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Physical characteristics of soybean cultivated under the conditions of integrated agrosystems

Características físicas de la soja cultivada en condiciones de sistemas integrados

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ABSTRACT

Integrated crop-livestock-forest (ICLF) systems involve intercropping of various crops to achieve beneficial and synergistic outcomes, enhancing both economic viability and environmental sustainability. Considering the complexity of integrated agrosystems and the economic importance of soybean production in Brazil, we aimed to investigate the effects of two ICLF systems on the physical characteristics and quality of soybeans produced. The treatments comprised plots (two ha) with either single-row ($ICLF_S$) or triple-row ($ICLF_T$), tree configurations intercropped with soybean (maize and forage grass), and control plots (one ha), whose crops were cultivated under full sunlight (CFS). Soybeans were harvested from plants located at 3, 6, 10 and 15 m from tree bands in the north and south faces of the ICLF systems and at random positions in the CFS plots. The moisture content, electrical conductivity of the exudate solution, hue angle and chroma index of grains harvested from $ICLF_S$ and $ICLF_T$ were similar to those of CFS-grown soybeans. However, the mass of 1000 grains and the bulk density values of ICLF-grown soybeans were significantly higher ($P \leq 0.05$) than those of grains harvested from CFS plots. We conclude that the quality of soybean seeds was not negatively affected by the conditions prevailing in the ICLF systems. Moreover, it appears that the forest component contributed positively to the ecosystem by providing a favorable microclimate for the development of soybean grains.

Key words: bulk density, *Glycine max*., grain color, integrated farming, moisture content.

RESUMEN

Los sistemas de integración cultivo-ganadería-bosque (ICLF) se basan en la intercalación de cultivos. Con ello se pretende lograr efectos positivos y sinérgicos entre las actividades agrícolas alcanzando viabilidad económica a más sostenibilidad social y ambiental. Considerando la complejidad de los agrosistemas integrados y la importancia económica de la producción de soja en todo el mundo y particularmente en Brasil, nuestro objetivo fue investigar los efectos de dos sistemas ICLF diferentes sobre las características físicas y la calidad de la soja producida en estas condiciones. Los tratamientos consistieron en parcelas ICLF con configuración de una sola hilera ($ICLF_S$, 2 ha) y parcelas ICLF con configuración de triple hilera ($ICLF_T$, 2 ha) intercaladas con soja y cultivos control de soja a pleno sol (CFS, 1 ha). La soja se cosechó de plantas ubicadas a 3, 6, 10 y 15 m de las bandas de árboles en las caras norte y sur, y en posiciones aleatorias en CFS. Nuestros resultados revelaron que la humedad, la conductividad eléctrica de la solución de exudado, el ángulo de tono y los valores de chroma index de la soja cultivada en $ICLF_S$ e $ICLF_T$ fueron similares a las de la soja cultivada en CFS. Sin embargo, la masa de mil granos y los valores de masa específicos aparentes en la soja cultivada en los sistemas ICLF fueron significativamente más altos ($P \leq 0.05$) en comparación con la soja cultivada en CFS. Por lo tanto, podemos concluir que la calidad de las semillas de soja no se vio afectada negativamente por las condiciones imperantes en los sistemas ICLF. Además, el componente forestal contribuyó positivamente al ecosistema al proporcionar un microclima favorable para el desarrollo de los granos de soja.

Palabras clave: Masa específica aparente; *Glycine max*; color de los granos; cultivos intercalados; humedad.

INTRODUCTION

Integrated crop-livestock-forest (ICLF) systems are based on the intercropping of cultures, either in succession or rotation, with the aim of attaining positive and synergistic effects between farming activities while improving economic viability and meeting social and environmental sustainability goals (Balbino *et al*., 2012).

In ICLF systems, the shade created over the cropped area by the tree canopies changes the microclimate of the environment and, consequently, interactions between components of the system. Plants grown under shaded areas respond to the reduced amount of photosynthetically active radiation by undergoing physiological adaptations to improve light capture, including, for example, increasing leaf area (Gobbi *et al*., 2011; Viana *et al*., 2015). Shading may also affect plant development and productivity through changes in the point of physiological maturity, plant height, number of branches and seed mass. For these reasons, the design and implementation of ICLF systems must ensure the balanced spatial and temporal distribution of all the agricultural components to reduce competition and enhance productivity (Macedo, 2009; Sediyama, 2009).

