 2001). Basal temperature for *Chenopodium album* germination was calculated to be about 3.5°C (Leblanc et al. 2003). The highest *Xanthium strumarium* L. germination observed at 25°C (Saric et al. 2012). Leguizamon et al (2005) estimated the germination basal temperature of *Avena sativa* in Spain at 0.8°C. In the common waterhemp (*Amaranthus tuberculatus*), optimum germination temperature was variable and dependent on the alternating temperature (Leon et al 2004). In another experiment, different populations of cowpea basal temperature estimated in the range of 1.5-1 (Loddo et al. 2013). Cassia Low and high germination thresholds reported between 10 and 12.5 and 45, respectively (Norsworthy and Oliveira 2005).

Turgenia litifolia (L.) Hoffm is an annual weed of the Apiaceae family that is propagated by seeds and usually begins to germinate in wheat and other grain crops, vineyards and lowlands in early spring. its processing is in May and June (Rashed Mohassel et al. 2001). In the Iran climatic conditions, orchards, fields and vegetables become problematic (Karimi 2008). This plant is one of the most important weeds in Iran (Zand et al. 2009).

Datura (*Datura stramonium* L.) is an annual potato genus that is considered as an important weed in summer fields, orchards and sometimes along roadsides (Veblen et al. 2012). Also, this weed has been included in the list of the most important weeds in Iran by Zand et al (2009). Due to dormancy in fields, lack of simultaneous germination of weed seeds also causes many problems in controlling them (Nowjavan 2001).

To clarify the dispersibility and weeds competitiveness as well as the development of mechanistic models effect of temperatures basic and partial information on weeds life cycle is

necessary (Swanton et al. 2000). Due to importance of recognizing the effect of temperature on the germination of the mentioned weeds, this experiment purpose was to estimate the cardinal temperature (base, optimum and ceiling) through four models and compare the models in order to select the best model for each weed.

Material and Methods

Seed collection

T. litifolia (L.) Hoffm and *D. stramonium* L. ripe and healthy seeds were collected with a longitude of 46 degrees and 28 minutes and a latitude of 33 degrees and 37 minutes, and an altitude of 1174 meters above sea level from the western of Iran in Ilam's fields. Seeds were collected from 500 plants and after mixing each seed mass, a 500 g sample of each weed was prepared and stored in paper bags in the dark at room temperature. It should be noted that *T. litifolia* is a weed of problematic wheat fields and *D. stramonium* is a common weed and problematic weed of corn fields in Ilam and Iran.

General seed germination conditions

In study of *T. litifolia* and *D. stramonium* weeds cardinal temperature, two distinct experiments were performed in the Department of Agriculture and Plant Breeding research laboratory, Faculty of Agriculture, Ilam University. All experiments were conducted based on completely randomized design (CRD) with four replications and in a growth chamber at 30% relative humidity, Day/dark conditions (12/12) were performed. Two experiments were carried out twice, the data of the experiments were pooled for analysis, as there was no time-by treatment interaction. Experimental treatments were; Constant temperatures 0, 5, 10, 15, 20, 25, 30, 35 and 40°C.

For break the seeds dormancy of *T. litifolia*, refrigerate was used in moist sand for 4 weeks in the refrigerator at 5°C (Ghadiri and Niazi 2014) and also for break seeds dormancy of *D. stramonium* Gibberellin (100 mg/lit) was applied for 24 hours (Mousavi et al. 2019).

Before starting the germination test of seeds, weeds with four replications and 25 seeds disinfected by Mancozeb fungicide Proportional of two per thousand in 9 cm glass spinners containing Whatman filter paper number one Done. In order to disinfect the petri dishes, first put them in 5% sodium hypochlorite for 24 hours, next wash them with plain water, and after drying and placing the filter paper in the bottom of them for 24 hours in the oven with Temperatures were exposed to 80°C. afterwards 10 ml of distilled water was added to them and the pterygiums were closed with paraffin and sent to the germinator at a relative humidity of 30% with a temperature of 25.15°C and light conditions of 12.12 hours (night/day) Were located. Germination count started 24 hours later and lasted up to 14 days. Germination criterion was root germination.

