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Article

MORPHOLOGICAL AND PHENOLOGICAL RESPONSES OF *Eragrostis plana* NEES AND *Eragrostis pilosa* (L.) P. BEAUV. PLANTS SUBJECTED TO DIFFERENT SOIL MOISTURE CONDITIONS

Resposta Morfológico e Fenológico de Plantas de ***Eragrostis plana*** *Nees e* ***Eragrostis pilosa*** *(L.) P. Beauv. Submetidas a Diferentes Condições Hídricas do Solo*

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ABSTRACT - Experiments were run in a greenhouse where samples of *Eragrostis pilosa* and *Eragrostis plana*, species that infest rice crops, were subjected to three soil moisture conditions (50% of soil water retention capacity (WRC), 100% of WRC, 10 cm water depth), simulating three different environments (upland, lowland and irrigated rice farm, respectively), with the aim of studying how these conditions affect the morphology and vegetative cycle of these plants, by means of development and growth assessments. Results show that each species responds differently when subjected to varying amounts of water in the soil. Soaking the soil with 10 cm of water was the treatment that most negatively influenced the development of *E. plana* plants, reducing the formation of panicles per plant, as well as the aerial part dry mass. The responses of *E. pilosa* plants to the waterlogged environment manifested as reductions in tillering parameters, number of panicles per plant, root and aerial part dry mass, changes in flag leaf formation, and vegetative cycle increases, which allows inferring that these plants are more sensitive to hypotoxic environments. Thus, the water depth treatment is possibly what caused negative effects on the development of the study plants, which indicates that water management in irrigated rice farming is of uttermost importance for management of invasive plants.

Keywords: anaerobiosis, soil, waterlogging, acclimatization, grasses.

RESUMO - Realizou-se um experimento em casa de vegetação onde submeteu-se acessos de ***Eragrostis pilosa*** *e* ***Eragrostis plana****, espécies infestantes da cultura do arroz, a três condições de umidade do solo (50% da Capacidade de retenção de água do solo (CRA), 100% da CRA, lâmina de água de 10 cm) simulando três ambientes diferentes (ambiente de terras altas, ambiente de terras baixas e o ambiente de lavoura de arroz irrigado, respectivamente), com o objetivo de estudar o efeito destas condições na morfologia e no ciclo vegetativo dessas plantas através de avaliações de desenvolvimento e crescimento. Os resultados apontam que cada espécie apresenta respostas diferentes quando submetidas a diferentes quantidades de água no solo. Observou-se que o alagamento do solo com lâmina de água foi o tratamento que mais influenciou negativamente o desenvolvimento das plantas de* ***E. plana****, com a redução da formação de panículas por plantas e redução da massa seca da parte aérea. As respostas das plantas de* ***E. pilosa*** *ao ambiente alagado refletiram em redução nos parâmetros de perfilhamento, número de panículas por planta, massa seca de raiz e parte aérea, alterações na formação da*

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folha bandeira e aumento do ciclo vegetativo, podendo-se inferir que essas plantas são mais sensíveis ao ambiente hipóxico. Logo, o tratamento de lâmina de água é o possível causador de efeitos negativos no desenvolvimento das plantas estudadas, o que indica que o manejo da água na cultura do arroz irrigado é de suma importância para o manejo das plantas invasoras.

Palavras-chave: anaerobiose, solo, inundação, aclimatação, gramínea.

INTRODUCTION

Poaceae (Gramineae) is one of the largest families among the Angiosperms, composed of species found in several ecosystems around the world, with 18 grass species documented in Brazil (Shirasuna, 2015). The *Eragrostis* genus (Poaceae) comprehends annual and perennial grasses that mainly inhabit nutrient-poor areas (Giraldo-Cañas et al., 2012). In the state of Rio Grande do Sul, the *Eragrostis* genus has 22 species with forage and ornamental importance (Longhi-Wagner, 2015).

The *E. plana* Nees species, popularly known as South-African lovegrass, as a reference to its place of origin, was introduced in Rio Grande do Sul in the 1950s as a forage species, but it has been causing serious problems to crops (Dotta Filho et al., 2017). This species presents high prolificity, rusticity, mechanical resistance to traction, and ability to adapt to poor soils, characteristics that make it highly competitive and easy to adapt to the environment (Favaretto et al., 2015).

