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Origin and temperature on the germination of beggartick seeds

Renato T. de Barros[1], Cibele C. Martins[1], Givanildo Z. da Silva[1] & Dagoberto Martins[1]

[1] Universidade Estadual Paulista/Faculdade de Ciências Agrárias e Veterinárias/Departamento de Produção Vegetal. Jaboticabal, SP. E-mail: renatotbarros@hotmail.com; cibele@fcav.unesp.br (Corresponding author); givanildozildo@hotmail.com; dmartins@fcav.unesp.br

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ABSTRACT
The invasive behavior of beggarticks (*Bidens pilosa* L.) in cropped areas is due to its ecological adaptation and aggressive regeneration, which is dependent on seed germination. The objective of this research was to verify the effects of *B. pilosa* seed origin and temperature on seed germination. The seeds were collected in Entre Rios do Oeste, PR, Botucatu, SP, Capão Bonito, SP, São Joaquim da Barra, SP, Sertãozinho, SP, Selvíria, MS, Barra do Garças, MT, Areia, PB and Manaus, AM. The seeds were evaluated regarding moisture content, 1000-seed weight, germination speed index and germination at 60 days (normal seedlings, dormant seeds and dead seeds) at the temperatures of 10, 15, 20, 25, 30, 35, 40, and 45 ºC. The replicates were distributed according to a completely randomized design in a 9 x 8 factorial arrangement (seed origin x temperature) with four replicates. The means were compared by the Scott-Knott test. *B. pilosa* seeds germination depends on seed origin. Temperatures higher than 35 ºC are lethal to the seeds. The temperature of 15 ºC allows maximum germination in the shortest time whichever the seed origin.

Palavras-chave:
Bidens pilosa
planta daninha
local de produção
dormência

Procedência das sementes e temperatura na germinação de picão-preto

RESUMO
O comportamento invasivo do picão-preto (*Bidens pilosa* L.) em áreas de cultivo se deve à sua adaptação ecológica e regeneração agressiva, alicerçada na germinação das sementes. Objetivou-se, com a presente pesquisa, conhecer o efeito de diferentes procedências e temperaturas na germinação de sementes de *B. pilosa*. As sementes foram coletadas em Entre Rios do Oeste, PR, Botucatu, SP, Capão Bonito, SP, São Joaquim da Barra, SP, Sertãozinho, SP, Selvíria, MS, Barra do Garças, MT, Areia, PB e Manaus, AM e avaliadas quanto ao teor de água, massa de 1000 sementes, índice de velocidade de germinação e germinação conduzida a 10, 15, 20, 25, 30, 35, 40 e 45 ºC e avaliada aos 60 dias. O delineamento experimental adotado foi o inteiramente casualizado em esquema fatorial 9 x 8 (procedências x temperaturas) com quatro repetições e as médias foram comparadas pelo teste de Scott-Knott. A germinação, o vigor e a massa de sementes de *B. pilosa* dependem do local de procedência. Temperaturas superiores a 35 °C são letais às sementes. A temperatura de 15 ºC permite a máxima germinação das sementes em menor tempo da quase totalidade das procedências.

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Introduction

Beggartick is an important weed species spread all over Brazil, infesting areas of annual and perennial crops (Santos & Cury, 2011). The existence of ecotypes adapted to various edaphoclimatic conditions, due to the genetic variability, represents a worrying factor for weed management, because this species tends to invade and establish itself in regions where it was not present before (Schwanke et al., 2008).

Germination is a fundamental process in weed population dynamics and differences of germination behavior between populations of different localities have been reported for some species, such as *Oryza sativa* L. (Schwanke et al., 2008) and *Digitaria insularis* L. (Mendonça et al., 2014).

D. insularis plants from regions with higher annual maximum and mean temperatures produced seeds adapted to these conditions, because they germinated and remained viable under high temperatures as opposed to those produced in regions with mild climate (Mendonça et al., 2014).

