Australian Journal of Crop Science AJCS

AJCS 16(07):933-940 (2022) ISSN:1835-2707
doi: 10.21475/ajcs.22.16.07.p3603

Productive characteristics and economic analysis of tropical forage grasses cultivated under different sowing methods in intercropping production systems

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Abstract

This study aimed to evaluate sowing methods of different tropical grasses in integrated production systems on morphogenic and structural characteristics, chemical composition, and corn yield. The experiment was carried out in a completely randomized design, with a 3 x 3 + 1 factorial arrangement, with three forages: andropogon grass (*Andropogon gayanus* Kunth cv. Planaltina), massai grass (*Megathyrsus maximum* cv. Massai) and ruziziensis grass (*Urochloa ruziziensis*), three ways of sowing intercropped with corn (one row, two rows and broadcast) with four replications and corn in monoculture. Soil preparation, corrective practices and monitoring were carried out as recommended by the species. The results revealed that the sowing methods did not interfere with the interaction for morphogenic and structural characteristics of the grasses. Leaf elongation rate (LER) did not differ among grasses and sowing forms for Andropogon, Massai, and Ruziziensis grasses. There was an interaction effect ($P<0.05$) for leaf production (LP); the massai grass exhibited higher production compared to other grasses. The spread sowing method produced less leaf availability for the massai grass. There was no effect ($P>0.05$) of interaction for the variables of the chemical composition of grasses. Maize production was not altered due to the different consortia; however, a much lower value was found when producing corn in monoculture. The average production of intercropped corn was 3420 kg and ha^{-1}, against 1680 kg of single cultivated corn. Massai grass and Ruziziensis grass is an attractive alternative for intercropping with corn in integrated systems.

Keywords: *Andropogon gayanus* Kunth; *Megathyrsus maximum;* Intercropped system; *Urochloa ruziziensis; Zea may.*

Abbreviations: %_ Percentage, ADF_ Fiber in Acid Detergent, Al_ Aluminum, Ca_ Calcium, $CaCl_2$_ Potassium chloride , cm_ Centimeters, CONAB_ National supply company, CP_ Crude protein, , AE_ Days after emergence, DFB_ Dead forage bromass, DM_ Dry matter, M^3_ Cubic decimeter, EE_ Ether extract, FBL_ Final blade length, FLL_ Final leaf blade length, g_ Gram, ha_ Hectare, ICLS_ Crop_Livestock Integration, K2O_ Potassium oxide, K_ Potassium, kg_ kilograms, LDM_ Dry Leaf Mass, LAR_ Leaf appecerance rate , LER_ Leaf elongation rate, LI_ Tipping Index, LP_ Leaf reproduction, L/S_ Leaf/ stalk blade, LSR_ Leaf senescence rate, m_ meters, m^2_ Square meter, mg_ Magnesium, mm_ Millimeter, MM_ Mineral matter, NDF_ Fiber in Neutral Detergent, NLL_ Number live leaves, NLT_ Number of live tillers, OM_ Organic matter, P_ Phosphor, pH_ hydrogen potential, PHYL_ Phyllochron, PVC_ Polyvinyl chloride, SDM_ Dry thatch mass, SER_ Stem elongation rate, SP_ System production, TFDM_ Total dry forage mass, TPD_ Tiller Population Density, TFP_ Total forage production.

Introduction

Global food production and consumption have become a great concern towards socio-economic and environmental impacts (Allaoui et al., 2018). It is necessary to Integrated Crop-Livestock Systems (ICLS) sustainably to meet the growing population demand and environmental conservation (Costa Júnior et al., 2019).

Sustainable cultivation is part of the reality of many farmers who seek benefits for agriculture and livestock through technologies (Kamble et al., 2020). Integrated systems are tools used in this new technology; besides collaborate to environmental preservation, they also provide greater food production in increasingly smaller areas, ideal to meet global needs and grant higher profitability (Dias et al., 2021).

The most used in integrated systems are *Brachiaria decumbens* and *Brachiaria ruziziensis*. The knowledge of the requirements and competition for factors inherent to the development of both species are relevant for the correct recovery or implantation of pastures and greater grain crop productivity. It is worth underlining that due to the many interactions that occur between the grass and the annual crop, choosing the appropriate grass will lead to optimum performance of the production system (Guarnieri et al. 2019; Pariz et al. 2011).