E. pilosa (L) P. Beauv, known as Indian lovegrass, and native from South Africa as well, is an annual grass with 70 centimeters in height and narrow leaves. This plant is capable of surviving to flooded and disturbed environments, adapts well to poor sandy soils or clay soils, and the main characteristic that makes it distinctive in the field compared to other species of the genus is its greyish-red inflorescence (Kissmann, 1997).

For presenting characteristics of rusticity, high competitiveness due to their growth habit, and capacity to adapt to new environments, the abovementioned species have been reported in competition with rice crops (*Oryza sativa* L.)

Characterizing invasive plants is important to develop strategies for an effective control, and so is the investigation of the morpho-physiologically adaptive mechanism developed for these plants to survive in hypoxic environments (anaerobic). Thus, the objective of this research was to assess the influence of different soil moisture conditions on plants of species *Eragrostis*, as well as the morphological and phenological differentiations of *E. plana* and *E. pilosa* plants when subjected to these soil moisture conditions. Soil interference was studied with 50% WRC, 100% WRC and 10 cm water depth by analyzing plant development and growth.

MATERIAL AND METHODS

Eragrostis samples were collected in an irrigated rice crop area in the municipality of Itaqui – Western Border of Rio Grande do Sul, Brazil (29°14’58.43" S, 56°20’57.51" W), in February 2014. Ripe seeds were collected from a population of *E. plana* (South-African lovegrass) and *E. pilosa* (Indian lovegrass), which were then characterized and identified at the place of collection. Collection points were defined based on prior information on occurrence of said species at that location. Approximately 100 g of seeds were sampled for each species. The seeds were packaged in porous paper bags labeled with the species name and the geographical coordinates of the sampling location. Removal of impurities and drying were performed in laboratory so they could be better stored in a dry chamber at a temperature of 20 °C and humidity of 15%, which thus allowed greater disease control and inhibited germination start.

To analyze the phenotypical plasticity of *Eragrostis* samples, the previously collected caryopses were put to germinate in a soil sourced from a systemized rice farming area (Mapping unit of São Pedro, Red argisol, horizon A). The soil was put through 5 mm mesh sieves for removal of invasive plant seeds and chunks. After sieving, the soil was placed inside plastic pots with capacity for 7.5 L, each receiving 6 kg of sieved soil, then stored in greenhouse (plastic cover measuring 6 x 20 meters, and 5 m in ceiling height).

Five *Eragrostis* caryopses were sowed in each pot, totaling 30 pots for each species. After seedling emergence, thinning was performed, resulting in one plant per pot. Sowing took place on December 30th, 2014, and emergence happened between January 6th and 9th, 2015. Pots containing the same samples were divided into three groups with 10 pots (repeats) for each group: the first group received irrigation until reaching 50% of water retention capacity, simulating the moisture conditions of upland soils; the second one received constant irrigation with 100% of water retention capacity; and the third pot was irrigated so as to maintain the soil with a 10 cm water depth, simulating a rice farming environment (flooded paddy).

Two trials were run through a completely randomized experimental design. The first trial assessed *E. Pilosa* under three soil moisture conditions (50% of WRC; 100% of WRC; 10 cm water depth), while the second one assessed *E. plana* under the same conditions, totaling 3 treatments for each trial, with each treatment being composed of 10 repeats.

The water retention capacity (WRC) of the sieved soil was determined by drying the latter in an oven at 100 ^{o}C, then weighing it on a 0.01 g precision scale every 30 minutes until reaching constant mass. At this point, the soil was completely dry. After drying, 3 kg of dry soil were placed in pots with holes at the bottom. Their masses were checked, and the soil was soaked until water leaked through the bottom holes of the pot. After the last drops, the soil was considered to have reached 100% of WRC, so it was weighed once again on the 0.01 g precision scale. With the difference in mass between the pot with dry soil and the pot with soil at 100% of WRC, it was possible to find the mass necessary to reach 100% of WRC, considering that the specific mass of water is 1000 kg m^{-3} or 1 kg L^{-1}.

