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Rice and Barnyardgrass: Water Stress and Initial Establishment

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Abstract

The present work aimed to evaluate the effect of different water stress levels on the development of both rice and barnyardgrass. The study was established into greenhouse, in completely randomized design, in factorial scheme 2 × 5, with four replications. Factor "A" comprised the plant species (rice cv. BRS Querência, or the weed *Echinochloa crusgalli*), and factor "B" comprised the water stress levels: (T1) continuous flood (CF); (T2) 0 kPa (saturated soil); (T3) 10 kPa; (T4) 40 kPa; and (T5) 100 kPa. Plant emergence was assessed every day; plant length was measured 30 days after planting. At the end of the experiment, the number of leaves per plant, root length and shoot and root dry mass were determined. Our data supply evidence that under moderate water stress, up to approximately 40 kPa, rice tends to perform better than barnyardgrass in the initial stage of crop growth, when under equivalent plant density. However, barnyardgrass is usually present in much higher plant density than crop plants in fields traditionally cropped with rice. Thus, efficient control of barnyardgrass should be accomplished to avoid damage to rice crop by competition for environmental resources.

Keywords

Echinochloa crusgalli, Intermittent Irrigation, *Oryza sativa*

1. Introduction

In Southern Brazil, rice cultivation stands out among the main agricultural activities, and this region is responsible for most of the national rice production. The states of Rio Grande do Sul (RS) and Santa Catarina (SC) grow about 1.26

million hectares of rice every year, whose production is around 9.7 million tons, resulting in an average productivity of 7.6 t·ha^{-1} [1]. Among the factors that limit crop productivity, weed infestation can be highlighted. These compete directly with rice plants for light, water and nutrients, limiting both grain yield and quality [2].

In this region, rice is predominantly cropped under continuous flood irrigation [3]. In SC, rice is planted mainly in the water-seeded system, where the water layer is established approximately 20 days before planting and maintained throughout the crop cycle. However, in RS, the water layer is established only from the V_3 - V_4 development stage onwards [2]. One of the main aims of flooding is to reduce weed establishment, as it inhibits the emergence of weed plants and may delay the development of those already emerged. However, there are some species that can tolerate and even be favored by this method of irrigation, as barnyardgrass (*Echinochloa* spp.) [4].

The genus *Echinochloa* comprises the most troublesome grass weeds in rice [5], which is mainly associated with their adaptability to the culture ecosystem [6]. These species are adapted to the hypoxic environment and, therefore, they compete with rice plants throughout the life cycle. Moreover, high infestation levels are associated with fast initial growth, high nitrogen requirement, C_4 photosynthetic cycle and difficulties to chemically control them, which occur due to morphophysiological similarities with the crop [7]. According to [8], one *Echinochloa* plant per square meter reduces rice yields by 64 kg·ha^{-1}.

In the period prior to water establishment into paddies, both crop and weed plants are subjected to water stress, depending mostly on the occurrence of precipitation for establishment. Thus, plant adaptation to moderate water stress levels may determine crop/weeds competition dynamics. Similarly, when the intermittent water management is used in rice, there is risk of water stress to be imposed to both crop and weed plants [9]. The same may be observed when rice is grown under sprinkler irrigation [10].

Thus, the effect of water stress on the development of rice and weed plants should be further understood. The present work aimed to evaluate the effect of different water stress levels on the development of both rice and barnyardgrass.

2. Material and Methods

The study was established in a greenhouse with controlled environment at Embrapa Clima Temperado—Terras Baixas Experimental Station, Capão do Leão (RS), Brazil, from June to September 2016, in a completely randomized experimental design, in factorial scheme (2 × 5), with four replications. Environmental conditions into the greenhouse were as follows: temperature of 27˚C ± 2˚C; relative air humidity between 70% and 95%; natural light conditions. Factor "A" comprised the plant species (rice cv. BRS Querência, or the weed *Echinochloa crusgalli*), and factor "B" comprised the water stress levels applied to the plots, as follows: (T1) continuous flood (CF) with 5 cm water layer (no water deficit);

(T2) 0 kPa (saturated soil), no stress, no water layer; and three stress levels: (T3) 10 kPa; (T4) 40 kPa; and (T5) 100 kPa.