Data analysis

Since cumulative recording for each day's seed germination, using the Germin program in Excel software. Time required to achieve 10% (D_{10}), 50% (D_{50}) and 90% (D_{90}) Finding internal germination was calculated. Also, the inverse time to reach 50% of maximum seed germination ($1/D_{50}$) considered as germination rate (ER) (Hosseini et al. 2017). To quantify the germination toward temperature and determine the cardinal temperatures as well as the number of biological hours (the number of hours required to germinate under favorable temperature conditions or in other words the minimum number of hours from planting to germination) required for germination from The following model was used:

Equation (1)

$$1/e = f(T)/e_o$$

Where $1/e$ is the germination rate, (T) is a function of temperature, and (e_o) is the number of biological hours required for germination. In this experiment, segmented temperature function (Equation 2) and dent-like (Equation 3), beta (Equation 4) and modified beta (Equation 5) were used to describe changes in germination rate versus temperature.

Equation (2): segmented model

$$\begin{aligned} f(T) &= \frac{(T - T_b)}{(T_o - T_b)} & \text{if } T_b < T \leq T_o \\ f(T) &= \left[1 - \left(\frac{T - T_o}{T_c - T_o} \right) \right] & \text{if } T_o \leq T < T_c \\ f(T) &= 0 & \text{if } T \leq T_b \text{ or } T \geq T_c \end{aligned} \quad (2)$$

In this function, T_b is the base temperature, T_o is the optimum temperature and T_c is the ceiling temperature.

Equation (3): dent-like model

$$\begin{aligned} f(T) &= \frac{(T - T_b)}{(T_{o1} - T_b)} & \text{if } T_b < T \leq T_{o1} \\ f(T) &= \frac{(T_c - T)}{(T_c - T_{o2})} & \text{if } T_{o2} < T \leq T_c \\ f(T) &= 1 & \text{if } T_{o1} < T \leq T_{o2} \end{aligned}$$

$$f(T) = 0 \quad \text{if} \quad T \leq T_b \text{ or } T \geq T_c$$

T_b , T_{o1} , T_{o2} , T_c and T represent the base, lower optimum, upper optimum, ceiling and tested temperatures, respectively.

Equation (4): beta model

$$f(T) = \left\{ \left[\left(\frac{T - T_b}{T_o - T_b} \right) \left(\frac{T_c - T}{T_c - T_o} \right) \right]^{((T_c - T_o)/(T_o - T_b))} \right\}^\alpha \quad \text{if } T > T_b \text{ and } T < T_c$$

$$f(T) = 0 \quad \text{if} \quad T \leq T_b \text{ or } T \geq T_c$$

In this function, T_b is the base temperature, T_o is the optimum temperature and T_c is the ceiling temperature.

Equation (4): Beta-Modified function (Yan and Hunt1999).

$$r = R_{max} \left(\frac{T_c - T}{T_c - T_o} \right) \left(\frac{T - T_{min}}{T_o - T_{min}} \right)^{\frac{T_o - T_{min}}{T_{max} - T_o}}$$

where r is the daily rate of growth (or development) at any temperature, T_o is the optimum temperature, T_{max} is the maximum temperature, and R_{max} is the maximum rate of growth or development at T_o .

The model's parameters estimated by frequent optimization method using PROC NLIN procedure of SAS software. Best model choice for each species was based on RMSE, R^2 and r parameters (Hosseini et al. 2017).

The R^2 was obtained as shown in Equation 6: $R^2 = 1 - (SSE/SST)$

In this equation, SSE and SST are the sum of squared error and sum of squared total, respectively.

Results:

***T. litifolia* Cardinal Temperatures Calculation:**

According to experiment results, all fitted models significant for this weed germination (Table1). In segmented model, base temperature, optimum temperature and maximum germination were estimated to be 0.12, 18.5 and 35°C, respectively (Table 2, Figure 1-a). According dent-like model such as zero base temperature, first optimum temperature was estimated at 15 degrees, the second optimum at 29.5 degrees and maximum germination at 35 degrees (Table2, Figure 1-b). according beta model, the optimum temperature and maximum germination temperature estimated to be 4.6, 21.01 and 35 degrees, respectively (Table 2, Figure 1-c). according modified beta model, the optimum temperature was estimated to be 20.3°C (Table 2, Figure 1-d). according experiment results, suitable model for *T. litifolia* germination is the dent-like and beta models (Table 3).

***D. stramonium* Cardinal Temperatures Calculation:**

This experiment results showed, while other three models were significant the beta model was not significant for *D. stramonium* germination (Table 1). Based on segmented model, base and optimum temperature and maximum germination were estimated to be zero, 29.7 and 35 ° C, respectively (Table1, Figure 2-a). In dent-like model, such as zero base temperature, first optimum temperature estimated at 25, second optimal temperature at 30, and maximum temperature at 35 degrees (Table 2, Figure 2-b). In modified beta model, optimum germination temperature was estimated to be 25.07 (Table 2, Figure 2-c). According to this experiment results, suitable model for *D. stramonium* germination is segmented model (Table 3).