The physical characteristics of grains are important quality indicators that dictate the market value of the final product, irrespective of the agrosystem employed. Grain quality is associated with several factors, including integrity of the seeds, physical aspects such as specific mass, phytosanitary conditions as indicated by the presence or absence of contaminants and/or diseases, and nutritional aspects, notably the content of protein and oil (Silva, 2008). In the case of integrated agrosystems, the amount of information available regarding the effect of the system variables, particularly those of the forest component, on grain quality is somewhat scarce.

Considering the complexity of integrated agrosystems and the economic importance of soybean production worldwide, and most especially in Brazil, we aimed to investigate the effects of two different ICLF systems on the physical characteristics of soybeans produced under these conditions.

MATERIAL AND METHODS

Growth conditions, plant material, and experimental design. The study was performed in the experimental fields of Embrapa Agrosilvopastoral (Sinop, Mato Grosso, Brazil), located at 11°51’ S and 55°35’ W, 384 meters above sea level, in a transition zone between the Cerrado and the Amazon Forest. The ICLF plots, each of an area of 2 ha, were founded in November 2011 and planted with triple-row bands of *Eucalyptus urograndis* (*E. grandis* x *E. urophylla*; clone H13) in the east-west orientation with 30 m between bands, 3.5 m between rows, and 3.0 m between trees.

In the 2011/2012 and 2012/2013 seasons, forage grass for cattle grazing was planted between the tree bands. Whereas in 2013/2014 and 2014/2015, a sequential rotation of soybean and maize was integrated into the eucalyptus plantation, followed by pasture crop and cattle grazing after the maize had been harvested. After the 2014/2015 harvest, a number of the initial ICLF plots were submitted to systematic thinning, in which the outer two rows of each band of trees were removed to leave a single-row tree configuration ($ICLF_S$) with 37 m between the rows. In 2015/2016, other initial ICLF plots were submitted to selective thinning, during which 50% of the trees were removed while maintaining the original triple-row tree configuration ($ICLF_T$). Following two consecutive seasons of pasture and cattle grazing between the trees, the sequential rotation of soybean, maize, and pasture crops affected both $ICLF_S$ and $ICLF_T$ plots in seasons 2017/2018 and 2018/2019. In these plots, the north-facing cropped areas were shaded in the morning but sunlit in the afternoon, while the south-facing cropped areas received direct sunlight in the morning but were shaded in the afternoon (Magalhães *et al*., 2020). Control plots, each of 1 ha, were established in which the successive rotation of soybean, maize, and pasture for cattle grazing was carried out using a conventional cultivation system in full sunlight (CFS).

Experiments were performed according to a randomized block design comprising three treatments and four repetitions per 5 ha-block consisting of 1ha CFS, 2ha $ICLF_S$, and 2 ha $ICLF_T$. Various agronomical parameters were evaluated, but the present study focused exclusively on the physical parameters of soybean grains (glyphosate-resistant cultivar BRS7380RR) collected between February 10th and 15th, 2019. Harvesting was carried out by sampling soybeans at five random positions in the CFS and along two 5.45m lines, each at distances of 3, 6, 10, and 15 m from the tree bands in the $ICLF_S$ and $ICLF_T$. Harvested grains were threshed and cleaned manually to remove impurities, after which they were dried, if necessary, to a moisture level of 14% (w.b.).

Photosynthetically active radiation during experiment. In experimental units, recording stations were installed to collect weather data during the experimental period and use them to perform the evaluations in the present study. The photosynthetically active radiation (PAR; μmol photons m-2 s-1) was monitored continuously in each of the systems. For this, the PAR sensor PQS-1 quantum sensor (Kipp & Zonen, Delft, Netherlands - accuracy: ± 4 nm) was installed at 1.9 m and connected to a CR3000 datalogger (Campbell Scientific, Logan, Utah, USA) programmed to sample readings every 5 s and to record mean hourly values. In the ICLF systems, sensors were located at five positions in the north-south transect perpendicular to the eucalyptus rows (east-west) as follows: (i) ICLFT - under the canopy in the center of the triple-row grove and at 7.5 and 15 m from the edges of the grove in each direction (north and south faces); (ii) ICLFS – under the canopy in the center of the single row and at 11 and 18.5 m from the edge of the tree row, on the north and south faces. In the CFS system, the sensor was placed in a single position at the center of the plot. The space-time dynamics of the incidence of PAR are shown in Figure 1.

