Acta Scientiarum

http://periodicos.uem.br/ojs/acta
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v41i1.46127

BOTANY

Phenology and dry mass production of *Urochloa plantaginea* and *Urochloa platyphylla* submitted to different water quantities in the soil

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ABSTRACT. The genetic variability and genetic versatility of plants belonging to Poaceae provide morphophysiological responses that allow these individuals to adapt to environmental changes, especially in relation to soil moisture. *Urochloa plantaginea* and *U. platyphylla* are grasses typical of dry environment, also found as weeds in rice fields, where there are high amounts of water in the soil. The objective of this work is to analyze the development of these two species in different environments, subjecting them to three different amounts of water in the soil. Morphological parameters were analyzed in order to verify and quantify which suffered alteration with respect to water variation. Caryopsis of the two species were collected in a commercial irrigated rice crop. Seeds were sown in pots containing a substrate-sand system, and housed in a greenhouse, where during the experiment the control of different moisture contents (shallow water table, 100% of field capacity and 50% of field capacity) took place. Weekly evaluations were carried out according to the parameters analyzed. The following parameters were evaluated: duration of the vegetative and reproductive life cycle, number of the inflorescences per plant, number of branches per inflorescence, number of spikelets per branch, number of seeds per plant, and dry mass production. The *U. plantaginea* cycle had shorter duration under the shallow water table, while for *U. platyphylla* the shorter duration was under the condition 50% of field capacity. Both species produced higher dry mass of shoots under the condition of 100% of field capacity. The main responses observed for both species, due to the flooding, were the change of the cycle, reduced dry matter production, and reduced seed production.

Keywords: morphometry; Poaceae; weeds.

Received on January 10, 2019.
Accepted on April 22, 2019.

Introduction

Poaceae (Gramineae) is one of the largest families among Angiosperms, composed of species that occur in various environments around the world. The latest survey records 18 species of grasses for Brazil (Shirasuna, 2015) and is one of the major weeds of the Rio Grande do Sul. Many species of this family have great economic and ecological importance, as is the case of the genus *Urochloa*, an exotic genus with several species introduced to Brazil as fodder plants.

Urochloa plantaginea (Link) R.D. Webster, popularly known as alexander grass, is characterized by having forage value, being a plant with aggressive development, found as a weed in cultivated areas. An annual plant, reproduced by seed, which has an erect and/or semi-erect posture (reaching up to 1 m high) with heavy tillering forming an ascending clump. The fruit, karyotype type, is shown varying from ovate to ovate-rounded (Kissmann, 1997; Moreira & Bragança, 2010; Marques, Rodella, & Martins, 2012). *Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster, popularly known as broadleaf signalgrass, is described by Kissmann (1997) as an annual plant, which reproduces by seed, occurring in the warmer months. Decumbent or ascending size can reach up to 70 inches tall (Moreira & Bragança, 2010).

The distribution of plants in the earth's surface depends more upon the availability of water than any other environmental factor (Turner, 1986), because virtually all physiological processes that occur in plants are regulated by water. During their evolution, many species evolved adaptive mechanisms to survive in flooded soils (Ramos, Šimůnek, Gonçalves, Martins, Prazeres, Castanheira, & Pereira, 2011) and plants tolerant to flooding, according to Kozlowski (1984), survive because of complex anatomical, metabolic and physiological interactions. The expression of genes responsible for the formation of aerenchyma and adventitious roots seems to be directly related to the mechanisms of tolerance in plants (Fries, Alves, Delú, Filho, Magalhães, & Goulart, 2007).

The plants possess strategies to cope with variations in water availability in the environment in which they develop. These strategies can trigger reflexes that change some physiological processes and can affect the growth and development of the plants (Taiz & Zeiger, 2013). However, the morphological parameters which are affected by the difference in the amount of water available in the environment, or how the plant physiology changes, especially regarding the life cycle of plants, have not been defined yet.

Since grasses are weeds that exert the greatest effects of competition on rice and since they were found to be acclimatized to flooded soils, the aim of this study was to evaluate the morphophysiological *ex situ* behavior of two species of the genus *Urochloa* under different water conditions in the soil.

