PRODUCTION AND QUALITY OF UROCHLOA BRIZANTHA PASTURES GRAZED UNDER CONTINUOUS STOCKING IN INTEGRATED CROP-LIVESTOCK-FOREST SYSTEMS

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ABSTRACT
Season may change pasture responses even in innovative, sustainable crop-livestock-forest (ICLF) systems. The objective of this work was to evaluate production and quality of *Urochloa brizanta* cv. Piatã pastures grazed by buffaloes under continuous stocking in open pasture system (OP), ICLF with African mahogany (*Khaya ivorensis*) (ICLF-M) and ICLF system with teak (*Tectona grandis*) (ICLF-T) in the dry and rainy seasons. Forage mass was lower in the ICLF systems than in the OP system in the dry season. In contrast, ICLF-T system produced forage with higher crude protein content in this season. In the rainy season, no difference between systems was observed. ICLF systems may be less productive in forage than the OP system in the dry season. However, they can deliver forage with higher crude protein content in this season depending on the tree species.
Key words: Amazon; Buffalo; Humid Tropics

INTRODUCTION

Integrated crop-livestock-forest (ICLF) systems combine sustainable production of crops, grazing animals and forest species in a same area simultaneously or over time (BALBINO et al., 2011). By combining different economic activities, ICLF systems have been found to be a low risk, economically viable enterprise (MULLER et al., 2011; OLIVEIRA JUNIOR et al., 2016). For livestock, these systems can provide thermal comfort for grazing animals by decreasing the air temperature due to presence of trees, resulting in better animal welfare (KARVATTE Jr. et al., 2016). Furthermore, decrease in greenhouse gas emission (GHG) is a potential benefit of integrated systems for animal production, as found by Figueiredo et al. (2017), who estimated carbon (C) footprint for beef cattle at –28.1 kg CO_2eq per kg body weight in an ICLF system with eucalyptus, value expressively lower than those in managed pasture (of 7.6 kg CO_2eq per kg BW) and degraded pasture (18.5 kg CO_2eq per kg BW). Due to these and other economic advantages and environmental benefits, ICLF systems have been adopted at large scale in Brazil, covering an area of at least 11 million ha (ICLF NETWORK, 2019).

However, shade of trees can consecutively decrease photosynthesis and growth of tropical forage plants (DIAS-FILHO, 2000; DIAS-FILHO, 2002; GUENNI et al., 2008; GÓMEZ et al., 2012) and consequently influence both productivity and quality of forage in pasture under continuous grazing in ICLF systems. Studies conducted in the tropics have shown lower forage mass in integrated systems compared with open pasture (OP) systems, but this difference can depend on the season. Lima et al. (2019) found 36% less forage mass of *Urochloa decumbens* cv. Basilisk in a silvopastoral system with legume trees in relation to the OP system in the rainy season (summer). In the dry season (autumn), however, the forage mass was similar between the systems. For crude protein content, it was higher in silvopastoral system in both seasons. These results contrast with those of Santos et al. (2018), according to which the forage mass of *U. brizantha* cv. Piatã in two silvopastoral systems with eucalyptus was at least 27% lower than that in the OP system in both the rainy and dry seasons, but no difference was observed for the crude protein contents in forage between the systems. Such conflicting findings may be due to a complex interaction between systems and weather conditions in each season. Therefore, influence of season is a matter to be studied in ICLF systems.

The objective of this work was to evaluate production and quality of *Urochloa brizanta* cv. Piatã pastures grazed by buffaloes under continuous stocking in open pasture system (OP), ICLF with African mahogany (ICLF-M) and ICLF system with teak (ICLF-T) in the dry and rainy seasons.

MATERIAL AND METHODS

The field study was conducted in an Embrapa Amazônia Oriental's experimental station (01°01'33.4" S, 47°53'58.3" W, elevation 40 m) located in the Terra Alta municipality, state of Pará, Brazil. The local climate is Am (tropical monsoon) by the Köppen's classification. Mean annual precipitation ranges from 2300 to 2800 mm, with a mean annual temperature of 26°C (Moraes et al., 2005). The soil in this area is an *Argissolo Amarelo Distrófico textura arenosa/média* (Gama et al., 2000) (Ultisol) and it was being occupied with a degraded pasture of *Urochloa humidicola* (Rendle) Morrone & Zuloaga for a number of years previously to the beginning this study. This soil had the following characteristics in the layer of 0-20-cm depth before the installation of the study: pH in water (1:2.5 soil:water ratio) 5.4, OM (organic matter by the Walkley-Black method) = 17.76 g/kg, Mehlich-1 P = 1 mg/dm^3, exchangeable K = 0.07 cmol$_c$/dm^3, exchangeable Ca = 0.7 cmol$_c$/dm^3, exchangeable Mg = 0.4 cmol$_c$/dm^3, exchangeable Al = 0.5 cmol$_c$/dm^3, H+Al (potential acidity) = 3.3 cmol$_c$/dm^3, CEC (cation exchange capacity) at pH 7 = 4.5 cmol$_c$/dm^3, V (base saturation) = 26%, m (aluminum saturation) = 30%, sand = 779 g/kg, silt = 86 g/kg, and clay = 135 g/kg.

