

Research Article

Rice root growth and development in competition with weedy rice

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ARTICLE INFORMATION

Received: November 13, 2018

Accepted: March 17, 2020

Keywords:

Oryza sativa
solar radiation
root system

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Cite this article:

Schaedler CE, Taborda CUM, Goulart FAP, Chiapinotto DM, Pinho PJ. Root rice development with weedy rice competition in response to light competition. *Planta Daninha*. 2020;38:e020216460. <https://doi.org/10.1590/S0100-83582020380100086>

Conflict of Interest:

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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HIGHLIGHTS

- Competition for light causes morphological changes in weedy and cultivated rice.
- Regardless of the competition condition, weedy rice has higher root traits than cultivated rice.
- Weedy rice has greater competitive capacity using resources beneath the soil.

ABSTRACT

Background: Weedy rice belongs to the same taxon as irrigated rice (*Oryza sativa* L.), and is the main weed of the crop. However, it exhibits different traits that produce greater competitive capacity using solar radiation. In competition for light, plants invest in photoassimilates for the shoots and can reduce their root development.

Objectives: The objective of this work is to evaluate the initial growth of weedy and cultivated rice roots in response to light competition.

Methods: The experiment was conducted in a greenhouse (hydroponic system), using a completely randomized design, arranged in a 2x2x6 factorial scheme, with five replications. Factor A consisted of the weedy rice biotype Q35B and the rice cultivar IRGA 424; factor B of light competition conditions (presence or absence of 75 weedy rice plants); and factor C of assessment time. At 0, 7, 14, 21, 28 and 35 days after transplanting, samples were taken from each experimental unity to measure the root area, perimeter, length, number of tips, and root dry weight (RDW), and shoot dry weight (SDW).

Results: Competition for light reduced the area, perimeter, length, number of root tips, reduced the RDW and the SDW of both, the weedy rice biotype and crop rice. However, regardless of the competitive condition, the weedy rice showed a higher area, perimeter, initial growth, number of tips, RDW and SDW than that of cultivated rice.

Conclusion: Weedy rice exhibits greater competitive capacity using the resources beneath the soil.

1 INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food sources for half the world's population (Chauhan, 2013; Fukagawa and Ziska, 2019). It supplies around 20% of human calorie intake and is

essential to food security. In order to meet the demand of the growing population, production must increase in the coming decades (Ziska et al., 2015). In Brazil, Rio Grande do Sul state is the largest producer of irrigated rice. However, an average yield of 7.2 ton ha⁻¹ is less than the productive

potential of the main cultivars used, which is more than 10 ton ha⁻¹ (Irga, 2020).

Inefficient weed control is one of the major limiting factors of the productive potential of irrigated rice (Venske et al., 2013). In this respect, weedy rice (*Oryza sativa* L.), also known as red rice, is one of the main weed species (Shivrain et al., 2010). Competing for nutrients, water and sunlight (Zhang et al., 2014) may cause yield losses of up to 90%, and reduce grain quality (Dai et al., 2016).

By exploiting basically, the same ecological niche, weedy and cultivated rice genotypes compete for the same resources in time and/or space (Fleck et al., 2008). However, a number of distinct traits, such as early vigor, greater tiller emission and height (Abraham and Jose, 2014), give weedy rice a competitive advantage, primarily from sunlight (Streck et al., 2008). Solar radiation regulates the physiological and biophysical processes of plants (Yang et al., 2013), acts as an environmental signaler (Jiao et al., 2007), and is a significant source of competition for several weed species (Rizzardi et al., 2001).

Neighboring plants can change the amount and quality of the intercepted light, due to alterations in the red/far red ratio (V:Ve). The morphophysiological responses to the decrease in this ratio may include an increase in plant height (Liu et al., 2009; Page et al., 2010; Afifi and Swanton, 2011), since they invest a greater proportion of photoassimilates in increasing leaf area, and optimizing light energy capture (Gobbi et al., 2011). However, this may affect root length and development (Wang et al., 2011).

