Initial Establishment and Physiological Performance of Rice as Affected by Ryegrass Mulching Levels

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***Abstract*— *We aimed to evaluate the initial growth and physiological characteristics of rice planted following ryegrass in lowland areas. The experiment was conducted in Capao do Leao, Brazil, in Typic Albaqualf. Ryegrass was planted preceding the experiment installation. Prior to rice planting, the area was burndown with herbicide, when treatments were established: ryegrass plants were cut at 0, 15, 30 or 45 cm above ground, resulting in different mulching levels. Rice was then planted, being managed according to local recommendations for the crop. We evaluated the variation in soil moisture levels, rice establishment in density and seedling height, and physiological parameters: relative fluorescence, chlorophyll, flavonoid and nitrogen balance indexes. High mulching levels by ryegrass allowed rice five additional days on a dry season, before harmful soil water tension, compared to bare soil; seedlings able to emerge under the ryegrass mulching, grew without considerable barriers; plant physiology in fields with residual ryegrass mulching was little affected, and ryegrass cut up to 45cm height prior to planting rice seem not to affect it. This corresponds to a maximum of about 4500 kg ha-1 of ryegrass straw on soil surface prior to planting rice to avoid damages to crop establishment.*

***Keywords*— *Oryza sativa, Lolium multiflorum, lowlands, growth.*

I. INTRODUCTION

The state of Rio Grande do Sul is the main rice producer in Brazil, accounting for about 70% of the country's total production in an approximate area of one million hectares produced annually (Sosbai, 2016), of a total area of three million hectares available for the crop (Gomes et al., 2006).

Currently the predominant planting system, used in approximately 60% of the areas, involves low soil disturbance (involving minimum tillage, fall tillage and no-tillage) aiming for immediate planting as soon as the weather allows it. The conventional tillage system, involving soil harrowing and disking prior to planting, is present in 30% of the areas, and the water-seeded rice is used in about 10% of the area (Irga, 2016). This management based on conservation principles has various benefits, from the improvement of soil properties to the possibility of income diversification, allowing the crop-livestock integration (Marchesi et al., 2011) or crop rotation (Gomes et al., 2006).

However, innate characteristics of lowland soils such as high macro / micropore ratio, high density and low drainage capacity, which is the consequence of a subsurface layer with low permeability, among other factors, limit root growth of plants that are not adapted to the hypoxia (Pauletto et al., 2004). These traits influence rice planting in succession to mulching plants, since soil humidity alters the rate of mass decomposition and releasing organic acids to soil, that may lead to delayed rice seedling establishment and poor development of rice plants (Marchesi et al., 2011).

Studies show that ryegrass (*Lolium multiflorum* Lam.) is relatively adapted to lowland soils, promoting benefits such as nitrogen cycling, fast mulching establishment, as well as helping to suppress weeds (Reddy, 2001).

However, the inadequate management of the rice-ryegrass succession system may result in unsatisfactory results, since the release of organic acids occurs when the soil has low oxygen concentrations (Adeleke et al., 2017). These acids can cause phytotoxicity in seeds when in high concentrations, generating physiological disturbances such as cell wall degradation, inhibition of respiratory functions, and consequently, decrease of the cellular division of the root system (Tunes et al., 2013) and damages in the photosynthetic apparatus.

Therefore, the study aimed to evaluate the initial growth and physiological characteristics of rice plants planted following ryegrass in lowland areas.

II. MATERIAL AND METHODS

The experiment was carried out in the experimental field of the Center for Herbology Studies (CEHERB), plant health department, Federal University of Pelotas, Capão do Leão - RS, Brazil (31° 48' 22" S; 52° 28' 56" W). The soil was classified as Solodic Eutrophic Hydromorphic Planosol (Embrapa - CNPS, 2006), corresponding to the Typic Albaqualf in the North American soil classification system.

The area chosen for the experiment was previously under fallow and went through harrowing and disking prior to planting. Ryegrass (*Lolium multiflorum*) - cv. BRS-Ponteio was planted as cover crop on 05/30/2017 at the density of 30 kg ha^{-1}; fertilization consisted of 90 kg ha^{-1} of nitrogen, being $^{2}/_{3}$ applied at early tillering and $^{1}/_{3}$ applied at stem elongation.