Experimental units consisted of plastic pots, filled with 2 kg of soil. The soil used at the experiment was an Albaqualf collected in rice fields at the same Institution where the study was conducted. Soil pH was correct to 6.0 in order to guarantee equal soil conditions in all experimental units. Twenty five rice or barnyardgrass seeds were planted into each experimental unit, according to the treatment.

For CF treatment (T1), water layer was established prior to planting. For the other treatments, the water tension corresponding to each treatment was established, and after stabilization the seeds were planted. The pots were irrigated with tap water when needed according to the soil moisture readings. Soil water potentials were monitored by using sets of Watermark electro-tensiometers (Irrometer Co.), with a single sensor installed horizontally in each experimental unit, at 2 cm soil depth.

Plant emergence was assessed every day, starting one day after planting (DAP), by registering the number of seedlings per plot which were at least 1 cm in height. The length of all plants into the plot was measured with a ruler, from the soil surface to the tip of the longest leaf 30 DAP. In the end of the experiment (45 DAP), the number of leaves per plant was counted. Soil from plots was washed under tap water, and root length was also measured with a ruler, from the seed to the tip of the longest root. Root volume was measured by immersion of these into a graduated cylinder with known water volume. Thereafter, the fresh biomass was separated in shoots and roots, put into paper bags, and taken to oven for drying at 65˚C for five days. After this period, shoot and root dry mass were weighted.

Emergence rate was studied by adjusting a quadratic regression by the Loess method [11] to the data, as function of days after planting and water stress levels, being established the 95% confidence interval [12]. For the other variables, the same local regression was applied as function of plant species and water stress levels, also with 95% confidence interval. Data were analyzed into the "R" statistical environment [13].

3. Results and Discussion

The emergence curves (**Figure 1**) shown that the establishment of both species was minimal when seeds were subjected to CF, with only barnyardgrass being able to emerge under a continuous water layer, with approximately 8% emergence. Low seedling emergence was also observed when the soil was kept at 0 kPa (saturated, no flood), where both species were able to establish about 12% of the population 30 DAP (**Figure 1**). The best results for plant establishment were obtained when the soil was kept at about 10 kPa, where both species reached around 77% emergence 30 DAP. However, the emergence peak for rice plants occurred 5 days before barnyardgrass. Plant establishment in the other water tensions, especially for barnyardgrass, was mild (**Figure 1**).

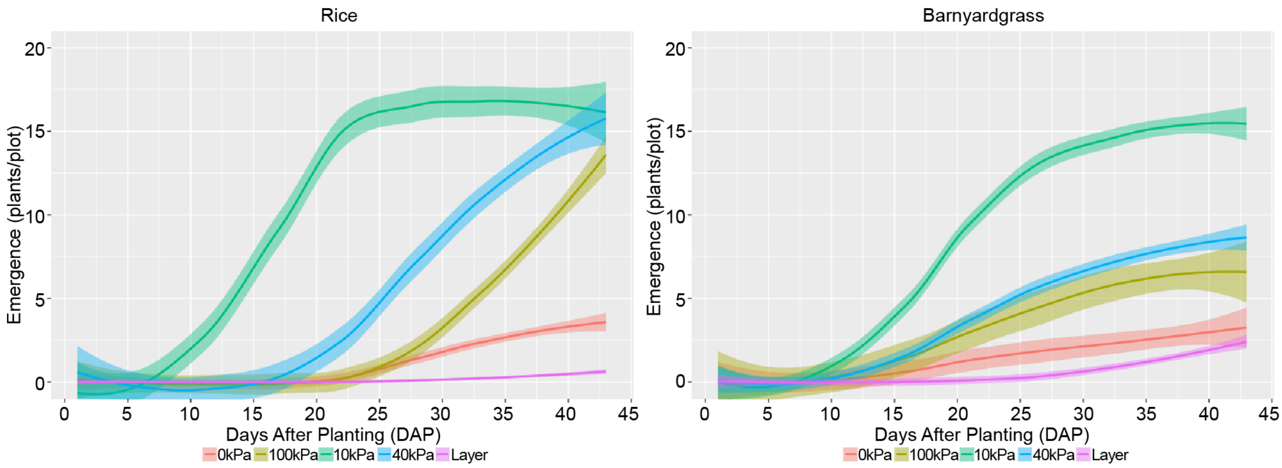

Figure 1. Emergence of rice and barnyardgrass (%), as function of days after planting for each water tension. Confidence intervals at 95% are presented.

