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Intercropping soybean and palisade grass for enhanced land use efficiency and revenue in a no till system

C.A.C. Crusciol[a,*], A.S. Nascente[b], G.P. Mateus[c], C.M. Pariz[d], P.O. Martins[a], E. Borghi[e]

[a] São Paulo State University (UNESP), College of Agricultural Science, Department of Crop Science, P.O. Box 237, 18.610-307 Botucatu, São Paulo, Brazil
[b] Brazilian Agricultural Research Corporation (EMBRAPA), Rice and Beans Research Center, P.O. Box 179, 75.375-000 Santo Antônio de Goiás, Goiás, Brazil
[c] São Paulo Agency of Agribusiness Technology (APTA), P.O. Box 67, 16.900-000 Andradina, São Paulo, Brazil
[d] College of Veterinary Medicine and Animal Science, Department of Animal Nutrition and Breeding, 18.618-970 Botucatu, São Paulo, Brazil
[e] EMBRAPA Fisheries, Aquaculture and Agricultural Systems, Block 103 South, JK Avenue, Acess 01, Lot 17, Ground Floor, Southern Master, 77.015-012 Palmas, Tocantins, Brazil

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ABSTRACT

Integrated no-till crop and livestock production systems may help rejuvenate degraded pastures, increase land use efficiency (LUE), and increase enterprise revenue. Our objectives were to evaluate: (1) planting date effects on seed yield and nutrient concentration of an early-maturing, no-till system (NTS) soybean (*Glycine max*) when intercropped with palisade grass (*Brachiaria brizantha*); (2) dry matter production and protein concentration of the grass pasture after soybean harvest; and (3) overall revenue and LUE for the intercrop system. Experiments were performed during two growing seasons in Botucatu, Brazil using a randomized complete block experimental design. When palisade grass and soybean were sown simultaneously, soybean yield averaged 3.28 Mg ha^{-1}. Similar seed yields were observed when palisade grass was planted either 30 d after soybean emergence (DAE) (3.29 Mg ha^{-1}) or at the soybean reproductive stage R6 (full seed) (3.50 Mg ha^{-1}). Monocrop soybean yield averaged 3.50 Mg ha^{-1}. First cut dry matter forage production was greater when palisade grass was sown at the same time as soybean or 30 DAE of soybean. This indicates that interseeding palisade grass with soybean does not significantly affect soybean nutrition or yield. Intercropping did increase LUE and resulted in 1.6 times more revenue than soybean alone. However, sowing palisade grass at the soybean reproductive stage R6 (full seed) significantly reduced the forage yield compared to early planting.

1. Introduction

While global demand for food increases, agricultural expansion faces more stringent environmental preservation demands and sustainability laws aimed to prevent deforestation (Rufino et al., 2006; Satheeshkumar et al., 2011; Nascente and Crusciol, 2012). The Cerrado Region of Brazil encompasses an area of approximately 80 million hectares of cultivated pasture, of which 62.5% exhibits some degree of degradation (Borghi et al., 2013). Integrated crop–livestock systems are characterized by diversification, rotation, and cropping related to grain and animal production within the same land area (Tedla et al., 1999; Reda et al., 2005; Sulc and Tracy, 2007; Ryan et al., 2012). Crop–livestock integration can be utilized to simultaneously increase soybean (*i.e.*, food) production and recover degraded pastures without expansion into new agricultural areas (Garcia et al., 2008; Tracy and Zhang, 2008; Maughan et al., 2009; Takin, 2012). Therefore, integrated crop–livestock systems could be a key form of ecological intensification needed for achieving future food security and environmental sustainability.