The experimental design was a randomized block with four replications. Four soil mulching levels were tested, being established by the cutting height of the ryegrass plants: 15 cm, 30 cm and 45 cm from soil level, plus a control treatment with no ryegrass (0 cm). The mass cut from plants was entirely removed from the experimental plots.

After treatment establishment, ryegrass residual mass was randomly sampled into the experimental area, and drying was accomplished in oven at 60 °C (± 5 °C) to establish the relationship between cutting height and straw mass. The resulting straw corresponded approximately to 0 (control), 1.5, 3.0 and 4.5 t ha^{-1} of dry mass remaining on soil surface, proportionally to the cutting heights.

Subsequently, on 09/18/2017, two days after cutting, ryegrass was burndown with glyphosate at 1620 g$_{a.e.}$ha^{-1} to establish the mulching. On 09/25/2017, soil moisture sensors (Watermark electro-tensiometers, Irrometer Co.) were installed, one per plot at depth of 5 cm in order to monitor moisture in the 0-10 cm soil layer. All sensors were connected to dataloggers which recorded the soil water tension every hour.

Rice was planted on 10/09/2017, with the cv. IRGA 424 RI in the density of 90 Kg ha^{-1}. Nitrogen fertilization amounted 150 kg ha^{-1} of N, being 55% applied in the V4 stage and 45% in the R2 - booting stage (Counce et al., 2000). The other cultural managements were carried out according to the technical recommendations of the rice research for Southern Brazil (Sosbai, 2016).

Before rice emergence, high rainfall events were reported (126 mm between 10/10/2017 and 10/15/2017 and 62 mm on 10/18/2017), with 50% emergence occurring in 10/19/2017. On 10/27/2017, when seedling emergence and plant height were evaluated daily. Plant emergence was quantified by marking two permanent sub-samples 1 m long in different planting rows of each plot. Rice plant height was measured in five plants per plot.

On 11/22/2017, chlorophyll and flavonoid indexes and nitrogen balance index were assessed, with the aid of a chlorophyllometer (Dualex FORCE-A, Orsay, France), being registered four readings per plot, from distinct plants, amounting 16 readings per treatment. The quantum efficiency of photosystem II was obtained by using a fluorometer (Opti-Sciences, OS-30p), and readings were performed in two plants per plot, totaling 8 readings per treatment. Prior to fluorescence readings, leaves were submitted to 20 minutes dark and then the readings were taken according to Murchie & Lawson (2013). Rice plants were in the overall developmental stage V6 by the time of the assessments.

Statistical analyzes were performed into the "R" environment (R Core Team, 2017). Plant density and height were scatter plotted against time (days after planting - DAP), by treatment, while all physiological variables were scatter plotted against the ryegrass cutting height. In all cases were adjusted to each data set a 2nd degree Loess curve (Cleveland & Devlin, 1988), with the respective 95% confidence intervals, according to Patino & Ferreira (2015).

III. RESULTS AND DISCUSSION

The oscillations of soil water status, depending on the environmental conditions, were dependent on the cutting height of ryegrass, since the higher water tension was observed in the soil where there was no cover with ryegrass (0 cm cutting height), in periods with sparse rains (Figure 1). The highest values of soil water tension were obtained approximately 25 - 30 days after rice emergence (DAE), where the bare soil (0 cm cutting height) presented 160 kPa of water tension; the soil with 15 cm cutting height presented 150 kPa, and at the one with the highest cutting height (45 cm) presented 120 kPa of water tension (Figure 1).

