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Germination Performance of Yellow Cosmos: Understanding Its Invasion under Tropical Conditions

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Abstract

To further investigate the recently observed invasion of a new weed in the São Paulo areas, Brazil, we studied the germination performance and emergence characteristics of *Bidens sulphurea*. We measured the seed germination under different fixed temperatures (15, 20, 25, 30 and 35°C), photoperiods (18h/6h, 12h/12h, 6h/18h and 0h/24h [light/dark], respectively), light quality (white, blue, yellow, green, red and dark condition); and emergence in two seasons (winter and spring) in different sowing depths (0, 1, 3, 5, 7 and 9 cm). This species has the ability to germinate and emerge above 90% in a range of conditions of light, but it is very sensitive to variations in temperature, and several reductions on its germination and emergence are found bellow 20°C. The emergence of this species is severely controlled by seasonality and could occur up to 9 cm depth in Brazilian spring.

Keywords: *Bidens sulphurea*, emergence, temperature, light quality, sowing depth

1. Introduction

Bidens sulphurea (yellow cosmos) is an annual weed with sexual reproduction, originated in Central America and disseminated for ornamental purposes (Kissmann & Groth, 1999). Its population is building-up rapidly and spreading around agricultural and urban sites on São Paulo state, Brazil. As well as *Bidens pilosa* (Kissmann & Groth, 1999), this species has the potential to be one of the main weeds in tropical zones. Indeed neither biological nor ecological information are available on the environmental factors influencing seed germination and seedlings emergency for this species.

The environmental conditions such as light, temperature, and the association of both (J. M. Baskin & C. C. Baskin, 2004) and the vertical distribution of the seeds on the soil (Souza, Pitelli, Simi, & Oliveira, 2009) are the main factors that influence seed germination and emergence in the tropics, promoting or breaking the dormancy of the seeds. Seed banks are the main source of weeds regeneration and potential for spreading in agricultural sites (Carmona, 1992).

Seeds, in general, germinate within a broad temperature range; the optimum temperature allows the highest seed germination performance (Roberto & Habermann, 2010). In addition, the maximum and minimum temperatures, above and below which seed germination may not occur, help to characterize the geographical and climatic region where seeds or fruits were harvested.

The knowledge of optimum conditions for seed germination, mainly temperature and light, are fundamental, since germination success is directly linked to each species' ecological characteristics (Figliolia, Oliveira, & Pinã-Rodrigues, 1993; Sousa, L. F. Braga, F. B. Braga, Sá, & Moraes, 2000) as well as speed (Carvalho & Nakagawa, 2000). The soil depth from which a seed can germinate and produce seedlings is variable between species (Guimarães, Souza, & Pinho, 2002), as *Euphorbia heterophylla* (Machado Neto & Pitelli, 1988), *Desmodium purpureum* (Oliveira Jr. & Delistoianov, 1996), *Ipomoea asarifolia* (Dias Filho, 1996) and *Amaranthus retroflexus* (Ghorbani, Seel, & Leifert, 1999). These data are very important to adopt a more appropriate management practice, such as herbicides on pre or post emergence or mechanical control (harrows and cultivators).

Weeds use efficiently the natural resources in nature, especially sunlight (Schmitt & Wulff, 1993). Consequently, they are also very well adapted to specific environments, showing highly heritable traits such as the high seed production (Ackerly et al., 2000; Masin, Zuin, Archer, Forcella, & Zanin, 2005), aggressiveness and success in spreading.

To further investigate the invasion "aggressiveness" of *B. sulphurea*, we measured the influence of temperature, photoperiod, quality of incident light and seeds sowing period at different depths, on seed germination and seedling emergence of this species. The main question addressed was testing the assumption that high spreading of *B. sulphurea* occurs because the species show high germination and the environmental changes related to light and temperature exercise small influence in this process.

2. Material and Methods

2.1 Plant Material

Bidens sulphurea achenes (seeds) were randomly collected from mature capitula of healthy adult plants, in a few hours before beginning each experiments at the agricultural fiels on Faculdade de Ciências Agrárias e Veterinárias (FCAV-UNESP), Jaboticabal city, São Paulo state, Brazil. We adopted this procedure to avoid seed dormancy caused by storage (Finch-Savagel & Leubner-Metzger, 2006).