Plants use different parts (leaves/roots) to compete above (space and light) and beneath (nutrients and water) the soil (Giora and Osborne, 2014). In irrigated rice crops, sunlight and nutrients rapidly become more limiting resources (Burgos et al., 2006). Thus, in addition to competition for light, when plants of the same species grow or occupy the same environment, interactions for resources may occur in the root system (Rizzardi et al., 2001). Roots play an important role in absorbing water and nutrients from the soil (Wang et al., 2011). Thus, the size of the root system is also directly related to the competitive capacity of species (Page et al., 2010).

The hypothesis of this study is that when plants compete for light they prioritize photoassimilates in shoot growth and consequently reduce root development, which may influence competition. Thus, the aim of the present study was to assess

initial weedy and cultivated rice root growth in response to competition for light.

2 MATERIALS AND METHODS

The experiment was conducted in a greenhouse with coordinates 29°09'22.4"S and 56°33'11.9"W, in October and November 2013. The irrigated rice cultivar IRGA 424 and weedy rice biotype Q35B were used. A completely randomized design was applied, arranged in a 2x2x6 factorial scheme, with five replications. Factor A consisted of cultivated rice and the weedy species; factor B, of competition for light (presence or absence of weedy rice); and factor C, assessment times: 0, 7, 14, 21, 28 and 35 days after transplanting (DAT).

In October 2013, cultivated and weedy rice seeds were placed in a BOD (Biochemical Oxygen Demand) for germination. 12 seeds were placed in germitest paper, at 25 °C. At seven days after germination, the seedlings were individually relocated to the hydroponic system (transplanted). This system consisted of 0.4 L plastic cups (where seedlings were fixed using Styrofoam discs – Figure 1A), containing nutrient solution diluted to 25% ionic strength, that is, 1.5 mL of 1.5 M KNO₃; 1 mL of 1M Ca (NO₃)₂; 1 mL of 0.5M MgSO₄; 0.25 mL of 0.5M Mg³(PO₄)₂; and 1.1 mL of Fe-EDTA solution (Hoagland and Arnon, 1950). The nutrient solution was changed weekly and, when necessary, topped up with distilled water.

Immediately after relocation to the nutrient solution, the cups were placed in the soil in 8 L pots (surface area = 0.05 m²), as illustrated in Figure 1B. In treatments with competition, 75 weedy rice plants were used to simulate initial competition for sunlight (Figure 1C) – a methodology similar to that adopted by Lamego et al. (2015). This population was established five days before the cups were placed in the soil and irrigated daily with 0.4 L of water.

At each assessment time, the plants were collected from the hydropony and the shoot and root removed. At 0, 14, 21, 28 and 35 DAT the area, diameter, length and number of root tips were counted, using the digital image processing (DIP) method. The roots were digitally scanned, the images processed in Adobe Photoshop Elements 3.0 and converted into a format compatible with the Delta-T Scan Root Analysis System. At 0, 7, 14, 21, 28 and 35 DAT, root (RDW) and shoot dry weight (SDW) were determined in a forced air oven at 65 °C, until reaching constant weight, and root length was measured with a graduated ruler.

