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ESTABLISHMENT OF DIVERSIFIED CROP-LIVESTOCK-FORESTRY SYSTEMS BY ARBOREAL FORAGE ASSOCIATION

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ABSTRACT
Integrated Crop-Livestock-Forest (ICLF) systems tend to be less sensitive to variations in their component prices and are more stable than exclusive crops. To confirm these advantages, however, more species options are needed, especially for those farms in which soybean cultivation may not be interesting. The present study aims to identify options of forage species (*Cajanus cajan*, *Leucaena leucocephala*, *Vigna unguiculata* and *Tithonia diversifolia*) to increase the diversification of herd food supply in ICLF systems. The ICLF Technological Reference Unit (TRU) Sítio Nelson Guerreiro (established in 2009) is located in Brotas, São Paulo State, Brazil. The establishment process of these four alternative forage species has been carried out in a mature ICLF system, and the difficulties and first conclusions are presented. The project's expectations are to advance in the recommendation of practices for ICLF diversification, to verify the cost-benefit ratio of its implementation and management, and to assess the resulting socio-environmental impacts, as to contribute with the public policies of the 'Low carbon agricultural Plan' (Plano ABC).
Key words: pigeon pea; legumes; alley crop

INTRODUCTION

The diversification of production systems is an important strategy for reducing the risks of agricultural activities, and one existing option is the implementation of integrated Crop-Livestock-Forest (ICLF) systems. The decrease in production costs with the maintenance of good productivity is a main goal for farmers, in order to maintain the activity's economic viability. This is even more decisive when production scales are not sufficient to favor negotiation of input purchase prices, nor the sale prices of the products. Hence, most of the available ICLF systems include crop rotations with high-value species, such as soybeans and maize. However, due to logistic difficulties, higher production costs, or commercial restrictions, intensive cropping is not always feasible or desired by the farmer, for whom alternatives must be offered. For example, forage plants with complementary nutritional characteristics can be introduced in arrangements aimed at improving soil fertility and increasing the diversification of livestock feeding resources. The adoption of the ICLF system at the Technological Reference Unit (TRU) Sítio Nelson Guerreiro arose from the need for productive diversification, given its almost exclusive economic dependence on orange cultivation, more than a decade ago. Although orange is an important source of income in the region, it has been recently submitted to constant losses, due to the instability of prices practiced by industries and the incidence of HLB or greening disease. The TRU consists of a total area of 88 ha, destined to beef cattle, grain crops (maize consortiated with palisade grass - *Urochloa brizantha* - in no tillage system, in some

areas associated with pigeon pea and other legumes), both in ICLF; maize production associated with a mini maize sorter; silviculture in ICLF, with several species and varied clones of eucalyptus; mini sawmill for wood/firewood and fence posts for own use (from eucalyptus clearing and thinning); technological tourism, ICLF project consultancy, citriculture consultancy, partnership beekeeping and hibiscus planting. Even though there has been a great improvement in the commercialization conditions due to product diversification, the search for the reduction of production costs is a management permanent goal. In this context, animal supplementation with good quality forage, especially during the dry season, is still a challenge. The incorporation of woody forage species, nitrogen fixers, favors the balance of the diet, demands less quantity of external inputs, and adds advantages related to the production and recovery of ecosystem services. The diversification of species in an animal's diet enhances the use of diet components, by a more efficient metabolism, improves palatability and consumption, and may even reduce possible toxic effects of certain forages. The production and management of woody forages need, however, to be evaluated under the conditions of its use so that they can be more widely disseminated. The use of other forages, preferably legumes, in consortium with tropical grasses, in the present case *Brachiaria brizantha* cv. BRS Piatã, can be one of the main means of achieving good dry matter productivity, and consequently good animal productivity, with low cost, as also suggested by Paulino et. al. (2008). Consortium cultivation, as in the case of agroforestry systems is a traditional technology, but with the use of new species in different regions, it is important to describe fundamental steps to maximize their yield (CECCON et al., 2007). Of the four species evaluated, *Cajanus cajan* cv. BRS Mandarim, *Leucaena leucocephala*, *Vigna unguiculata* and *Tithonia diversifolia*, the first three are legumes, and their use in intercropped pasture can provide increase in the nutritional value of the diet, as they present high levels of crude protein and elevated digestibility. According to Broderick (2003), the increase in the available protein content of the diet supplies the limitation of rumen nitrogen, common in the dry season, with better utilization of dietary fiber by the animals. The choice of these species considered the demand defined by the farmer, the availability of reproductive material in the region, and the characteristics of the plants described in the literature (MOREIRA et al., 2003; SEIFFERT, 1988; COOK et al., 2005; NAS, 1977; COOK et al., 2005; MAIA, 2010; BEVILAQUA, 2008; COOK et al., 2005; MAHECHA and ROSALES, 2005; IBRAHIM et al., 2005; RUÍZ et al., 2014). That said, the project aims to identify options of forage species to diversify the food supply for the herd, by offering species with complementary characteristics and capable of exploring distinct ecological niches in the landscape. This work presents the implantation process of the four forage species in a mature ICLF system, the main difficulties, and the first conclusions.