Two integrated crop-livestock-forest (ICLF) systems were installed in the study area in February 2009. A system was implanted with African mahogany (*Khaya ivorensis* A. Chev.) (ICLF-M) and the other with teak (*Tectona grandis* L. f.) (ICLF-T) as forest components since these species produce high-quality woods (WIEMANN, 2010). Initially, 1.5 t/ha of limestone was applied to the soil surface following a conventional soil tillage. Then three forest species strips spacing 50 m to each other were established in the area of each system. In the ICLF-M system, three rows of African mahogany with trees spacing 5 × 5 m were planted in each strip, while four rows of teak with trees spacing 3 × 3 m were planted in each strip in the ICLF-T system. For both forest species, fertilization consisted of 100 g P_2O_5 (reactive phosphate rock) per hole at planting, 25 g N (urea) and 25 g K_2O (potassium chloride) per plant in March 2009 and also 20 g N and 20 g K_2O (20-0-20) per plant in April 2009.

In both ICLF systems, maize (*Zea mays* L. cv. BRS 1030) was cultivated in the areas between tree strips in 2009, 2010, 2011, 2012 and 2013. Soil tillage was conventional in the first year, as cited above, and no-tillage system was adopted in the subsequent years. Fertilization in each year was carried out to supply 33 kg N/ha, 92 kg P_2O_5/ha and 66 kg K_2O/ha (10-28-20) at sowing, and 40 kg N/ha and 40 kg K_2O/ha (20-0-20) at top-dressing. Cowpea [*Vigna unguiculata* (L.) Walp cv. BRS Guariba] was only sown in the first year after harvest of maize as a second crop. No fertilizer was applied for cowpea.

In 2013, a pasture of *Urochloa brizantha* (Hochst. ex A. Rich.) R. Webster cv. BRS Piatã [syn. *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf cv. BRS Piatã] was established in the areas between the tree strips in both ICLF systems. Grass seeds were distributed together with the fertilizer applied at top-dressing for maize. In 2015, an open pasture (OP) of the same grass was also established in an area contiguous to the areas with ICLF systems in order to serve as a reference of conventional pasture system (i.e., only pastoral system, not integrated to other production systems). At the establishment of this pasture, 70 kg N/ha (urea), 110 kg P_2O_5/ha (triple superphosphate) and 60 kg K_2O/ha (potassium chloride) were applied.

In 2017, the areas between tree strips for each ICLF system were divided into four subareas. Similarly, OP system area was also divided into four subareas. Thus, the three production systems (OP, ICLF-M and ICLF-T) were replicated Divisions of the areas were done using electric fences, and mineral salt trough and water trough were shared every two subareas. Each subarea was considered as a paddock of approximately 0.6 ha. The ICLF-M and ICLF-T systems had trees with average height of 14.24 and 12.72 m and average diameter at breast height of 23.78 and 19.61 cm, respectively.

All pastures were mown and then fertilized in May 2017. For fertilization, 50 kg N/ha (urea), 50 kg P_2O_5/ha (single superphosphate) and 50 kg K_2O/ha (potassium chloride) were applied. No fertilizer was subsequently applied to the pastures until the end of this study. In July 2017, pastures were again mown at a height of 35 cm for standardizing the sward canopy height.

Pastures were grazed from July 2017 to April 2018 (252 days) by buffaloes (*Bubalus bubalis* L.) under continuous stocking with variable stocking rate. Two tester steers at age of 18 months and each one weighting 332 kg [standard error of the mean = 14 kg, n = 24] were put into each paddock. However, only one animal was maintained until October 2017 in the ICLF-M system's paddocks in order to stimulate the plant growth in sward patches with a very low canopy. Additional buffaloes (regulator animals) were occasionally put into and take from the paddocks (i.e., put-and-take stocking) as an attempt to maintain the canopy height by about 35 cm. All animals received both mineral salt and water freely.

Ten points in the pasture in each paddock were selected randomly every 28 days July 2017 to April 2018. In each point, plants in an area of 0.25 m^2 (0.50 ´ 0.50 m) were cut at the soil level. Plant samples collected in each paddock were bulked, and three subsamples were taken. Subsamples were then oven-dried at 65°C until constant weight. The weighted plant material was used to estimate the forage mass. Crude protein in forage was calculated by multiplying the total nitrogen (TN) content by 6.25, with TN determined by the Kjeldahl method (AOAC, 1990).