In the Brazilian Northeast region, a principal obstacle for pasture production is the long dry period. Nevertheless, some species, such as Andropogon grass and Massai grass, exhibit resistance to climatic disturbances. These grasses offer a large forage production with high nutritional value (Costa et al. 2017a, b). Hence, it becomes an alternative for these production systems; however, there is a gap in the literature wherein the use of these grasses in integrated production systems. Therefore, it is necessary for further studies on the behavior of forage grasses in intercropping to define management strategies to avoid reductions in crop production.

Another important point is the forage sowing strategy in integration systems. Several authors investigated some approaches, such as spread and line, obtaining good results (Pariz et al. 2011; Guarnieri et al. 2019; Oliveira et al., 2020). Also, the proper definition of sowing strategy might lead to cost-cutting regarding seeds purchase.

In this context, the hypothesis considered in this study is that the intercropping of different forage species and sowing methods can alter the morphogenic, structural, productive characteristics, and grass composition. Thus, the objective was to evaluate the effects of intercropping and sowing methods on morphogenic, structural, yield characteristics, grass composition, and corn yield in an integrated production system.

Results

Morphogenic and structural characteristics of forage grasses

The results of the experiment showed there was no effect (p>0.05) of forage x sowing form interaction for morphogenic and structural characteristics of grasses. However, there was a significant effect (p<0.05) from the grasses (Table 1). The mean leaf elongation rate (LER) for Andropogon, Massai, and Ruziziensis grasses were 3.78, 3.32, and 3.75, respectively. It was verified for the Massai grass lower stem elongation rate regarding other forages (Table 1).

For senescence rate, it was verified that massai grass produced lower rates while sowing carried out by spread provided higher rates when compared to sowing in line. Ruziziensis grass had a higher number of live leaves per tiller compared to the other grasses under study; however, the sowing form was not influenced (p>0.05) for this variable (Table 1). The findings also revealed that ruziziensis grass presented a higher leaf appearance rate (LAR), and phyllochron had a lower value. Masai grass, on the other hand, had lower LAR and higher phyllochron (Table 1). About leaf length, the shortest value was observed for ruziziensis grass, whereas among the sowing forms, the smallest leaf blade length was verified when sowed broadcast (Table 1).

There was an interaction effect (p<0.05) for leaf production (LP). Massai grass showed higher production in relation to other forages, in relation to the sowing methods. The broadcast system provided less availability of leaves for the massai grass. Ruziziensis grass, on the other hand, did not change the availability of leaves between the sowing methods (Table 2). On the other hand, the andropogon grass when sown in a row presented lower LP.

There was a significant effect (p<0.05) among the studied forages, to the SP only. The lowest availability of stalk was recorded for the massai grass, followed by the andropogon grass.

About dead forage biomass (DFB), the lowest value was observed for andropogon grass; the sowing of a row provided lower values of DFB (Table 2). For total forage production (TFP), it was verified that the results for the spread system were not significant (p>0.05) among forages. From the adoption of the two-line system, the massai grass presented higher total forage biomass. When the one-line system was adopted, andropogon grass exhibited lower TFP (Table 2). The blade/stem ratio was not altered by sowing methods. However, this ratio was influenced by forages, which favored a greater result of Massai grass (Table 2).

There was no interaction effect (P>0.05) for the variables of the chemical composition of forages (Table 3). The dry matter content was not modified by sowing forms among the forages. The andropogon grass showed higher dry matter values, followed by the Ruziziensis and Massai grasses. The spread planting provided greater availability of crude protein (CP) for forages. The andropogon grass had lower CP contents, being below 70 g kg^{-1} DM. As for the fibrous fractions, the sowing forms had no effect (p>0.05) on forages. On the other hand, Massai and Andropogon grasses presented higher values of neutral detergent fiber (NDF) and acid detergent fiber (ADF). Hemicellulose was not influenced by the interaction and isolated factors (Table 3).

Corn crop

Corn productivity was not affected as a result of the different systems. However, a lower value was found when producing corn in monoculture. The average production of intercropped corn was 3420 kg ha^{-1} against 1680 kg when cultivated alone. The intercropping corn yield was 3400 kg ha^{-1} (Table 4). The corn planting system in monoculture showed negative economic indicators, with a loss of R$ 32.16 per 60 kg produced. The corn sowing system intercropped with massai grass with a 1 row showed a profit of R$ 12.12 per sack (60 kg) produced, followed by the system with andropogon grass, which was R$ 12.12 sowed in 1 row. Adopting an intercropped with two rows for massai grass resulted in a loss of R$ 5.49 per sack produced, followed by spread sowing, which presented a profit of only R$ 1.41 (Table 5).

