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CROP PRODUCTION

Effect of thinning eucalyptus trees on soybean productivity in integrated crop-livestock-forestry systems

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ABSTRACT: The aim of the study was to evaluate the effects of integrated crop-livestock-forestry (ICLF) systems and the thinning of eucalyptus trees on the agronomical performance of soybean. Treatments consisted of cultivation under: crops under full sunlight (CFS) conditions; ICLF with triple-row tree configuration ($ICLF_T$) in which trees were submitted to selective thinning in the fifth year after planting through removal of 50% of trees while maintaining triple-row bands; and ICLF with single-row tree band configuration ($ICLF_S$) in which the lateral rows of the triple-row tree bands were subjected to systematic thinning at the fourth year after planting. The physiological and agronomical variables of the soybean crop were evaluated at the R5 and R8 reproductive stages during the eighth harvesting season (2018/2019). Soybean sampling was carried out at five random positions in the CFS and in four transects at distances of 3, 6, 10 and 15 m from the tree bands in both the north and south faces of the ICLF systems. There were no differences between soybean grown under the ICLF and CFS systems with respect to specific leaf area, plant density, lodging index and mass of a thousand grains. However, the ICLF increased dry leaf mass and leaf area index and reduced soybean plant heights. Soybean productivity was reduced by 26% in ICLF-T and 14% in ICLF-S, that is, a 12% reduction in the productivity loss with systematic thinning. It is concluded that ICLF reduces soybean productivity in the effective grain production area of the system, regardless of the degree of thinning, although systematic thinning by removing the lateral tree lines to conversion of triple-rows into single-rows minimizes the loss of soybean grain yield.
Key words: agrosilvopastoral, hybrid eucalyptus 'urograndis', *Glycine max*.

Efeito do desbaste das árvores de eucalipto sobre rendimento da soja em sistemas de integração lavoura-pecuária-floresta

RESUMO: O objetivo do trabalho foi avaliar o efeito da integração lavoura-pecuária-floresta (ILPF) e do desbaste das árvores de eucalipto sobre o desempenho agronômico da soja. Os tratamentos consistiram em cultivo convencional a pleno sol (CPS), ILPF com configuração de fileira tripla (ILPF-T), em que as fileiras triplas de árvores foram submetidas ao desbaste seletivo no quinto ano após o plantio por meio da remoção de 50% das árvores e ILPF com configuração de fileira simples (ILPF-S), em que as faixas triplas de árvores foram submetidas ao desbaste sistemático no quarto ano após o plantio resultando em fileiras simples. As variáveis fisiológicas e agronômicas da soja foram avaliadas nos estágios reprodutivos R5 e R8 durante a oitava safra (2018/2019). As amostragens de soja foram realizadas em cinco posições aleatórias no CPS, enquanto as coletas foram realizadas em quatro transectos a distâncias de 3, 6, 10 e 15 m das faixas das árvores nas faces norte e sul dos sistemas ILPF. Não houve diferenças entre a soja cultivada nos sistemas ILPF e CPS em relação à área foliar específica, densidade de plantas, índice de acamamento e massa de mil grãos. No entanto, a ILPF aumentou a massa de folhas secas e o índice de área foliar e reduziu as alturas das plantas de soja. No desbaste seletivo de 50% das árvores (ILPF-T) a perda de produtividade da soja foi de 26%, enquanto no desbaste sistemático (ILPF-S) ela foi de 14%, ou seja, redução de 12% na perda de produtividade da soja. Portanto, a ILPF reduz o rendimento de grãos da soja independente da intensidade do desbaste realizado e o desbaste sistemático, com remoção das linhas laterais para conversão do sistema para linhas simples (ILPF-S) proporciona menor perda de rendimento de grãos da soja.
Palavras-chave: agrossilvipastoril, eucalipto híbrido 'urograndis', *Glycine Max*.

INTRODUCTION

Integrated crop-livestock-forestry (ICLF) is an agricultural production system that aims to intensify land use in a sustainable manner and, at the same time, maximize income for the producer (BALBINO et al., 2011). Integrated production systems are gaining significant momentum in Brazil as confirmed by the total area dedicated to this type of farming, which has increased from about 11.5

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million hectares in 2016 (EMBRAPA, 2017) to 17.4 million hectares in 2021 (POLIDORO et al., 2020). This expansion has been stimulated by public policies such as the Plano ABC (*Plano Setorial de Mitigação e de Adaptação às Mudanças Climáticas para a Consolidação de uma Economia de Baixa Emissão de Carbono na Agricultura*) launched in 2010 with the purpose of responding to commitments to reduce greenhouse gases produced by the agricultural sector.