2.2 Effects of Temperature and Light on Germination

The three experiments were conducted independently in a germination chamber using a completely randomized design, being determined the effects of: 1- temperature (15, 20, 25, 30 and 35°C, under 12/12 photoperiod); 2- photoperiod (18/6, 12/12, 6/18 and 0/24 hours light/dark at 25°C); 3 - quality of incident light (yellow, blue, white, green, red and complete dark at 25°C), on germination of *B. sulphurea*. In all experiments 20 seeds were used in each box per repetition (4 repetitions), distributed in five columns in each box. For moisture maintenance and standardization, two filter paper sheets moistened with 10 mL of distilled water were used per treatment. Seed was considered germinated when the radicle visibly protruded through the seed coat (Reddy & Singh, 1992).

To test germination in the dark, boxes were wrapped in a double layer of aluminum foil. The light quality was obtained wrapping the box in a cellophane foil (yellow, blue, white, green and red) (Almeida & Mundstock, 2001). Germination was recorded daily during seven days, by removing germinated seeds. At the end of this period germination (G%) and germination rate (GR) were calculated (Maguire, 1962). All the evaluations were done in a dark room under green light (Felippe, Válio, Pereira, Sharif, & Vieira, 1983).

2.3 Influence of Seasonality on Seed Burial Depth

These experiments were conducted using two sowing seasons, the first one conducted on June 2009 (winter) and the second one on September 2009 (spring).

Fifty seeds were sowed in pots of 5 L at depths of 0 (soil surface), 1, 3, 5, 7 and 9 cm, in a randomized design with five repetitions. The soil (38% clay, 5% silt and 57% sand) was dried in the shadow and passed through a 5-mm sieve. Soil in the pots was moistened initially using a mist sprayer and then sub irrigated to maintain adequate soil moisture. Daily, for 21 days after sowing (DAS), seedlings were counted and removed (Souza et al., 2009). With the daily emergence data, for each sowing season, emergence rate was calculated (ER) (Maguire, 1962). Seedling emergence was defined as the coleoptile being visible at the soil surface (Reddy & Singh, 1992).

2.4 Statistical Analysis

The data were statistically analyzed using one-way ANOVA, and the means were compared by Tukey test at 5% level. For germination (G%) and emergence (E%) percentage, arcsin (sqr(x+0.5)/100) was calculated to perform the statistical analysis.

3. Results and Discussion

3.1 Effects of Temperature and Light on Germination

The highest germination percentage (G%) was observed between 25 and 30°C (94 and 73% respectively) and the lowest between 15 and 20°C (1.25% for both treatments). Similar effects were observed in germination rate (GR), where the highest rate (11.79) was observed at 25°C and the lowest between 15 and 20°C (0.08 and 0.04 respectively) (Figure 1). Seeds placed at 25 and 30°C treatments spent three days to achieve 50% germination; at 35°C spent seven days and at 15 and 20°C did not reach two percent (Figure 1), suggesting that the optimum temperature for this species occurs near 25°C.

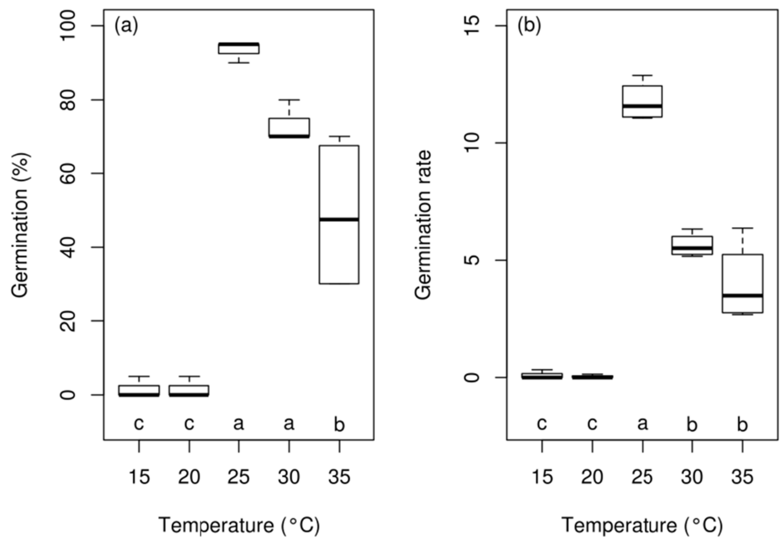

Figure 1. Boxplot of germination (G%) and germination rate (GR) of *Bidens sulphurea* seeds submitted to different temperatures. The line in the middle of each box indicates the 50th percentile of the observed distribution; the bottom and top parts of each box represent the 25th and 75th percentiles, respectively; the bottom and top error bars of each box are the 5th and the 95th percentiles of the observed distribution. Different letters indicate significant difference ($P<0.05$) between the treatments