Discussion

In previous study, reported that segmented and dent-like models of wild barley (*Hordeum spontaneum* Koch.), barley grass (*H. murinum* L.) and hoary cress (*Cardaria draba* L.) were estimated, which the best for the *C. draba* was the dent-like model (Hosseini et al. 2017). Besides that, germination differences of 9 weed species at different temperatures have been reported (Steinmaus et al. 2000). as regards the best model for *T. litifolia* germination described as a dent-like model (Table 3), this experiment results correspond with the results of previous experiments (Steinmaus et al. 2000; Hosseini et al. 2017). Climate change is an important issue in crop production. The temperature in Iran will increase by 1.5-4°C by 2100. (Amiri and Eslamian 2010; Gohari et al. 2013). According to experiment results, if Iran temperature changes being in this temperature range, germination and competitiveness of these two weeds will not increase significantly.

In different *D. stramonium* populations, Base temperatures are varied (Loddo et al. 2013). The optimum germination temperature of datura in Kosovo was reported in the temperature range of 24.9 / 27/27 and its maximum temperature was 35 degrees (Mehmeti et al. 2010). Using modeling, the optimal germination temperature of four annual summer grasses was predicted to be 25°C (Masin et al. 2005). Field experiments showed that the segmented model was the best model for the emergence of corn crop (Edalat and Kazemeini.2014). Based on this experiment results, segmented model estimates the datura germination better than other models (Table 3). Considering that Datura is one of the weeds of corn field, it seems that segmented model can predict the germination and emergence of corn and weeds of Iranian corn fields better than other models.

experiment results consistent with previous experiments (Mehmeti et al. 2010; Edalat and Kazemeini 2014; Masin et al. 2005).

Base temperatures for each plant are related to the type of life cycle, taxonomic relationship (Steinmaus et al. 2000). They estimated the basal temperature for the two weeds of *Amaranthus albus* and *Sonchus oleraceus* to be 15.20 and 8.74 degrees, respectively. The difference in basal temperature between these two weeds was 6.46 degrees, while in our experiment the difference in this trait was 0.12 and 4.69 based on the segmented and beta models, respectively. The differences between the two studies may be related to the taxonomic relationship of the species.

Numerous information exists such as history, biology, ecology and weed control methods for the fields. Information integration, will result in knowledge-based systems evaluations that are effective in weed management (Swanton et al. 2008). modeling information use, makes it possible to build computer programs for the appropriate time of weed management and herbicide application (Masin et al. 2005). Relative germination time of crops and their competitiveness with weeds is an important factor in the effective use of IWM in the cultivation system (Swanton et al. 2008; Swanton and Murphy 1996). IWM must go from descriptive to predictive. Transform and consciousness support systems play an important role in this effort (Hosseini et al. 2017; Swanton et al. 2008).

Conclusion

Study results showing the highest percentage of germination and competitiveness of *T. litifolia* occurs between zero and 30°C, while the optimum temperature is between 15 and 30. Management tactics such as chemical operations must occur within this time frame. In addition, since the optimum germination temperature of *D. stramonium* is estimated to be 29.7, it seems that mechanical, chemical or integrated weed management management (IWM) operations can be performed at this temperature. The data from this experiment provide the basic information required for the models on weed seeds bank dynamics. They also provide the parameters needed

to predict plant development models that are useful for constructing They are systems that support consciousness.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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Table 1: F value of Segmented, Dent-like, Beta and Beta modified models on seed germination in *Turgenia litifolia* (L.) Hoffm and *Datura stramonium* L

Model	<i>T. litifolia</i>	<i>D. stramonium</i>
Segmented	< 0.003**	< 0.0121*
Dent-like	< 0.0001**	< 0.0152*
Beta	< 0.0009**	< 0.1884NS
Beta Modified	< 0.0002**	<0.0408*
NS: non-significant, * and ** significant at 5% and 1%, respectively.		