Among Brazilian producers whose main activity is animal husbandry, 83% have adopted integrated crop-livestock (ICL) systems, 9% have implemented ICLF systems, 7% have embraced integrated livestock-forestry (ILF) systems and 1% have deployed integrated crop-forestry (ICF) systems. On the other hand, of the producers whose main activity is soybean and maize farming, some 99% have adopted ICL (99%), while only 0.4% have implemented ICLF and 0.2% have deployed ICF (SKORUPA & MANZATTO, 2019). These figures indicate that the foremost issue curbing the expansion of ICLF as an integrated production system is the consolidation of the forestry component.

The main benefits of ICLF systems are the improvement of the chemical, physical and biological qualities of the soil, the diversification of production with the ability to market commodities deriving from animals, plants and trees, the assurance of a steady income for the producer, the recovery of degraded areas and the reduction of reliance on agricultural inputs such as fertilizers, antimicrobials and pesticides (BALBINO et al., 2011). However, it is important to note that the success of integrated production techniques that involve forest ecosystems depends on appropriate management of the tree plantations or natural stands, since they can have positive or negative impacts on the other components (REYNOLDS et al., 2007; SARTO et al., 2020). Among the negative effects are excessive shading produced by the tree canopy and competition for water and nutrients, either of which may impede the development of intercropped cultures and cause loss of productivity (MOSQUERA-LOSADA et al., 2010; GAO et al., 2013; LI et al., 2014; MAGALHÃES et al., 2018; PEZZOPANE et al., 2020).

Soybean is currently one of the principal grain crops implemented in ICLF systems (GAO et al., 2013) not only by virtue of its prominence in agribusiness in Brazil but also because its high market value makes the operation economically viable with guaranteed financial returns to the producer. In addition, soybean utilizes the C3 carbon fixation pathway and is considered tolerant to shading (BERTOMEU, 2012). Nevertheless, shading can influence the development of soybean grown in ICLF systems, causing an increase in leaf area, elongation of the main stem and branches, and a reduction in photosynthetic rate (WEN et al., 2020). According to PEZZOPANE et al. (2020), management of tree stands by thinning and pruning can help to maintain the balance between the yields of the various ICLF components.

Increased understanding of the interactions between the agricultural and the forestry components of an ICLF system will not only assist in minimizing the negative effects of trees on crop productivity but will also encourage the adoption of the approach by producers. Hence, the objective of the present study was to evaluate the effects of ICLF system and the thinning of eucalyptus trees on the agronomical performance of soybean.

MATERIALS AND METHODS

The ICLF system was implemented during the 2011/2012 season in the fields of Embrapa Agrossilvipastoril, Sinop, MT, Brazil (11°51'S; 55°35'W; 384 m altitude), situated in the transition zone between the Cerrado and the Amazon rain forest. The climate in the region is tropical with a dry winter, classified as Aw according to the Köppen-Geiger scheme, and characterized by a well-defined rainy season from October to March and a dry season from April to September (SOUZA et al., 2013). The mean annual air temperature of the region is 25 ºC, the mean relative humidity is 74% and the accumulated rainfall is 2,100 mm (EMBRAPA, 2018).

The area is of flat relief with a dystrophic red-yellow latosol soil of clayey texture (560 g kg^{-1} clay, 322 g kg^{-1} sand and 118 g kg^{-1} silt) (VIANA et al., 2015). The chemical characteristics assessed in the 0 to 20 cm layer before the experiment was implemented were: pH 5.7 (water), 8.76 mg dm^{-3} P (Mehlich-1), 73.61 mg dm^{-3} K (Mehlich-1), 2.53 $cmol_c$ dm^{-3} Ca, 0.81 $cmol_c$ dm^{-3} Mg, 0.02 $cmol_c$ dm^{-3} Al, and 3.6 dag dm^{-3} of organic matter.