MATERIAL AND METHODS

The ICLF Technological Reference Unit (TRU) “Sítio Nelson Guerreiro” is located in Brotas, São Paulo State, Brazil, at coordinates 22º10'58” S and 48º15'48” W, 550 meters altitude, and was established in 2009. At that time, eucalyptus (*Eucalyptus citriodora*) was planted following soil level lines so that the average distance between rows, called alleys 1, 2, 3 and 4, were 37 m, 30 m, 13 m and 43 m, respectively. The diversified ICLF system was installed in January 2020 on a pasture of 8.11 ha of total area and 7.68 ha of usable area. The distribution of the four species followed a 'cell arrangement' (Figure 1), considering the given spacing between the eucalyptus rows.

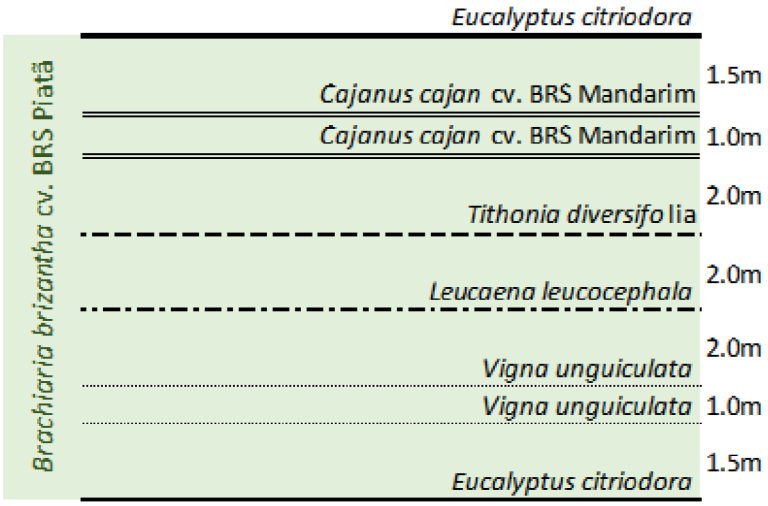

Figure 1. 'Cell arrangement' of the diversified Integrated Crop-Livestock-Forestry system deployed at the Technological Reference Unit at Brotas, State of São Paulo, Brazil

The forages were implanted on the existing palisade grass (*Brachiaria brizantha* cv. BRS Piatã), which was overgrazed and only mowed (not desiccated) in the rows, prior to sowing. An area of sole Piatã was kept to allow comparisons with the diversified systems (consisted of Piatã + four alternative species). Soil analyses showed satisfactory levels of nutrient contents, except phosphorus, which was supplemented. The control of ants was carried out from the beginning and according to recurrence. Cowpea sowing took place on 01/18/2020 and pigeon pea on 01/19/2020, both in double rows 0.9 m apart, and 4 seeds m^{-1}, with an Imasa PHS 63 seeder-fertilizer, from two lines (Massey Fergusson 65X tractor, reduced 3rd gear, at 5.3 km h^{-1}) and Imasa's own discs. Cuttings of tithonia (40 cm each) were planted on January 21 and 28 (2020) in a single line, with spacing of 0.7 m between cuttings. Leucena was sown on 02/12/2020, in a single row, by manual seeder, with a density of 5 to 7 seeds per hole, after several attempts of mechanized sowing. The determination of the availability of BRS Piatã happened on 02/12/2020, by the direct method with a 0.5 m x 0.5 m square, five samples in each plot and plants cut at ground level. Samples were weighted and dried in an oven with forced air circulation at 60 °C until constant mass and again weighted to obtain the dry matter mass. With the occurrence of the Covid-19 pandemic, only essential and non-extendable assessments were carried out, according to the guidelines of the institutions responsible for conducting the project. Plant density and height were measured in 10 m in each of the lines of each species, in all four eucalyptus alleys.