The tension of 40 kPa resulted in 11 - 20 rice plants and 5 - 13 barnyardgrass plants per plot; when submitted to 100 kPa there was reduction to 8 - 17 rice plants and 3 - 10 barnyardgrass plants (**Figure 2(a)**). For 0 kPa and 10 kPa, the establishment was similar for both species. Soil water tensions between 40 and 100 kPa were harmful for barnyardgrass establishment compared to 10 kPa.

It is pointed out the greater importance of soil water availability for barnyardgrass emergence as compared to rice. This weed prefers wet soils, developing mainly in paddy fields, and on water edges in wetlands [14] [15]. In addition, seed germination is limited by the water layer; thus, the species presents mechanisms that confer germination unevenness, and guarantee perpetuation by waiting for adequate conditions to germinate [16] due to factors as seed coat hardness or impermeability and immature embryos [17].

The number of leaves per plant was similar for both species in low water tensions, decreasing from 10 kPa onwards for rice while keeping almost stable for barnyardgrass (**Figure 2(b)**).

Chauhan [18], also evaluating the effect of water regime, associated to fertilization and plant density, found that in a flooded environment *E. crusgalli* alone, produced a larger number of seeds, but also showed higher plant height, biomass, leaf number and area, compared to the aerobic environment.

Our data supply evidence that rice is most prone to overcome water stress conditions compared to barnyardgrass, when under equivalent plant density. However, barnyardgrass is usually present in much higher plant density than crop plants in fields traditionally cropped with rice [5]. Thus, efficient control of barnyardgrass should be accomplished to avoid damage to rice crop by competition for environmental resources.

Shoot length (**Figure 3(a)**) of rice decreased almost linearly between water tensions of 10 and 100 kPa, which ranged from 15 - 22 cm (10 kPa) to 10 - 15 cm (100 kPa). For the same water tensions, barnyardgrass varied from 8 - 16 cm to 4 - 11 cm, according to the respective confidence intervals at 95%.