The ICLF systems involved he following species: eucalyptus hybrid 'urograndis' (*Eucalyptus urophylla* x *Eucalyptus grandis*, clone H-13; Myrtaceae), soybean [*Glycine max* (L.) Merr.; Fabaceae] cultivar BRS 7380 RR, maize (*Zea mays* L.; Poaceae) cultivar 2B810PW, and forage grass [*Urochloa brizantha* (A.Rich.) R.D. Webster; Poaceae] cultivar Marandu. In November 2011, ICLF plots of 2 ha (100 m x 200 m) each were planted with triple-row bands of eucalyptus in the east-west orientation with 30 m between bands, 3.5 m between rows and 3.0 m between trees [(30 m + 3'(3.5 m x 3 m)] with 270 trees ha^{-1}. Trees in the ICLF plots were pruned up to 3 m high at 25 months of age and up to 5 m high at 69 months of age.

All experiments were performed according to a randomized block design that included three treatments with four repetitions each. The treatments were :- (i) control treatment involved crops under full sunlight (CFS) in which an area of 1 ha (100 m x 100 m) were cultivated with soybean in the growing season followed by maize intercropped with forage grass in the off-season (known in Brazil as a safrinha); (ii) single-row tree configuration (ICLF$_S$) in which the original triple-row bands of eucalyptus [30 m + 3'(3.5 m x 3 m)] were subjected to systematic thinning of the external rows in the fourth year after planting, resulting in single rows (~37 m x 3 m) and leaving 90 trees ha^{-1}: the cultivation regime involved forage grass and livestock for two years followed by soybean, maize/forage grass and livestock for two years and continuing in this pattern; (iii) triple-row tree configuration (ICLF$_T$) in which the original bands of eucalyptus [30 m + 3'(3.5 m x 3 m)] were submitted to selective thinning of 50% of the trees (mainly the small and imperfect trees) in the fifth year after planting, resulting in triple-rows [(30 m + 3'(3.5 m x ~ 6 m)] with 135 trees ha^{-1}; the cultivation regime comprised soybean followed by maize intercropped with livestock forage grass.

In both ICLF systems, control of eucalyptus shoots was initiated within 72 h after thinning by spraying 30 to 40 mL of a 2% (v/v) solution of a commercial product based on imazapyr (250 g a.e.L^{-1}) onto the stumps with total wetting in the cambial region. At 90 days after thinning, the process was repeated with 300 mL of glyphosate (360 g a.e. L^{-1}) applied using a 20 L backpack sprayer. The arable areas in the ICLF$_S$ and ICLF$_T$ plots were similar after thinning (76% of the total area) by virtue of the presence of stumps. Soybean seeds were planted in the arable areas of CFS, ICLF$_S$ and ICLF$_T$ plots in rows 45 cm between apart with 20 seeds per linear meter, totalizing 445,000 plants ha^{-1}.

The physiological and agronomical characteristics of soybean were assessed in the eighth harvesting season (2018/2019) after the experiment had been implemented. In November 2018, i.e. 85 months after planting, the trees presented a mean height of 23.67 ± 1.15 m and a mean diameter at breast height of 24.91 ± 1.81 cm. Soybean plants in reproductive stage R5 (beginning seed) were evaluated with respect to leaf area (LA; cm^2), leaf dry matter (LDM; kg), specific leaf area (SLA; m^2 kg^{-1}), leaf dry matter per area (LMA; kg ha^{-1}) and leaf area index (LAI). For the measurement of LA, LDM and SLA in the CFS, second fully developed trifoliate leaves were collected from five plants at five random positions in the plots. In the ICLF$_S$ and ICLF$_T$ plots, samples were obtained from four equidistant (every 50 m) transects commencing 25 m from the end of the plot (corresponding to a working area of 4,500 m^2 or 2,250 m^2 on each face of the tree band [15 m x 150 m]) with 20 trifoliate leaves collected at each location 3, 6, 10 and 15 m away from the central row of the tree bands in the north and south faces. Leaves were transferred to plastic bags and transported to the laboratory in expanded polystyrene boxes containing ice in order to preserve the fresh characteristics of the samples. The LA values of leaf samples were determined using a LI-3100 model leaf area meter (LI-COR Biosciences, Lincoln, NE, USA), following which the leaves were transferred to paper bags and LDM values measured by weighing the leaves after drying to constant weight in a forced air oven at 55 °C (~72 h). SLA was obtained as the quotient of LA divided by LDM. Values of LMA were determined in a total sample area of 3.6 m^2 by collecting leaves from soybean plants in four 1-m sections of two adjacent rows spaced 0.45 cm apart either at five random points in the CFS plots or in four transects at positions 3, 6, 10 and 15 m away from the central row of the tree bands in the north and south faces in the ICLF$_S$ and ICLF$_T$ plots. Sub-samples (300 g) of the collected leaves were dried to constant weight to obtain the dry matter and the moisture correction factor. The variable LAI, which represents the ratio of total leaf area (m^2) to the ground surface area (m^2), was obtained from SLA and LMA.