Material and methods

Plant material

Mature inflorescences were collected from one access of each species of the genus *Urochloa*, *U. plantaginea* (Figure 1A) and *U. platyphylla* (Figure 1B), obtained in March 2013 in rice production area in West Frontier Rio Grande do Sul, Brazil, in the municipality of Itaqui (Lat: 29 ° 14 '11.97' 'S and Long: 56 ° 20'11.92' 'W). Approximately 50g of seed were collected from a representative plant species studied, wrapped in porous brown paper bags and separately identified with the species name, geographical coordinates of the location, collector's name and number of the sample. The inflorescences underwent processing in the laboratory, proceeding to remove impurities, separating the kernels and pre-drying of the same, in order to reduce humidity for storage in a dry chamber.

Figure 1. Morphological difference between *Urochloa plantaginea* (A) and *Urochloa platyphylla* (B) in 100% of field capacity of soil.

Greenhouse management and treatments

To implement phenological analysis and dry matter production of *Urochloa* accesses, the seeds were placed for germination in pots with a capacity of 7.5 L, filled with 2.5 kg of organic substrate and 4.0 kg of sand of medium texture, which was sterilized.

The pots were maintained in a greenhouse with temperature monitoring and rotation of the vessel in order to mix the light of the experimental units. In each pot five seeds were sown, and after emergence, there was thinning of plants, leaving only one plant per pot.

For each of the species, seeds were sown in 80 pots, and after the initial establishment of the plants, 20 were discarded, there remaining 60 vessels (30 for each species). Each set of 30 homogeneous pots was divided into three groups (treatments) 10 (repetitions).

One group received irrigation up to 50% of the system's field capacity-sand substrate, another group received constant irrigation, keeping the system-sand substrate with 100% of field capacity and the third group received constant irrigation, keeping the water table at 5 cm of water (as recommended for irrigated rice production in Rio Grande do Sul).

The uniformity of irrigation during the test was carried out through the gravimetric moisture calculation of system-sand substrate as per the manual of methods and soil analyses (Empresa Brasileira de Pesquisa Agropecuária [Embrapa], 1997). The actual dry weight of the soil-substrate contained in the vessel system was determined. The amount of water needed for each experimental unit was determined using the wet column method (Forsythe, 1975), in which a certain amount of water is added using a PVC pipe 75 mm in diameter and 50 cm in length, awaiting the completion of percolation of said water into the tube. After the saturation of the system, a sample was removed from the tube and the gravimetric moisture was calculated, resulting in the field capacity of the sand-substrate system. Thus, with the mass of the empty vessel, mass of sand and dry substrate and the system capacity of the field-substrate sand, it was possible to determine the amount of water required to achieve 50 and 100% of the field capacity. Irrigation of the vessels was performed daily. To determine the amount of water required every day for each pot, the mass of each pot was measured, using an electronic scale (Scale Electronic System ACS brand) with 5 g precision, adding water until the total weight (vase + system sand dry substrate + 100% field capacity for lowland environments and 50% for highland environment) was achieved.

The experiment began on January 4th, 2014, when the vessels were prepared with the system-sand substrate and sowing. The emergence of the plants of *U. platyphylla* species occurred from 9 to 14 of January and the emergence of *U. plantaginea* occurred from 8 to 14 of January. The different treatments were initiated after the initial establishment of the plants, when plants had an average of 2-3 leaves, after thinning to standardize the plots.

Data collection and statistics

The evaluations were composed of duration of the growing phase (days), which was determined from emergence to the production of the first inflorescence; reproductive cycle, the inflorescence produced to natural dehiscence of the plant (80% of leaf senescence and abscission above 50%) and life cycle (vegetative reproductive +). We also quantified the production of dry matter (DM) of shoot and root, number of inflorescences per plant, number of branches per inflorescence, number of spikelets per branch and number of seeds per plant, when the plants were in full bloom, scale 65 from BBCH (Meier, 2001). The mother plants were scored in each experimental unit with the purpose of evaluating the parameters related to each species' inflorescences. For dry mass analysis, four plants were removed from the vessels and their shoots were separated from their roots. Afterward the root system was cleaned with running water in a closed container. The separated and cleaned roots and shoots were placed in paper bags, and placed in an oven with forced air drying at a temperature of 65°C until they reached a constant dry weight.

