

# Productivity and nutritive value of *Urochloa brizantha* cultivar Piatã, *Megathyrus maximus* cultivar Zuri and cultivar Tamani in Silvopastoral Systems in the Central Region of Minas Gerais<sup>1</sup>

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## Research Article

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# Abstract

To evaluate the forage yield *Urochloa brizantha* cultivar Piatã, *Megathyrsus maximus* cultivar Zuri and the Tamani cultivar, in silvopastoral systems (SSP) with different tree densities and in pasture in full sun (FS), an experiment was carried out in the municipality of Sete Lagoas located in the Cerrado biome in the central region of Minas Gerais. The experimental design was completely randomized, with split-plots in space and six replications. The plots corresponded to four spatial arrangements: three silvopastoral system arrangements (SSP) with *Eucalyptus grandis* GG100 (15×2, 15×4 and 15×8 m) and one grass monoculture. The subplots were composed of three grasses: *U. brizantha* cv. Piatã, *M. maximus* cv. Zuri and cv. Tamani. In the subplots, three cuts were made at 20 cm height from the soil surface, with six replications in each. The forage biomass yield and the proportion of leaf and stem components in the forage biomass were evaluated. At tree densities of 166 and 333 trees/ha in the SSPs, pastures suffered significant reductions in whole-plant biomass production, and in the leaves-to-stems ratio in forage when compared to full pasture. On the other hand, at the density of 84 plants per hectare, the production was similar to that in full sun.

## I. Introduction

The association of trees with pastures and agricultural crops emerges as an alternative to enhance livestock activities, constituting agrosilvopastoral systems. Integration can promote the recovery of degraded pastures and provide greater stability in food production with the intensification of land use, reducing the need to incorporate new areas for agricultural activities, and ultimately increasing profitability in the activity, combined with the sustainability of agricultural activities (Pérez-Lombardini, et al., 2019; Broom, 2021). However, maintaining the productivity of pasture and tree species is the major challenge for the sustainability of the system in tropical regions (Dias-Filho, 2015).

Competition between trees and crops for solar radiation, water, and nutrients is an important factor limiting the adoption of these systems by farmers, especially in systems with a high tree population (Santos et al., 2018). Depending on the tree population, thinning and pruning should be carried out to increase wood quality and decrease competition for resources between trees and crops (Reynolds et al., 2007; Gomes et al., 2019).

In order to have a good performance of these systems, the present study aimed to compare ICLF (integration crop-livestock-forest) integrated production systems consisting of Eucalyptus intercropped with *U. brizantha* cv. Piatã, *M. maximus* cv. Zuri and cv. Tamani and single pasture in monoculture through the evaluation of the yield of the components of the integrated systems, involving yields and pasture quality.

## II. Material and Methods

The experiment was carried out in the rainy season, from November 2021 to May 2022, at the Demonstration Unit of the Crop-Livestock Integration System (UD-ILP) of the Brazilian Agricultural Research Corporation (Embrapa) Maize and Sorghum located in the municipality of Sete Lagoas-MG (19° 29' 05.1" South Latitude, Longitude 44° 10' 40.0" W) whose altitude is 744m. The experimental area corresponded to a total of four hectares, characterized by a very clayey Dystrophic Red Latosol, with smooth undulating relief and subdeciduous savannah, according to the Brazilian Soil Classification System (Santos et al., 2013). It is possible to identify as the most striking characteristic of the Cerrado the presence of two well-defined seasons, a dry winter and a humid summer. The concentrated distribution of rainfall throughout the region has a direct influence on vegetation (Nascimento et al., 2020).

The ICLF system of the UD-ILP has been established since 2009, in modules of four rows of simple rows of eucalyptus (*Eucalyptus urophylla* clone GG 100) that are implanted at a spacing of 15 x 2 meters (m) by 80 m in length for each row, corresponding to 333 trees per hectare. During this period, annual crops of maize intercropped with *U. brizantha* cv. Piatã among the rows. The first thinning took place in 2014, reducing the tree population to 50% of the initial stand. The experimental design was completely randomized, in a 4x3 factorial arrangement, with six replications, consisting of modules of four rows of single rows. These eucalyptus rows were introduced in each module between 2009 and 2011.