These results can be attributed to the adaptive differences of germination and dormancy of these species to the seed origin sites, which contributes to the ecological and evolutive success of the plant (Schwanke et al., 2008; Vivian et al., 2008). Studies on the intrinsic and extrinsic factors that affect germination can be used to develop strategies of reduction of the seed bank and, consequently, of the infestations of cropped areas (Canossa et al., 2008; Martins et al., 2013).

Thus, this study aimed to evaluate the effect of different origins and temperatures on the germination of beggartick seeds in order to help to understand the emergence flow of the soil seed bank and in the adoption of control practices.

Material and Methods

B. pilosa seeds were collected in agricultural areas from nine origins: Entre Rios do Oeste-PR, Botucatu-SP, Capão Bonito-SP, São Joaquim da Barra-SP, Sertãozinho-SP, Selvíria-MS, Barra do Garças-MT, Areia-PB and Manaus-AM. The climatic conditions and geographic coordinates of the seed origin sites were recorded and are presented in Table 1.

After harvested, the seeds were sent to the Laboratory of Seed Analysis of the Unesp in Jaboticabal/SP, placed in paper bags and stored in dry chamber (45% RH and 20 °C). The moisture content of the seeds was determined through the method of the oven at 105 ± 3 °C for 24 h, using two subsamples of 25 seeds, whose results were expressed in percentage (Brasil, 2009). Then, the seeds were evaluated regarding the 1000-seed weight, using eight subsamples of 100 units weighed on precision scale (0.001 g), with results calculated and expressed in grams (Brasil, 2009).

The germination test was conducted with four replicates of 50 seeds, at constant temperatures of 10, 15, 20, 25, 30, 35, 40 and 45 °C, on two paper sheets for germination, previously moistened with distilled water at the proportion of 2.5 times their dry weight, and placed in transparent plastic boxes (11.0 x 11.0 x 3.5 cm) under photoperiod of eight hours.

In the evaluation of germination, normal seedlings were considered as germinated, at 60 days after sowing. The results were expressed in percentage (Brasil, 2009). The data of daily count of germination from 6 to 60 days were used to calculate the germination speed index using the formula established by Maguire (1962).

The remaining seeds of the germination test were longitudinally and transversely cut, through the embryo and one of the halves of each seed was immersed in a 0.2% tetrazole solution, in dark chamber at 35 °C for 2 h, after which the seeds were washed and the reading was immediately performed, classifying the seeds as viable (dormant) and non-viable (dead) (Novembre et al., 2006).

The adopted experimental design was completely randomized, in a 9 x 8 factorial scheme (origins x temperatures) with four replicates. The means of the treatments were compared by Scott-Knott test at 0.05 probability level.

Results and Discussion

B. pilosa seeds from different regions showed moisture contents between 10.1 and 12.9% (Table 2). These percentages are similar to those recommended for receiving seeds of major crops in conventional warehouses: between 10.0 and 13.0% (Carvalho & Nakagawa, 2012). The similarity between the moisture content of seeds from the various origins is primordial so that the tests of germination speed and percentage are not affected by differences of water potentials of the treatments (Tomaz et al., 2015).

There were differences between the weight of seeds from different origins. Seeds produced in Capão Bonito were the lightest ones (0.11 g), because they weighed approximately one fourth of the weight of the heaviest seeds, from Manaus (0.46 g). These differences can be attributed to the genetic variability between the populations and also to the climatic conditions occurring during the formation of the seed, because

Table 1. Geographic and climatic data of the origin sites of the *B. pilosa* seeds