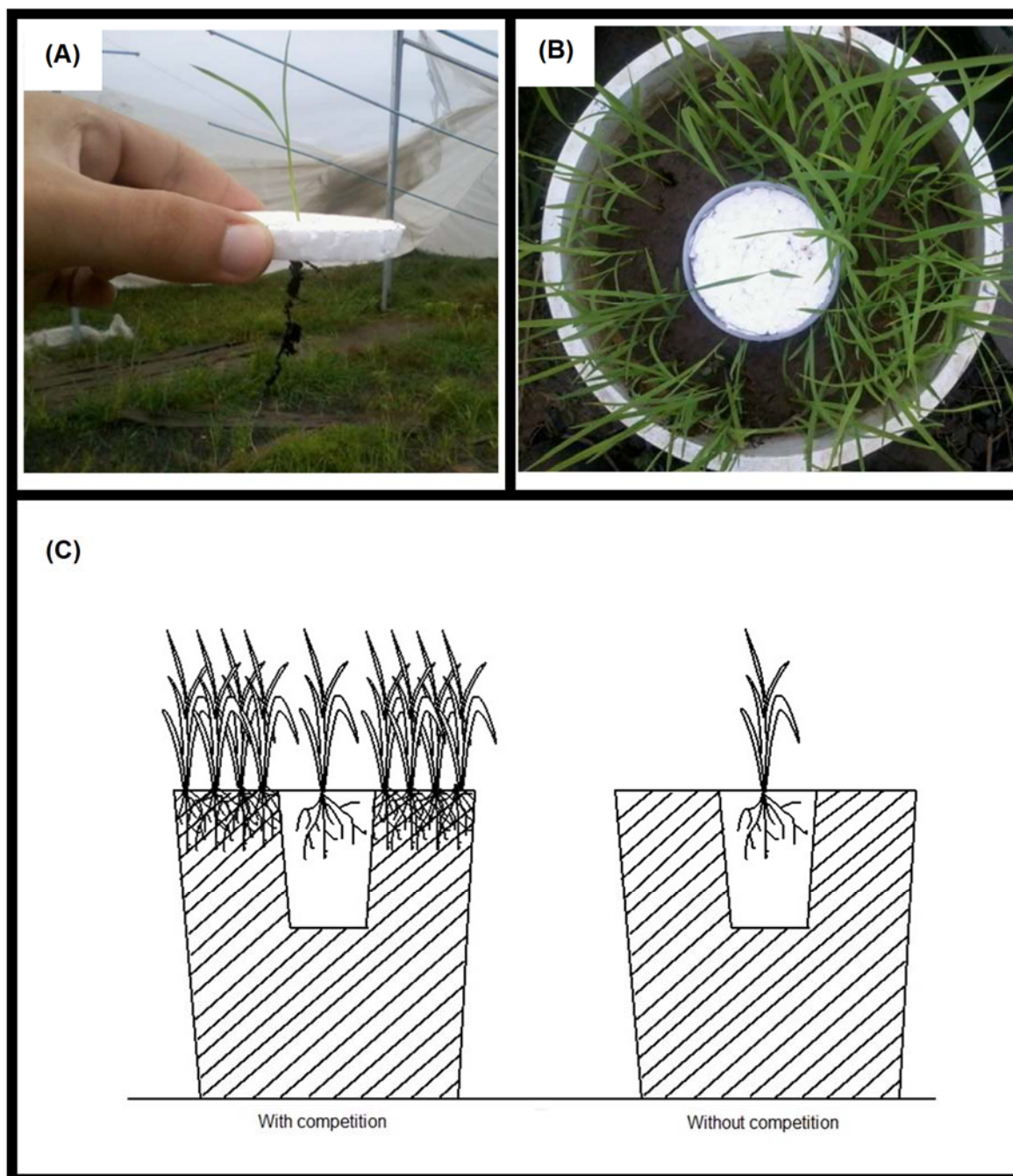


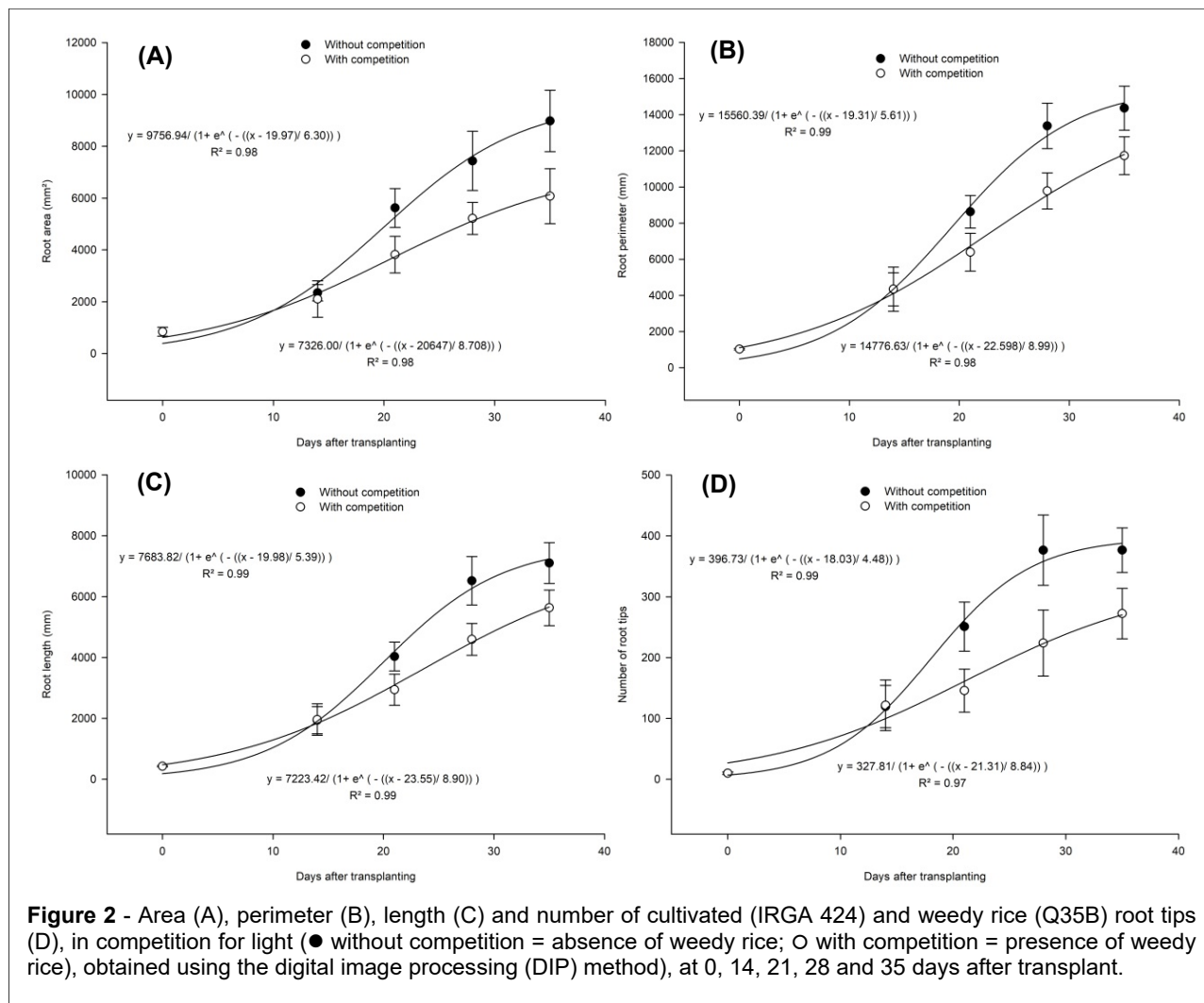
Figure 1 - Illustration to simulate initial competition for light in cultivated and weedy rice root growth. Rice anchoring in a hydroponic system (A); experimental unit at 28 days after transplant (B) – cultivar (IRGA 424) in the center and weedy rice (Q35B) as competitor plants; treatment with and without competition for light (C).

The data obtained underwent analysis of variance – ANOVA ($p \leq 0.05$). Treatment averages were compared using Fisher's DMS test ($p \leq 0.05$). When a significant difference was detected between the cultivar/biotype \times with/without competition \times times analyzed, regression analysis with curve fitting was conducted, using models according to the greatest parameter significance ($p \leq 0.05$).

3 RESULTS AND DISCUSSION

The results obtained demonstrate the interaction between competition for light (absence or presence

of weedy rice) and the times assessed ($p \leq 0.05$) for the variables area, perimeter, length and number of root tips (Figures 2A, 2B, 2C and 2D, respectively), RDW (Figure 3A) and SDW (Figure 3B). For root length (Figure 4), there was interaction between the rice cultivar (IRGA 424) and weedy rice biotype (Q35B), in response to different assessment times. There was also interaction between cultivar/biotype and competition for the number of root tips (Table 1). The cultivar/biotype factor was significant according to Fisher's DMS test ($p \leq 0.05$), for length, perimeter and root area (Table 2).