The data obtained in the evaluations were analyzed to check for normality and homogeneity using the software SISVAR 5.3 (Build 77) an analysis of variance was used (ANOVA) and the averages were compared. Using the Scott-Knott mean comparison test $p < 0.05$.

Results

Life cycle and phenology

Both species developed and completed the biological cycle in the three different soil water conditions. The cycle duration in number of days is quite different between species: *Urochloa plantaginea* had full cycle between 120 and 140 days and *Urochloa platyphylla* had its full cycle between 80 and 90 days.

In the *U. plantaginea,* the cycle time was 5-7 days shorter in the conditions of higher amount of water in the soil (shallow water table and 100% of field capacity) in relation to the conditions of lower availability of water (50% of field capacity) (Figure 2A).

The least water condition in the soil (50% of field capacity) led to the shortening of the *U. platyphylla* cycle, in relation to the treatment with shallow water table and 100% of field capacity, environments which are more conducive to the development of the species (Figure 2B).

The two species showed similar behavior in relation to the emission of inflorescences. In the treatment where the soil was maintained with a shallow water table, induced plants to produce inflorescences before the other treatments, thus shortening the vegetative period for both species (Figure 2).

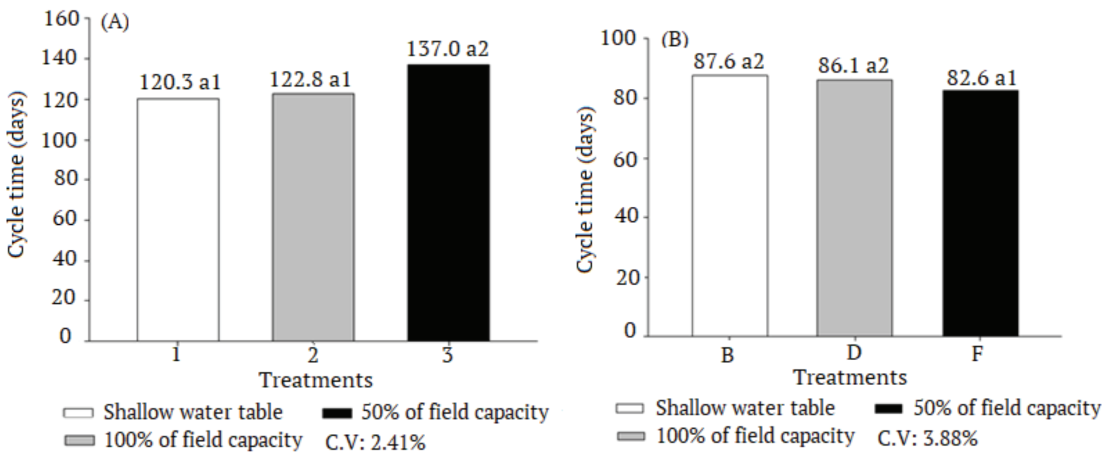

Figure 2. Cycle time in days from emergence to seed maturation and seed shattering, to *Urochloa plantaginea* (A) and *Urochloa platyphylla* (B) under different water conditions in the soil.

Dry matter production

From the analysis of the results for dry matter production (MS) of shoot, Figure 3 shows that the environment where moisture content remained at 100% of field capacity produced the highest yield of DM for both alexander grass (*U. plantaginea*) and broadleaf signal grass (*U. plantyphylla*).