Origin[1]	Climate[2]	Mean annual temperature			Latitude	Longitude	Altitude (m)	Annual rainfall (mm)
		Minimum	Mean	Maximum				
ERRO	Cfa	18.8	23.5	28.2	24º 42’ 14” S	54° 14’ 32” W	230	1762
BOT	Cwa	16.2	20.9	25.7	22° 53’ 09” S	48° 26’ 42” W	840	1373
CB	Cwa	15.4	19.6	23.8	24° 00’ 21” S	48° 20’ 58” W	730	1622
SJB	Aw	18.8	23.6	28.3	20° 34’ 53” S	47° 51’ 17” W	625	1616
STZ	Aw	14.4	22.3	30.3	21° 08’ 16” S	48° 58’ 22” W	579	1452
SEL	Aw	20.9	26.1	31.3	20º 22’ 01” S	51° 25’ 08” W	357	1296
BG	Aw	17.4	24.4	31.3	15° 53’ 24” S	52° 15’ 25” W	322	1484
ARE	As	20.8	24.6	28.3	06º 57’ 46” S	35° 41’ 31” W	623	795
MAN	Am	23.3	27.4	31.5	03º 06’ 00” S	60° 01’ 00” W	92	2307

[1] ERRO (Entre Rios do Oeste), BOT (Botucatu), CB (Capão Bonito), SJB (São Joaquim da Barra), STZ (Sertãozinho), SEL (Selvíria), BG (Barra do Garças), ARE (Areia) and MAN (Manaus)
[2] Köppen’s climate classification. Source: CEPAGRI – Center of Meteorological and Climatic Research Applied to Agriculture

Table 2. Moisture content (MC) and 1000-seed weight (TSW) of *B. pilosa* seeds from different sites of origin

Parameters	Origin									F	CV (%)
	Entre Rios do Oeste	Botucatu	Capão Bonito	São Joaquim da Barra	Sertãozinho	Selvíria	Barra do Garças	Areia	Manaus		
MC (%)	11.3	11.9	12.0	10.7	11.0	11.3	11.9	10.1	12.8	-	-
TSW (g)	0.25 b	0.15 e	0.11 f	0.15 e	0.18 d	0.19 c	0.17 d	0.14 e	0.46 a	908.6**	4.9

Means followed by the same lowercase letter in the row do not differ statistically by Scott-Knott test at 0.05 probability level

Capão Bonito (Cwa climate) is a region colder than Manaus (Am climate), with minimum, mean and maximum annual temperatures of 15.4, 19.6 and 23.8 °C, and 23.3, 27.4 and 31.5 °C, respectively (Table 1).

The temperatures recorded in Manaus, and the mean annual rainfall, were the highest ones among all the municipalities where the samples were collected. The higher 1000-seed weight observed in the seeds from Manaus can be attributed to the climate of the region, because of the greater water availability and higher temperature associated with the high incidence of light in the Amazonian region, compared with the others. These environmental conditions favor the process of photosynthesis, plant metabolism and synthesis of reserve substances accumulated in the seeds during their formation (Motta et al., 2002; Carvalho & Nakagawa, 2012; Lamarca et al., 2013).

Germination was influenced by the interaction of the factors temperature and origin (Table 3). The seeds from all origin sites germinated within a temperature range from 10 to 35 °C, except those from Manaus, for which this process was observed from 15 °C on. This locality showed the highest minimum, mean and maximum annual temperatures among all sites of origin (Table 1). Thus, in Manaus, the plants may have undergone a selection process over time, adapting to initiate germination under higher temperatures.

Seeds of some sites of origin showed higher phenotypic plasticity compared with the others regarding the ideal temperature range for germination. Seeds from Entre Rios do Oeste and Areia, for instance, showed maximum germination within a wide range of temperatures, from 10 to 30 °C. On the other hand, seeds from São Joaquim da Barra and Capão Bonito showed maximum germination only at individual temperatures of 15 and 20 °C, respectively. This phenomenon indicates lower aggressiveness of the seeds from these latter sites in the occupation of new areas with various thermal conditions.

In comparison to the other sites, seeds from Botucatu, Sertãozinho, Selvíria, Barra do Garças and Manaus can be considered as intermediate regarding phenotypic plasticity and ideal temperature of germination.