With respect to the variables assessed using the DIP method, that is, area, perimeter, length and number of root tips (Figures 2A, 2B, 2C and 2D, respectively), there was no difference between competitive conditions during the first two assessment times. However, from 21 DAT onwards, the competition for light obtained lower values. Competition for light for at 35 DAT reduced the area (32.33%), perimeter (18.3%), length (20.71%) and number of cultivated and weedy rice root tips (27.68%) in relation to the lack of competition. Similar behavior was observed for RDW and SDW, which decreased in a competitive condition, by 47.85% and 31.43%, respectively (Figures 3A and 3B).

For the variable root length, the weedy rice biotype showed greater initial growth up to 21 DAT. After this period, the cultivar and biotype were equivalent (Figure 4). In a competitive condition, biotype Q35B and cultivar IRGA 424 exhibited fewer root tips. However, the number of cultivated rice tips declined by 33%, compared to weedy rice (Table 1). Irrespective of competitive condition, for the variables area, perimeter and length, weedy rice values were

13.9%, 12.3% and 12.4% higher, respectively, than those of its cultivated counterpart (Table 2).

The root system is the result of coordinated control of genetic factors and the action of abiotic and biotic environmental stimuli (Slovak et al., 2016). Competitive condition affects physiological regulation using signs of light quality (Merotto Jr. et al., 2009), influencing the asymmetric distribution of auxin (a plant hormone that plays an important role in controlling tropism, root length and development) to the roots (Wang et al., 2011).

The present study showed that in a competitive situation for light, the variables related to root development decrease. However, weedy rice is superior to the cultivated variety. These traits may be related to the ontogeny and/or adaptive plasticity of the competitors (Ziska et al., 2015; Dai et al., 2016). The greater weedy root development, irrespective of competitive condition, provides more nutrient acquisition capacity – the primary determinant in the establishment, dissemination and persistence of weed species (Giora and Osborne, 2014).

