JEAP

ISSN: 2525-815X

Journal of Environmental Analysis and Progress

Journal homepage: www.jeap.ufrpe.br/

SCIENTIFIC NOTE

10.24221/jeap.2.1.2017.968.7-10

Density-dependent regulation in a weed *Bidens sulphurea* (Cav.) Sch. Bip. (Asteraceae)

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ARTICLE INFO

Received 20 Sept 2016
Accepted 27 Sept 2016
Published 31 Jan 2017

ABSTRACT

The density effects on performance of a weed *Bidens sulphurea* (Asteraceae) were evaluated experimentally. There are very few studies available to improve the process of density-dependent to invasive species. We used an experimental set-up in which the population of this weed species is partitioned into different density groups (1, 2, 4 and eight plants per pot) based on local conspecific density to investigate density-based population strategies. The difference between the greatest and the lowest density (8 and 1 plant per pot) was considerably high, around 41%, regarding the variables measured (stem height and diameter, leaf number and size). Plants at higher densities become taller and thinner as a consequence of intraspecific competition. Results suggest that the responses of *B. sulphurea*, in dense populations, can affect the persistence of population over time. It may be useful in the future for the biological control of this species.

Keywords: intraspecific competition, invasive species, plant performance, population ecology.

Introduction

Biological invasion of natural communities by invasive species is a major threat to biodiversity globally (Levine et al., 2003; Pyšek et al., 2012). Weeds can affect negatively the structure and functioning of ecosystems around the world, reducing the wealth of native species, changing water or fire regimes, and altering the nutritional status of the soil (Strayer et al., 2006; Didham et al., 2007; Ehrenfeld, 2010; Weidenhamer & Callaway, 2010; Ricciardi et al., 2013). The ability to develop a mechanism or pathway to predict biological invasions is still a major challenge for researches in Ecology (see Peterson, 2003).

The density-dependent and its effects have been recognized as a crucial role in population dynamics of terrestrial plants (e.g., Brook & Bradshaw, 2006). Density-dependent is related to population responses (growth, mortality, and fecundity) to increased plant density of neighbors. To our knowledge, the density dependence has been considerably less investigated in invasive than native species in Brazil. For this reason, the density effect on the vegetative output of invasive species is still poorly documented in Neotropical regions. Moreover, the interplay of density, growth, and size have not previously been explored in *Bidens sulphurea* (Cav.) Sch. Bip. (Asteraceae). Thus, we aimed to quantify the density-dependent processes acting in populations of the weed *B. sulphurea* using experimental data and to examine the adverse effects of the different density dependence types on plant performance.

Bidens sulphurea (Asteraceae), a synonymous *Cosmos sulphureus* Cav. in the literature, is commonly known in Brazil as yellow cosmos or 'cosmo-amarelo', 'picão-grande' and 'aster does México'. It is a native herbaceous species from Mexico that is widely used as an ornamental. It has been introduced in Brazil, and it became a weed widely distributed in urban, crop and pasture areas (Lorenzi, 2008). *Bidens sulphurea* presents rapid growth and is known for its invasive capability and weed status, inhibiting the establishment of economically important crops and ornamental plants (Lorenzi & Souza, 2008). Their individuals can tolerate a wide range of environmental as well as germinate in different substrates (Sena et al., 2012). Its inflorescence can attract native bees (Apidae) due to the large amount of nectar produced (Mouga & Krug, 2010). Additionally, this plant is also traditionally used in treatments of tropical diseases such as malaria in Brazil (e.g., Botsaris, 2007; Aguiar et al., 2013).

