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Article

WATER STRESS IN THE PRODUCTION AND QUALITY OF *Bidens pilosa* AND *Raphanus raphanistrum* SEEDS

Estresse Hídrico na Produção e Qualidade de Sementes de Picão-Preto e Nabiça

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ABSTRACT - Plants in soils with low water availability may present a reduction of their leaf area and photosynthetic rate, as well as lower assimilated compound supply for seeds. Knowing the physiological quality and seed production of weeds generated under water deficit conditions can help understanding the survival and competition strategies of species. The objective of this work was to evaluate the effect of water stress on the production and germination of *Bidens pilosa* and *Raphanus raphanistrum* seeds. Plants were maintained in soils with different water potentials (-0.03, -0.07 and -1.5 MPa) throughout their cycle, until seed production, when they were harvested. Then, evaluations were performed to find out the number of seeds per plant and number of seeds per pod (*Raphanus raphanistrum*). The evaluation on the germination of these seeds was performed on moistened paper, with four replications, at 20-35 ^{o}C and 8 hours of light per day, weekly, until 28 days after seeding. The experimental design was completely randomized with three treatments (soil water potential: -0.03 MPa, -0.07 MPa and -1.5 MPa). The results were submitted to analysis of variance by F test, and the means of the treatments were compared by Tukey's test at 5% probability. It was concluded that *Bidens pilosa* is more adapted to water deficit conditions than *Raphanus raphanistrum*, due to the higher production of seeds, better germination and seedlings with greater vigor.

Keywords: germination, vigor, water availability.

RESUMO - Plantas em solos com baixa disponibilidade hídrica podem apresentar redução da área foliar, da taxa fotossintética e menor suprimento de assimilados para as sementes. O conhecimento da qualidade fisiológica e da produção de sementes de plantas daninhas geradas sob condições de déficit hídrico pode contribuir para o entendimento de estratégias de sobrevivência e competição das espécies. O objetivo deste trabalho foi avaliar o efeito do estresse hídrico da planta sobre a produção e a germinação das sementes de ***Bidens pilosa*** *e* ***Raphanus raphanistrum****. As plantas foram mantidas em solos com diferentes potenciais hídricos (-0,03, -0,07 e -1,5 MPa) durante todo o ciclo, até a produção de sementes. Na fase de produção de sementes, estas foram colhidas e realizaram-se as seguintes avaliações: número de sementes por planta e quantidade de sementes por vagem (nabiça). A avaliação da germinação dessas sementes foi feita sobre papel umedecido com quatro repetições, a 20-35 ^{o}C e 8 horas de luz, semanalmente, até os 28 dias após semeadura. O delineamento utilizado no experimento foi inteiramente casualizado com três tratamentos (potenciais hídricos no solo: -0,03 MPa, -0,07 MPa e -1,5 MPa). Os resultados foram submetidos à análise de variância pelo teste F, e as médias dos tratamentos, comparadas pelo teste de Tukey a 5% de probabilidade. Concluiu-se que o picão-preto é mais adaptado às condições de déficit hídrico do que a nabiça, devido à maior produção de sementes com maior vigor e germinação.*

Palavras-chave: germinação, vigor, disponibilidade hídrica.

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INTRODUCTION

As a result of the increase in the greenhouse effect and global warming, the planet has been undergoing climate change, which has triggered changes in the seasons and in the rainfall regime. Consequently, drought periods are caused this phenomenon, which makes it more critical (IPCC, 2007). These alterations may cause changes in agricultural practices, such as nutrient cycling and soil water availability, as well as losses in productivity (Nobre et al., 2007). In Brazil, droughts or dry seasons are a frequent and characteristic phenomenon (Reddy et al., 2004; Meneses et al., 2006).

When the environmental conditions are antagonistic to the cultivated species, weeds, which present a high degree of adaptation and can be ecologically called factors or degrees of aggression, can survive and perpetuate more easily (Ronchi et al., 2010). Weeds can germinate, develop and reproduce under unfavorable environmental conditions in terms of water availability, temperature, fertility and salinity (Abouziena and Haggag, 2016). The *Eleusine indica* Gaertn species is an example; under conditions of compacted, low-fertility and high-acidity soil, it has a competitive advantage over the other species (Azevedo, 2002).