Discussion

Through the investigation of morphogenic characteristics, it was possible to understand forage production at the level of tillers, is also verified that the leaf elongation rate was similar among forages. Rodrigues et al. (2014) found LER values of 3.23 and 2.64 for Ruziziensis and Massai grasses, respectively, results similar to those observed in this study.

Leaf elongation rate of grasses was not affected by intercropping with corn. Different results were observed by Rodrigues et al. (2014), who obtained LER of the andropogon grass in monoculture for this grass of 6.02. However, it is worth emphasizing characteristics that are intrinsic to this grass, such as the high stem elongation that results in a higher proportion of this fraction in the forage mass available to the animal. Moreover, LER is a significant variable as the increment in leaf biomass is proportional to its increase; in other words, the higher LER, the higher leaf biomass (Lopes et al., 2013).

The lower stem elongation rate obtained in massai grass can be explained by the morphology of this forage plant, which is small, with a greater influence of competition for water, light, and nutrients with the corn crop. This characteristic was also observed by (Lopes et al., 2013; Lopes et al., 2019) in the massai grass but not being found in the grass species

Ruziziensis and Andropogon, whose SER were similar. Furthermore, the results indicated that the Andropogon grass had a lower number of live leaves per tiller, which resulted in a lower leaf/stem ratio. It must be noted that the number of live leaves is constant for each species.

Another variable assessed was the leaf appearance rate (LAR), which is directly associated with the availability of leaf mass per area. The lowest LAR value obtained in massai grass probably was due to the physiology of the species; this characteristic is genetically determined, although it would be influenced by water, light, temperature, and fertilization. A similar result was reported by Rodrigues et al. (2014), who found a lower LAR value for massai grass compared to Ruziziensis and Andropogon grasses. These authors also verified the highest phyllochron, which is the time required for the appearance of two consecutive leaves.

The shorter leaf length of Ruziziensis grass could be associated with the higher number of live leaves per tiller, which is intrinsic to this forage; this factor also resulted in a higher leaf appearance rate. Moreover, it is important to consider the sowing forms that do not change these characteristics; therefore, what will define the choice of the best sowing form will be the logistics adopted on the property and the economic viability.

When evaluating the productivity, at the level of the tiller community, the massai grass was highlighted in the intercropping with corn in all forms of sowing as it presented higher leaf production.. In the study conducted by Rodrigues et al. (2014), who evaluated different grasses in eastern Maranhão State, they evidenced these characteristics of massai grass.

Massai grass has gained further attention because, when analyzing the morphogenic characteristics, it was a lower leaf appearance rate, that is, lower leaf biomass availability. Nonetheless, the massai grass presented a high tillering rate, which collaborated to a higher tiller population density (TPD). According to Matthew et al. (1999), TPD is the component with the greatest flexibility of adjustment by the plant. So, in this study, the higher leaf area index provided a greater availability of leaves per area since the stem biomass was also lower.

Sowing form in a row provides a lower population density of tillers. In this study, the sowing form resulted in lower leaf mass for the andropogon grass since it has a lower number of live leaves, high stem elongation rate, and lower leaf appearance rate when compared to the other grasses under study.

The lower stem biomass of the Massai grass aroused a higher leaf blade/stem ratio (3.87), a feature of importance for decision-making regarding pasture management, and it is also a characteristic that is directly linked to animal behavior in grazing.

As mentioned before, the andropogon grass does not stand out for being used in integrated systems since the greater stem biomass in relation to the massai grass reflected in a lower leaf blade/stem ratio than, even without showing a difference between the Ruziziensis grass, the ratio was lower than one (<1), which can compromise the performance of grazing animals and result in pasture degradation.

The production of total forage was influenced by factors in which spread planting does not alter the production between grasses. As for sowing in one and two rows, Massai grass stood out concerning to other grasses. This result is linked to the higher leaf production and higher tiller population density. Total forage production was similar to that observed in the study by Kichel et al. (2014), who observed dry mass production of 4,780 kg ha^{-1} for massai grass.

The crude protein content of the forage is a factor responsible for the most cost of feeding ruminants, resulting in a greater economic impact on the system (Dias et al., 2021). The andropogon grass presented values below 70 g kg^{-1}, being considered as the minimum necessary for the regular functioning of the rumen (Van Soest, 1994).

Andropogon grass is not a good alternative to be used in systems that demand free growth, as in the integrated systems, where the forage is only used after the annual crop has been harvested. Andropogon grass is not a good alternative to be used in systems that demand free growth, as in the case of integrated systems, where the forage is only used after the annual crop has been harvested. The problems of high stalk elongation rates and potential reduction in chemical composition can be observed, which can compromise the animal performance and increase investments with external nutritional resources. Massai and Ruziziensis grasses are excellent alternatives for use in systems intercropped with corn because they maintained their nutritional value, even with an increase in the growing cycle.