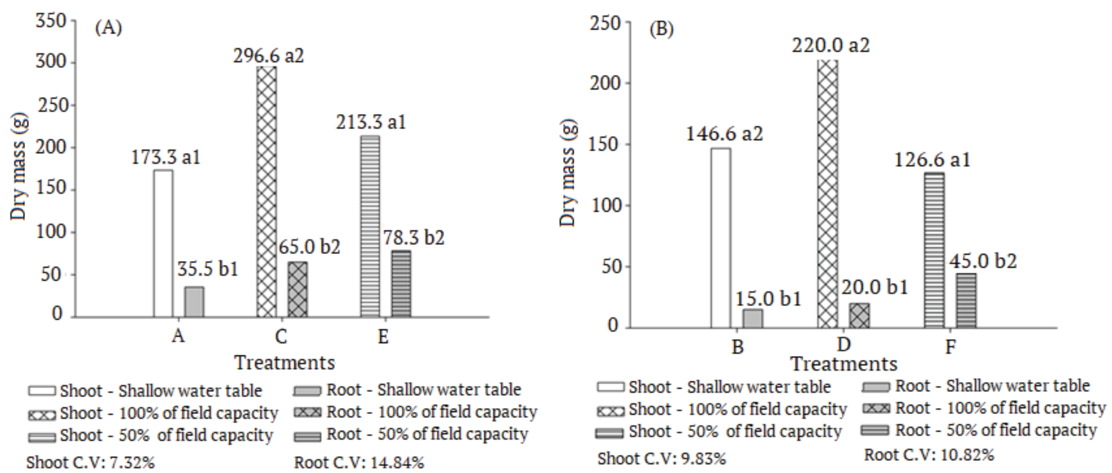

Figure 3. Dry mass of roots and shoots in *Urochloa plantaginea* (A) and *Urochloa platyphylla* (B) under different water conditions in the soil.

There was a difference in dry matter production, with distinct responses occurring for both species as they are more or less adapted to the anaerobic environment brought about by the shallow water table. *Urochloa plantaginea* produced larger amount of DM shoot when subjected to 100% of field capacity condition *Urochloa platyphylla* had the lowest production of DM of shoot when it was submitted to the condition of the least amount of water in the environment (50% of field capacity).

The dry matter production of root showed distinction between different water conditions in the soil. *Urochloa plantaginea* presented a reduction of dry root mass when it was submitted to the shallow water table. The greatest production of root DM occurred in *Urochloa platyphylla* when the specie was subjected to development in environments with lower availability of water, as characterized by the condition 50% of field capacity.

Other parameters that have been affected by increasing soil moisture, for both *U. plantaginea* and *U. platyphylla*, were the number of inflorescences per plant (Figure 4), average number of branches per inflorescence (Figure 5) and number of seeds per plant (Figure 7). It can be seen that as the amount of water added to the soil increased, with greater negative effect on the shallow water table condition, there was a reduction in the number of inflorescences per plant as well as a reduction in the number of branches per inflorescence. The number of spikelets per branch varies by species. *U. plantaginea* presented a reduction when submitted to a 50% of field capacity. However, *U. platyphylla* showed an increase when submitted to the same water condition (Figure 6). The number of seeds per plant was higher when the species were submitted to a condition of 100% of field capacity, being higher in 43% and 61% for *Urochloa plantaginea* and *Urochloa platyphylla*, respectively, when compared to 50% of field capacity (Figure7).

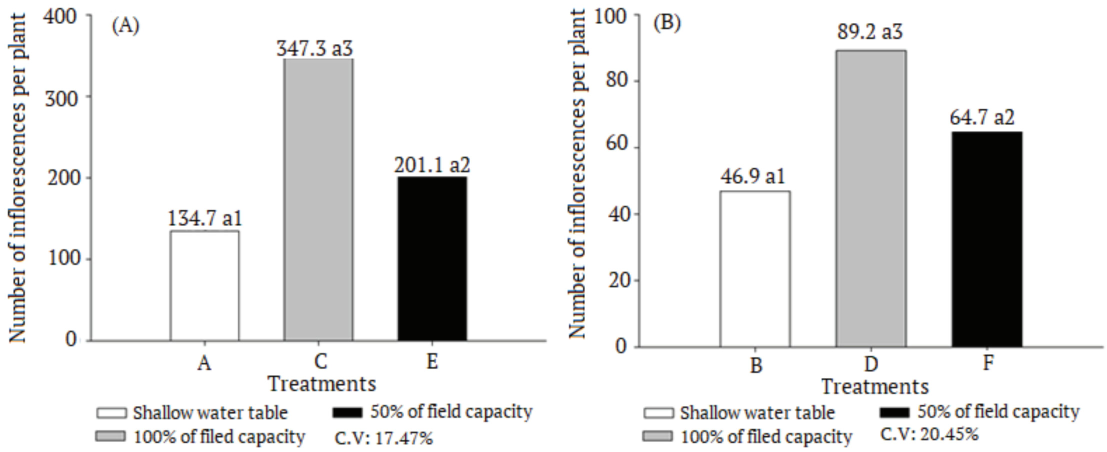

Figure 4. Number of inflorescences per plant in *Urochloa plantaginea* (A) and *Urochloa platyphylla* (B) under different water conditions in the soil.