Several authors report the influence of water restriction on weed development and herbicide efficiency, such as Pereira et al. (2015), who verified higher tolerance to herbicides in *Eleusine indica* plants submitted to water stress, but they also found impaired control in plants of *Cenchrus echinatus* (Klar et al., 2015), *Ipomoea grandifolia* (Vitorino and Martins, 2012) and *Urochloa decumbens* (Pereira et al., 2012).

Information about the influence of water stress, particularly on seed production, is only found for cultivated plants, such as a lower photosynthesis rate, which can be compensated by reducing the number of seeds in maize (Quarttar et al., 1987); by reducing the filling period in soybean pods (dry matter transfer), which causes in a remarkable reduction in yield due to the formation of smaller, lighter seeds and, depending on the cultivar, wrinkled and deformed seeds (Neto and Krzyzanowski, 1990); and by producing a larger quantity of seeds with a reduced size, especially when water restriction occurs during flowering (Marcos Filho, 2005).

However, there is limited information on the effect that water stress may cause on the production and vigor of seeds, aiming at a later recharge of the seed bank. Thus, the objective of this research was to evaluate the seed production and vigor of *B. pilosa* and *R. raphanistrum* plants submitted to water stress.

MATERIAL AND METHODS

This work was divided in two experiments; the first one was related to seed production by *B. pilosa* and *R. raphanistrum* plants submitted to water stress, and the second one had the objective of evaluating the germination of the produced seeds.

The first study was conducted in a greenhouse, whose geographical coordinates are 22°51’03” south latitude and 48°25’37” west longitude from Greenwich, with an altitude of 786 m.

The soil, before sowing, was air-dried, rotated twice a week until constant weight and fertilized according to the needs recommended by the chemical analysis (Table 1). Due to the low natural fertility of the soil, a correction was made with dolomitic limestone, with PRNT equal to 91%. The base saturation method (V%) (Raij et al., 1997) was used to calculate the liming requirement, in order to increase it to 70%. Limestone was mixed homogeneously with the soil, which was left in moist incubation at approximately 60% of its water retention capacity for 30 days.

Table 1 - Chemical analysis of the soil used in the study

pH	M.O	P resin	H+Al	K	Ca	Mg	SB	CTC	V
$CaCl_2$	(g dm^{-3})	(mg dm^{-3})	(mmol dm^{-3})						(%)
4.6	7	3	22	0.2	2	2	4	26	15

To obtain the water retention curve, the Richards' pressure plate and the Klar's methodology (1984) were used. From the results of the retention curve, three water potentials (water managements) were established: -0.03, -0.07 and -1.5 MPa, corresponding to soil moisture of 13%, 10% and 8%, respectively. All pots were weighed daily until they reach the weight corresponding to the predetermined water potentials. When reaching the defined potential for each treatment, the evapotranspired water was replaced, until reaching a weight corresponding to the water potential of -0.01 MPa (field capacity). Water management started at the two-leaf development stage of the plants.

Ten seeds of *B. pilosa* (black jack) and *R. raphanistrum* (wild radish) were sown separately, in 2.0 L plastic pots with soil, and kept in a greenhouse with a controlled constant temperature at 26 °C. After the emergence of the seedlings, thinning was performed, leaving one seedling per pot.

Plants were maintained at the established water potentials throughout their cycle. Seeds were harvested at the stage of full physiological maturity, when the following evaluations were conducted: number of seeds per plant (black jack and wild radish) and number of seed per pod (wild radish).

The design used in the first experiment was completely randomized with three treatments (soil water potentials: -0.03 MPa, -0.07 MPa and -1.5 MPa) and eight replications: there was one plant per replication. The results were submitted to analysis of variance by F test, and the means of the treatments were compared by Tukey's test at 5% of probability.

The second study was conducted in the Seed Analysis Laboratory (Laboratório de Análise de Sementes). Seeds from plants of *B. pilosa* (black jack) and *R. raphanistrum* (wild radish) developed at different soil potentials (-0.03 MPa, -0.07 MPa and -1.5 MPa) were used in the study.

All the seeds collected at the previous stage were distributed evenly on two sheets of blotting paper moistened with distilled water, in the amount of 2.5 times the weight of the paper, in four replications with the same numbers of seeds, placed in transparent plastic boxes (11 x 11 x 3.5 cm) and put in 0.05 mm thick plastic bags to maintain the substrate moisture. They were maintained at 20-35 °C and eight hours of light (Brazil, 2009).