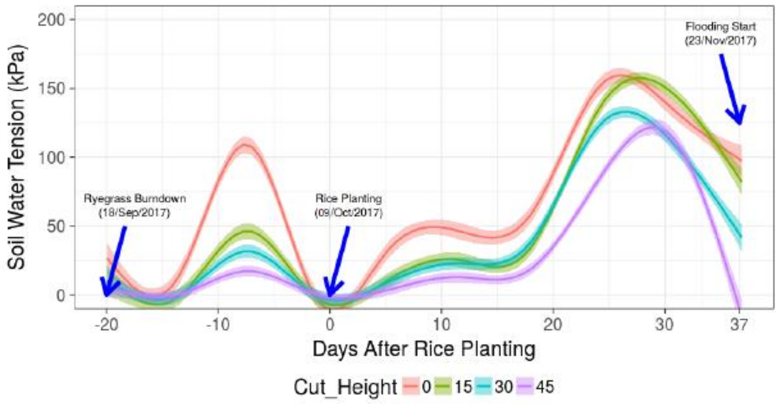

Fig. 1: Variation on the soil water tension (kPa) from the ryegrass burndown, in the distinct cutting heights. Capão do Leão, RS, Brazil, 2017.

The soil mulching has the effect of attenuating water evaporation; thus, the water tension in soil increases more slowly the greater the soil mulching (Monteiro et al., 2013). Our data show that high soil mulching (45 cm cutting height) allowed rice five additional days on a dry season, before high soil water tension was reached, compared to the bare soil treatment. This is particularly important for rice fields grown under schemes and / or alternative irrigation methods such as intermittent or sprinkler irrigation (Parfitt et al., 2017b). In addition, the maximum soil water stress levels obtained in the same period (25 - 30 DAP) also differed (Figure 1); while the treatment with bare soil reached water tensions of 163 kPa, the mulched soil reached a maximum of 126 kPa. Under milder conditions of lack of water (10 DAP), the treatment with 45 cm ryegrass cutting height presented water tensions of approximately 18 kPa while the bare soil already reached tensions around 50 kPa (Figure 1).

Ryegrass used as winter mulching helped to maintain adequate levels of soil moisture for longer after rains (Figure 1), but on the other side, it harmed rice emergence (Figure 2). From 9 days after planting (DAP) onwards, there was a reduction in rice density in treatments with any mulching level in comparison to the control treatment (bare soil).

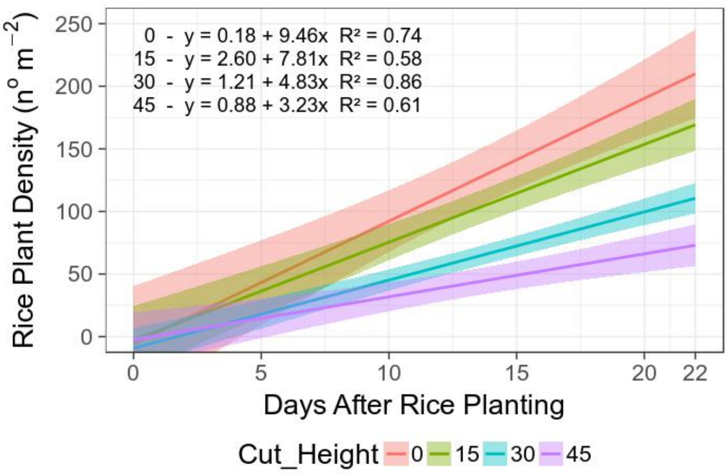

Fig. 2: Rice plant density (nº m^{-2}) as function of days after planting (DAP) and ryegrass cutting heights. Capão do Leão, RS, Brazil, 2017.

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The worst results were reported in treatments with ryegrass cutting height of 30 and 45 cm, where the density of plants 22 DAP was remarkably lower than those observed for control (Figure 2). The high mulching level makes it difficult to the soil to lose the excess water quickly following heavy rains, intensifying the decomposition of residues under hypoxia. The toxicity by organic acids occurs, mainly, in the beginning of the rice development, causing lower germination rate, slow initial growth rate, lower root development, and the consequent lower nutrient absorption by roots and reduced grain yield (Bortolon et al., 2009).

The stabilization in the increase of rice density was achieved around 20 DAP (Figure 2), where 150 - 220, 127 - 174, 86 - 110 and 50 - 79 plants m^{-2} were observed for the cutting heights of 0, 15, 30 and 45 cm, respectively. This difference was not recovered before the beginning of permanent flood irrigation (Figure 2). However, rice is a species with high phenotypic plasticity, and under favorable development conditions, the tillering is expected to compensate at least in part for this lower seedling establishment (Martinez-Eixarch et al., 2015). It should be noted, however, that in the highest ryegrass cutting height, rice seedling density was approximately 30% of that observed in the control with bare soil; differences of this magnitude may not be fully compensated by tillering (Zhong et al., 2002). In climatic conditions of Southern Brazil (cold and wet winter), where the mulching provided by the plant used as winter cover crop is very high, pre-planting operations such as the knife-roller (Silva et al., 2012) or shallow mowing (Brito et al., 2016), may be necessary for both reducing mulching and controlling weeds.