The intercropping of corn with Massai and Ruziziensis grasses proved to be a promising cultivation technique for grain and forage production to be used off-season. The advantage of using the integrated system for these purposes is that after harvesting the grain crop, the area can be used as grazing for the animals during the off-season (Carvalho et al., 2019).

The NDF and ADF contents were higher for Massai and Andropogon grasses when compared to Ruziziensis grasses. These results were probably due to the structure of these grasses, that as they are taller than Ruziziensis, they need a more rigid structure reflecting in a larger proportion of fibers. For Andropogon, the values were similar to those observed by Costa et al. (2017a), who evaluated this forage as a function of different regrowth ages. They found a value of 759 g kg^{-1} at 55 days of development. While for massai grass, the values were also similar to those observed by Costa et al. (2017b) when evaluating the massai grass deferred for 120 days.

Generally, a higher fiber proportion is expected in forages submitted to long periods of growth, as in integrated systems. The use of forage is only possible after harvesting the annual crop. Therefore, it is necessary to adopt technologies that make it possible to circumvent this problem, such as the use of the correct supplementation strategy. As a strategy to optimize fiber degradation, it is necessary to supply diets with at least 10% crude protein, thus ensuring at least 8 mg dL^{-1} of ammonia in the rumen, thus providing fuel for the development of cellulolytic bacteria (Lazzarini et al. 2009; Detmann et al. 2014).

Corn crop

The grain productivity of the corn crop in the 2018/2019 harvest was 4,521 and 5700 kg ha^{-1} at the state and national

Table 1. Morphogenetic and structural characteristics of three forages intercropped with corn in different sowing forms.

Forages	Sowing forms			Means	s.e.m[1]	*p*-value		
	1L	2L	Spread			Grass[2]	SF[3]	Grass*SF[4]
Leaf elongation rate (cm day^{-1})								
Andropogon	3.86	4.34	3.13	3.78A	0.32	0.265	0.269	0.255
Massai	3.52	3.42	3.02	3.32A				
Ruzizienses	3.29	3.93	4.03	3.75A				
Means	3.56a	3.90a	3.39a					
Stem elongation rate (cm day^{-1})								
Andropogon	0.81	0.30	0.35	0.56A	0.07	0.0001	0.148	0.180
Massai	0.19	0.21	0.23	0.21B				
Ruzizienses	0.56	0.50	0.79	0.62A				
Means	0.52a	0.35a	0.52a					
Total senescence rate (cm day^{-1})								
Andropogon	1.43	1.79	0.93	1.39A	0.14	0.0001	0.094	0.540
Massai	0.08	0.40	0.26	0.19C				
Ruzizienses	0.79	1.25	0.79	0.94B				
Means	0.72a	1.15a	0.66b					
Number of live leaves (leaves)								
Andropogon	3.81	3.52	3.93	3.75B	0.29	<0.0001	0.6397	0.9887
Massai	3.56	3.06	3.18	3.27B				
Ruzizienses	6.31	6.02	6.31	6.21A				
Means	4.56a	4.20a	4.47a					
Leaf appearance rate (tiller leaves^{1} days^{-1})								
Andropogon	0.10	0.09	0.12	0.10B	0.01	<0.0001	0.461	0.551
Massai	0.08	0.07	0.08	0.08C				
Ruzizienses	0.15	0.15	0.14	0.15A				
Means	0.11a	0.10a	0.10a					
Phyllochron (days/leaves. Tillers^{-1})								
Andropogon	12.48	10.57	9.66	10.90B	0.74	<0.0001	0.951	0.393
Massai	14.24	16.04	17.33	15.87A				
Ruzizienses	7.99	7.02	7.50	7.51C				
Means	11.57a	11.21a	11.50a					
Final blade length (cm day^{-1})								
Andropogon	38.09	41.77	30.95	36.94A	2.89	<0.0001	0.099	0.726
Massai	36.61	40.73	30.07	35.80A				
Ruzizienses	20.37	23.21	21.81	21.80B				
Means	31.69a	35.24a	27.61b					

Means followed by different uppercase letters in columns and lowercase letters in rows differ by Tukey's test (P>0.05). [1]sem = Standard Error Means; [2]Grass effect; [3]Sowing form effect; [4]Effect of interaction between grasses and sowing form.