In the first three years of introduction of eucalyptus seedlings, annual crops of corn were intercropped with *U. brizantha* cv. After the corn harvest in the third year, the forage remained intercropped with eucalyptus, in order to evaluate dry matter productivity.

In 2014 and 2015, half of the area that was planted with the *E. urophylla* introduced in 2009 and 2011 was thinned, and on this same occasion the tree population was reduced by 50% of the initial stand in the thinned area. Continuing, the initial module was divided into

two sub-areas with respective densities of 333 and 166 trees per hectare (ha). In 2019, the planted area of eucalyptus in 2009 had its tree population reduced by 50%, resulting in a density of 84 trees per hectare. After this management, the grass *U. brizantha* cv. Piatã introduced in the area was desiccated and replaced by soybean planting, and, in the following year, at the end of 2020, the area underwent corn intercropping with three grass cultivars among the rows: *U. brizantha* cv. Piatã, *M. maximus* cv. Tamani and *M. maximus* cv. Zuri. Based on these considerations, the evaluated systems were established as shown in Table 1.

Table 1 – Treatments of the 2021/2022 grazing cycle, in the three forage collections *M. maximus* cv. Tamani , *U. brizantha* cv. Piatã and *M. maximus* cv. Zuri em Sete Lagoas, MG

| Cultivate                     | Tree density/hectare   |                                               |                                               |                                                |
|-------------------------------|------------------------|-----------------------------------------------|-----------------------------------------------|------------------------------------------------|
|                               | 0 (without Eucalyptus) | 84 (Eucalyptus with 12 years of implantation) | 168 (Eucalyptus with 8 years of implantation) | 333 (Eucalyptus with 10 years of implantation) |
| Tamani ( <i>M. maximus</i> )  | PS402                  | iLPF102 (15x8 m)*                             | iLPF302 (15x4 m)*                             | iLPF202 (15x2 m)*                              |
| Piatã ( <i>U. brizantha</i> ) | PS403                  | iLPF103 (15x8 m)*                             | iLPF303 (15x4 m)*                             | iLPF203 (15x2 m)*                              |
| Zuri ( <i>M. maximus</i> )    | PS404                  | iLPF104 (15x8 m)*                             | iLPF304 (15x4 m)*                             | iLPF204 (15x2 m)*                              |

\*Eucalyptus spacing between rows (rows) and in the planting row.

The fertilization and cultural treatments of the areas followed the agronomic recommendations throughout the experimental period. It should be clarified that pasture areas in monoculture of *M. maximus* cv. Tamani, *U. brizantha* cv. Piatã and *M. maximus* cv. Zuri, with one year of establishment, (PS402, PS403 and PS404), and the subareas are adjacent and have a total area of approximately one hectare.

On September 27, 2021, a uniformity cut of the pasture areas was carried out using a tractor mower, and this operation was repeated on March 10, 2022, due to the unwanted entry of cattle into the experimental area. Forage samples were collected between November 23, 2021 and May 6, 2022. Three cuts were performed for the evaluation of the pastures according to the cutting intervals and accumulated periods specified in table 2. The interval of days between the cuts were not fixed, being carried out when the height and forage accumulation were visually interesting for all cultivars (need to be evaluated, because the cultivars analyzed have different growth pattern and size, fixing the period could favor a cultivar).

Table 2 – Experimental period of the 2021/2022 grazing cycle, in forage collections *M. maximus* cv. Tamani, *U. brizantha* cv. Piatã and *M. maximus* cv. Zuri em Sete Lagoas, MG

| Cuts              | Dates                | Cut-off intervals (days) | D0 trial time (days) |
|-------------------|----------------------|--------------------------|----------------------|
| Standardization*  | 27/09/2021           | -                        | -                    |
| 1°                | 23 and 24/11/2021    | 57                       | 57                   |
| 2°                | 20/12/2021           | 26                       | 83                   |
| 3°                | 30/01 and 01/02/2022 | 41                       | 124                  |
| Standardization** | 10/03/2022           | 37                       | 161                  |
| 4°                | 04 and 06/05/2022    | 45                       | 206                  |

\* First cut made for standardization of forage in all areas at the beginning of the experimental period; \*\*Second Cutting carried out to standardize the forage in all areas after the unwanted entry of animals into the area.