Optimum temperature is classified as promoting the highest germination rate in the shortest period of time (Malavasi, 1988). Therefore, high temperatures may result in decreased amino acid supply, compromising protein synthesis, and can also denaturate proteins, compromise anabolic reactions, and alter cellular membrane fluidity, causing cellular material loss (Riley, 1981). On the other hand, lower temperatures decrease metabolic rates to the point where vital reactions can no longer operate, and can also influence the cellular membrane physical state, from the liquid-crystalline to crystalline state (Hendricks & Taylorson, 1976).

Non plastic weeds require a critical temperature to germinate, while plastic species germinate over a range of temperatures (Burke, Thomas, Spears, & Wilcut, 2003). In this case *B. sulphurea* presented moderate plasticity, germinating above 50% between 25 and 35°C. The same plasticity can be observed in a congeneric species, *B. pilosa*, in which maximum germination occurs between 25 and 30°C, and inhibition occurs below 20°C and above 35°C (Reddy & Singh, 1992). Considering that in tropical fields the soil average temperature is around 25°C, temperature would not be a limiting factor for germination throughout the year. Not only congeneric species present this behavior, the highest germination of *Rottboellia cochinchinensis* occurs at 25ºC and a severe reduction could be observed bellow 10ºC and above 30ºC (Silva, Parreira, Alves, & Pavani, 2009).

In general, when exposed to light (treatments 18/6, 12/12 and 6/18), germination was higher than 90%, while at the dark it was around 70%. In addition, germination rate decreases drastically when we compare light (10.0 – 14.54) and dark (4.66) treatments (Figure 2). The time to 50% germination (T_{50}) was 1 day for the 18/6 treatment, 2 days for 12/12 and 6/18, and 4 days to 0/24 treatment.

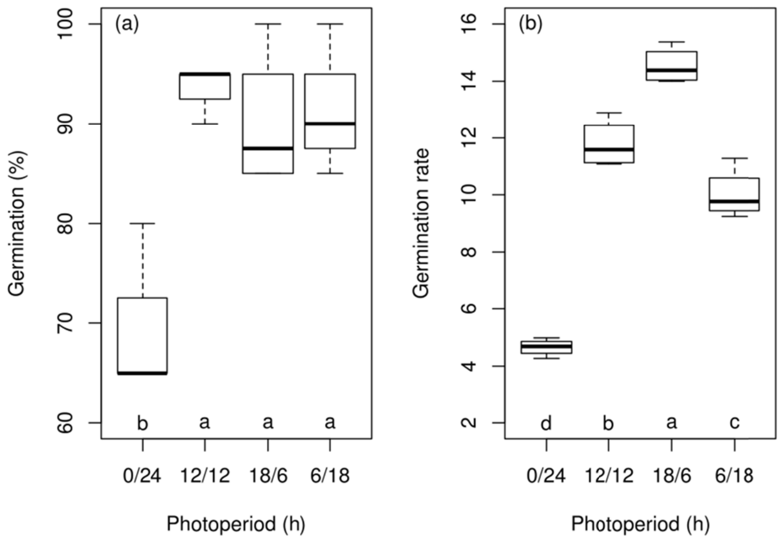

Figure 2. Boxplot of germination (G%) and germination rate (GR) of *Bidens sulphurea* on different photoperiods. Box plot characteristics are as described in Figure 1

For most of aggressive weeds, light is not a requirement for germination. Several weeds such as *Rumex obtusiflius* (Benvenuti, Macchia, & Miele, 2001) and *Alternanthera tenella* (Canossa et al., 2008) germinate above 70% in absence of light, suggesting that these species could germinate well on the surface and in depth sowing, facilitating its spread.

In an agricultural environment, the seeds can be exposed to light for prolonged periods, and light, in most cases, presents a complex spectral composition (Ishimine, Murayama, & Matsumoto, 1988). Light qualities did not affect the germination percentage (93.3 – 97.5%) and neither the germination rate (7.60 – 9.36). We observed reductions in absence of light in G% (68.80%) and GR (4.62) (Figure 3), and the T_{50} was similar in all treatments, being around 2 days in presence of light (R, G, Y, B and W) and 3 days in absence of light (D).