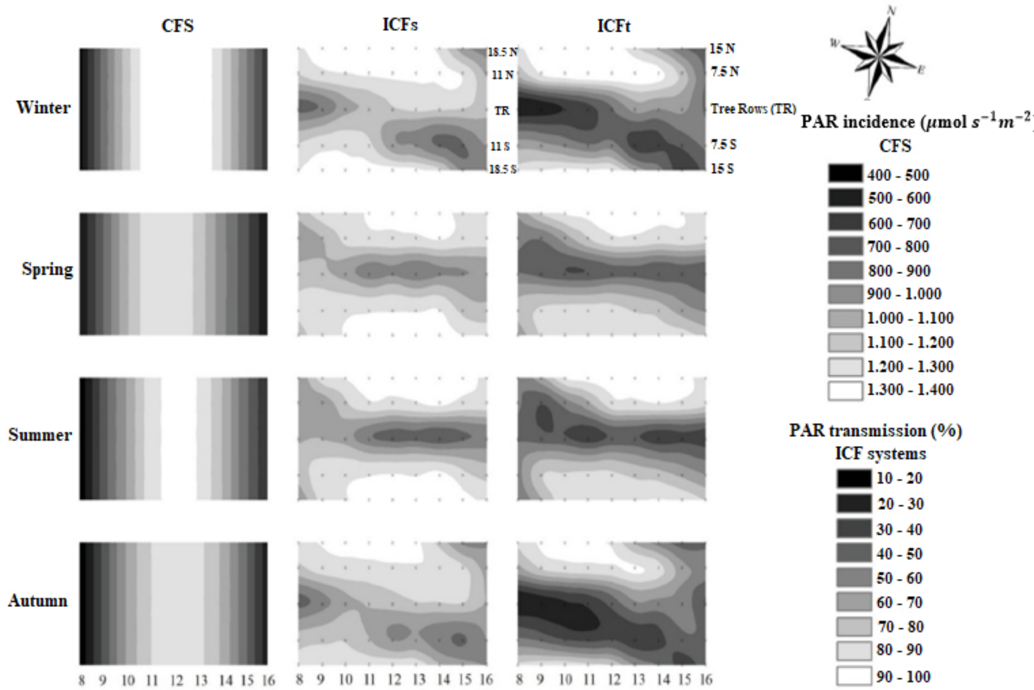

Figure 1. Space-time dynamics of the incidence of photosynthetically active radiation (PAR) between 8:00 to 16:00 in three agricultural systems located during four seasons, in Sinop, Mato Grosso, Brazil. Abbreviations: CFS, crop under full sun; ICFs, integrated crop-forestry single row configuration; ICF_T, integrated crop-forestry triple row configuration. Source: Magalhães *et al*. (2020).

Physical characteristics. Moisture content was established using the gravimetric method, in which three replicate samples of seeds (30 g per sample) were dried in a forced air oven at 105±1°C for 24 h (Ministério da Agricultura, Pecuária e Abastecimento, 2009). The mass of 1000 grains (M1000) was determined by weighing eight replicate samples of 1000 seeds each, using an analytical scale with a resolution of 0.01g (Ministério da Agricultura, Pecuária e Abastecimento, 2009). Bulk density (BD) was assessed using a method described by Botelho *et al*. (2018), in which a 1L cylindrical container with a diameter: height ratio of 1 was filled to overflow with soybean seeds. In order to ensure the natural and uniform accommodation of seeds, the filling was performed with the aid of a funnel attached to a metal support, with the funnel outlet positioned over the center of the container. Excess seeds were removed by leveling the top of the container with the edge with a plastic ruler, and the total mass of seeds present in the container was determined using an analytical scale with a resolution of 0.01g. Four replicate assessments of BD were carried out for each sample of seeds. The electrical conductivity of seed exudate solution (ECE) was determined by soaking grains for 24 h in distilled water at 25°C and measuring the conductivity of the resulting solution using a pre-calibrated Digimed (São Paulo, SP, Brazil), model DM-32 digital conductivity meter (Ministério da Agricultura, Pecuária e Abastecimento, 2009). Grain color was assessed quantitatively using a HunterLab (Reston, VA, USA) tristimulus colorimeter with a 10° D60 illuminant to provide color parameters on the CIELAB color scale comprising lightness (L^*), red and green (a^*), and yellow and blue (b^*) axes. Hue angle (h°) and chroma index (C) were calculated from the values of a^* and b^*, according to equation 1 and equation 2.