Treatments: ICLF102, ICLF103, ICLF104, ICLF202, ICLF203, ICLF204, ICLF302, ICLF303, ICLF304, PS402, PS403, and PS404 were evaluated from November to December 2021 and late January/early February 2022. To determine the cutting area, a 2 m metal ruler was used in a row (planting in a row with a spacing of 0.5 m; thus representing 1 m<sup>2</sup>) placed at three different distances from the two eucalyptus planting rows of each treatment (0.5, 3.0 and 7.0 m), characterizing the six replications in randomly chosen rows in monoculture pastures.

The cut was carried out with 0.2 m distance from the ground and all the forage collected in identified plastic bags. After weighing all forage collected, a sample of 500 gr (grams) was taken and separated into two subsamples with 250 gr, one for evaluation of green weight, and the other separated into leaf blade and stem to determine the morphological composition by manual separation. The samples were dried in a forced air oven at 55°C until they reached constant weight, to determine the amount of dry matter (DM) in kilograms per hectare (kg/ha)

To estimate the forage accumulation rate, in kg/ha/day of DM, the value of the total forage accumulation was divided by the collection interval (days) of each cycle. The total forage accumulation during the test period was obtained from the sum of the partial accumulation of each collection cycle.

Forage yield and quality data were analyzed by cutting (1, 2 and 3) for leaves, according to a completely randomized design with a 3x4 factorial arrangement (cultivar x density). All data were evaluated in relation to the assumptions of normality and homoscedasticity by the Shapiro-Wilk and Bartlett tests, respectively ( $p>0.05$ ) (Bartlett, 1937; Shapiro et al., 1965). When necessary, transformations of the response variable and modeling of the variance and covariance matrix were used (Pinheiro and Bates., 2000). The effect of the factors and the interaction were evaluated by analysis of variance ( $p<0.05$ ) and the means of treatments were compared according to Tukey's test ( $p<0.05$ ). Data analyses were performed using the statistical analysis software R (R Core Team, 2022).

### III. Results and Discussion

The means and standard deviation of the variables related to the yield of grass cultivars grown at different tree densities are shown in Table 3. There was a significant effect of cultivar, cultivar density and interaction, and density for all variables ( $p<0.01$ ).

Table 3. Means and standard deviations of yield of cultivars in systems with different tree densities in four sections, regardless of the cultivar

| Variable             |                    | DM content in biomass (%) |         |         | Daily forage accumulation (kg/day) |         | DM yield (kg/ha) | Stem Leaf Ratio |
|----------------------|--------------------|---------------------------|---------|---------|------------------------------------|---------|------------------|-----------------|
| Cut                  |                    | 1                         | 2       | 3       | 2                                  | 3       | 3                | 4               |
| Tree Density         | 0                  | 16.73 B                   | 17.80 A | 20.95 A | 46.08 A                            | 57.10 A | 2455.31 A        | 6.32A           |
|                      | 83                 | 17.56 AB                  | 17.38 A | 18.22 B | 46.51 A                            | 65.91 A | 3215,04 A        | 3.54B           |
|                      | 168                | 18.82 A                   | 17.12 A | 18.92 B | 32.27 B                            | 37.47 B | 1611.27 B        | 3.45B           |
|                      | 333                | 17.85 AB                  | 17.36 A | 17.67 B | 36.97 B                            | 37.32 B | 1604,96 B        | 2.82B           |
| P-value <sup>1</sup> | C <sup>2</sup>     | 0,88                      | <0.01   | <0.01   | <0.05                              | 0,138   | 0,07             | <0.05           |
|                      | D <sup>3</sup>     | <0.01                     | 0,21    | <0.01   | <0.05                              | <0.01   | <0.01            | <0.01           |
|                      | C x D <sup>4</sup> | 0,24                      | 0,11    | 0,56    | 0,44                               | 0,10    | 0,34             | 0,06            |
| DP <sup>5</sup>      |                    | 0,37                      | 0,23    | 0,53    | 4,05                               | 3,95    | 161,94           | 0,48            |

<sup>1</sup> Means followed by distinct letters on the same line differ statistically based on the Tukey's testy ( $p<0.05$ ); <sup>2</sup> Cultivate; <sup>3</sup> Density of trees per hectare; <sup>4</sup> Interaction between Cultivar and Tree Density; <sup>5</sup> Standard deviation

The total dry matter production (TDMP) of forage cultivars, after 168 days of experimentation, is shown in tables 4 and 5, where it is observed the absence of significant interaction between the treatments ( $p>0.05$ ), where the monoculture and the density of 84 trees/ha presented higher productivity (approximately 35%) when compared to the other arrangements.