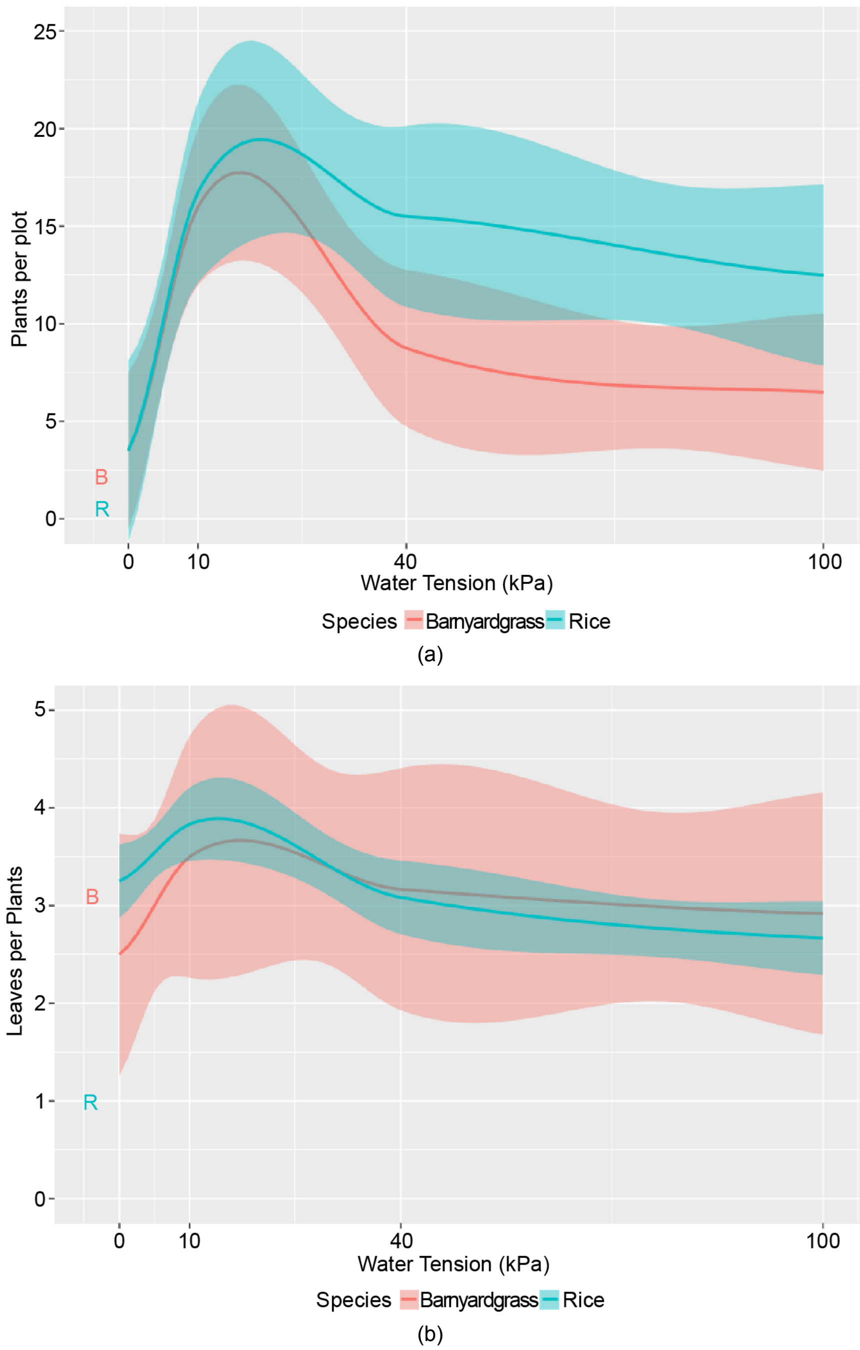

Figure 2. Plants per plot and leaves per plant (a and b, respectively), as function of water tension for each plant species. Confidence intervals at 95% are presented.

Under these conditions, rice is most prone to perform better in shoot length compared to barnyardgrass, being this confirmed for water tensions below 10 kPa. Surely this advantage for rice would exist only under equivalent plant densities in the field. The root length of both species (**Figure 3(b)**) on the other side, were clearly equivalent as their confidence intervals overlapped, ranging from 12 - 17 cm (rice) and 8 - 18 cm (barnyardgrass) at 10 kPa, to 7 - 14 cm (rice) and 4 - 14 cm (barnyardgrass) at 100 kPa.

Figure 3. Shoot and root length (a and b, respectively), as function of water tension for each plant species. Confidence intervals at 95% are presented.

Under water stress, rice may present reduced plant height, leaf area and biomass production, tiller death, root dry mass and depth, and delay in reproductive development. However, water deficiency, when imposed gradually to moderate levels (up to ~40 kPa), does not interfere with assimilate partitioning between shoot and roots. On the other hand, under severe stress, root growth is interrupted [19].

Root volume was bigger for barnyardgrass compared to rice, for 0 kPa (0.2 - 0.75 $cm^3 \cdot plot^{-1}$) and 10 kPa (0.75 - 1.4 $cm^3 \cdot plot^{-1}$), decreasing onwards up to 100 kPa (0 - 0.4 $cm^3 \cdot plot^{-1}$). Rice presented 0.1 - 0.2 $cm^3 \cdot plot^{-1}$ and 0.2 - 0.4 $cm^3 \cdot plot^{-1}$, respectively at 0 kPa and 10 kPa (**Figure 4**). In addition to volume, the root depth, which is directly related to its architecture, is essential for the plant to seek and absorb water from deeper soil layers [20].