$$h° = actg \times (b^*/a^*) \tag{1}$$

$$C = \sqrt{(a^*)^2 + (b^*)^2} \tag{2}$$

Statistical analysis. For data processing, mean values obtained for treatments in $ICLF_S$ and $ICLF_T$ were weighted according to the percentage that each transect position (distance from the trees) represented within the system, i.e., 20, 20, 27, and 33% for the distances of 3, 6, 10, and 15 m, respectively. The normality of data and homogeneity of the variance were assessed. Mean values were submitted to analysis of variance (ANOVA) and compared using the Tukey test ($P \leq 0.05$). Comparisons between positions in the transects and between the north and south faces within each ICLF system were performed using the Tukey test ($P \leq 0.05$), considering the mean squares of the residuals.

RESULTS AND DISCUSSION

The moisture content, ECE value, hue angle, and chroma index of soybeans produced under ICLF conditions were similar to those of grains produced in the CFS system (Table 1). Thus, the environmental conditions prevailing in the ICLF systems, such as low PAR incidence, temperature, nutrient competition, and evapotranspiration, did not influence these physical characteristics when compared with CFS-cultivated soybeans. In contrast, the M1000 and BD values of grains harvested in the $ICLF_S$ and $ICLF_T$ systems were significantly higher ($P \leq 0.05$) than those of soybeans grown under CFS conditions (Table 1).

Table 1. Physical characteristics of soybean grains grown in different agrosystems.

Agrosystem	Moisture (%)	M1000 (g)	BD (kg m^{-3})	ECE (µS cm^{-1} g^{-1})	Hue angle (°)	Chroma index
Integrated crop-livestock-forestry system with single tree row configuration- $ICLF_S$	13.95a	167.62a	694.13 a	152.45a	73.66a	16.84a
Integrated crop-livestock-forestry system with triple-tree row configuration - $ICLF_T$	12.67a	170.29a	705.99 a	135.63a	73.86a	17.35a
Cultivation under full sunlight - CFS	12.32a	156.67b	679.78 b	138.37a	75.05a	17.15a
Mean	12.98	164.86	693.30	142.15	74.45	17.25
CV (%)	11.96	2.15	1.70	11.20	0.60	4.13

M1000 (mass of 1000 seeds). BD (bulk density). ECE (electrical conductivity of the exudate solution). CV (coefficient of variation). In each column, mean values bearing dissimilar lower-case letters are significantly different according to Tukey test at 5% probability.

The qualitative improvement in the M1000 and ASM values of grains produced in $ICLF_S$ and $ICLF_T$ suggests that the conditions imposed by the integrated systems, such as lower temperature and evapotranspiration, may have favored the formation of grains in comparison with soybean grown in the CSF system. Regarding crops cultivated under conventional conditions, Ramos-Junior *et al.* (2019) obtained mean M1000 values of 163 and 155 g for soybean cultivars BRS7380RR (as used in the present study) and BRS7780IPRO, respectively, whereas Silva *et al.* (2020) recorded an overall M1000 mean of 148.33 g for soybean cultivars AS7307, ANTA82, and MSOY9144. In addition, the ASM values described herein are within the range of 610 to 740 kg m^{-3} obtained by Pinto *et al.* (2017) in a study involving the soybean cultivar TMG132RR.

The values obtained in the present experiment were similar irrespective of the cultivation system employed and are well within the range of 20 – 190 µS cm^{-1} g^{-1} reported by Pinto *et al.* (2017) for the cultivar TMG132RR grown under conventional conditions.

As shown in Table 2, no significant differences between the ICLF systems were observed in the mean values of parameters in relation to the south or north aspect of the crop or the distance of plants from the tree rows. The overall mean moisture value of soybean grains grown under ICLF conditions was 13.37%. According to some researchers (Botelho *et al*., 2016; Sousa *et al*., 2016), moisture content is the factor that most influences the physical characteristics of grains. Nonetheless, in the present study, moisture content was similar in all samples regardless of the ICLF conditions.