Table 4. Means and standard deviations of productivity variables accumulated in four sections, in systems with different tree densities, regardless of cultivar

| Variable             |                    | Total Dry Matter Production (kg/ha) | Daily forage accumulation rate (kg/day) |
|----------------------|--------------------|-------------------------------------|-----------------------------------------|
| Tree Density         | 0                  | 8428,42 A                           | 50.16 A                                 |
|                      | 84                 | 9402.28 A                           | 55.96 A                                 |
|                      | 168                | 5735,04 B                           | 34.13 B                                 |
|                      | 333                | 5933,50 B                           | 35.31 B                                 |
| P-value <sup>1</sup> | C <sup>2</sup>     | <0.01                               | <0.01                                   |
|                      | D <sup>3</sup>     | <0.01                               | <0.01                                   |
|                      | C x D <sup>4</sup> | 0,18                                | 0,18                                    |
| DP <sup>5</sup>      |                    | 455,15                              | 2,71                                    |

<sup>1</sup> Means followed by distinct letters on the same line differ statistically based on the Tukey's testy ( $p < 0.05$ ); <sup>2</sup> Cultivate; <sup>3</sup> Density of trees per hectare; <sup>4</sup> Interaction between Cultivar and Tree Density; <sup>5</sup> Standard deviation

The cv. Zuri obtained the highest TDMP (9013.68 kg/ha) and the highest forage accumulation rate (53.65 kg/day) among those analyzed, which reveals the highest production potential. On the other hand, the Tamani and Piatã grasses did not show significant differences in the different densities of trees.

Table 5. Means and standard deviations of yield variables accumulated in the four cultivars' cuts, regardless of tree density

| Variable             |                    | Total Dry Matter Production (kg/ha) | Daily forage accumulation rate (kg/day) |
|----------------------|--------------------|-------------------------------------|-----------------------------------------|
| Cultivate            | Tamani             | 6869,13 B                           | 40.88 B                                 |
|                      | Piatã              | 6241,63 B                           | 37.15 B                                 |
|                      | Zuri               | 9013,68 A                           | 53.65 A                                 |
| P-value <sup>1</sup> | C <sup>2</sup>     | <0.01                               | <0.01                                   |
|                      | D <sup>3</sup>     | <0.01                               | <0.01                                   |
|                      | C x D <sup>4</sup> | 0,18                                | 0,18                                    |
| DP <sup>5</sup>      |                    | 380,74                              | 2,27                                    |

<sup>1</sup> Means followed by distinct letters on the same line differ statistically based on the Tukey's testy ( $p < 0.05$ ); <sup>2</sup> Cultivate; <sup>3</sup> Density of trees per hectare; <sup>4</sup> Interaction between Cultivar and Tree Density; <sup>5</sup> Standard deviation

The means and standard deviation of the variables related to the yield of grass cultivars cultivated at different tree densities are shown in Table 6 and Table 7. There was a significant effect of cultivar, cultivar density and interaction, and density for all variables ( $p < 0.01$ ).

Table 6. Means and standard deviations of yield variables of cultivars in systems with different tree densities in the four sections