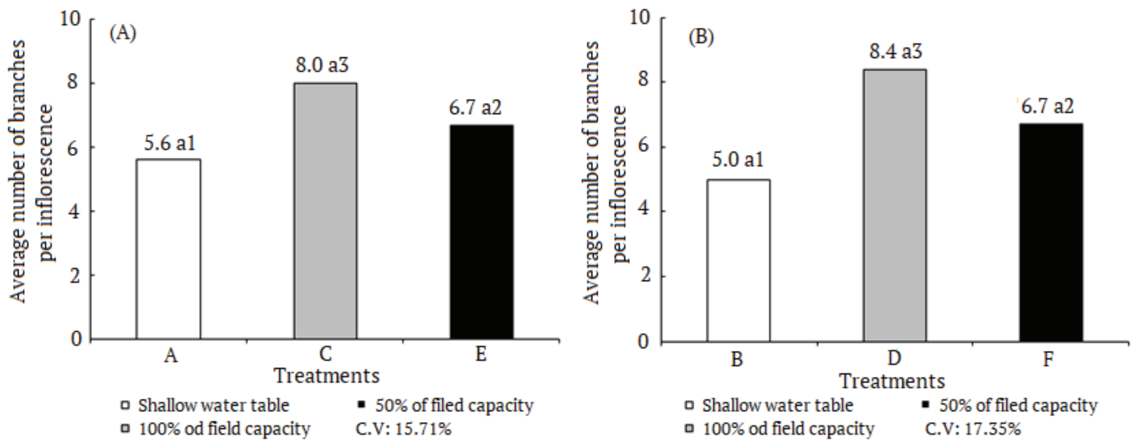

Figure 5. Average number of branches per inflorescence of *Urochloa plantaginea* (A) and *Urochloa platyphylla* (B) under different water conditions in the soil.

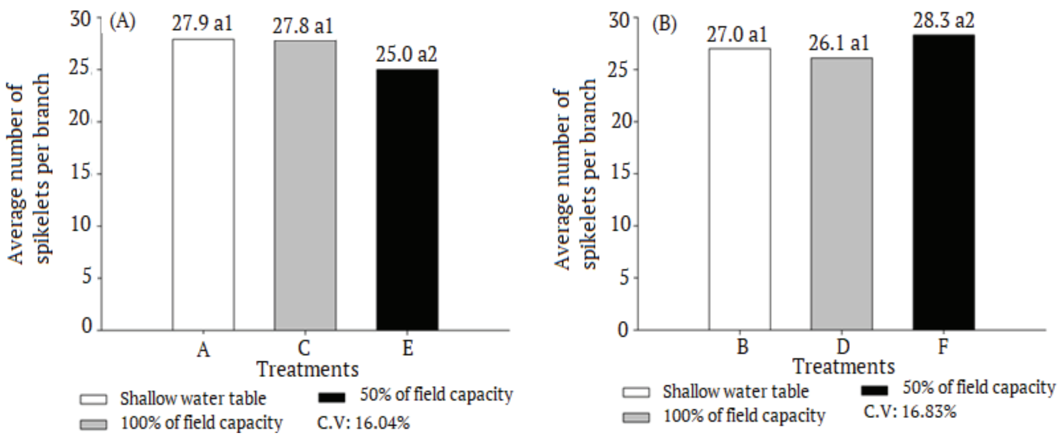

Figure 6. Average number of spikelets per branch in *Urochloa plantaginea* (A) and *Urochloa platyphylla* (B) under different water conditions in the soil.