Shoot and root fresh mass performed better up to approximately 50 kPa, for rice than for barnyardgrass (**Figure 5(a)**; **Figure 5(b)**). Similarly, shoot (**Figure 5(c)**) and root (**Figure 5(d)**) dry mass clearly differed, with rice always performing better compared to barnyardgrass up to 40 kPa for shoot dry mass, and up to 100 kPa for root dry mass, as the 95% confidence intervals did not overlap. These results corroborate with the findings by [21], in which soil water tension of 50 kPa promoted reduction in rice dry mass, since water is involved in cellular turgescence process promoting cell expansion. Thus, with reduction of water availability in soil, plant growth and development are reduced.

When under moderate or severe short-term water deficiency, the first reaction of plants is to turn the osmotic potential most negative (most intensive), by accumulation of cellular solutes [22], in order to increase the potential gradient and promote water absorption, or to reduce transpiration in an attempt to maintain a positive water balance [23].

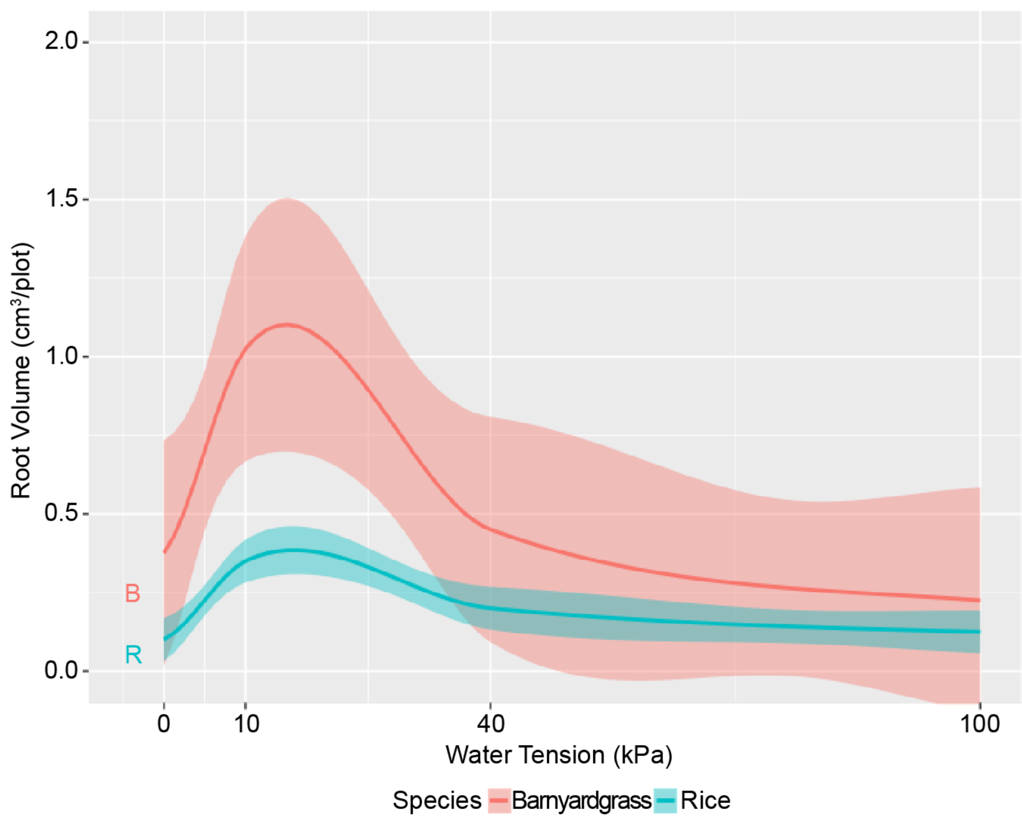

Figure 4. Root volume ($cm^3 \cdot plot^{-1}$), as function of water tension for each plant species. Confidence intervals at 95% are presented.