Seedlings that were able to emerge and establish under the wilted ryegrass cover, on the other hand, have grown without considerable barriers (Figure 3). The greatest difference in height of rice plants was observed around 15 DAP (five days after the average emergence) when the plants measured between 4 and 6 cm, with a difference of only 1 - 2 cm between the largest plants from the bare soil treatment, and those growing in the treatment with 45 cm cutting height. There was no significant effect of soil mulching levels on rice plant height at the time of irrigation start (Figure 3).

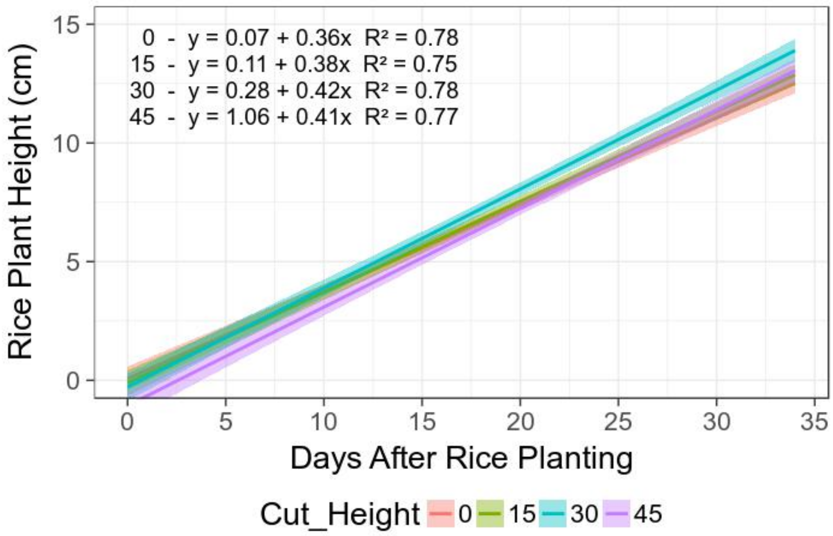

Fig. 3: Rice plant height (cm) as function of days after planting (DAP) and ryegrass cutting height. Capão do Leão, RS, Brazil, 2017.

The chlorophyll index (SPAD) did not vary enough among treatments to reach statistical significance, with mean value of 19.4 (Figure 4), although ryegrass cutting at 15 cm height presented a tendency for augmented chlorophyll index. This is an indication that the photosynthetic ability of rice plants grown on distinct heights of ryegrass straw was not affected. According to Martinazzo et al. (2007), chlorophylls (a and b) are the most important light-absorbing pigments at tylacoid membranes, being preponderant in plant growth and adaptability to distinct environments and, thus, defining crop productivity.

The flavonoid index, on the other side, was affected by ryegrass cutting height (Figure 5). A linear increase from 1.24 to 1.50 in flavonoid index was observed when the ryegrass cutting height increased from 0 cm to 45 cm, with a narrow confidence interval which positively support treatment effect on this variable. Flavonoids are secondary metabolites in the polyphenol class, formed when plants grow under nitrogen deficiency (Demotes-

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Mainard et al., 2008), acting in the protection of the photosynthetic system against photo inhibition by excessive radiance levels (Zhou et al., 2016). Thus, most possibly, the low initial availability of nitrogen and the exsudation of organic acids by the ryegrass straw may help explaining the increase in the flavonoid index in rice plants as the straw level on soil was increased.