For the *B. pilosa* species, a total of 960 seeds were used, distributed in 16 replications, namely: 25 seeds in treatments with a soil water potential of -0.07 and -1.5 MPa and 10 seeds in the treatment of -0.3 MPa. For the *R. raphanistrum* species, a total of 228 seeds, distributed in four replications of 12, 20 and 25 seeds, were used in treatments with a soil water potential of -0.03, -0.07 and -1.5 MPa, respectively.

Germination readings were made weekly from day 7 to 21 for the wild radish, and up to 28 days after sowing (DAS) for the black jack; seeds that originated normal seedlings (Brazil, 2009) and with a minimum length of 0.3 mm and a root extension equal to or greater than 2 mm were considered as germinated.

The design used in the second experiment was completely randomized with three treatments (soil water potential: -0.03 MPa, -0.07 MPa and -1.5 MPa). The results were submitted to analysis of variance by F test and the means of the treatments were compared by Tukey's test at 5% probability.

RESULTS AND DISCUSSION

Wild radish plants produced larger numbers of pods with a single seed, regardless of the water potential to which they were submitted (Table 2). This seems to be a predominant characteristic of the species. However, under conditions of higher water stress (-1.50 MPa) the production of single seed pods was lower than under the other conditions (-0.03 and -0.7 MPa), and the production of pods with three seeds was up to 73.3% higher. Pods containing four seeds were not produced under intermediate stress conditions, equivalent to -0.07 MPa.

Water deficit is a common situation for many crops due to climate changes, and it may have a substantial negative impact on the growth and development of plants (Lecoeur and Sinclair, 1996). There is a conflict between the conservation of water by the plant and the CO^2 assimilation

Table 2 **-** Number of wild radish pods produced with different seed numbers per plant, under different water conditions

Water potential (Mpa)	Number of pods			
	1 seed	2 seed	3 seed	4 seed
-0.03	10.0 a	0.8	0.8 b	1.2 a
-0.07	8.8 a	0.6	0.4 b	0.0 b
-1.50	1.9 b	1.6	1.5 a	0.8 a
$F_{treatments}$	88.402**	3.764^{ns}	7.475**	12.60**
VC (%)	19.14	-	17.7	27.03
MSD	1.65	1.00	0.75	0.57

Means followed by the same letter in the column do not differ by Tukey's test at p> 0.05); * - significant value by F test (p≤0.05); ** - significant value by F test (p≤0.01); ^{ns} - not significant; VC - variation coefficient; MSD - minimum significant difference.

The germination of wild radish seeds was fast and similar in all evaluated treatments, since it occurred predominantly seven days after sowing.

Some researchers provide justifications for this lower seed production in plants submitted to water deficit. For maize, the occurrence of water deficit during anthesis and pollination impairs the expansion in the female reproductive organs (stylet) and increases the abortion of flowers and seeds, reducing their production even after fertilization (Schussler and Westgate, 1991; Bassetti and Westgate, 1993; Santos and Carlesso, 1998).

Schussler and Westgate (1994) observed that the inhibition of photosynthesis for six days during the pollination period practically eliminated the formation of seeds in plants subject to water deficit.

rate for carbohydrate production, and this leads the plant to develop morphophysiological mechanisms to retain water in order to survive for a longer time (McCree and Fernández, 1989; Taiz and Zeiger, 2002). Thus, the most adapted species to water deficit are able to produce seeds, and this allows their perpetuation in the soil bank.

As for the germination and vigor evaluated during the first count, performed seven days after sowing (Table 3), seeds produced under lower water stress presented a significantly higher performance than those from the other treatments, with 55%, while the germination of seeds from plants kept in soil with water deficit was, on an average, 31.5%.

Table 3 **-** Germination of wild radish seeds produced by plants under different water conditions

Water potential (Mpa)	Germination (%)			
	7 DAS	14 DAS	21 DAS	Total
-0.03	55.0 a	3.0	1.0	59.0 a
-0.07	31.0 b	3.9	2.5	37.4 b
-1.50	32.5 b	6.7	0.0	39.2 b
$F_{treatments}$	29.563**	1.038^{ns}	1.055^{ns}	13.945**
VC (%)	12.54	-	-	14.24
MSD	9.78	7.37	6.07	12.07

Means followed by the same letter in the column do not differ by Tukey's test p> 0.05); ** - significant value by the F test (p≤0.01); ns - not significant; VC - coefficient of variation; MSD - minimum significant difference; DAS - days after sowing.