| Variable                                | Cut | Cultivate | Tree density/hectare |             |            |            | DP <sup>2</sup> | P- value <sup>1</sup> |                |                  |
|-----------------------------------------|-----|-----------|----------------------|-------------|------------|------------|-----------------|-----------------------|----------------|------------------|
|                                         |     |           | 0                    | 84          | 168        | 333        |                 | C <sup>3</sup>        | D <sup>4</sup> | CxD <sup>5</sup> |
| Dry Matter Production (kg/ha)           | 1   | Tamani    | 3410,98 Ba           | 2283,30Bb   | 3097.89 Aa | 1884,37Bb  | 431,38          | <0.01                 | <0.01          | <0.01            |
|                                         |     | Piată     | 2349,92 Ba           | 2716,77 Ba  | 1514,33Bc  | 2008,37Bb  |                 |                       |                |                  |
|                                         |     | Zuri      | 4880.74 Aa           | 5378.34 Aa  | 2656,85ABC | 4280,89Ab  |                 |                       |                |                  |
|                                         | 2   | Tamani    | 1083,39 ABa          | 1108.19 Aa  | 1003.56 Aa | 870.72 Aa  | 142,64          | 0,96                  | <0.01          | <0.05            |
|                                         |     | Piată     | 1310.06 Aa           | 1027,54 Aab | 714,00 Ab  | 969,63 Aab |                 |                       |                |                  |
|                                         |     | Zuri      | 764,52 Bb            | 1352.52 Aa  | 703,30 Ab  | 1094,48Aab |                 |                       |                |                  |
|                                         | 4   | Tamani    | 2068.36 Aa           | 1214,87 Bb  | 719,95 Bbc | 587.62 Ac  | 162,78          | <0.01                 | <0.01          | <0.01            |
|                                         |     | Piată     | 696,00 Ba            | 937,55 Ba   | 719,10 Ba  | 612.73 Aa  |                 |                       |                |                  |
|                                         |     | Zuri      | 1056,60 Bb           | 1943.96 AA  | 1242,31 Ab | 838,39Ab   |                 |                       |                |                  |
| Daily forage accumulation rate (kg/day) | 1   | Tamani    | 77,52 Ba             | 51,89 Ba    | 70.40 Aa   | 42,82Bb    | 3,38            | <0.01                 | <0.01          | <0.01            |
|                                         |     | Piată     | 53,40 Ba             | 61,74 Ba    | 34,41 Bb   | 45,64 Ba   |                 |                       |                |                  |
|                                         |     | Zuri      | 110.92 Aa            | 122.23 Aa   | 60,38Abb   | 97.29 Aa   |                 |                       |                |                  |
|                                         | 4   | Tamani    | 36.93 Aa             | 21,69 Bb    | 12,85 Abb  | 10,49 Ab   | 3,32            | <0.01                 | <0.01          | <0.01            |
|                                         |     | Piată     | 12.42 Ba             | 16,74 Ba    | 12,84 Ba   | 10.94 Aa   |                 |                       |                |                  |
|                                         |     | Zuri      | 18,86 Bb             | 34.71 Aa    | 22,18 Ab   | 14,97 Ab   |                 |                       |                |                  |
| Dry Matter Content (%)                  | 4   | Tamani    | 33,69 ABa            | 22,34 Bc    | 24.30 Ac   | 28,06 Ab   | 0,84            | <0.01                 | <0.01          | <0.05            |
|                                         |     | Piată     | 35.42 Aa             | 27.73 ABC   | 24.58 Ac   | 28,06 Ab   |                 |                       |                |                  |
|                                         |     | Zuri      | 32,53 Ba             | 22,83 Bb    | 22,04 Ab   | 24,57 Bb   |                 |                       |                |                  |

<sup>1</sup> Means followed by distinct letters per section, lowercase in the row and uppercase in the column, differ statistically based on the Tukey's testy (p<0.05); <sup>2</sup> Standard Deviation; <sup>3</sup> Cultivate; <sup>4</sup> Tree density; <sup>5</sup> Interaction between Cultivate and Tree Density.

Cv. Zuri showed the best results in relation to DM production and daily forage accumulation rate. On the other hand, cv. Tamani had the highest leaf/stem ratio, which indicates a higher proportion of leaves in relation to the stem. It was also noted that the daily forage accumulation rate showed no significant difference between PS and density of 84 trees/ha, and the worst performances occurred at tree density of 168 arv/ha.