At the reproductive stage R8 (full maturity), the agronomic characteristics of soybean plants were determined, namely plant density (plants ha^{-1}), lodging index (scores), plant height (cm), mass of thousand grains (MTG; g) and productivity (kg ha^{-1}). Soybean plants were sampled in 5-m sections of two adjacent rows spaced 0.45 cm apart either at five random points in CFS plots or in four transects at positions 3, 6, 10 and 15 m away from the central row of the tree band in the north and south faces in the ICLF$_S$ and ICLF$_T$ plots. The lodging index was determined as described by BERNARD et al. (1965) with scores varying between 1 (> 90% of plants erect) and 5 (> 80% of plants recumbent). Productivity was determined by harvesting the plots, threshing the samples, determining the grain mass, correcting the value to 13% moisture content, and extrapolating to one hectare considering that the effective area of production in ICLF systems was limited to 30 m between the tree bands (76% of the total area). MTG values were determined using a Sanick (Chapecó, SC, Brazil) model ESC2011 electronic seed counter.

The mean values of variables determined for ICLF treatments in both north and south faces were weighted in accordance with the contribution of each collection point to the system as follows: 3 m ~ 20% [(3-0)/15], 6 m ~ 20% [(6-3)/15], 10 m ~ 27% [(10-6)/15] and 15 m ~ 33% [(15-10)/15]. The assumption of normality was assessed using Lilliefors test, while homogeneity of variance was appraised using Hartley, Cochran and Bartlett's tests. Once the statistical assumptions were met, data were submitted to analysis of variance (ANOVA) and mean values compared using Tukey test at 5% probability.

RESULTS AND DISCUSSION

The key objective of our study was to evaluate the effects of ICLF system and the thinning of eucalyptus trees on the agronomical performance of soybean. First then we compared CFS and ICLF systems with respect to the leaves characteristics of soybean. In this respect, there were no significant differences ($P > 0.35$) in mean SLA values between plants cultivated in the CFS, $ICLF_S$ and $ICLF_T$ systems, between those grown in the north (shaded in the morning and sunny in the afternoon) and south (sunny in the morning and shaded in the afternoon) faces within an ICLF system ($P > 0.64$) or those located at different distances (3, 6, 10 and 15 m) from the tree band within an ICLF system. Regarding LMA and LAI, there were significant differences ($P < 0.05$) between treatments, with the lowest overall mean values recorded in the CFS system (Figure 1). The overall mean LMA value obtained for soybean grown in the $ICLF_S$ system was marginally higher than that observed in the $ICLF_T$ system, while the inverse situation was recorded for variable LAI. In the $ICLF_S$ and $ICLF_T$ systems, there were no differences