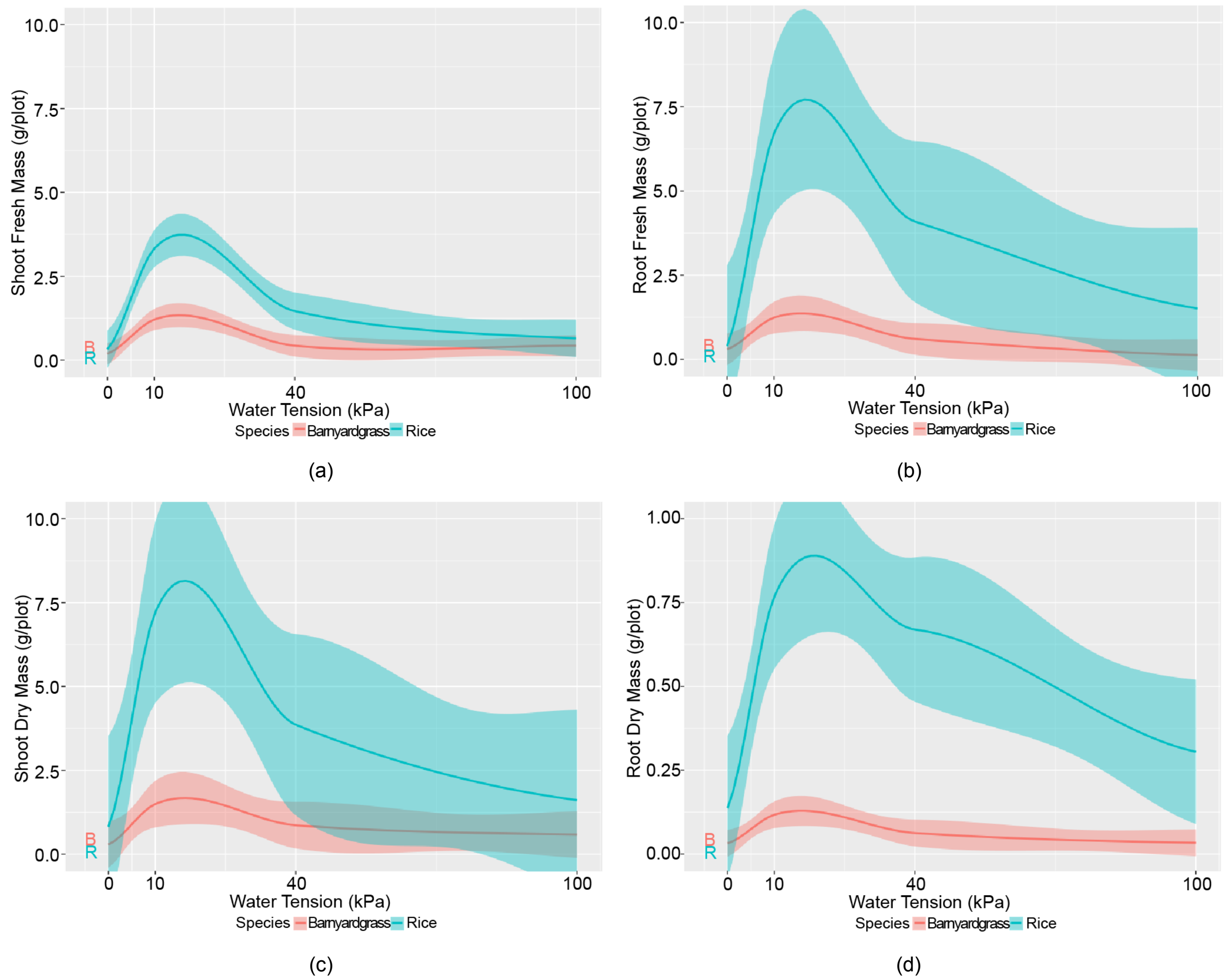

Figure 5. Shoot and root fresh (a) and (b), respectively) and dry (c) and (d), respectively) mass (g·plot^{-1}), as function of water tension for each plant species. Confidence intervals at 95% are presented.

4. Conclusion

Under moderate water stress, up to approximately 40 kPa, rice tends to perform better than barnyardgrass in the initial stage of crop growth, when under equivalent plant density.

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