The “Santa Fe System” (Kluthcouski et al., 2003) encourages seed crop production, especially corn (*Zea mays* L.), sorghum [*Sorghum bicolor* (L.) Moench], pearl millet [*Pennisetum glaucum* (L.) R. Br.] and soybean, and interseeding with tropical forages from the *Brachiaria* and *Panicum* genera. Those annual grain crops exhibit robust initial growth and development, thereby exerting a high level of competition on the forage and avoiding a significant decrease in crop yield (Kluthcouski et al., 2003). After harvesting the cash crops, forages, if developed properly, can grow quickly and be used to recover degraded pastures using residual fertilizer from the grain crops. Portes et al. (2000) evaluated palisade grass interseeded

Abbreviations: NTS, no-tillage system; DAE, days after emergence; NPP, number of pods per plant; NSP, number of seeds per pod; W100, weight of 100 seeds; SY, seed yield; PDMF, palisade grass dry matter.

* Corresponding author. Tel.: +55 14 3880 7564; fax: +55 14 3880 7000.
E-mail addresses: crusciol@fca.unesp.br (C.A.C. Crusciol), adriano.nascente@embrapa.br (A.S. Nascente).

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simultaneously with maize, sorghum, pearl millet and rice (*Oryza sativa* L.) by measuring its regrowth after the cereals were harvested. They observed that the presence of the cereals reduced tiller number, leaf area index, total leaf matter, dry matter of green leaves and stems, and palisade grass growth rate prior to the cereal harvest. Additionally, they noted that the leaf areas of intercropped palisade grass were lower than that of the cereals and that low competition for light from palisade grass favored a good seed yield. Approximately 60–70 d after the cereals were harvested, palisade grass regrowth displayed an herbage yield similar to that of a palisade grass monoculture 70 d after emergence. Without competition, palisade grass can grow rapidly because its stems develop roots when they come in contact with soil and therefore the plant can spread quickly with time (Valle and Pagliarini, 2009). This integrated system is advantageous because it does not change the schedule of agricultural activities and does not require special or costly equipment (Kluthcouski et al., 2003; Crusciol et al., 2010). Furthermore, forage has a dual purpose in this system, as food for cattle in times of drought and as straw to protect soil resources within the NTS (Borghi and Crusciol, 2007). Additionally, intercropping soybean with palisade grass does not typically reduce nutrient concentrations in soybean plants (Crusciol et al., 2010). Borghi et al. (2013) observed that leaf nutrient concentrations of soybean cultivars simultaneously sown with palisade grass were within the expected range. Borghi and Crusciol (2007) also did not observe a reduction in nutrient uptake by corn that was intercropped with palisade grass. As an additional information, it is important to study competition effects between the crops and to evaluate intercrop performance, for this, different competition functions such as the relative yield should be calculated (Agegnehu et al., 2006; Takin, 2012).

Simultaneously sowing soybean with palisade grass promotes legume growth by reducing weed incidence. The grass forage also disrupts soybean pest and diseases cycles (Silva et al., 2009). Forages grow quickly and display an aggressive root system that favors nutrient cycling, which improves soil physical properties, increases biological activity and organic matter, and provides a persistent surface residue cover. This residue is important because it can reduce soil erosion, weed growth and, consequently, herbicide application (Rosolem et al., 2004; Crusciol and Soratto, 2007, 2009; Nascente and Crusciol, 2012). Additionally, grass forages benefit from residual fertilizer, biological nitrogen fixation by legumes, soil liming and from the disruption of pest and disease cycles (Kluthcouski et al., 2003).

Although sowing corn or sorghum with palisade grass has shown promising results in several studies (Portes et al., 2000; Borghi and Crusciol, 2007; Crusciol et al., 2010), more research is required to elucidate effects of interseeding palisade grass with soybean. This combination is challenging to manage, as it requires knowledge of the optimal time to sow the grass, since it can grow rapidly in some situations and can adversely affect soybean development, harvest or yield (Silva et al., 2009). These authors suggest that adequate forage management is essential for successful intercropping to prevent any interference with the crop. After evaluating the effects of six rates of the herbicide fluazifop-p-butyl in establishing soybean and palisade grass intercropping, they concluded that low doses of herbicide could be used to intercrop soybean and palisade grass. However, the presence of other grass species may invalidate these findings because species such as *Brachiaria plantaginea* have fast initial growth and can quickly overcome palisade grass.