Data were analyzed using a randomized complete block design with four replicates, each one allocated in a paddock. Replicates were considered as blocks in order to capturing possible variability among paddocks. Effects of production systems were tested using an analysis of variance (ANOVA) performed for each season (dry and rainy). When F test showed significance means were compared according to the least significant difference (LSD). Spearman's correlation was processed between selected variables. All analyses were performed at $P < 0.05$ using the R software (R Core Team, 2018).

RESULTS AND DISCUSSIONS

There was difference in forage mass between production systems in the dry season (Figure 1a), with OP having greater mass as compared with the ICLFs systems. However, for rainy season, no difference was observed among the systems (Figure 1b). The greater forage mass in the OP system compared with ICLF systems was probably a consequence of a low (re)growth of plants in these integrated systems due to shading imposed by trees. Similar results were obtained by Santos et al. (2018) for the same grass used in this study (i.e., Piatã grass) in silvopastoral systems with *Eucalyptus urograndis* as tree species. Lima et al. (2019) have also found lower forage mass of other *Urochloa* species (*U. decumbens*) in a long-term silvopastoral system with three tree species (*Acacia mangium, Eucalyptus grandis* and *Mimosa artemisiana*) as compared with a OP.

Severe decrease in growth of genus *Urochloa* grasses has been found under shading conditions (CASTRO et al. 1999; DIAS-FILHO, 2000; GUENNI et al., 2008; GÓMEZ et al., 2012). The mechanisms that account for this decreased growth are not fully understood. However, decline in net photosynthesis rate (DIAS-FILHO, 2002) accompanied by less tillering and reduced relative growth rate (DIAS-FILHO, 2000) resulting in lower shoot dry matter (GUENNI et al., 2008; GÓMEZ et al., 2012) have been observed in shaded *U. brizantha*. In addition, this species submitted to shading has shown lower total nonstructural carbohydrate (TNC) content in stem base due to negative impact on photosynthesis derived of decrease in incident light (CASTRO et al., 1999). As a consequence, regrowth of shaded *U. brizantha* can be affected negatively, since TNC is potentially important in recovery of forage plants defoliated by cut or grazing animals, especially when a considerable proportion of leaves are removed (PEDREIRA et al., 2000). All these negative effects associated with shading may have occurred in the ICLF systems tested in the present study. Although the degree of shading was not determined as it did in the work of Lima et al. (2019), who have measured photosynthetically active radiation (PAR), shade due to trees in these systems covered by about one-third of paddock area. This relatively extensive shade cover may then have inhibited grass growth such that the forage mass in the whole paddock was decreased as we found. However, less forage mass in the ICLF systems occurred only in the dry season, which suggests a seasonal fluctuation for the effect of shading on forage mass.

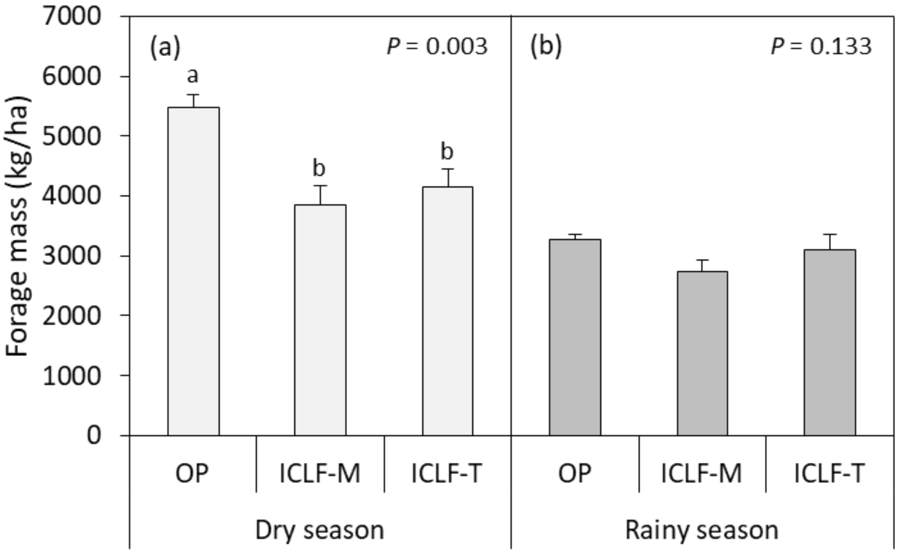

Figure 1. Forage mass of *Urochloa brizanta* cv. Piatã grazed by buffaloes under continuous stocking in open pasture system (OP), integrated crop-livestock-forest system with African mahogany (ICLF-M) and ICLF system with teak (ICLF-T) within the dry season (Jul-Nov 2017) (a) and the rainy season (Dec 2017-Apr 2018) (b). *P*-value: probability for the *F* test from ANOVA. Different letters on the bars within the dry season indicate difference between means according to LSD ($P < 0.05$). Bars without letters within the rainy season indicate *F* test from ANOVA not significant ($P > 0.05$). Lines on the bars represent standard error of the mean.