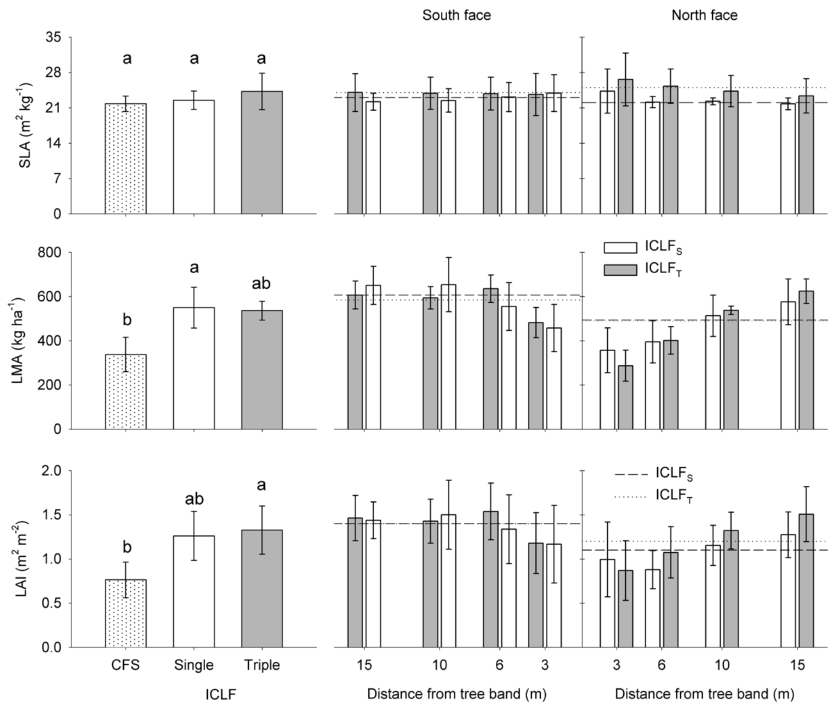

Figure 1 - Effects of integrated crop-livestock-forestry (ICLF) systems and the distances from the tree bands on the leaves characteristics of soybean: Crops under full sunlight (CFS); single-row ICLF configuration ($ICLF_S$); triple-row ICLF configuration ($ICLF_T$). Bars bearing similar lowercase letters are not significantly different according to Tukey test at 5% probability. The dotted and dashed horizontal lines represent the averages of the variables on each face exposed to the sun. Abbreviations: SLA, specific leaf area; LMA, leaf dry matter per area; LAI, leaf area index.

between the north and south faces regarding LMA or LAI. On the other hand, distance from the tree band influenced LMA since this variable was lower in both ICLF systems at 3 m in the south faces and at 3 and 6 m in the north faces.

According to CARVALHO (2017), the SLA of soybean cultivar BRSGO 8560RR was higher in the $ICLF_T$ system compared with that in the CFS in the fourth harvesting season. However, our results indicate that there were no differences between the CFS and ICLF systems regarding the SLA values of cultivar BRS 7380 RR in the eighth harvesting season. The discrepancy between the findings of the two studies indicates that phenotypic adaptation response depends on the soybean cultivar. The growth habit of BRSGO 8560RR is determinate with maximum LA occurring until the R1 stage, while the growth habitat of BRS 7380 RR is indeterminate with the maximum LA occurring until the R5 stage (ZANON et al., 2015). Thus, the vegetative growth of the indeterminate cultivar is slow until grain filling, allowing the formation of a homogeneous photosynthetic apparatus with the ability to capture an increased amount of light energy for the production of photoassimilates and biomass.

The variable LAI is associated directly with LMA, which was higher in the ICLF systems compared with CFS in the present study, and a consequence of a higher LAI value is that a greater amount of light is captured per unit area of soil. When the amount of light transmitted along the canopy is reduced, the LA of the plant increases in order to allocate more carbon to the leaves to allow the interception of increased amounts of light (WEN et al., 2020).

The second step was to evaluate the effects of ICLF system and the thinning of eucalyptus trees on the agronomic characteristics of the soybean plants. Regarding plant density and lodging index, there were no differences ($P > 0.15$) between the CFS and ICLF systems, or between the north and south faces within an ICLF system (Figure 2). Soybean densities were within the range 240,000 to 320,000 plants ha^{-1}, which is recommended for the BRS 7380 RR cultivar, while the lodging indices were below the maximum limit (< 2.0).

The overall mean plant height was significantly lower ($P < 0.05$) in $ICLF_T$ compared with the other systems, a situation that was particularly noticeable in positions near the tree bands in both the north and south faces (Figure 2). In contrast, the overall mean MTG values were significantly higher ($P < 0.05$) in the $ICLF_S$ and $ICLF_T$ systems compared with the CFS, although there were no differences between the two integrated systems and the variable was not influenced by distance from the tree bands.

Regarding soybean productivity, there were significant differences ($P < 0.002$) between the CFS, $ICLF_S$ and $ICLF_T$ systems, with the triple-row system presenting the lowest grain yield (Figure 2). In $ICLF_T$, the productivity in the north face was lower than that in the south face, whereas in the $ICLF_S$ productivities were similar in both faces. In both ICLF systems, and for both faces, productivity decreased the nearer the plants were to the tree band.

The reductions in plant height and productivity observed in the ICLF systems were associated with lower photosynthetically active radiation (PAR) on the north face close to the trees during the period of soybean growth (MAGALHÃES et al., 2020). Despite the thinning of trees in the $ICLF_S$ at the fourth year and in the $ICLF_T$ at the fifth year, the canopies recovered in subsequent years and shading increased near the trees, affecting the growth of soybean in those positions. PAR transmission ranged from 78 to 82% in $ICLF_S$ and from 61 to 75% in $ICLF_T$ (MAGALHÃES et al., 2020). According to KHALID et al. (2019) soybean yield is decreased when the incidence of PAR is reduced by more than 25%.