Table 2. Physical characteristics of soybean grains grown in the south and north faces of integrated agrosystems with single- and triple-tree row configurations

Agrosystem	Distance (m)	Moisture (%)		M1000 (g)		ASM (kg m^{-3})		ECE (μS cm^{-1} g^{-1})		Hue angle (º)		Chroma index	
		South face	North face	South face	North face	South face	North face	South face	North face	South face	North face	South face	North face
ICLF$_S$	3	15.52^{ns}	13.48^{ns}	162.50^{ns}	175.20^{ns}	702.68^{ns}	696.01^{ns}	131.91^{ns}	134.60^{ns}	74.08^{ns}	74.00^{ns}	17.07^{ns}	17.25^{ns}
	6	15.58	13.74	166.70	172.40	700.32	690.71	149.38	147.11	72.46	73.53	17.33	16.21
	10	14.47	13.33	166.55	163.95	699.10	683.52	150.13	157.66	72.27	75.26	15.94	18.36
	15	13.79	13.12	165.95	169.70	700.13	687.02	142.48	177.51	74.52	73.08	17.51	15.63
ICLF$_T$	3	12.01^{ns}	12.41^{ns}	172.80^{ns}	167.95^{ns}	712.34^{ns}	719.62^{ns}	120.36^{ns}	174.25^{ns}	73.47^{ns}	73.75^{ns}	16.56^{ns}	17.36^{ns}
	6	12.40	12.38	169.70	171.80	706.08	711.26	128.59	141.31	73.74	73.58	17.02	17.63
	10	13.50	12.79	169.05	167.90	698.69	698.54	130.83	99.63	73.85	73.83	18.06	17.39
	15	13.31	12.15	171.50	171.30	703.06	705.52	155.25	95.64	73.75	74.52	17.59	16.99

ICLF$_S$: Integrated crop-livestock-forestry system with single tree row configuration; ICLF$_T$: Integrated crop-livestock-forestry system with triple tree row configuration; n.s. (not significant).

The overall mean M1000 value for soybeans harvested from ICLF systems was 169.06 g, and grain filling occurred even in the more shaded areas near the eucalyptus trees, showing that reduced PAR did not impair the full development of the seeds. According to Magalhães *et al.* (2019), one explanation for this finding would be that plants grown in shaded areas contain fewer pods and grains, so the seeds enlarge normally. In addition, species with a C3 metabolism, such as soybean, appear to adapt more easily to environments with reduced sunlight (Fioreze *et al.*, 2013).

Nevertheless, Almeida *et al.* (2014) observed that soybeans cultivated between triple-rows of eucalyptus sited in the north/south orientation and located 15 m apart produced seeds with higher M1000 values when grown at the extremity of the west face (144 g) in comparison with those grown at the extremity of the east face (83 g). This may be due to the higher incidence of sunlight on the former compared with the latter location. Moreover, following a study involving five soybean cultivars planted in an ICLF system with a single-tree row configuration, Werner *et al.* (2017) reported higher M1000 values for seeds harvested from the west face compared with those from the east face in both the first and second cultivation cycles. These results suggest that the performance of soybean intercropped with eucalyptus forests may be affected directly by the adverse environmental conditions and the configuration of the production system, such as the orientation and number of tree rows and the distance between tree stands. This implies that farming activities involving ICLF systems must be planned carefully to be successful.

Although bulk density (BD) is a meaningful indicator of the quality of soybean grains, it is not normally employed for commercialization purposes. The overall BD value of soybeans grown under ICLF conditions was 700.91 kg m^{-3}, and grains with comparable BD values typically present well-formed structures with fully developed embryos and nutritive reserve tissues (endosperm and perisperm) (Carvalho & Nakagawa, 2000). Thus, according to this parameter, the quality of soybean seeds was not negatively affected by the reduction in PAR occasioned by the tree canopies.