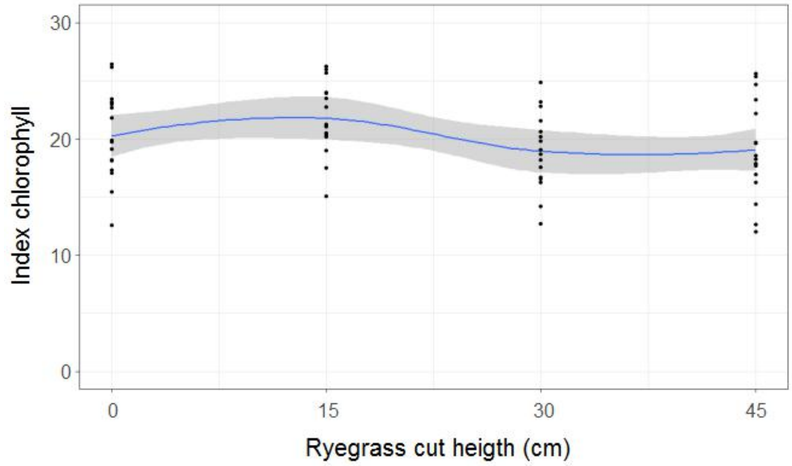

Fig. 4. Chlorophyll index as function of ryegrass cutting height. Capão do Leão, RS, Brazil, 2017.

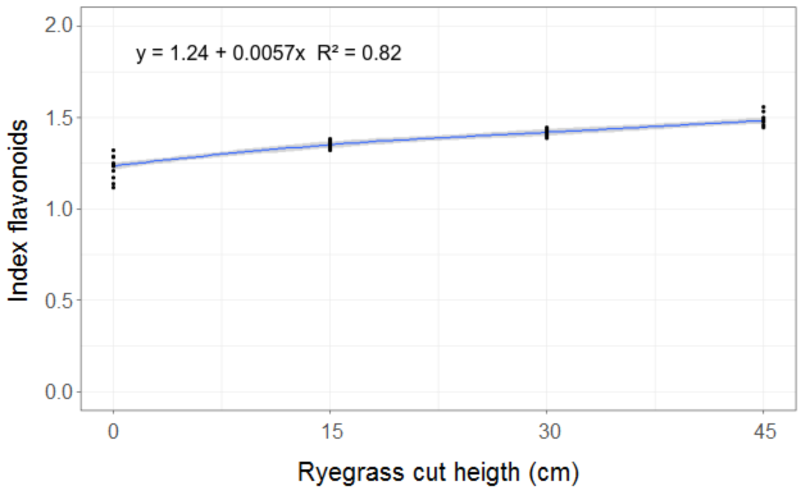

Fig. 5. Flavonoid index of rice plants as function of ryegrass cutting height, prior to planting rice. Capão do Leão, RS, Brazil, 2017.

The nitrogen balance index was also not affected by the ryegrass cutting height (Figure 6).The overall mean for nitrogen balance index was about 14.8, ranging from 12.3 and 17.5 among treatments. Although Xiong et al. (2015) report that chlorophyll readings used to guide N application in agricultural crops are widely affected by environmental factors, our data showed high and consistent correlation (data not shown) between chlorophyll index (Figure 4) and nitrogen balance index (Figure 6). Gholizadeh et al. (2017) concluded that this correlation reduces with the growth stage, reporting better relationship between rice leaf N content ($R^2 = 0.93$), as well as yield ($R^2 = 0.81$), with SPAD readings at the panicle formation stage.

The $^{Fv}/_{Fm}$ ratio (Figure 7), an indicator of the maximum efficiency of the photosystem II (PSII), also did not vary statistically among treatments, with mean of 0.62 and absolute variation between 0.50 and 0.75. Falqueto et al. (2010) reported $^{Fv}/_{Fm}$ values for rice cv. BRS-Pelota and BRS-Firmeza as ranging between 0.80 and 0.85, which are above the reported in the present study. Weng (2006) found that in sunny days of subtropical locations, the $^{Fv}/_{Fm}$ ratio may often be underestimated. The author reports that under these conditions, in summer large Fo (minimum fluorescence) values are consequence of high leaf temperature caused by the clipping fixed on the leaf, especially for long dark periods (e.g. 20 min). This would reduce $^{Fv}/_{Fm}$ ratio. In the present study, we defined 20 min as the darkening period prior to fluorescence assessments.