Increases in MTG observed in the ICLF systems in this study corroborated the findings of KHALID et al. (2019) in which greenhouse-grown soybean plants were subjected to different shading intensities, the highest of which (75%) resulted in the largest MTG values that were some21% greater than those of CFS grown plants. However, the enhanced MTG values were not reflected in increased grain productivity, probably because extreme shading conditions are not favorable to the partitioning of dry matter in the pods (KHALID et al., 2019).

In a previous study, MAGALHÃES et al. (2018) demonstrated that four years after the implementation of the initial ICLF system (i.e. the triple-row tree configuration prior to thinning), soybean yield in the effective production area was reduced by 18% compared with the CFS system, a result that was attributed to excessive shading. The present study revealed an even higher loss of productivity (26%) in $ICLF_T$ in the eighth harvest season (2018/2019) despite the selective thinning that had been performed at the fifth year. In contrast, productivity was reduced by only 14% in the $ICLF_S$ system that had been submitted to systematic thinning at the fourth year. The explanation for the difference in yield is that the larger number of trees remaining in the $ICLF_T$ compared with the $ICLF_S$, created a greater amount of shade and increased the drainage

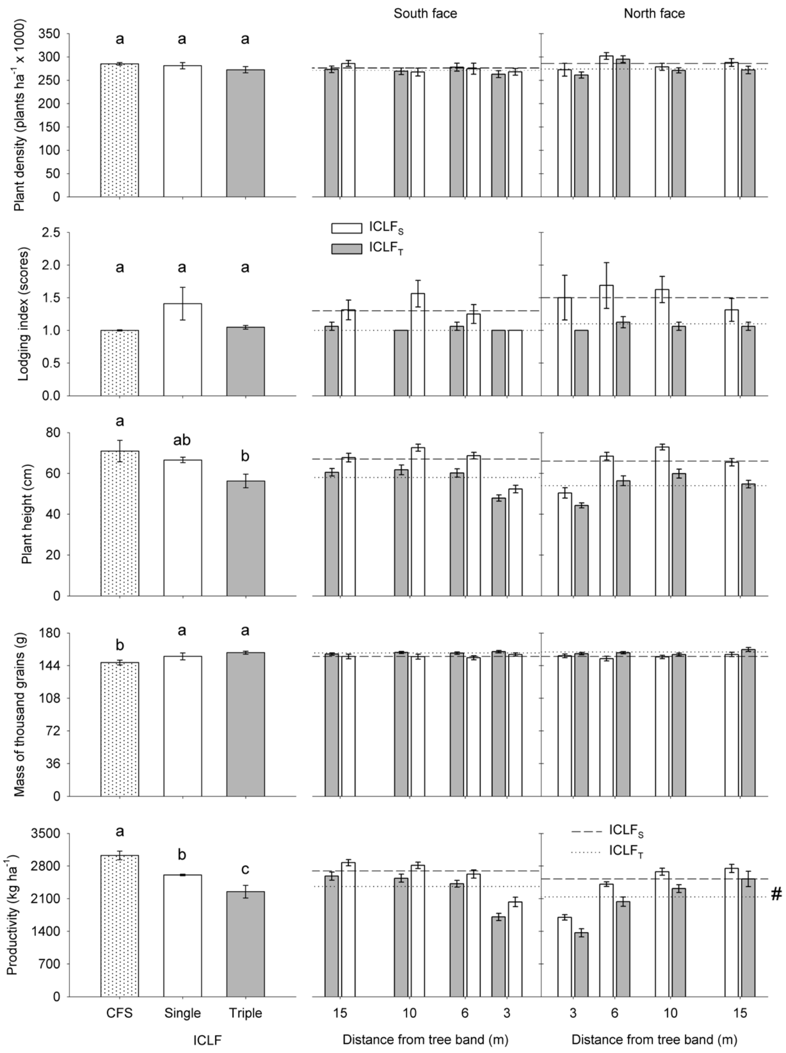

Figure 2 - Effects of integrated crop-livestock-forestry (ICLF) systems and the distances from the tree bands on the agronomical characteristics of soybean: Crops under full sunlight (CFS); single-row ICLF configuration ($ICLF_S$); triple-row ICLF configuration ($ICLF_T$). Bars bearing similar lowercase letters are not significantly different according to Tukey test at 5% probability. The dotted and dashed horizontal lines represent the averages of the variables on each face exposed to the sun.