Twenty leaves and inflorescences were collected for plant identification at Campus Glória, Universidade Federal de Uberlândia, Uberlândia, Minas Gerais, Brazil. Dr. Jimi Nakajima made plant identification at Universidade Federal de Uberlândia. Seeds of *B. sulphurea* were randomly collected in June 2012 from a population growing in a degraded area of Brazilian tropical savanna (Campus Glória, 48°12'33.34" W and 18°57'17.55" S). In March 2013, the seeds were germinated in Petri dishes under controlled conditions in incubator [at a mean temperature of 25°C and a photoperiod of 12 hours light per 12 hours dark, under white fluorescent lamps (12.1 ± 5.1 $\mu mol.m^{-2}.s^{-1}$ of photosynthetically active radiation)]. After five days, seedlings were individualized and transferred to plastic pots [thickness (0.9 mm); height (7.8 cm); area (81.71 cm^2) and volume (415 ml)]. The pots were filled with 50% of the commercial substrate (Bioplant©) containing organic humus and nutrients, and 50% of vermiculite. Moreover, no further fertilizer input was done, and the pots were watered daily.

This experiment was conducted during March 2013 in a greenhouse at the Instituto de Biologia of Universidade Federal de Uberlândia, under natural light conditions and with temperatures ranging from 20-40°C. The greenhouse remained closed to avoid the entry of insect herbivores and uncontrolled background herbivory, which might interfere with the research. Aiming to verify the effect of density-dependent on the performance of *B. sulphurea*, an experiment was set up based on four groups with different plant densities, following a geometric proportion: G1 (group with one plant per pot or density of 0.012 cm^{-2} per plant); G2 (group with two plants per pot or density of 0.024 cm^{-2} per plant); G4 (group with four plants per pot or density of 0.049 cm^{-2} per plant) and G8 (group of eight plants per pot or density of 0.098 cm^{-2} per plant). The number of samples for the groups of plants were: G1 (n = 40 pots and 40 plants); G2 (n = 40 pots and 79 plants); G4 (n = 40 pots and 157 plants) and G8 (n = 40 pots and 308 plants), with a total of 160 pots and 584 plants (16 plants were lost due to unknown mortality factors). After four weeks, plants of each group were examined for growth and development. It was measured the stem height (cm), the diameter of stems (cm), leaf number and length of the first leaf pair (cm). Plants infected by pathogens were occasionally discarded.

Normality was tested using Shapiro-Wilk test and homoscedasticity using Levene's test. The number of leaves is not showed normal distribution neither homogeneous variance. Original data was transformed in Log whenever necessary to fit the assumptions of normality and to permit the use of parametrical statistical tests. Quantitative data are presented as mean ± standard error per pot. Comparisons among density-dependence groups and plant performance parameters were analyzed using a One-way ANOVA test to parametric data and Kruskal-Wallis test for non-parametric data. Post hoc pairwise multiple comparisons were carried out using Tukey's test for parametric data and Dunn's test for non-parametric data. Statistical procedures were performed using Statistica 10 software and graphics were performed using Minitab Statistical Software.

According to plant density (1 to 8 plant per pot) all sampled variables differed [number of leaves ($KW\text{-}H_{(3;160)} = 128.21$; $p < 0.0001$), stem size ($F_{(3;156)} = 35.91$; $p < 0.0001$), diameter ($F_{(3;156)} = 350.98$; $p < 0.0001$) and the length of the first leaf pair ($F_{(3;153)} = 121.41$; $p < 0.0001$)] (Figure 1). The results showed that the higher density of *B. sulphurea* leads to a lower development of those plants. Post hoc pairwise multiple comparisons showed that about leaves number, G1, and G2 did not differ, but the other groups showed a reduction of leaves number with an increased plant density (Figure 1A). The difference between groups with the lowest density (G1) to the higher density (G8) was 36.13%. Considering the stem size, G1, and G2, and G2 and G3 did not differ among them, but there was a reduction of stem size with an increased plant density (Figure 1B). The difference between groups with the lowest density (G1) to the higher density (G8) was 39.58%. In relation the stem diameter and leaf size, all groups were statistically different among them. The difference among groups with the lowest density (G1) to the higher density (G8), for stem diameter and leaf size, was 51.23 and 36.53%, respectively (Figure 1CD). In general, as the density is folded, the plant performance is reduced to 16.03% on average.