Table 7. Means and standard deviations of Yield of cultivars in systems with different tree densities in the four sections

| Variable                         | Cut | Cultivate | Tree density/hectare |             |             |             | DP <sup>2</sup> | P-value <sup>1</sup> |       |                    |
|----------------------------------|-----|-----------|----------------------|-------------|-------------|-------------|-----------------|----------------------|-------|--------------------|
|                                  |     |           | 0                    | 84          | 168         | 333         |                 | C                    | D     | L x D <sup>3</sup> |
| Stem Leaf Ratio                  | 1   | Tamani    | 4.67 Aa              | 4.68 Aa     | 3,71 Ab     | 5.08 Aa     | 0,38            | <0.01                | <0.01 | <0.01              |
|                                  |     | Piată     | 1.90 Ba              | 1.45 Ca     | 2.08 Ba     | 1.58 Ba     |                 |                      |       |                    |
|                                  |     | Zuri      | 3,36 Aab             | 2,17 Bb     | 3.83 Aa     | 2.60 Bab    |                 |                      |       |                    |
|                                  | 2   | Tamani    | 3,36 Abb             | 8.78 Aa     | 5.07 Bab    | 8,46 Ba     | 1,61            | <0.01                | 0,14  | <0.05              |
|                                  |     | Piată     | 2.71 Ba              | 2,60 Ba     | 3.30 Ba     | 2.55 Ca     |                 |                      |       |                    |
|                                  |     | Zuri      | 7.06 Ac              | 9,74 Ab     | 10,28 Ab    | 12.78 Aa    |                 |                      |       |                    |
|                                  | 3   | Tamani    | 10.63 AA             | 3.31 Ac     | 6,81 Ab     | 4.24 Abc    | 0,49            | <0.01                | <0.01 | <0.01              |
|                                  |     | Piată     | 1,74 Bbc             | 1,00 Cc     | 2,27 Cb     | 3.52 Aa     |                 |                      |       |                    |
|                                  |     | Zuri      | 8.07 Aa              | 1,66 Bc     | 4,00 Bb     | 1,20 Bc     |                 |                      |       |                    |
| Mass Production Leaf Dry (kg/ha) | 1   | Tamani    | 2803,66 ABa          | 1863.83 Bab | 2505,93 Aab | 1572,68 Bb  | 312,83          | <0.01                | <0.01 | <0.01              |
|                                  |     | Piată     | 1563,29 Ba           | 1590,59 Ba  | 987,05 Bb   | 1193,38Bb   |                 |                      |       |                    |
|                                  |     | Zuri      | 3730.04 Aa           | 4059.49 Aa  | 2048,50 ABC | 2954,00 Ab  |                 |                      |       |                    |
|                                  | 2   | Tamani    | 353,72 Bb            | 997,16 ABa  | 792.72 Aa   | 803.31 Aa   | 102,61          | 0,13                 | <0.01 | <0.01              |
|                                  |     | Piată     | 942.24 Aa            | 718,01 Bab  | 533,02 Ab   | 690,30Aab   |                 |                      |       |                    |
|                                  |     | Zuri      | 669,28 Abb           | 1173.32 Aa  | 623,73 Ab   | 997,59 Aab  |                 |                      |       |                    |
|                                  | 4   | Tamani    | 1645.14 Aa           | 1100,91 Ab  | 656.96 ABC  | 489.44 Ac   | 127,5           | <0.01                | <0.01 | <0.01              |
|                                  |     | Piată     | 583,01 Ba            | 605,96 Ba   | 582.65 Aa   | 560.24 Aa   |                 |                      |       |                    |
|                                  |     | Zuri      | 900,86 Bab           | 1377.05 Aa  | 962,71Aab   | 734,10Ab    |                 |                      |       |                    |
| Stem Dry Mass Production (kg/ha) | 1   | Tamani    | 607,32 Ba            | 419,47 Ba   | 591.95 Aa   | 311,68 Ba   | 143,63          | <0.01                | <0.01 | <0.01              |
|                                  |     | Piată     | 607,04 Bab           | 1126.17 Aa  | 527,27 Ab   | 612,50 Ab   |                 |                      |       |                    |
|                                  |     | Zuri      | 1150,69 Aab          | 1682.35 Aa  | 608,35 Ab   | 932,34 Abab |                 |                      |       |                    |
|                                  | 2   | Tamani    | 285,86 ABa           | 79,06 Bab   | 162.36 Aa   | 35,73 Bb    | 48,58           | <0.01                | <0.01 | <0.05              |
|                                  |     | Piată     | 353.83 Aa            | 281.54 Aa   | 168.21 Aa   | 271.89 Aa   |                 |                      |       |                    |
|                                  |     | Zuri      | 133,55 Ba            | 132,95 Aba  | 61,22 Ba    | 53,69 Ba    |                 |                      |       |                    |
|                                  | 3   | Tamani    | 176,93 Bb            | 827.74 Aa   | 160,67 Bb   | 253,98 Bb   | 90,58           | <0.01                | <0.01 | <0.01              |
|                                  |     | Piată     | 1083.50              | 1169,46     | 518.51 Ac   | 702,35      |                 |                      |       |                    |