effect of the trees by enhancing the competition between soybean and eucalyptus roots for water and nutrients (MOSQUERA-LOSADA et al., 2010; LI et al., 2014). Clearly, thinning is a very useful technique in the management of an ICLF, but it is important to define the most appropriate time for its execution since it may differ from that established for homogeneous stands (TONINI et al., 2019). Thus, thinning of ICLF systems should take into consideration the culture to be intercropped and the producer's objectives. In particular, when the focus is on the agricultural crop, the most appropriate time for thinning would be three years after planting the trees at which point interspecific competition commences (TONINI et al., 2019).

The results recorded herein are in agreement with those reported for other crops cultivated in ICLF systems with eucalyptus. For example, a reduction of 56% in maize productivity was observed three years after implementation of a system comprising eucalyptus rows spaced 15 m apart, and this was attributed to excessive shading over the crop (MOREIRA et al., 2018) as well as interspecific competition for water and nutrients (DING & SU, 2010; BERTOMEU, 2012). On the other hand, FRANCHINI et al. (2014) reported a 27% reduction in soybean productivity near to the trees of an ICLF system four years after implementation in the northwest region of Paraná state, but assigned the loss to competition for water between the forestry component and the soybean crop rather than to excess shading.

In the present study, the loss of productivity in the $ICLF_T$ system, induced by a reduction in PAR, was observed mainly in plants cultivated near to the trees and was 33.51% in the north face and 26.12% in the south face. The remarkably poor performance in the north face of the $ICLF_T$ (Figure 2) can be associated with the east-west orientation of the tree rows, which favored shading during soybean growth, resulting in a lower PAR close to the trees (MAGALHÃES et al., 2020). According to CARVALHO (2017), four years after implementation of the ICLF system, the shadow projection in the morning was 20 m on the north face during the grain filling phase, whereas eight years after implementation the shadow projection in $ICLF_T$ attained 29 m despite pruning and selective thinning of 50% of the trees.

The superior performance of soybean in the $ICLF_S$ compared with $ICLF_T$ indicated that thinning associated with tree pruning contributed to minimizing the loss of yield by reason of the improved light availability within the system (LEROY et al., 2009). In addition, the conversion of a triple-row to a single-row configuration reduced shading and increased PAR within the $ICLF_S$ (MAGALHÃES et al., 2020). Shading caused by trees has a strong effect on the balance of the microclimate, and this can result in benefits or detriments to components of the system (GEREMIA et al., 2018).Thus, while tree management in the $ICLF_S$ does not lead to a gain in crop productivity, the system increases forage accumulation and provides a favorable microclimate that impacts positively on beef cattle, as exemplified by live weight gains of 940 kg ha^{-1} (DOMICIANO et al., 2020) and 1194 kg ha^{-1}(CARVALHO et al., 2019) recorded in this system. An additional benefit of the ICLF approach is the production of high value-added wood.

The results presented herein permit us to infer that single-row ICLF systems may be more interesting in the long term provided that the forestry component is properly managed through pruning and thinning, since this configuration is less restrictive of light and minimizes the competition for water and nutrients. When the main objective of the producer is the long term permanence of the agricultural component, the triple-row configuration of an $ICLF_T$-type system can be converted to single-row after the third year of implementation (MAGALHÃES et al., 2018; TONINI et al., 2019) in order to reduce competitiveness for resources (water, light and nutrients).

It is worth noting that a key advantage of ICLF systems is that they ensure greater diversification of income resources for the producer, since the loss of productivity of one component can and must be compensated by the other components. There is also the possibility of returning to grain production in ICLF plots in the silvopastoral phase when the trees are old and the pasture requires renovation because of unexpected problems with the forage component (disease or pest). In this atypical scenario, tree management and agriculture could serve to minimize the cost of pasture restoration.

CONCLUSION

The ICLF reduces soybean productivity in the effective grain production area of the system, regardless of the degree of thinning, although systematic thinning by removing the lateral tree lines to conversion of triple-rows into single-rows minimizes the loss of soybean grain yield.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the manuscript and agree with final version of the manuscript.

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