Table 2. Estimation of base temperature (Tb, °C), optimum temperature (To, °C), ceiling temperature (Tc, °C) and eo (number of biological time for 50% germination) based on segmented, dent-like, Beta and Beta-modified models for *Turgenia litifolia* (L.) Hoffm and *Datura stramonium* L

Model	<i>T. litifolia</i>					<i>D. stramonium</i>				
	Tb	To		TC	eo	Tb	To		TC	eo
		To1	To2				To1	To2		
Segmented	0.12±3.05	18.54±2.45		35±0	68.74±74	0±0	29.70±2.08		35±0	80.04±19.48
Dent-like	0±0	15±0	29.52±0 .73	35±0	91.82±5.38	0±0	25± 0	30± 0	35±0	80.00±16.19
Beta	4.69±0.78	21.01±2.32		35±0	91.34±6.22	-	-		-	-
Beta Modified	-	-		20.34±1.3 6	82.19±7.16	-	-		25.07±3. 13	87.19±26.07

Table 3: Comparison of root mean squares of error (RMSE), coefficient of determination (R^2) and correlation coefficient (r) based on segmented, dent-like, Beta and Beta modified models to germination rate in *Turgenia litifolia* (L.) Hoffm and *Datura stramonium* L

Model	<i>T. litifolia</i>			<i>D. stramonium</i>		
	RMSE	R^2	R	RMSE	R^2	R
Segmented	0.0029	0.921	0.959	0.0044	0.77	0.877
Dent-like	0.0012	0.984	0.991	0.0045	0.752	0.867
Beta	0.0011	0.993	0.996			
Beta						
Modified	0.0019	0.966	0.983	0.0053	0.722	0.849

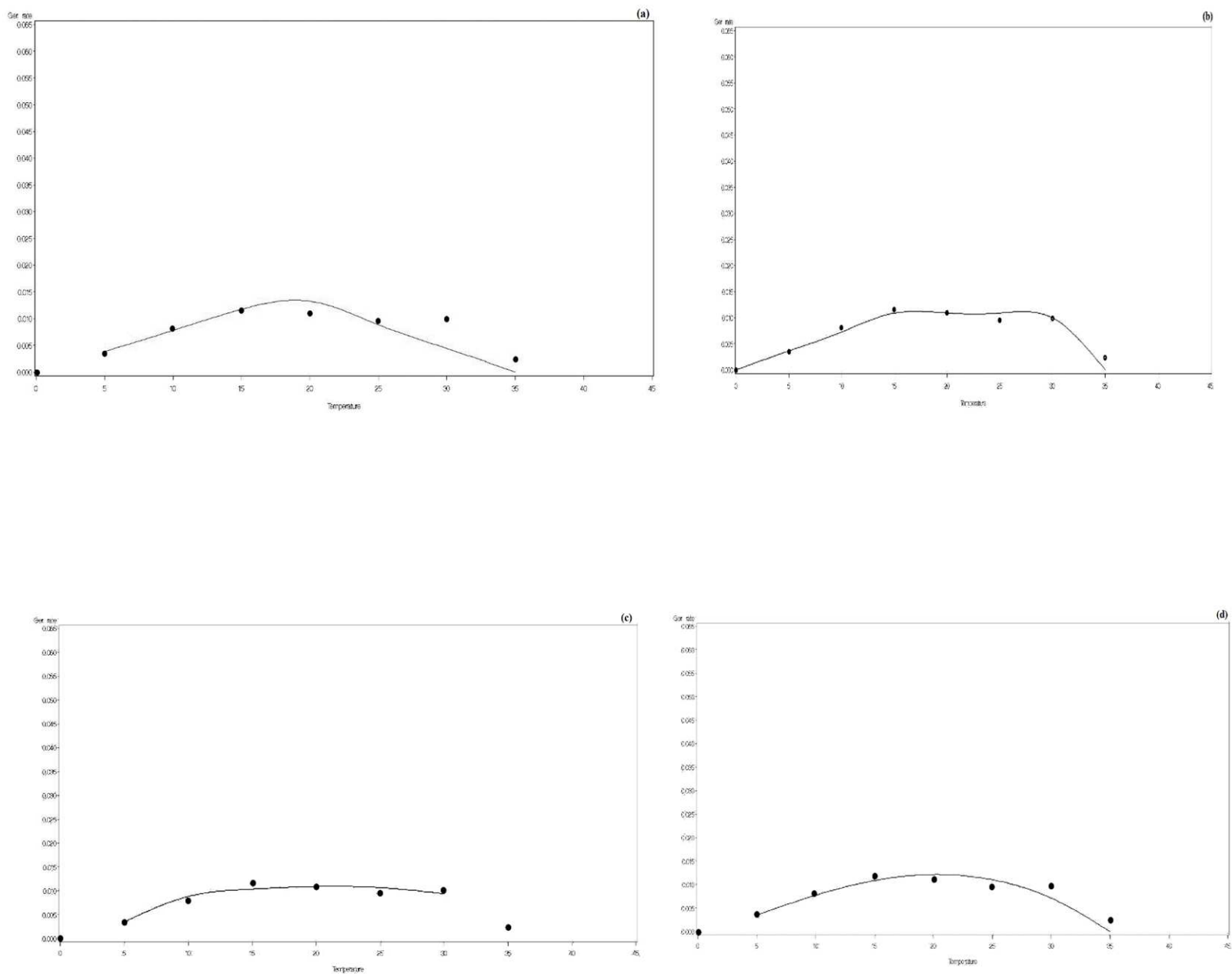


Figure 1: Related germination rate to temperature with segmented (a) dent-like (b), Beta (c) and Beta-modified (d) models for *Turgenia litifolia* (L.) Hoffm.