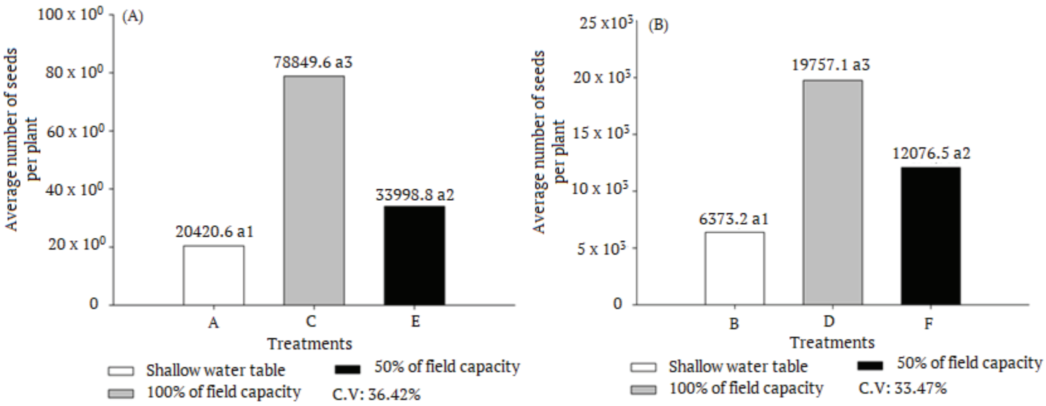

Figure 7. Average number of seeds per plant in *Urochloa plantaginea* (A) and *Urochloa platyphylla* (B) under different water conditions in the soil.

Discussion

The different amounts of water in the soil influenced the two species differently. The ability to tolerate O_2 restriction conditions is linked to the ability of each plant to transfer O_2 from the aerial parts to the roots, because inefficiency in the supply of oxygen to the roots induces anaerobic biochemical acclimatization of the plant, thus optimizing energy expenditure in the maintenance of basal metabolism (Irfan, Hayat, Hayat, Afroz, & Ahmad, 2010). The lack of oxygen for long periods induces the formation of adventitious and aerenquimous roots (Colmer & Voesenek, 2009). The *Urochloa* genus includes several species, which differ in regards to origin and the capacity to respond to each individual weather events and / or environmental factors that influence its development in environments other than their original environments.

Urochloa plantaginea (alexander grass) is a plant of African origin introduced in Brazil in colonial times (Kissmann, 1997). A common plant in rainfed environments, it is described by Velho, Crusciol, Velini, Castro, and Borghi (2012) as a highly aggressive invader, which can cause serious injury to the industry, especially in rainfed crops such as soybeans and corn. However, even when dealing with a plant usually found in non-flooded environments, *U. plantaginea* completed its life cycle under the three different amounts of water in the soil, developing even under the shallow water table (Figure 2A).

The shortening of the *U. plantaginea* cycle occurred under the shallow water table condition, is probably related to a physiological response expressed due to the stress of excess water (Taiz & Zeiger, 2013). Species that developed preferentially under aerobic conditions may retain many semi-aquatic adaptations, that is, there is aerenchyma development in the roots and the large amount of non stomatic water loss through the leaves (Lafitte & Bennett, 2002). Furthermore, mitochondrial destruction can be observed in anaerobic conditions, unlike what occurs in roots under aerobic conditions (Vartapetian & Andreeva, 1986). Thus, under deficit of root oxygenation, there is a reduction in the production of ATP (adenosine triphosphate), reducing cellular metabolism, interfering with photosynthesis and consequently in plant development (Kozlowski, 1984; Liao & Lin, 2001), affecting their biological cycle by shortening it.

Urochloa platyphylla also completed its life cycle under the three different conditions (Figure 2B). Such result is expected, as it is a species found in more humid environments in southern Brazil (Kissmann, 1997). The shortening of the cycle caused by the condition of reduced availability of water in the soil is probably due to a water deficit situation for this species, because according to Wright, Smith, and Mcwilliam (1983), the water deficit induces senescence in plants from flooded environments, shortening their life cycles. This is also a common occurrence in plants from flooded environments that have a high number of seeds per unit leaf area (Wolfe, Henderson, Hsiao, & Alvino, 1988) such as *U. platyphylla*.