Based on the evaluation of the nine sites of origin, the temperature identified as most favorable to seed germination was 15 °C. Only the seeds harvested in Capão Bonito and Manaus did not show maximum germination percentage at this temperature.

Temperatures higher than the ideal temperature for germination caused denaturation of proteins that are fundamental in the germination process, affecting the enzymatic reactions of the seeds and compromising germination percentage and speed (Dousseau et al., 2008). However, this harmful effect on beggartick germination above 15 °C was only observed in seeds from São Joaquim da Barra.

For the other sites of origin, the reduction of germination occurred at higher temperatures and was intensified as the values became close to the maximum cardinal temperature for the species. According to Carvalho & Nakagawa (2012), the maximum cardinal temperature is that above which germination no longer occurs, due to the death of the seeds. For beggartick seeds, it was observed that such temperature would be between 35 and 40 °C (Table 3). The seeds from all sites of origin did not germinate at temperatures equal to or higher than 40 °C and, based on the results of the tetrazole test, all seeds that did not germinate were dead and not dormant (Tables 4 and 5).

Table 5 shows the interaction between the effects of seed origin and temperature of the test on the percentage of dormant seeds. While seeds from Capão Bonito, Barra do Garças and Areia virtually did not show dormancy under any condition of temperature, those from the other sites manifested this phenomenon. Therefore, the dormancy would not be a characteristic of the species, but of the ecotype of the observed population. This can partially explain why some research

Table 3. Germination (%) of *B. pilosa* seeds from different sites of origin, subjected to different temperatures in the germination test

Temperature (°C)	Origin								
	Entre Rios do Oeste	Botucatu	Capão Bonito	São Joaquim da Barra	Sertãozinho	Selvíria	Barra do Garças	Areia	Manaus
10	70 aC	67 bC	56 bD	23 bE	53 bD	81 aB	69 bC	92 aA	0 eF
15	73 aC	76 aB	55 bD	39 aE	67 aC	88 aA	78 aB	92 aA	15 dF
20	67 aC	80 aB	69 aC	24 bE	60 bD	83 aB	70 bC	97 aA	55 bD
25	75 aA	68 bB	60 bB	27 bC	69 aB	68 bB	78 aA	82 aA	74 aA
30	76 aB	53 cC	59 bC	24 bD	57 bC	50 cC	87 aA	89 aA	72 aB
35	58 bA	60 cA	26 cB	15 bC	52 bA	28 dB	54 cA	20 bC	36 cB
40	0 cA	0 dA	0 dA	0 cA	0 cA	0 eA	0 dA	0 cA	0 eA
45	0 cA	0 dA	0 dA	0 cA	0 cA	0 eA	0 dA	0 cA	0 eA
F Temperature (T)	617.95 **								
F Origin (P)	103.42 **								
F TxO	18.36 **								
CV (%)	15.70								

Means followed by the same letters, lowercase in the column and uppercase in the row, do not differ statistically by Scott-Knott test at 0.05 probability level

Table 4. Dead seeds (%) of *B. pilosa* from different sites of origin subjected to different temperatures in the germination test

Temperature (°C)	Origin								
	Entre Rios do Oeste	Botucatu	Capão Bonito	São Joaquim da Barra	Sertãozinho	Selvíria	Barra do Garças	Areia	Manaus
10	15 cD	30 cC	44 cB	62 bA	39 bB	15 cD	28 cC	8 cD	43 cB
15	23 cB	25 cB	45 cA	45 cA	27 cB	5 dC	22 bB	9 cC	55 bA
20	20 cC	20 cC	32 cB	65 bA	32 bB	9 dD	30 dB	3 cD	24 dC
25	17 cC	31 cB	40 cA	45 cA	23 cC	20 cC	22 dC	18 cC	26 dC
30	20 cC	44 bB	41 cB	63 bA	40 bB	40 bB	13 dD	11 cD	28 dC
35	36 bD	30 cE	74 bA	70 bA	34 bD	22 cE	46 bC	76 bA	61 bB
40	100 aA	100 aA	100 aA	100 aA	100 aA	100 aA	100 aA	100 aA	100 aA
45	100 aA	100 aA	100 aA	100 aA	100 aA	100 aA	100 aA	100 aA	100 aA
F Temperature (T)	681.48 **								
F Origin (O)	57.31 **								
F TxO	9.88 **								
CV (%)	14.95								