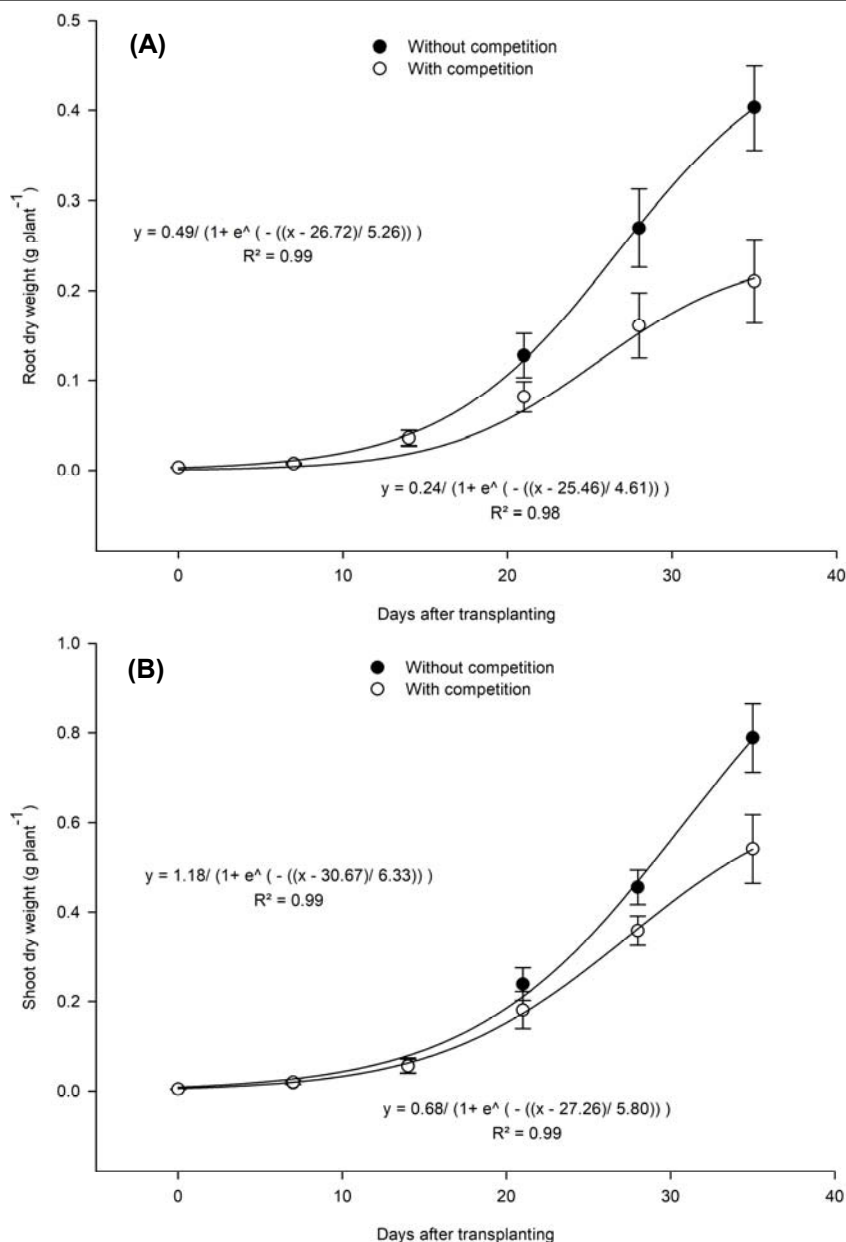


Figure 3 - Root dry weight (A) and shoot dry weight (B), in grams plant⁻¹ of cultivated (IRGA 424) and weedy rice (Q35B), in competition for light (● without competition = absence of weedy rice; ○ with competition = presence of weedy rice), at 0, 7, 14, 21, 28 and 35 days after transplant.

Another fact that should be underscored is that the weedy rice biotype shows greater initial root growth in the first 21 DAT, when compared to cultivated rice. The difference in initial growth is a determining factor in competitive capacity, given that early growth is an advantage in terms of access to available resources (Bastiaans et al., 2008). This results in water or nutrient depletion in the competitor (Rizzardì et al., 2001).

Venske et al. (2013) assessed the initial development of cultivated and weedy rice seedlings and found that the latter exhibits morphological variables superior to those of its cultivated counterpart, increasing in low light conditions. This study corroborates the results observed for the

morphological variables of the root system, such as the greater length, perimeter, and area of the weed species. As such, the fact that weedy rice roots exhibited rapid initial growth in the first 21 DAT, as well as greater length, perimeter, area and number of root tips, compared to cultivated rice, may result in their demonstrating superior skills when competing for resources beneath the soil.

Competition among plants depends on the morphological shoot traits, to capture light, and the root system, to absorb water and nutrients (Giora and Osborne, 2014). Competition for light may affect root length and development (Wang et al., 2011), with direct influences on the competitive capacity among species (Page et al., 2010). The