Fioreze *et al.* (2013) reported that the moisture content of the leaves of soybean plants grown in shaded environments or under full sunlight is similar during the full flowering phase (phenological stage R2). Water is crucial for the development of grains since it is required in abundance for the translocation of metabolites to the seeds and the subsequent accumulation of proteins and oils (Abud *et al.*, 2013). Accordingly, leaf moisture exerts a direct effect on M1000 and ASM parameters, especially in plants cultivated in shaded environments. In the present experiment, the microclimate within the ICLF systems, as characterized by lower temperature, wind speed, evapotranspiration, and sunlight but higher humidity (Magalhães *et al.*, 2020), may have reduced environmental stresses and led to an increase in leaf moisture content that favored grain filling and higher M1000 and ASM values.

The electrical conductivity of the exudate solution (ECE) value is a qualitative indicator of grain quality since the amount of leachate in the soaking solution is a reliable measure of the degree of degradation of cell membranes. Thus, low ECE values indicate the occurrence of a small level of leaching and, consequently, high physiological quality (Vieira *et al.*, 2002). The integrity of cell walls is particularly important for long-term grain storage because it prevents deterioration of quality by diminishing the rate of oxidative reactions (Ziegler *et al.*, 2017). In the present study, the ECE values of grains harvested from the two ICLF systems were similar, with an overall mean of 139.79 µS cm^{-1} g^{-1} that was not significantly different from the mean ECE of grains produced under CFS conditions (138.37 µS cm^{-1} g^{-1}). This finding indicates that, despite the differential configuration of ICLFS and ICLFT, both systems allowed the full development of grains with good physical/physiological characteristics and quality, as substantiated by the M1000 and BD values.

Grain color, represented by hue angle and chroma index, was similar for soybean grains produced in the two ICLF systems, with overall mean values of 73.73° and 17.12, respectively. Color is an inherited trait that depends on the soybean cultivar but is also one of the main indicators of grain quality and sample classification. Evaluation of color is a simple technique for the detection of damaged, immature or moldy products.

CONCLUSIONS

We conclude that the quality of soybean seeds was not negatively affected by the conditions prevailing in the ICLF systems, but rather that the forest component contributed positively to the ecosystem by providing a favorable microclimate for the development of the grains.

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BIBLIOGRAPHIC REFERENCES

Abud, H. F.; Araujo, E. F.; Araujo, R. F.; Araujo, A. V.; Pinto, C. M. F. (2013). Qualidade fisiológica de sementes das pimentas malagueta e biquinho durante a ontogênese. *Pesquisa Agropecuária Brasileira.* 48(12): 1546-1554. 10.1590/S0100-204X2013001200003

Almeida, F. L; Calonego, J. C; Catuchi, T. A; Tiritan, C. S; Araújo, F. F; Silva, P. C. G. (2014). Produtividade de soja em diferentes posições entre renques de eucalipto em cultivo consorciado. *Revista Colloquium Agrariae*. 10(1): 33-44. 10.5747/ca.2014.v10.n1.a098

Balbino, L. C.; Cordeiro, L. A. M.; Oliveira, P.; Kluthcouski, J.; Galerani, P. R.; Vilela, L. (2012). Agricultura sustentável por meio da integração Lavoura-Pecuária-Floresta (iLPF). *Informações Agronômicas*. 138: 1- 18.

Botelho, F. M.; Correa, P. C.; Botelho, S. C. C.; Vargas-Elias, G. A.; Almeida, M. D. S. D.; Oliveira, G. H. H. (2016). Propriedades físicas de frutos de café robusta durante a secagem: determinação e modelagem. *Coffee Science*. 11(1): 65-75.

Botelho, F. M.; Faria, B. M. E. M.; Botelho, S. C. C.; Ruffato, S.; Martins, R. N. (2018). Metodologias para determinação de massa específica de grãos. Revista Agrarian. 11(41): 251-259. 10.30612/agrarian.v11i41.7922

Carvalho, N. M.; Nakagawa, J. (2000). *Sementes: Ciência, Tecnologia e Produção.* 4th ed. Jaboticabal: FUNEP. 588p.

Fioreze, S. L.; Rodrigues, J. D.; Carneiro, J. P. C.; Silva, A. A.; Lima, M. B. (2013). Fisiologia e produção da soja tratada com cinetina e cálcio sob déficit hídrico sombreamento. *Pesquisa Agropecuária Brasileira.* 48(11): 1432-1439. 10.1590/S0100-204X2013001100003

Gobbi, K. F.; Garcia, R.; Ventrella, M. C.; Garcez Neto, A. F.; Rocha, G. C. (2011). Área foliar específica e anatomia foliar quantitativa do capim-braquiária e do amendoim-forrageiro submetidos a sombreamento. *Revista Brasileira de Zootecnia*. 40(7): 1436-1444.