To obtain the moisture of the treatments (50% and 100% of WRC), formulas were used for determination, as proposed by Schwab (2011):

$$PV100\% = (PVwrc - PVdry).1 + PVdry$$
$$PV50\% = (PVwrc - PVdry).0{,}5 + PVdry$$

where PVn% is mass pot for each treatment; PV_{WRC} is the soil water retention capacity (plus mass of the pot filled in with soil); PVdry is the mass of the pot filled in with dry soil. A 0.2 mm plastic mesh screen was used for covering the holes at the bottom of the pot to prevent the sieved soil from eventually escaping. Before the treatments started, there were maintenance irrigations until 75% of WRC to favor seed germination. This procedure was done until the plants reached the stage of 3 leaves, when definitive irrigation started, with 50% of WRC, 100% of WRC, and constant water depth of 10 centimeters. To determine 75% of WRC, the formula below was employed:

$$PV75\% = (PVwrc - PVdry).0{,}75 + PVdry$$

Different irrigations began on January 21st, 2015, that is, 15 days after seedling emergence, and happened daily; to determine the amount of water necessary for each day in each pot, the mass of each pot was measured using an ACS System electronic scale, with precision of 5 g, and adding water until the predetermined total mass was reached (pot + dry soil + water volume to reach 100% and 50% of WRC).

The pots received fertilization at the bottom according to prior soil analysis and as per recommendation table by the Brazilian Official Network of Soil Analysis Laboratory (Comissão de Química e Fertilidade do Solo, 2014) for irrigated rice farming. They also received cover fertilization with urea in accordance with the recommendation for irrigated rice farming of the South Brazilian Society of Irrigated Rice (SOSBAI, 2018). All treatments were subjected to the same bottom and cover fertilization conditions. The morphological parameters of study samples are listed in Table 1.

The parameters were assessed when the plants were at full flowering stage. For dry mass analysis, four plants were taken from the pots and split into aerial part (including mother plant and tillers) and roots. Then, the root system was cleansed with running water in a closed container, recovering the roots after they were dug out. When clean, the materials were placed in porous paper bags and then inside a forced-air drying oven at a temperature of 65 °C until reaching constant dry mass.

Statistical analysis was run by means of software SISVAR (Ferreira, 2011), using the Bootstrap analysis method to assess data normality and error homogeneity, after which the means were verified. For comparison of means, Tukey's test was employed, at 5% probability of error ($p<0.05$).

Table 1 - List of morphological variables used for assessing samples and respective scales

Morphological descriptors and respective scales
1. Culm thickness (mm), measured at the midsection with pachymeter
2. Flag leaf blade length (cm), measured with millimeter-scale ruler
3. Flag leaf width (mm), measured with millimeter-scale ruler
4. Number of panicles per plant
5. Plant height (cm), measured with millimeter-scale rulers
6. Number of tillers per plant
7. Plant phenology (days), from emergence to first inflorescence
8. Aerial part dry mass (g)
9. Root dry mass (g)

RESULTS AND DISCUSSION

Both investigated species presented specific morphological and phenological differences for each treatment, influenced by the tested WRCs. For morphological variables, *E. plana* plants differed as to number of tillers and number of panicles in response to the WRC treatments (Table 2).

The number of tillers in the 100% WRC treatment was smaller compared to that of the other treatments. This shows that one of the effects of soil saturation with water is fewer tillers developing in this species, which is originally found in well drained uplands. This effect of water on *E. plana* plants also reduces inflorescence, resulting in a smaller number of panicles per plant in the water depth condition than at 50% of WRC and 100% of WRC. The condition with the smallest amount of water (50% of WRC) led to the development of 90.3% more panicles than in the condition of highest moisture, with the 10 cm water depth.

Additionally, although the number of tillers formed in *E. plana* is statistically equivalent (Tukey's – 5%) between 100% of WRC and water depth, the hypoxia (anaerobiosis) caused by the water depth in the soil was enough to reduce the formation of panicles by 81% compared to both soil moisture conditions, according to data in Table 2.

Table 2 - Morphological variables assessed in E. plana plants subjected to different soil moisture conditions. Santa Maria – RS, 2015

Moisture condition	Number of tillers	Culm thickness (mm)	Number of panicles	Flag leaf length (cm)	Flag leaf width (mm)	Plant height (cm)
50% WRC	124.27 a	4.36^{ns}	19.73 a	11.17^{ns}	0.15^{ns}	48.98^{ns}
100% WRC	97.18 b	4.25	10.09 ab	19.28	0.27	57.28
Water depth	114.27 ab	2.90	1.91 b	12.18	0.21	55.01
CV (%)	21.39	64.31	92.35	61.05	65.44	39.98

Means followed by the same letter in the column do not differ from each other by Tukey's test at 5%. ^{ns} no significant differences found between treatments, according to the ANOVA test. WRC = Soil water retention capacity.