|   |        | Aa           | Aab           |               | ABC           |       |       |       |       |
|---|--------|--------------|---------------|---------------|---------------|-------|-------|-------|-------|
|   | Zuri   | 288,92<br>Bb | 1034.00<br>Aa | 370,73<br>Abb | 472,21<br>Abb |       |       |       |       |
| 4 | Tamani | 423.21<br>Aa | 113,96<br>Bb  | 169,84 Ab     | 149,75 Ab     | 69,35 | <0.05 | <0.05 | <0.01 |
|   | Piată  | 112,98<br>Ba | 331,58<br>Aba | 236.10 Aa     | 244.05 Aa     |       |       |       |       |
|   | Zuri   | 114,15<br>Bb | 566.90<br>Aa  | 279,60 Ab     | 254,76 Ab     |       |       |       |       |

<sup>1</sup> Means followed by distinct letters per section, lowercase in the row and uppercase in the column, differ statistically based on the Tukey's test ( $p < 0.05$ ); <sup>2</sup> Standard Deviation; <sup>3</sup> Interaction between Cultivar and Tree Density.

The cumulative results in the three ICLF treatments corroborate Paciullo et al. (2017) where they concluded that intense shading (65% shade) reduces forage mass, tiller density and leaf area index of pastures, but moderate shading (35% shade) does not alter these variables, in relation to PS cultivation.

In the evaluation of the first cut, it was observed that height interacted between the cultivar and tree density in the treatments. The cv. Zuri in PS obtained higher results, especially when compared to cv. Tamani at the tree density of 333 trees/ha (a difference of 61% in the average heights). This result is expected, because the morphogenic size of cv. Zuri is the largest among the three cultivars analyzed. This result indicates a trend towards higher productivity of cv. Zuri, being observed in the production of dry matter (kg/ha) and in the rate of forage accumulation (kg/day). The DM content in the biomass did not show a significant interaction between cultivar and density ( $p > 0.05$ ). There is a higher DM content in silvopastoral systems when compared to PS (about 6% higher). However, Castro et al. (1999) describe that grasses grown in the shade became juicier and had lower DM content.

In the second cut, all variables were found to interact with both cultivar and tree density in the treatments ( $p < 0.05$ ), except for the daily forage accumulation rate (kg/day) and DM content (%), which showed a significant difference only for cv. Zuri (approximately 11% lower, when compared to the other cultivars). Another important piece of data is the stem leaf ratio, where the highest data (12.78) was obtained in cv. Zuri with tree density of 333 trees/ha. It was observed that the daily forage accumulation rate (kg/day) did not show interaction between cultivar and tree density ( $p > 0.05$ ), but the density of 84 trees/ha and PS did not show a significant difference, which reflects that in this shading there is no significant reduction in forage mass production during the cutting period.

In the third cut, tree density factor in the daily forage accumulation rate (kg/day) interferes again negatively in the values of the average cultivars in the silvopastoral systems of 168 and 333 trees/ha, where they presented lower averages ( $p < 0.01$ ) when compared to the density of 84 trees/ha and the PS (reduction between 35 and 45% approximately). This fact converges with findings from the literature, where Pereira et al., (2015) point out that in the shading conditions under the forage in the understory, their potential was impaired to the growth and forage production in agrosilvopastoral and silvopastoral systems.