Macedo, M. C. M. (2009). Integração lavoura-pecuária: o estado da arte e inovações tecnológicas. *Revista Brasileira de Zootecnia*. 28: 133-146.

Magalhães, C. A. S.; Pedreira, B. C.; Tonini, H.; Farias Neto, A. L. (2019). Crop, livestock and forestry performance assessment under different production systems in the north of Mato Grosso, Brazil. *Agroforestry systems*. 93(6): 2085-2096. 10.1007/s10457-018-0311-x

Magalhães, C. A. S.; Zolin, C. A.; Lulu, J.; Lopes, L. B.; Furtini, I. V.; Vendrusculo, L. G.; Zaiatz, A. P. S. R.; Pedreira, B. C.; Pezzopane,

J. R. M. (2020). Improvement of thermal comfort indices in agroforestry systems in the southern Brazilian Amazon. *Journal of Thermal Biology*. 91(102636). 10.1016/j.jtherbio.2020.102636

Ministério da Agricultura, Pecuária e Abastecimento. (2009). *Regra para Análises de Sementes*. Brasília: Secretaria Nacional de Defesa Agropecuária. 399p.

Pinto, R. S.; Botelho, F. M.; Botelho, S. C. C.; Angeli, A. M. (2017). Qualidade de grãos de soja em diferentes épocas de colheita. *Nativa*. 5 (especial): 463-470. 10.31413/nativa.v5i7.4375

Ramos-Junior, E. U.; Ramos, E. M.; Bulhões, C. C. (2019). Densidade de plantas nos componentes produtivos e produtividade de cultivares de soja. *Revista Ciências Agroambientais*. 17(2): 52-56. https://doi.org/10.5327/rcaa.v17i2.2587

Sediyama, T. (2009). Tecnologias de produção e usos da soja. Londrina: Mecenas. 314p.

Silva, E. S.; Carvalho, M. A. C.; Dallacort, R. (2020). Cultivares de soja em função de elementos climáticos nos municípios de Tangará da Serra e Diamantino, MT. *Nativa*. 8(2): 157-164. 10.31413/nativa.v8i2.8382

Silva, J. S. (2008). Secagem e armazenagem de produtos agrícolas. In: Silva, J. S.; Berbert, P. A.; Afonso, A. D. L.; Ruffato, S. *Qualidade de grãos*. pp. 63-105. 2th ed. Viçosa: Aprenda Fácil. 560p.

Sousa, A. C.; Mata, M. E. R. M. C.; Duarte, M. E. M.; Almeida, R. D.; Rosa, M. E. C.; Cavalcanti, A. S. R de R. M. (2016). Influência do teor de água nas propriedades físicas dos grãos de arroz vermelho em casca. *Revista Brasileira de Produtos Agroindustriais*. 18(especial): 495-502.

Viana, J. H. M.; Spera, S. T.; Magalhaes, C. A. de S.; Calderano, S. B. (2015). Caracterização dos solos do sítio experimental dos ensaios do Projeto Safrinha em Sinop-MT. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/167364/1/com-210.pdf

Vieira, R. D.; Penariol, A. L.; Perecin, D.; Panobianco, M. (2002). Condutividade elétrica e o teor de água inicial das sementes de soja. *Pesquisa Agropecuária Brasileira*. 37(19): 1333-1338. 10.1590/S0100-204X2002000900018

Werner, F.; Balbinot Junior, A. A.; Franchini, J. C.; Ferreira, A. S.; Silva, M. A. A. (2017). Agronomic performance of soybean cultivars in an agroforestry system. *Pesquisa Agropecuária Tropical*. 47(3): 279-285. 10.1590/1983-40632016v4745937

Ziegler, V.; Ferreira, C. D.; Tonieto, L.; Silva, J. G.; Oliveira, M.; Elias, M. C. (2017). Efeitos da temperatura de armazenamento de grãos de arroz integral de pericarpo pardo, preto e vermelho sobre as propriedades físico-químicas e de pasta. *Brazilian Journal of Food Technology*. 20(2016051): 1-9. 10.1590/1981-6723.5116.