Low oxygenation rates caused by soil waterlogging affects plant growth and development in several ways and different parts, depending on the species; in adapted species, aerenchymas develop (Pires et al., 2015), which affects anaerobic respiration and photosynthetic and nutritional assimilation metabolism (Batista et al., 2008). Nevertheless, hypoxia produces toxic substances such as ethanol and lactate, which are generated in response to changes to the respiratory metabolism of roots (Kolb and Loly, 2009).

To Romero et al. (2003), drastic reductions in flower and seed production in some species are related to the species greater adaptive ability to the anaerobic environment of saturated soils. In a study conducted by Fante et al. (2010), no significant difference was found for grain dry matter and number of grains with soaking at stages V6, V8 and R4 for soybean cultivars. The same authors further add that, in one of the cultivars, there was a pronounced decline in grain dry matter and number of grains when soaked at stages V6 and V8.

Different moisture conditions caused no significant differences in culm thickness, flag leaf length and width, and plant height in *E. plana*. Concerning *E. pilosa* plants, soil moisture conditions promoted morphological changes as to number of tillers, number of panicles, flag leaf length and width (Table 3).

Table 3 - Morphological variables assessed in *E. pilosa* plants subjected to different soil moisture conditions. Santa Maria – RS, 2015

Moisture condition	Number of tillers	Culm thickness (mm)	Number of panicles	Flag leaf length (cm)	Flag leaf width (cm)	Plant height (cm)
50% WRC	46.15 a	1.84^{ns}	32.15 a	29.00 a	0.62 a	44.85^{ns}
100% WRC	42.30 a	1.70	28.69 a	23.45 b	0.58 ab	44.32
Water depth	15.54 b	1.56	1.46 b	20.86 b	0.48 c	42.81
CV (%)	21.24	17.95	15.44	21.67	20.57	14.81

Means followed by the same letter in the column do not differ from each other by Tukey's test at 5%. ^{ns} no significant differences found between treatments, according to the ANOVA test.

According to Almeida et al. (2003), hypoxia reduces liquid assimilation rates and, consequently, also reduces leaf expansion, which leads to smaller plant growth. In contrast, Tavares et al. (2017) reported that different soaking conditions of a soil cultivated with sugarcane did not interfere with the production of green and dry mass of culms, thus not affecting production of tillers per plant.

The water depth condition was related to decreased number of tillers in *E. pilosa* plants, with decreases of 66.33% and 63.27% in the number of tillers per plant compared to 50% and 100% of WRC, being statistically inferior to the tillering of plants subjected to lower moisture conditions, 50% and 100% of WRC, which presented 46.15 and 42.30 tillers per plant, respectively. Decreased plant tillering resulted in a smaller number of panicles in plants subjected to the water depth condition, with values 95.45% and 94.91% lower compared to 50% WRC and 100% WRC conditions, respectively.

E. pilosa plants subjected to high moisture conditions (100% and Water depth) grew flag leaves smaller in length and width, results that corroborate with what Dias-Filho and Carvalho (2000) reported for flooded grasses of the *Brachiaria* genus. Reduced leaf lengthening is related to the degree of tolerance that plants have to waterlogging (Pimentel et al., 2016); the less elongated the leaf, the higher the tolerance of the species.

E. pilosa plants had similar responses under the three tested soil moisture conditions for the morphological variables concerning culm thickness and plant height, without statistical differences. Macedo (2015) subjected two grass species of the *Urochloa* genus to waterlogging and studied their morphology, finding significant reductions in tillering for species *Urochloa plantaginea* as the amount of water in the soil of the experimental unit increase. However, the condition of highest soil moisture (water depth) reduced the number of inflorescences and, consequently, of plant seed yielding.