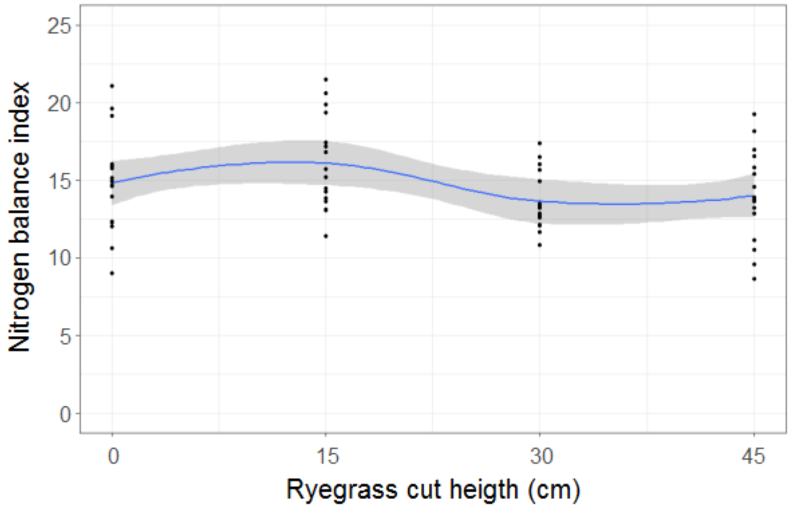

Fig. 6. Nitrogen balance index of rice plants as function of ryegrass cutting height, prior to planting rice. Capão do Leão, RS, Brazil, 2017.

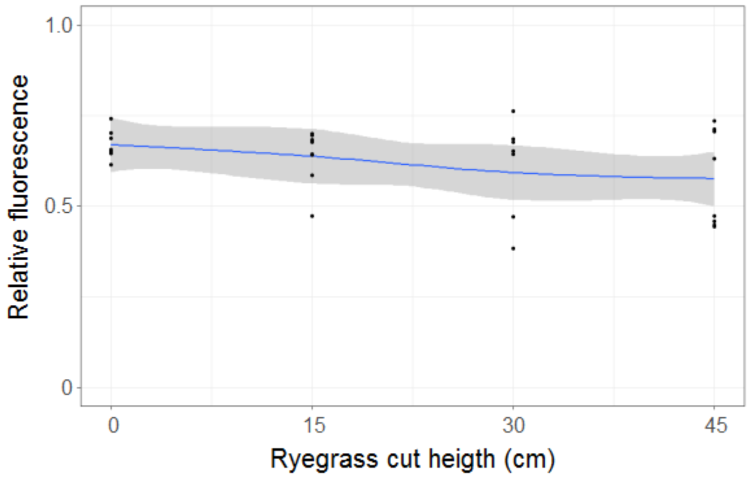

Fig. 7. Quantic efficiency / relative fluorescence of photosystem II (PSII) of rice plants as function of ryegrass cutting height prior to planting rice. Capão do Leão, RS, Brazil, 2017.

We hypothesize that the lower $^{Fv}/_{Fm}$ ratios observed for rice in the present study, for all treatments, may be regarded to the temperature effect reported by Weng (2006), as there was no treatment effect on this variable. To support this, Puteh et al. (2013) reported that the minimum fluorescence (Fo) of the cultivated and weedy rice genotypes increased under water stress; the maximum quantum yield ($^{Fv}/_{Fm}$) and maximum primary yield ($^{Fv}/_{Fo}$), of PSII, on the other side, declined. The author also reported high spikelet sterility levels (> 80%) for all genotypes.

IV. CONCLUSIONS

High soil mulching levels by ryegrass allowed rice five additional days on a dry season, before harmful soil water tension was reached, compared to the bare soil; rice seedlings able to emerge under the ryegrass mulching, have grown without considerable barriers; the physiology of rice plants growing in fields with residual ryegrass mulching were little affected, and ryegrass mulching cut up to 45 cm from soil prior to planting rice tends not to affect it. This would, in rough numbers, correspond to an acceptable volume of up to 4500 kg ha^{-1} of ryegrass straw on soil surface prior to planting rice to avoid damages to crop establishment.

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