The systems also influenced the crude protein content in forage but only in one of the seasons. Crude protein in the ICLF-T system was higher than those in the OP and ICLF-M systems in dry season (Figure 2a). However, in the rainy season, no difference was observed among the systems (Figure 2b). Shading also seems to have been the cause of the higher crude protein content in forage in the ICLF-T system in the dry season. Increase in crude protein in *Urochloa*-grass pastures shaded by trees at silvopastoral systems have been found in other studies (PACIULLO et al., 2007; FARIA et al., 2018; LIMA et al. 2019). Several factors have been pointed out to explain this phenomenon (LIMA et al. 2019). However, the “concentration effect” of N in forage is believed to have been a important factor in this work, since the crude protein content, which is proportional to N content, was negatively correlated with the forage mass in the the dry season ($r = -0.5874$, $P = 0.049$, $n = 12$).

The greater crude protein content found in forage of the ICLF-T can be considered an advantage for nutrition of animals grazing in this system. This is especially important because the increase occurred in the dry season, when the forage nutritive value, particularly in terms of crude protein, is generally low as compared with that in the rainy season. The less crude protein content in forage in the ICLF-M system than in the ICLF-T system is likely a consequence of apparent difference in shading between the tree species. African mahogany canopy was visually less dense than that of teak, resulting in a shade less uniform for the former in relation to the last. As a result of this less uniformity, more light reached the sward canopy in the ICLF-M system, thus limiting the concentration effect of N and consequently the accumulation of crude protein in forage. This greater crude protein content in forage in the ICLF-T system in relation to the ICLF-M system indicates that the effect of ICLF system on crude protein could be dependent on tree species.

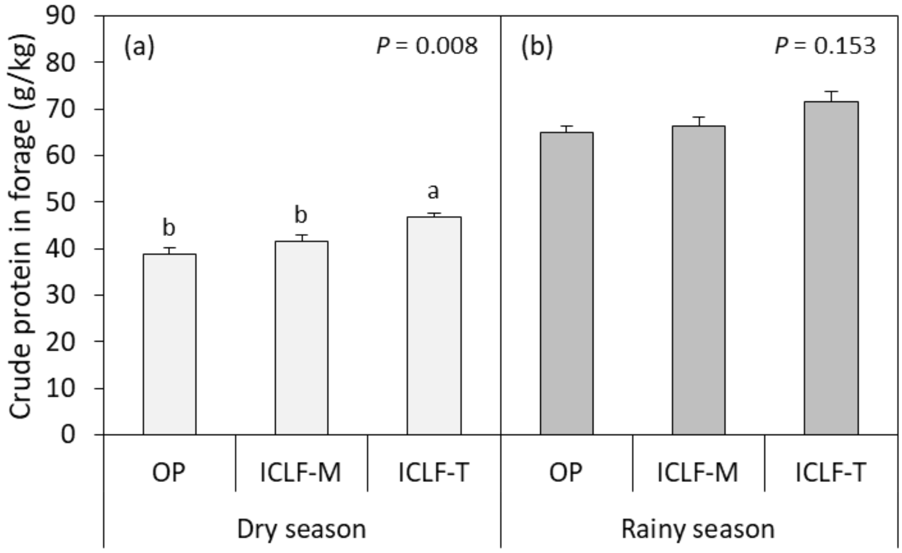

Figure 2. Crude protein in forage of *Urochloa brizanta* cv. Piatã grazed by buffaloes under continuous stocking in open pasture system (OP), integrated crop-livestock-forest system with African mahogany (ICLF-M) and ICLF system with teak (ICLF-T) within the dry season (Jul-Nov 2017) (a) and the rainy season (Dec 2017-Apr 2018) (b). *P*-value: probability for the *F* test from ANOVA. Different letters on the bars within the dry season indicate difference between means according to LSD ($P < 0.05$). Bars without letters within the rainy season indicate *F* test from ANOVA not significant ($P > 0.05$). Lines on the bars represent standard error of the mean.

CONCLUSIONS

ICLF systems may be less productive in forage than the OP system in the dry season. However, they can deliver forage with higher crude protein content in this season depending on the tree species. In the rainy season, all these differences tend to be eliminated.

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