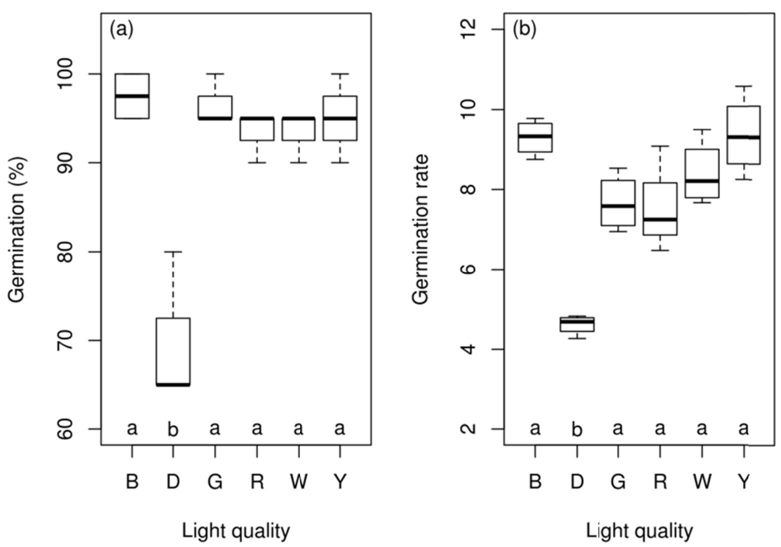

Figure 3. Boxplot of germination (G%) and germination rate (GR) of *Bidens sulphurea* in different light qualities (B-blue, D-dark, G-green, R-red, W-white, Y-yellow). Box plot characteristics are as described in Figure 1

While the seeds of some species need critical light and temperature conditions to germinate, others can germinate equally in both light and dark (Chauhan & Jonson, 2010) and a range of temperatures (Burke et al., 2003). The ability of *B. sulphurea* to germinate over a range of light and temperature conditions may explain its ability to emerge year round in tropical climates and its adaptations to spread from São Paulo state.

3.2 Influence of Seasonality on Seed Burial Depth

The seasonality and sowing depths had a marked influence on the emergence of *B. sulphurea* seedlings as well as observed for *B. pilosa* (Souza et al., 2009). In June the emergence of this species began around 7 days after sowing (DAS) and in September around 4 DAS. The highest average emergence (E%) observed in June was 22% (Figure 4A) while in September was 84% (Figure 4C).