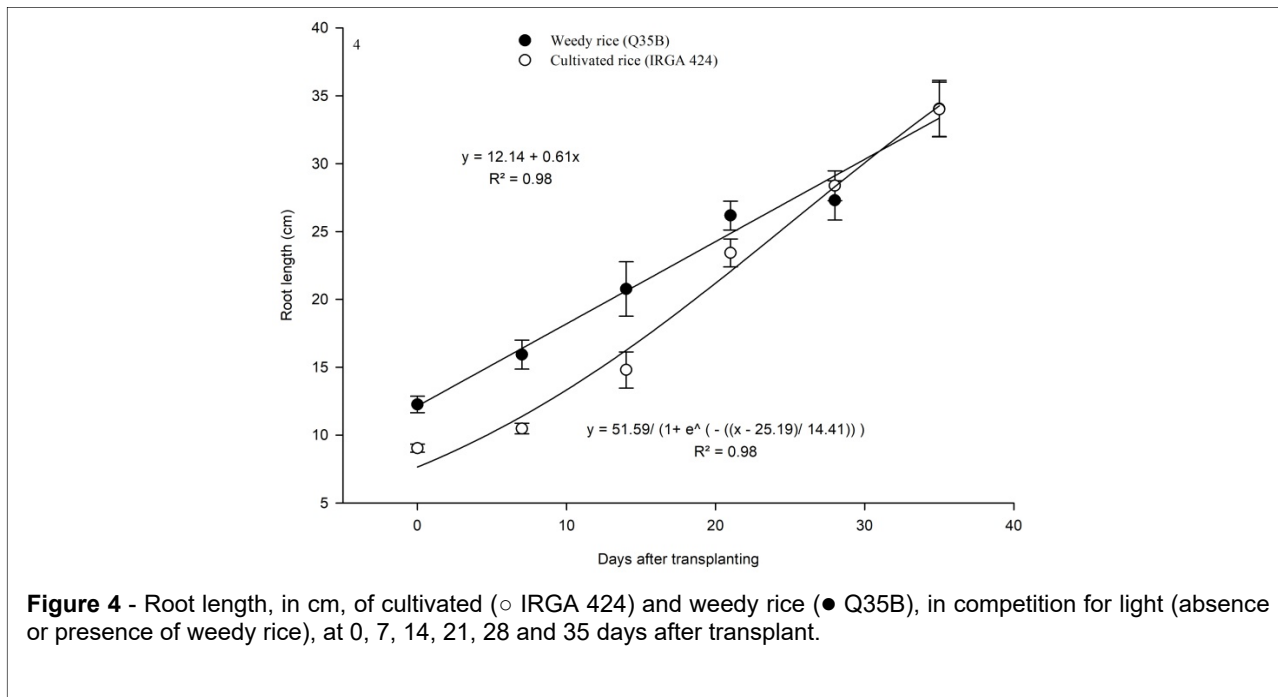


Figure 4 - Root length, in cm, of cultivated (○ IRGA 424) and weedy rice (● Q35B), in competition for light (absence or presence of weedy rice), at 0, 7, 14, 21, 28 and 35 days after transplant.

Table 1 - Number root tips for the cultivated (IRGA 424) and weedy rice (Q35B) as a function of competition for light (presence or absence of weedy rice)

Cultivar/biotype	Without competition	With competition
Q35B	224.11 Aa	185.57 Ba
IRGA 424	229.35 Aa	123.88 Bb
CV (%)	32.71	

Means followed by the same upper-case letter on the line and lower case in the column do not differ according to Fisher's DMS test (p≤0.05).

Table 2 - Root length (mm), perimeter (mm) and area (mm²) of cultivated (IRGA 424) and weedy rice (Q35B)

Cultivar/biotype	Length (mm)	Perimeter (mm)	Area (mm²)
Q35B	379.40 a	799.40 a	4653.00 a
IRGA 424	332.30 b	700.60 b	4005.00 b
CV (%)	28.78	25.57	28.34

Means followed by the same lower-case letter in the column do not differ according to Fisher's DMS test (p≤0.05).

superior competitive ability of a species means greater capacity to assimilate resources from the environment and, consequently, higher growth and development potential, which leads to increased damage to the competitor (Agostinetto et al., 2013).

Plant responses to light stress, caused by competition for sunlight, are varied. However, one of the main responses is changes in the root system and a smaller exploitation area, directly affecting water and nutrient absorption rates. This response may be an escape mechanism and search for sunlight with the necessary quality and quantity needed to reestablish the plant's energy balance (Lamego et al., 2015).

4 CONCLUSIONS

Competition for light changes the morphological traits of cultivated rice (IRGA 424) and the biotype of weedy rice (Q35B). The changes included a decline in root area, perimeter, length, number of tips and dry weight, and reduce the shoot dry weight as well. However, the weedy rice biotype experiences less interference in competition for light, indicating that it is more competitive than cultivated rice, since, irrespective of competitive condition, it displays greater initial growth, root length, perimeter and area.

5 CONTRIBUTIONS

CES: planned, provided advice on the development of activities, performed statistical analysis, and drafted the manuscript. CUMT: implemented, contributed to the development, organization of activities and data acquisition, and performed statistical analysis. FAPG: implemented, contributed to the development, organization of activities and data acquisition. DMC: reviewed the manuscript, contributed to statistical analysis and figures, and helped draft the manuscript. PJP: provided advice on the planning, development of activities, and hydroponic system, and reviewed the data and discussion.

6 ACKNOWLEDGMENTS

Thanks to Foundation for Research of the State of Rio Grande do Sul (FAPERGS) and National Council for Scientific and Technological Development (CNPq) for the Research scholarship of second and fourth authors, respectively.

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