Seed quality may also be affected by water stress, as verified by Padua et al. (2009) in soybean, which, when cultivated under water stress, produced greenish seeds with a remarkably lower quality.

Under extreme conditions of water stress (-1.50 MPa), black jack seeds presented a production with a higher percentage of germination, vigor (first count) and, also, a better distribution of germination over time, compared to the lowest stress condition for the plant (-0.03 MPa) (Table 4). This set of characteristics may suggest an adaptive evolution of this species to the condition of water deficit, which allows greater competition in the agricultural ecosystem, since it contradicts all reported studies. Depending on the species, the physiological potential of seeds produced under water stress may not be affected when occurring during flowering or at the beginning of seed formation, thus only reducing the number of produced seeds; this corroborates the results found in this study (Dornbos Jr, 1995).

Table 5 shows the numbers of black jack and wild radish seeds produced by plants under different water conditions, and these values support the evidence of greater adaptation of black jack compared to wild radish in situations of water deficit.

Seed development is highly dependent on a continuous supply of assimilated compounds, resulting from photosynthesis, which is impaired when the plant is under water stress, simply because it does not have sufficient reserves to maintain grain development. Although anthesis is considered as the most vulnerable to water deficit, it can cause serious decreases in grain

Table 4 **-** Percentage of germination of black jack seeds produced by plants under different water conditions

Water potential (Mpa)	Germination (%)				
	7 DAS	14 DAS	21 DAS	28 DAS	Total
-0.03	39.9 b	8.3 ab	4.3	0.0 b	51.3 b
-0.07	67.5 a	4.5 b	4.3	0.5 ab	77.0 a
-1.50	61.5 a	10.8 a	5.8	2.5 a	80.5 a
$F_{treatments}$	14.338**	3.405*	0.431^{ns}	4.038*	27.704**
VC (%)	27.3	36.9	28.9	26.31	17.45
MSD	13.2	5.85	4.52	2.25	10.4

Means followed by the same letter in the column do not differ by Tukey's test p> 0.05); * - significant value by F test (p≤0.05); ** - significant value by F test (p≤0.01); ns - not significant; VC - variation coefficient; MSD - minimum significant difference; DAS - days after sowing.

mass if occurring during the seed development stage, as climatic conditions in this period may affect the synthesis and allocation of photoassimilated compounds to the soil. (Quarttar et al., 1987; Schussler and Wesgate, 1991a; Uhart and Andrade, 1991).

Ney et al. (1994) demonstrated that water deficit caused a significant effect on the reduction of the grain number when it occurred along or after flowering, and that its final weight was in accordance with the development rate of the plant and the duration of the filling period of grains.

A single *Bidens pilosa* plant has the capacity to produce from 3,000 to 6,000 germinable seeds, resulting in three generations per year, according to Lorenzi (2006). It was verified that, in more intense periods of rain, the inhibitory effect of the germination of this species was weak, and with little rain the inhibitory effects were high (Carmona and Villas Boas, 2001).

Table 5 **-** Number of black jack and wild radish seeds produced by plants under different water conditions

Water potential (Mpa)	Number of seeds per plant	
	black jack	wild radish
-0.03	19.9 b	12.5 a
-0.07	48.1 a	9.8 b
-1.50	48.5 a	5.4 c
$F_{treatments}$	758.03**	92.79**
VC (%)	4.34	11.46
MSD	2.12	1.33

Averages followed by the same letter in the column, do not differ by Tukey's test p> 0.05); * - significant value by F test (p≤0.05); ** - significant value by F test (p≤0.01); ns - not significant; VC - variation coefficient; MSD - minimum significant difference.

The *R. raphanistrum* (wild radish) species has a large capacity to produce viable seeds as well, tending to intensely infest crops, especially winter cereals. It is one of the main competitive weeds in autumn/winter, causing significant reductions in winter crop productivity, even at low population densities, as well as the fact that its seeds and pods are often contaminants of the collected grains (Cheam and Code, 1995).

The germination means of black jack seeds emphasizes the sensitivity and low resistance of wild radish seeds to water deficit conditions and lower competitive capacity, in relation to black jack seeds, under the same environmental conditions. There are no reports in literature on plants that increase seed production when submitted to water stress.

For the conditions under which this study was carried out, it can be concluded that black jack is a more adapted species to survive under water deficit conditions than wild radish, due to its higher seed production and greater germination than the other one.

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