RESULTS AND DISCUSSIONS

The experience of planting with no desiccation had already been feasible on the property, even during midsummer, with high availability of light, water and high temperatures. In the present experience, this practice proved to be possible for both cowpea and pigeon pea whose sowing was mechanized. In the case of tithonia, which was furrowed, this does not apply, and in the case of leucena, this practice was not interesting, considering that sowing had to be manual with subsequent planting line weeding, so that it was possible to give them more advantage to grow, considering slow initial development. Until March 2020, the need to develop a mechanized sowing system for leucena was identified, as its implementation proved to be complex for the farmer, despite the technical material available for decades. For example, the seed dormancy breaking methods and the viability of the acquired leucena seeds posed difficulties, as in the present case 53% and 65% germinated, for the non-swollen and swollen ones, respectively, at 24 days after seeding (in sand). Additionally, seeds tended to overflow the sowing disc when not-swollen, while the swollen ones suffered damage in the sowing disc, even with the larger hole, a major problem given the high seed cost at R$ 75.00 kg^{-1}. A guideline adopted before and during the establishment of the diversified systems was to prioritize perennial forage species (leucena and tithonia) - and the most costly to implant, so that management

considered the survival of species in the leucena > tithonia > pigeon pea > cowpea order. Another factor for this prioritization in management was the finding that pigeon pea BRS Mandarin emerged showed good growth and development, comparing to leucena and tithonia, although it also seemed to suffer some competition by BRS Piatã, which was also observed in cowpea until the beginning of winter. Even with the intensified control of ants during the implantation of forages, the control was not satisfactory, especially in alleys 3 and 4. This is attributed to faulty control of ants in the sugar cane of the neighboring area. It is recommended that when choosing for leucena, consider infestation by ants in the vicinity, once within the five available species, leucena was the most susceptible. Another aspect to be considered for a system with different forage species is the waiting time for cattle to enter the diversified pasture. In the present case, the project area was closed for eleven months, being considered as a deferred pasture within the whole property, to guarantee the establishment of the perennial species. This decision was considered the most interesting, considering the cost of its implantation and its permanence in the system, to the detriment of the forage quality of cowpea and pigeon pea. This may even be a possible practice to be recommended for the diversified ICLF system and may vary according to the seeding date. The availability of BRS Piatã after the emergence of the four forages tested was 7.492 kg ha^{-1} of dry matter. The plant counting (Table 1) showed that cowpea and pigeon pea, which were mechanically sown, varied less. The sowing density of these two species was 4 seeds m^{-1} and the average of emerged plants was 0.94 for cowpea and 1.98 for pigeon pea, a possible indication of competition by BRS Piatã. The average of 1.50 m^{-1} clusters of leucena revealed that the dynamics of manual seeding changing the predicted density in clumps spaced every 0.5 m. The tithonia showed an average of 0.29 plants per meter, indicating that the sprouting was much lower than the amount planted. In fact, we observed many rotting cuttings in the furrows. The average height of pigeon pea plants (46.52 cm) indicates that this species has suffered competition, once it gets from 1.80 m to 1.95 m when sole cultivated, while tithonia allows to suppose that the sprouted cuttings had an expected growth. In case of leucena, the average height of the clump was provided, and this species was the smallest one, much shorter than it is indicated to get before herd pasture it, e.g. 1.0 m, when consortiated with palisade grass species (Seiffert and Thiago, 1983). The slowest initial development of leucena is attributed to the delay in its seeding and the ant attack suffered.

Table 1. Number of plants per meter and plant height (cm) (10-meter line averages) of cowpea (*Vigna unguiculata*), pigeon pea (*Cajanus cajan* cv. BRS Mandarim), leucena (*Leucaena leucocephala*) and tithonia (*Tithonia diversifolia*), in the Integrated Crop-Livestock-Forestry Technological Reference Unit of Brotas, São Paulo State, Brazil, on 06/06/2020.

Alley[1]	Cowpea	------- Pigeon pea -------		------- Tithonia -------		------- Leucena --------	
	Plants m^{-1}	Plants m^{-1}	Height (cm)	Plants m^{-1}	Height (cm)	Clump m^{-1}	Height (cm)
1	1.26	1.92	56.84	0.33	83.20	1.73	18.49
2	1.02	2.28	51.49	0.20	73.94	1.13	15.63
3	0.55	0.40	33.07	0.50	78.40	1.50	-
4	0.93	2.11	44.69	0.15	47.00	1.63	-
Average	0.94	1.68	46.52	0.29	70.64	1.50	17.06

[1]Average distance between eucalyptus rows in alleys 1, 2, 3 and 4 are 37 m, 30 m, 13 m and 43 m, respectively.

CONCLUSIONS

The main conclusions of the process of introducing *Cajanus cajan* cv. BRS Mandarim, *Leucaena leucocephala*, *Vigna unguiculata,* and *Tithonia diversifolia* to diversify a consolidated Integrated Crop-Livestock-Forestry (ICLF) system of *Brachiaria brizantha* cv. BRS Piatã with *Eucalyptus*

citriodora were (i) the forages suffered strong competition by BRS Piatã, and (ii) the diversification as tested is quite complex and unprecedented. Other consortia with fewer species are more common and therefore may be easier to manage in the day-to-day life at the farm. However, it is noteworthy, for now, that despite the difficulties faced for the proper establishment of perennial forages, this is a promising system, since practices are consistent with farmers' reality and their management have been used. The experience observed in the ICLF theme is clear regarding to the fact the main established arrangements have been screened by countless producers accompanied by scientific studies, which leads the team to maintain the arrangement initially outlined.