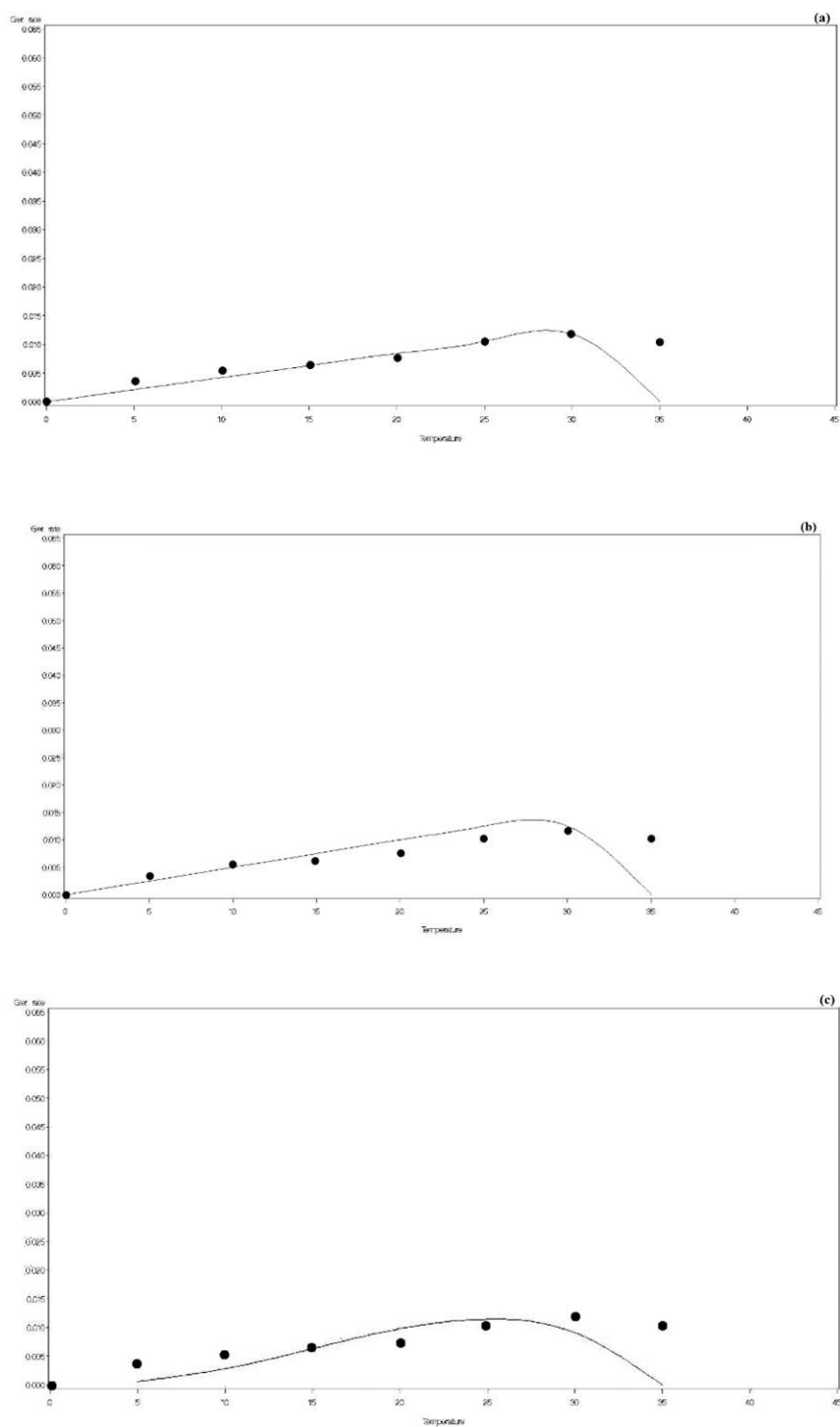


Figure 2: Related germination rate to temperature with segmented (a) dent-like (b) and Beta-modified (c) models for *Datura stramonium* L.