Means followed by the same letters, lowercase in the column and uppercase in the row, do not differ statistically by Scott-Knott test at 0.05 probability level

Table 5. Dormant seeds (%) of *B. pilosa* from different sites of origin subjected to different temperatures in the germination test

Temperature (°C)	Origin								
	Entre Rios do Oeste	Botucatu	Capão Bonito	São Joaquim da Barra	Sertãozinho	Selvíria	Barra do Garças	Areia	Manaus
10	16 aB	1 bC	0 Ac	16 bB	9 aB	5 cC	4 aC	0 aC	57 aA
15	5 bC	0 bD	0 aD	16 bB	7 aC	8 bC	0 aD	0 aD	30 bA
20	13 aB	0 bC	0 aC	11 bB	8 aB	9 bB	1 aC	0 aC	21 cA
25	9 aB	1 bC	0 aC	28 aA	9 aB	13 bB	0 aC	0 aC	0 dC
30	5 bB	3 bB	0 aB	14 bA	3 bB	11 bA	0 aB	1 aB	1 dB
35	7 bC	10 aB	0 aC	15 bB	15 aB	51 aA	1 aC	3 aC	4 dC
40	0 bA	0 bA	0 aA	0 cA	0 bA	0 cA	0 aA	0 aA	0 dA
45	0 bA	0 bA	0 aA	0 cA	0 bA	0 cA	0 aA	0 aA	0 dA
F Temperature (T)	31.38 **								
F Origin (O)	43.74 **								
F TxO	14.25 **								
CV (%)	80.13								

Means followed by the same letters, lowercase in the column and uppercase in the row, do not differ statistically by Scott-Knott test at 0.05 probability level

studies report the occurrence of dormancy in beggartick seeds (Pergo et al., 2008; Whitaker et al., 2010) and others do not (Dube & Mujaju, 2013; Huang et al., 2015).

Among the sites of origin that had seeds with dormancy, it was observed that dormancy can be found in wide ranges of temperatures, between 10 and 35 °C or 10 and 25 °C, respectively, as the seeds from Sertãozinho and Entre Rios do Oeste, or at individual high (35 °C), intermediate (25 °C) or low (10 °C) temperatures, as observed in seeds from Botucatu or Selvíria, São Joaquim da Barra and Manaus, respectively.

Some researchers refer to this phenomenon as thermo-dormancy, which would be a dormancy induced by extreme temperatures, high or low, and that prevents germination under non-ideal conditions for seed survival (Carvalho & Nakagawa, 2012). There are reports of thermodormancy in seeds of other weed species, such as *Melaleuca quinquenervia* (Cav.) Blake (Martins et al., 2013) and *D. insularis* L. (Mendonça et al., 2014).

The occurrence of dormancy due to the low temperature of 10 °C used in the germination test of the seeds from Manaus can be explained by the contrast with the high mean temperature of 27.4 °C of this site; thus, the beggartick population adapted and the seeds were harvested. In this case, there was induction of dormancy by low temperatures, as observed in seeds of *D. insularis* by Mendonça et al. (2014).

Considering the data of germination speed index and germination test evaluated together (Tables 3 and 6), it was possible to identify the optimal temperature for beggartick germination, since the optimal temperature can be considered as the one that leads to maximum germination in the shortest time interval (Carvalho & Nakagawa, 2012; Tomaz et al., 2015, 2016).