Phenological parameters showed statistically significant differences in response to soil moisture conditions, according to data displayed in Table 4. The dry mass of the aerial part of *E. plana* plants was greater under conditions of lower moisture (50% and 100% WRC) compared to the water depth condition. Lower biomass input is a common response in plants subjected to environments with soaked soil (Oliveira and Joly, 2010), and this response occurs even in grasses classified as tolerant to water-soaked soils (Dias-Filho, 2002) due to the effects of hypoxia on photosynthesis and photoassimilate production

For *E. plana* plants, different soil moisture conditions did not affect their vegetative cycle and root dry mass. As for *E. pilosa* plants, their vegetative cycle, aerial part dry mass, and root dry mass were affected by the amount of water in the soil (Table 4). *E. pilosa* plants under conditions of 50% and 100% of WRC did not significantly differ from each other when their vegetative cycles were assessed. However, the condition of highest soil moisture (water depth) caused increases in the vegetative cycle of *E. pilosa* plants and reductions in the dry mass of their aerial parts and roots.

Table 4 **-** Phenology and growth variables assessed in E. plana and E. Pilosa plants subjected to different soil moisture conditions. Santa Maria – RS, 2015

Moisture condition	*E. plana*			*E. pilosa*		
	Vegetative cycle (days)	Aerial part dry mass (g)	Root dry mass (g)	Vegetative cycle (days)	Aerial part dry mass (g)	Root dry mass (g)
50% WRC	85.85^{ns}	61.18 a	97.26^{ns}	50.00 b	56.09 a	53.75 a
100% WRC	90.83	50.34 a	84.49	51.40 b	58.32 a	67.74 a
Water depth	99.00	29.92 b	86.51	57.46 a	14.13 b	5.57 b
CV (%)	15.55	16.67	49.87	6.22	11.13	13.37

Means followed by the same letter in the column do not differ from each other by Tukey's test at 5%. ^{ns} no significant differences found between treatments, according to the ANOVA test.

Root acclimatization to environments with low oxygen concentrations occurs in several ways, depending on the species and its tolerance to hypoxia (Binotto et al., 2016). Dias-Filho and Carvalho (2000), while working with species of the *Brachiaria* genus, reported significant biomass reductions in the roots and leaf area of plants subjected to waterlogged environments.

Studies with grasses of the *Brachiaria* genus subjected to flooded conditions showed reductions in the liquid photosynthesis of plants as a result of oxygen deficit in the roots (Dias-Filho and Carvalho, 2000). Under this condition, there is a decline in ATP production, slowing down cell metabolism and photosynthetic efficiency, which thus reduces the plant biomass input (Summer et al., 2000).

According to Boru et al. (2003), the roots of plants are the most affected by changes caused by hypoxia because they suffer a direct action of oxygen deficit, consequently suffering rapid metabolic and morphological changes to adapt to the environment. Finally, the results found in the present research allow inferring that using water depth may be a management tool as it causes morpho-anatomical and physiological changes in *E. pilosa* and *E. plana* plants, providing the possibility of reducing their competitive capacity with crops such as rice, since the anaerobic conditions of the soil caused by the water depth interfere with tiller development, as well as with dry mass production in the aerial part and root system, thus reducing the formation of panicles, which may have as major impact reductions in the availability of seeds of these infesting species in the soil.

Therefore, ever-decreasing use of waterlogged paddies for rice farming, with more areas where intermittent irrigation is employed (shower-irrigated paddies), may be the factor that is allowing the invasiveness and naturalization of these exotic species in poorly drained lowland environments. Complementary field studies are suggested to assess this hypothesis.

REFERENCES

Almeida AM, Vriezen WH, Straeten D Molecular and Physiological mechanisms of flooding avoidance and tolerance in rice. Russ J Plant Physiol. 2003;50:743-51.

Batista CUN, Medri ME, Bianchini E, Medri C, Pimenta JA Tolerância à inundação de *Cecropia pachystachya*Trec. (Cecropiaceae): aspectos ecofisiológicos e morfoanatômicos. Acta Bot Bras. 2008;22:91-98.

Binotto B, Antoniazzi AP, Neumann GM, Sausen TL, Budke JC Tolerância de plântulas de Cedrela fissilis VELL. a diferentes amplitudes e intensidades de inundação. Cienc Flor. 2016;26(4):1339-1348.

Boru G, Vantoai T, Alves J, Hua D, Knee M. Responses of soybean to oxygen deficiency and elevated rootzone carbon dioxide concentration. Ann Bot. 2003;91:447-53.

Comissão de Química e Fertilidade do Solo – CQFSRS/SC. Manual de adubação e calagem para os Estados do Rio Grande do Sul e de Santa Catarina. 10ª.ed. Porto Alegre: SBCS Núcleo Regional Sul/UFRGS; 2004.