These results corroborate the density-dependent hypothesis, in which plants present in a limited space and reduced availability of nutrients can negatively affect the development of their neighbors. Thus, *B. sulphurea* plants that had better development during the study period were those with lower population density. According to Arenas et al. (2002), the increase in density may influence both, mean size and morphology, of the plants and thereby induce changes in the playback. Moreover, the negative effect of density on the plant size may reduce the percentage of fertile plants and possibly their annual reproductive assistance (Arenas et al., 2002). These density effects on reproductive parameters in *B. sulphurea* were not tested yet. In the future, new data will be collected such as flowering, fruiting, leaf area, nutritional analysis of macro and micronutrients.

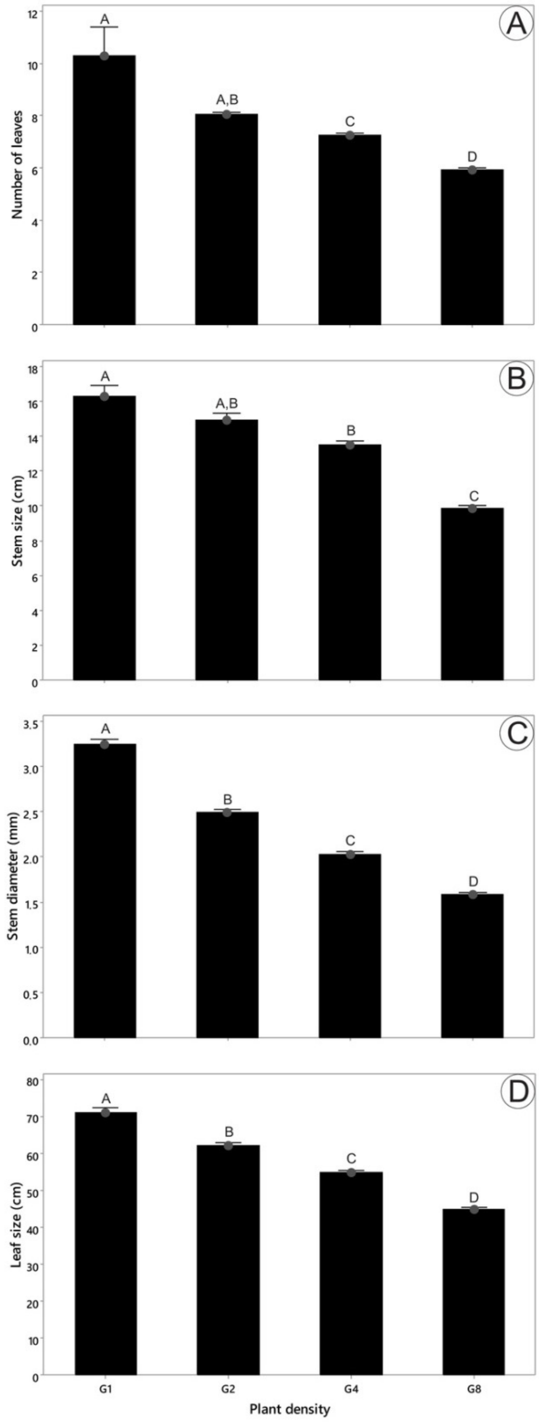

Figure 1. Performance characteristics of *Bidens sulphurea* individuals growing at the four experimental densities (G1 = 1, G2 = 2, G4 = 4, G8 = 8 plants per pot) as mean values (± SE). A. Number of leaves; B. Stem size; C. Stem diameter; and D. Leaf size. Letters indicate the groups differentiated by post hoc tests with significance at $p < 0.05$.

Acknowledgements

Authors thank Dr. Jimi Nakajima of the Universidade Federal de Uberlândia for the assistance with plant identification. This work was partially granted by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG), and Duratex S.A.

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