For seeds from São Joaquim da Barra, Sertãozinho and Selvíria, the optimal temperature for germination would be 15 °C; for Botucatu, Capão Bonito and Areia, it would be 20 °C; for Entre Rios do Oeste and Manaus, it would be two temperatures: 15 and 30 °C, and 25 and 30 °C, respectively; and for Barra do Garça, it would be three temperatures: 15, 25 and 30 °C. Based on this criterion, it can be claimed that beggartick seeds showed different optimal temperatures for germination depending on their origin (Tables 3 and 6). Nevertheless, in general, it can be said that the optimal temperature for *B. pilosa* seeds would be between 15 and 30 °C, but with predominance of 15 °C, because it allowed the highest germination percentage in the shortest time, for seeds from five out of the nine sites of origin.

Although germination can occur within wide limits of temperature, some of them allow maximum speed, uniformity and percentage of germination, together (Sbrussi & Zucareli, 2014). The lowest germination speed of seeds from São Joaquim da Barra, compared with the other sites, evidenced by the germination speed index, is due to the low vigor and physiological quality of this lot, also confirmed by the high percentage of dead seeds (Tables 6 and 4). The influence of seed vigor is also expressive on all aspects of germination, from its speed to the possibility of occurrence of germination (Martins et al., 2013; Sbrussi & Zucareli, 2014).

Table 6. Germination speed index of *B. pilosa* seeds from different sites of origin subjected to different temperatures in the germination test

Temperature (°C)	Origin								
	Entre Rios do Oeste	Botucatu	Capão Bonito	São Joaquim da Barra	Sertãozinho	Selvíria	Barra do Garças	Areia	Manaus
10	12.30 cA	12.68 cA	12.43 bA	11.38 aB	12.03 cA	12.81 cA	12.68 bA	13.13 cA	11.00 cB
15	15.95 aC	16.86 bC	15.87 aC	12.44 aD	18.80 aB	21.42 aA	16.75 aC	17.45 bC	11.25 cD
20	14.25 bC	17.66 aB	17.13 aB	12.26 aD	14.67 bC	15.74 bB	16.65 aB	20.25 aA	12.86 bD
25	14.98 bC	18.20 aA	17.59 aA	12.30 aD	16.38 bB	14.96 bC	17.46 aA	18.45 bA	16.54 aB
30	16.56 aC	15.40 bC	17.26 aB	12.76 aD	15.99 bC	12.61 cD	17.61 aB	18.94 bA	16.00 aC
35	14.39 bB	16.62 bA	12.07 bC	11.90 aC	15.35 bB	11.83 cC	13.11 bC	11.65 dC	12.14 bC
40	0.00 dA	0.00 dA	0.00 cA	0.00 bA	0.00 dA	0.00 dA	0.00 cA	0.00 eA	0.00 dA
45	0.00 dA	0.00 dA	0.00 cA	0.00 bA	0.00 dA	0.00 dA	0.00 cA	0.00 eA	0.00 dA
F Temperature (T)	1730.96 **								
F Origin (O)	34.79 **								
F TxO	10.21**								
CV (%)	9.10								

Means followed by the same letters, lowercase in the column and uppercase in the row, do not differ statistically by Scott-Knott test at 0.05 probability level

B. pilosa seeds from Areia showed higher germination and vigor (Tables 3 and 6), possibly due to the climatic conditions observed in this site, with constant rainfalls during the filling of the seeds and a dry period at the end of the maturation process. Carvalho & Nakagawa (2012) reported that these characteristics of the production site are favorable to the physiological potential of seeds of major crops.

Therefore, the knowledge on the ecophysiology of beggartick seeds germination is important to understand the emergence flow of the soil seed bank, as well as in the adoption of weed control and soil management practices that disfavor the emergence and survival of this species (Martins et al., 2011).

Conclusions

1. Germination, vigor and weight of *B. pilosa* seeds depend on the site of origin.

2. Temperatures higher than 35 °C are lethal to the seeds.

3. The temperature of 15 °C allows maximum seed germination in shortest time for almost all sites of origins.

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