In other cases, a soybean crop may have a quick-closing canopy that shades the grass, causing it to die and hindering recovery of the pasture after grain harvest (Crusciol et al., 2010). According to Silva et al. (2009), precise timing of the herbicide application is essential for managing palisade grass intercropped with soybean. Extremely late applications, near the soybean flowering stage, may not allow the grass to recover due to shading, whereas with early applications, weeds may emerge and decrease soybean yield. Therefore, studies designed to optimize sowing palisade grass with soybean need to be performed. Specifically, soybean losses must be avoided while promoting high forage biomass production by the forage for use in animal grazing and/or straw residues for NTS.

Our objectives were to evaluate: (1) nutrient concentration and seed yield of an early-maturing NTS soybean cultivar ‘Embrapa 48’, intercropped with palisade grass cv. ‘Marandu’ sown into the intercrop at different stages of soybean growth; (2) dry matter production and protein concentration of the palisade grass pasture after soybean harvest; and (3) land use efficiency (LUE) and revenue generated by intercropping.

2. Material and methods

2.1. Site description

The experiment was performed in Botucatu, State of São Paulo, in southeastern Brazil (48°23′ W; 22°51′ S; 765 m above sea level) during the 2005–2006 and 2006–2007 growing seasons. The soil (a clay loam, kaolinitic, thermic Typic Haplorthox) (FAO, 2006) contained 630, 90 and 280 g kg^{-1} of clay, silt and sand, respectively, had been managed for 5 years in a NTS consisting of 1st year – corn in the summer and oat (*Avena sativa* L.) in the fall; 2nd year – soybean in the summer and corn in the fall; 3rd year – corn in the summer and oat in the fall; 4th year – soybean in the summer and oats in the fall; and 5th year – corn in the summer, oat in the fall, and pearl millet in the spring.

The climate, according to the Koppen classification, is CWa that is tropical with a dry winter and a hot, rainy summer. The long-term annual temperatures (1956–2006) includes a maximum, minimum, and average of 26.1 °C, 15.3 °C and 20.7 °C, respectively. Average annual rainfall is 1359 mm. Actual rainfall and temperature measured during the experimental period are presented in Fig. 1. In the 2005–2006 growing season, the amount of rainfall (1212 mm, Fig. 1) was ~10% less than the long-term (1956–2006) average (1359 mm). The temperature (20.3 °C) was also cooler than the long-term average (20.7 °C), with the lowest temperatures in June (16.0 °C) and July (15.0 °C). During the second growing season (2006–2007), the annual precipitation (1720 mm) was ~27% higher than the long-term average. The annual average temperature of 20.8 °C was also similar to the long-term average, with the lowest temperatures occurring in May (17.0 °C) and June (18.0 °C).

Before initiating the experiment, soil chemical characteristics were determined (0–20 cm) according to van Raij et al. (2001).

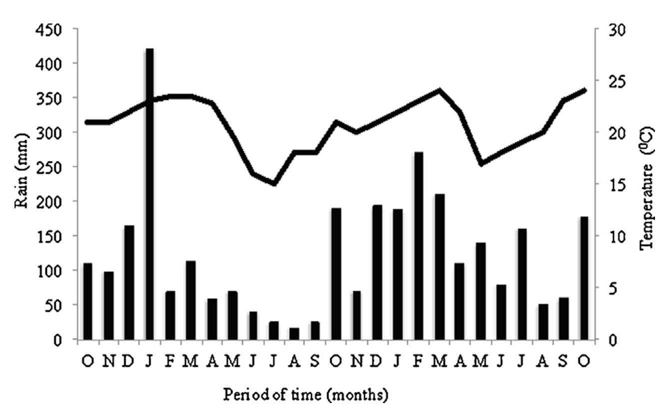

Fig. 1. Temperature and rainfall during the study period, which includes the first year, from October 2005 to September 2006, and the second year, from October 2006 to September 2007.