Dias-Filho MB. Tolerance to flooding in five Brachiaria brizantha accessions. Pesq Agropec Bras. 2002;37:439-47.

Dias-Filho MB, Carvalho CJR. Physiological and morphological esponses of *brachiaria* spp. to flooding. Pesq Agropec Bras. 2000;35:1959-66.

Fante CA, Alves JD, Goulart PFP, Deuner S, Silveira NM. Respostas fisiológicas em cultivares de soja submetidas ao alagamento em diferentes estádios. Bragantia. 2010;69(2):253-61.

Favaretto A, Chini SO, Scheffer-Basso SM, Sobottka AM, Bertol CD, Perez NB. Pattern of allelochemical distribution in leaves and roots of tough lovegrass (*Eragrostis plana* Nees) Aust J Crop Sci. 2015;9:1119-25.

Ferreira DF. Sisvar: a computer statistical analysis system. Cienc Agrotecnol. 2011;35(6):1039-42.

Dotta Filho AC, Mazzocato AC, Dotto GL, Thue PS, Pavan FA. *Eragrostis plana Nees* as a novel eco-friendly adsorbent for removal of crystal violet from aqueous solutions. Environ Sci Pollut Res. 2017;24:19909-19.

Giraldo-Cañas D, Peterson PM, Sánchez Vega I. "The Genus *Eragrostis* (Poaceae: Chloridoideae) in Northwestern South America (Colombia, Ecuador and Peru): Morphological and Taxonomic Studies. Bogotá: Universidad Nacional de Colombia; 2012. 195p. (Biblioteca José Jéronimo Triana, 24).

Kissmann KG. Plantas infestantes e nocivas. 2ª.ed. São Paulo: Basf Brasileira; 1997.

Kolb RM, Joly, CA Flooding tolerance of *Tabebuia cassinoides*: Metabolic, morphological and growth responses. Flora. 2009;204:528-35.

Longhi-Wagner HM. *Eragrostis.* In: Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro. [acessado em: 17 nov. 2015]. Disponível em: http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB13197.

Macedo LCP Alterações morfológicas em plantas do gênero *Urochloa* P. Beauv. submetidas a três condições de umidade do solo. [Dissertação]. Santa Maria: Universidade Federal de Santa Maria; 2015.

Oliveira VC, Joly CA. Flooding tolerance of Calophyllum brasiliense Camb. (Clusiaceae): morphological, physiological and growth responses. Trees. 2010;24;1:185-93.

Pimentel RM, Bayão GFV, Lelis DL, Cardoso AJS, Saldarriaga FV, Melo CCV, et al. Ecofisiologia de plantas forrageiras. PUBVET. 2016;10:636-720.

Pires MF, Castro EM, Magalhães PC, Silva Neta IC, Monteiro AGDP. Etileno e peróxido de hidrogênio na formação de aerênquima em milho tolerante a alagamento intermitente. Pesq Agropec Bras. 2015;50(9):779-87.

Romero JL, Magalhães PC, Alves JD, Durães FO, Vasconcellos CA. Efeito do cálcio sobre algumas características biofísicas e morfológicas de plantas de milho BRS-4154 submetidas ao alagamento do solo. Rev Bras Milho Sorgo. 2003;2(3):21-33

Schwab NT. Disponibilidade hídrica no cultivo de cravina em vasos com substrato de cinzas de casca de arroz [dissertação]. Santa Maria: Universidade Federal de Santa Maria, 2011.

Shirasuna RT. *Urochloa.* In: Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro; 2015. [acessado em 20 maio de 2017]. Disponível em: http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB20516.

Summer JE, Ratcliffe RG, Jackson MB. Anoxia tolerance in the aquatic monocot potamogeton pectinatus: absence of oxygen stimulates elongation in association with an unusually large Pasteur effect. J Exp Bot. 2000;51(349):1413-22.

Sociedade Sul-Brasileira de Arroz Irrigado – SOSBAI. Reunião Técnica da Cultura do Arroz Irrigado. Arroz Irrigado: Recomendações técnicas da pesquisa para o sul do Brasil. Gramado: SOSBAI; 2018.

Tavares ACS, Duarte SN, Dias NS, Sá FVS, Miranda JH, Fernandes CS. Produção e maturação de cana-de-açúcar submetida a encharcamento em diferentes estádios de desenvolvimento. Irriga. 2017;22(1):154.