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REFERENCES

BEVILAQUA, G. A. P.; ANTUNES, I. F.; MARQUES, R. L. L.; MAIA, M. S. Sistemas ecológicos de produção de sementes e forragem de feijão-miúdo. In: CONGRESSO DA SOCIEDADE BRASILEIRA DE ECONOMIA, ADMINISTRAÇÃO E SOCIOLOGIA RURAL, 46., Rio Branco, 2008. **Anais...** 2008.

BRODERICK, G. A. et al. Effects of varying dietary protein and energy levels on the production of lactating dairy cows. **Journal of Dairy Science**, v.86, p.1370-1381, 2003.

CECCON, G.; SAGRILO, E.; DECIAN, M.; NUNES, D. P. **Produção de sementes de adubos verdes e de forragem em cultivo consorciado com milho em pequenas propriedades.** Dourados: Embrapa Agropecuária Oeste, 2007. 6p. (Embrapa Agropecuária Oeste. Circular técnica, 13).

COOK, B. G.; PENGELLY, B. C.; BROWN, S. D.; DONNELLY, J. L.; EAGLES, D. A.; FRANCO, M. A.; HANSON, J.; MULLEN, B. F.; PARTRIDGE, I. J.; PETERS, M.; SCHULTZE-KRAFT, R. **Tropical Forages**: an interactive selection tool., [CD-ROM], CSIRO, DPI&F(Qld), CIAT and ILRI, Brisbane, Australia, 2005.

IBRAHIM, M.; VILLANUEVA, C.; MORA, J. Traditional and improved silvopastoral systems and their importance in sustainability of livestock farms. In: MOSQUERA-LOSADA, M. R. **Silvopastoralism and sustainable land management**. Wallingford, Oxfordshire, UK: CABI Publishing. 2005, p.13-18.

MAHECHA, L.; ROSALES, M. Valor nutricional del follaje de Botón de Oro (*Tithonia diversifolia* [Hemsl]. Gray) en la producción animal en el trópico. **Livestock Research for Rural Development,** v.17, n.9, 2005.

MAIA, M. B. **Caracterização morfológica e agronômica de genótipos de feijão-miúdo (*Vigna unguiculata* (L.) Walp.) no Rio Grande do Sul**. Pelotas, 2010. 150f. Tese (Doutorado em Ciência e Tecnologia de Sementes) – Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel, Pelotas. 2010.

MOREIRA, V. F.; PEREIRA, A. J.; GUERRA, J. G. M.; GUEDES, R. E.; COSTA, J. R. **Produção de biomassa de guandu em função de diferentes densidades e espaçamentos entre sulcos de plantio**. Seropédica: Embrapa Agrobiologia. 2003. 5 p. (Embrapa Agrobiologia. Comunicado técnico, 57).

NAS. National Academy of Sciences. **Leucaena**: promising forage and tree crop for the tropics. National Academy Press, Washington DC, 1977. 115 p.

PAULINO, V. T.; BRAGA, G. J.; LUCENA, M. A. C.; GERDES, L.; COLOZZA M. T. Sustentabilidade de pastagens consorciadas: ênfase em leguminosas forrageiras. In: ENCONTRO SOBRE LEGUMINOSAS FORRAGEIRAS, 2. PAULINO, V. T.; BRAGA, G. J.; LUCENA, M. A. C. et al., (Orgs.). **Anais...** Nova Odessa: IZ/APTA/SAA, 2008, v.1, p.1-55.

RUÍZ, T. E.; FEBLES, G. J.; GALINDO J. L. et al. *Tithonia diversifolia*, its possibilities in cattle rearing systems. **Cuban Journal of Agricultural Science**, v.48, n.1, p.79-82, 2014.

SEIFFERT, N. F. Manejo de leguminosas forrageiras arbustivas de clima tropical. In: SIMPÓSIO SOBRE MANEJO DA PASTAGEM, 9., Piracicaba, 1988. **Anais...** Piracicaba: FEALQ, 1988. p.285-314.

SEIFFERT, N. F.; THIAGO, L. R. L. S. **Legumineira**: cultura forrageira para produção de proteína. Campo Grande, MS: EMBRAPA-CNPGC, 1983. 52 p. (EMBRAPA-CNPGC. Circular técnica, 13).