It is noteworthy that the DM yield (kg/ha) in PS and in the tree density of 84 trees/ha does not present statistical difference ( $p < 0.01$ ) (1938.86 A SP and 1985.96 A 88 tree/ha), which may be an important criterion for choosing the strategy for implementing an SSP system. In PS, it obtained higher means (13%  $p < 0.05$ ) when compared to SSP, which contradicts the data of the first cut, but follows the results found by Castro et al. (1999). This result is also reported by Crestani (2017), when evaluating Piată grass in monoculture and in three shade regimes (0, 18 and 55% shading). He observed that the shading caused by the trees reduced the forage dry mass in the pre-grazing by 36 and 71%, respectively, for the shade regimes of 18 and 55% of shading, when compared to the pasture in PS.

In the fourth cut, specifically for DM production, F/C ratio and daily forage accumulation rate, there were significant differences among cultivars. For leaf and stem DM production, there were also significant differences between cultivars, but the effect of tree density and cultivar-tree density interaction was not significant ( $p > 0.05$ ). The Zuri cultivar showed the highest performance in relation to plant height, dry matter production, a result also reported by Souza et al. 2020, which indicates a trend of pastures under moderate shade showing greater heights when compared to pastures without shade. In the accumulated total DM production and daily forage accumulation rate, cv. Zuri had the highest performance and cv. Tamani and Piată showed no statistical difference ( $p > 0.01$ ).

Based on the results, it can be seen that cv. Tamani had the smallest size, compared to Piată and Zuri grasses. In terms of MS production, cv. Zuri showed higher productivity indexes, while the Piată and Tamani cvs showed similar values. The F/C ratio was

higher for the cv. Tamani in SSP compared to PS. The production of DM from leaves, as well as the rate of daily forage accumulation was higher for cv. Zuri.

In the last cut, a different behavior was observed in DM production among the grass cultivars evaluated. A cv. Tamani had a higher mean at PS, while cv. Zuri had a higher mean in the SSP with 84 trees/ha, with this difference being greater than 50% in relation to the PS. Piatã did not show significant difference in the four treatments. Gobbi et al. (2009) did not observe any difference in the forage mass of *U. decumbens* at 50 and 70% in the levels of artificial shading and in PS during the period of reduced availability of growth resources (climatic conditions). The study also points to a significant effect of tree density on both variables, with higher densities leading to lower production and accumulation rates. However, surprisingly, the production of cultivars at a tree density of 84 tree/ha was statistically equal to the PS, showing a high potential for use, since ICLFS still have several benefits in their use (carbon sequestration, increased animal welfare, improvement in the microbiological profile of the soil, increase in income per hectare with the use of wood).

De Carvalho (2019) also found similar results in a study comparing forage production in different cropping systems in the Brazilian Amazon biome. He analyzed four systems, cattle ranching with *U. brizantha* Marandu in monoculture, pastures of Marandu grass integrated with eucalyptus (*Eucalyptus urograndis*) in three rows of rows, grass with two years of cultivation and grass after two years of cultivation with simple rows of eucalyptus spaced apart. The experiment took place from July 2016 to July 2017, and all experimental units were stored continuously, using a variable stocking rate. The results showed that the highest forage accumulation was observed in the systems with signalgrass with two years of cultivation and signalgrass after two years of cultivation with single rows of eucalyptus spaced, with 21,310 kg/DM/ha and 24,050 kg/DM/ha, respectively, compared to Marandu grass in monoculture (19,500 kg/DM/ha) and Marandu grass pastures integrated with eucalyptus in three rows (18,890 kg/DM/ha).

## IV. Conclusions

The results indicate that higher tree densities may not be beneficial for forage production and accumulation, regardless of the cultivar used. However, in terms of accumulation, regardless of the cultivar, the density of 84 trees/ha has proved to be as productive as the condition of the PS, bringing with it the benefits of the use of the SSP system, combined with good forage productivity.

The results suggest that the choice of cultivar can have a significant impact on forage production and that different cultivars may be more suitable for different purposes, depending on the technological level adopted, or edaphoclimatic conditions where the system is inserted.

## Declarations

## Author Contribution

All authors whose names appear on the submission made substantial contributions to the conception or design of the work; - or the acquisition, analysis, or interpretation of data; - drafted the work or revised it critically for important intellectual content; - approved the version to be published; and agree to be accountable for all aspects of the work in ensuring that questions related to the - accuracy or integrity of any part of the work are appropriately investigated and resolved.

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