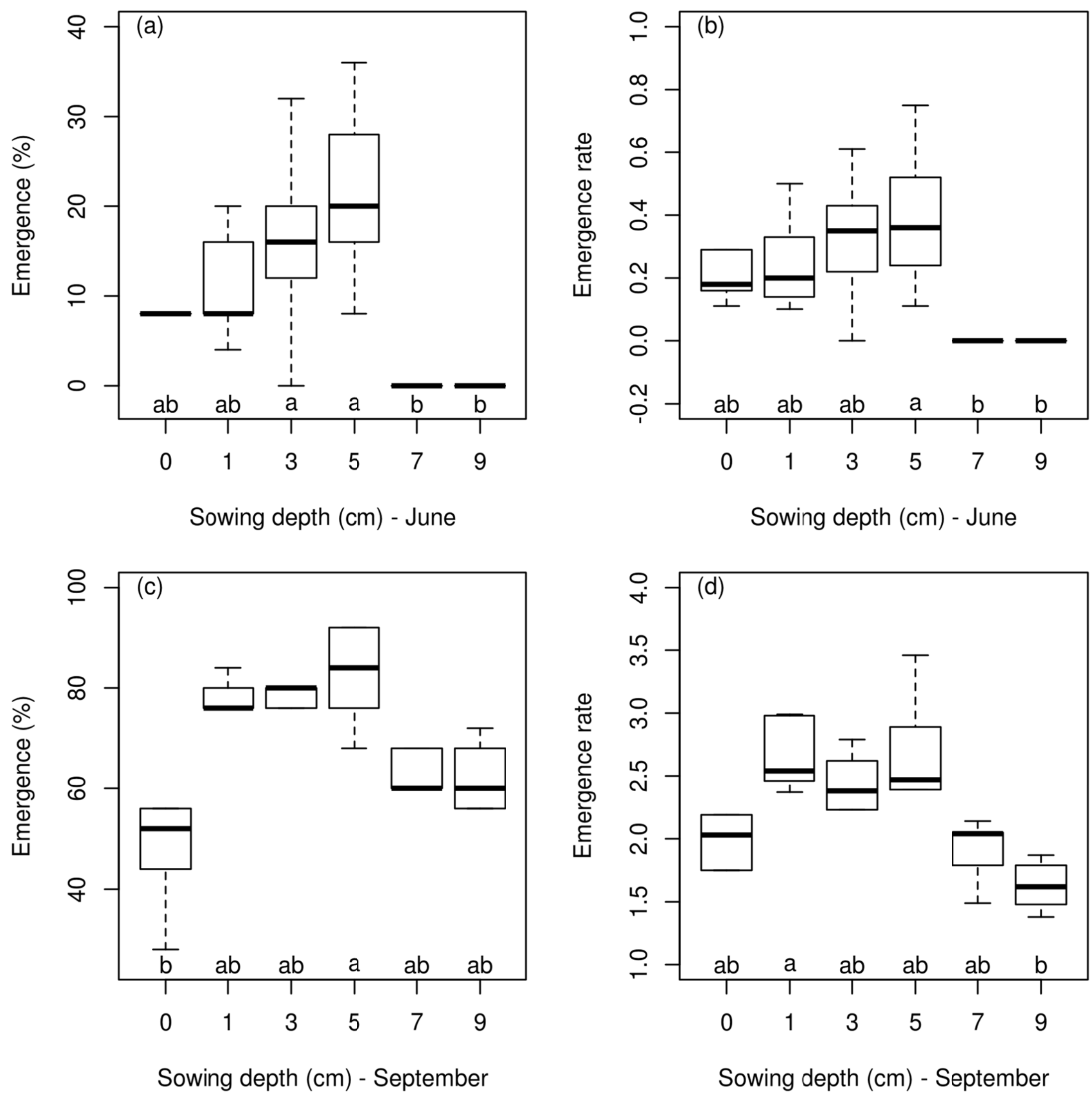

Figure 4. Boxplot of emergence (E%) and emergence rate (ER) of *Bidens sulphurea* seeds deposited on different sowing depths in two seasons (June [E% (A), ER (B)] and September [E% (C), ER (D)] 2009). Box plot characteristics are as described in Figure 1

This anticipation and the increment at the seedlings emergence are probably due to a temperature increase recorded in September compared to June, being that in June 2009 the minimum registered temperature was 8.6ºC and maximum 27.7ºC (monthly average 17.8ºC) and in September 2009 varied between 12.9ºC and 33.5ºC (monthly average 22.5ºC). These results are consistent with the stimulation of germination by temperature (Figure 1).

Seedling emergence of *B. sulphurea* was greatly influenced by seed burial depth mainly in June when the emergence bellow 7 cm depth was less than 1% and the ER was near zero (Figure 4B). The highest emergence was observed between 3 and 5 cm depth (18 and 22%) and the ER was 0.32 and 0.40. In September, as a result of temperature increase, the E% was above 50% (Figure 4C) even in the all depths and the ER increased in all depths too. In general the highest emergence in June was 24% and in September 84%.

In our study of temperature and light (Figures 1 and 2) germination percentage was higher than observed at the soil surface in September. This difference could be due to poor soil-seed contact or limited water availability on the soil surface than on the filter papers (Ghorbani et al., 1999). Seeds buried below 2 mm on the soil surface usually receive less than 1% of incident light (Egley, 1986). According to our study of light (Figures 2 and 3) *B. sulpurea* seeds germinated above 60% in dark conditions. In this case the observed variations on emergence at different sowing depths in both seasons are exclusively related to variations on soil temperature, suggesting that this species is light insensible but very sensible to temperature.

4. Conclusions

The results of this study highlight the *B. sulphurea* ability to germinate and emerge above 90% in a broad range of conditions of light, confirming our hypothesis, but this species is very sensitive to variations in temperature, and a severe reduction on germination and emergence is found bellow 20°C. The emergence of this species is severely controlled by seasonality and could germinate up to 9 cm depth in Brazilian spring.

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