The difference in the number of inflorescences by the two species is directly related to increased ethylene production in plants under root hypoxia, which promotes rapid formation of aerenchyma (Joshi & Kumar, 2012) and shortens the growing season due to the acceleration of the physiological processes involved in plant senescence caused by the production of phytohormone (Taiz & Zeiger, 2013).

Despite its adaptability to climatic adversities and to different environments, each species has an environmental condition that provides better conditions to develop and express their full potential. The plant development and the production of dry matter (DM) are traits that vary due to changes in light levels, temperature, humidity and nutrient availability (Hunt, 1990).

Gomathi, Chandran, Gururaja, and Rakkiyappan (2010) stated that in plants that do not come from soils with high level of humidity, the reduction of DM when exposed to this water condition is frequent. Such results were found for the performed statistics, which produced high DM contents in shoots when cultivated under the water condition in 100% of field capacity.

The lower tolerance of species to environments with excess water (shallow water table) as it was the case with *U. plantaginea*, leads to a reduction in the exchange of gases between the environment and the plant (Kozlowski, 1997), which according to Liao and Lin (2001), alters the cellular metabolism leading to a decrease in root respiration, thereby reducing the production of ATP, leading to lower plant development. As with *U. plantaginea*, which produced lower shoot DM when made to develop under the shallow water table.

The excess moisture in the soil promotes root oxygenation deficit in plants, which triggers functional and developmental responses to promote acclimatization to hypoxia or anoxia. These conditions, which lead the production of aerenchyma (Pereira, Castro, & Souza, 2008), cannot however, maintain aerobic metabolism and sufficient energy production for the proper plant growth (Kozlowski, 1984).

The reduction in the growth of plants under adverse conditions is due to the following factors: decreased production of ATP (adenosine triphosphate) resulting from anaerobic metabolism; stomata closure, with reduction in CO_2 capture; lower photosynthesis; lower nutrient absorption and translocation of carbohydrates; besides the beginning of production of specific stress proteins from anaerobic environment, named polypeptides (ANP) (Liao & Lin, 2001).

Low water supply is a condition that leads to stomata closure, bringing about a smaller supply of CO_2 in the leaves, compromising the development of the plant and, consequently, a lower production of biomass (Paiva, Fernandes, Rodrigues, & Turco, 2005), a result which is consistent with lower dry matter yield of aerial part by *U. platyphylla* when grown under a low amount of water in the soil (50% of field capacity).

The production of root DM showed variation between environments. This result is common in plants that do not come from environments with high soil moisture, reducing dry mass when exposed to that water condition (Gomathi et al., 2010).

Coelho et al., (2013) found that the total DM production, stem and root in both maize leaves was significantly reduced by the interaction of flooding conditions with shading (light deficit) when compared to control plants. These results, are in agreement with those found for *U. plantaginea* and *U. platyphylla*, which showed lower DM production in roots and increased availability of water in the soil, with the lowest DM content found when species were developed under a shallow water table (Figure 4).

Studying the effect of flooding in pea, Sá, Cerri, Piccolo, Feigl, Fornari, Sá, and Paulleti (2004) found that the higher water level maintained until the flowering stage, promoted reduction of more than 50% in the thousand seed weight and seed production. They found that the negative effects were increased as the period in which the root system was submerged increased, as well as depending on the crop stage at which flooding started. According to Wolfe (1988), the dramatic reduction in yield and seed production in some species, is related to greater or lesser adaptation to the hypoxic environment and the changes in plants, especially with the reduction of shoot and area PAR caused by root oxygenation deficit. In this condition, there is a reduction in the production of ATP (adenosine triphosphate), reducing cell metabolism and photosynthetic efficiency and hence the development of the plant, reducing the number of inflorescences and seeds forming ability and these filling.

Conclusion

Both species have developed and completed the biological cycle in the three different water conditions in the soil. The flooding of the soil caused changes in the plant's morphology, with the species differing in their adaptability to water levels. The main responses observed for both species, due to the flooding, were the alteration of the cycle, reduction of the dry matter production, and reduction of seed production.

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