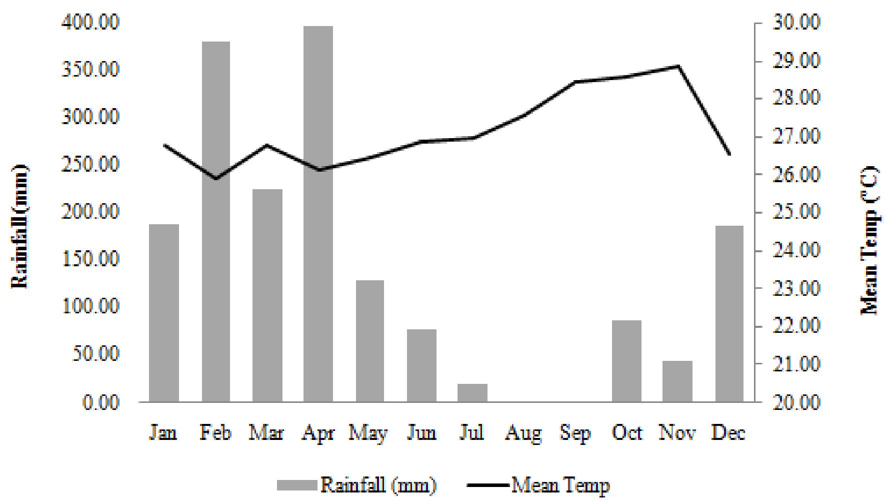

Figure 1. Rainfall and mean temperatures in Chapadinha – MA, Brazil in 2018 (IMET, 2019).

Table 2 .Productive characteristics of three forages intercropped with corn in different sowing forms.

Forages	Sowing forms			Means	s.e.m[1]	*p*-value		
	1L	2L	Spread			1L	2L	Spread
Leaf production (kg ha^{-1})								
Andropogon	1350.0Cb	2133.3Ba	2502.7Ba	1872.2	165.51	< 0.001	0.421	0.002
Massai	3975.0Aa	4000.0Aa	3300.0Ab	3758.3				
Ruzizienses	2500.0Ba	2000.0Ba	2075.0Ba	2191.6				
Means	2608.3	2711.1	2502.78					
Stem production (kg ha^{-1})								
Andropogon	1625.0	1500.0	2466.6	1863.8B	126.75	0.003	0.719	0.082
Massai	975.0	1200.0	810.0	995.0C				
Ruzizienses	2400.0	1800.0	1775.0	1991.6A				
Means	1666.6a	1500.0a	1500.0a					
Dead forage biomass (kg ha^{-1})								
Andropogon	500.0	800.0	633.3	644.4A	40.46	< 0.001	0.075	0.666
Massai	650.0	800.0	650.0	700.0A				
Ruzizienses	300.0	350.0	300.0	316.6B				
Means	483.3b	650.0a	527.7a					
Total dry forage biomass (kg ha^{-1})								
Andropogon	3475.0Bb	4300.0Ba	5233.3Aa	4336.1	198.08	0.0064	0.8767	0.0113
Massai	5600.0Aa	6275.0Aa	4760.0Ab	5545.0				
Ruzizienses	5200.0Aa	4150.0Ba	4150.0Aa	4500.0				
Means	4758.3	4908.3	4714.4					
Tiller population density (Tiller m^{2})								
Andropogon	246	363	380	330B	48.61	< 0.001	0.0789	0.2283
Massai	791	913	797	834A				
Ruzizienses	283	300	207	263B				
Means	440b	525a	461a					
Leaf blade/stem ratio								
Andropogon	1.01	0.81	0.76	0.86B	0.2692	< 0.001	0.2233	0.3337
Massai	4.20	3.56	3.87	3.87A				
Ruzizienses	1.05	1.10	1.18	1.11B				
Means	2.08a	1.82a	1.94a					

Means followed by different uppercase letters in columns and lowercase letters in rows differ by Tukey's test (P>0.05). [1]sem = Standard Error Means; [2]Grass effect; [3]Sowing form effect; [4]Effect of interaction between grasses and sowing form.

Table 3. Chemical-bromatological composition of three forages intercropped with corn in different sowing forms.

Forages	Sowing forms			Means	s.e.m[1]	*p*-value		
	1L	2L	Spread			1L	2L	Spread
Dry Mass (g kg^{-1} of natural matter)								
Andropogon	378.2	444.4	388.2	403.6A	1.48	<0.0001	0.6344	0.6008
Massai	272.9	299.9	307.5	293.4B				
Ruzizienses	254.8	233.2	237.1	241.7C				
Means	301.9a	325.8a	310.9a					
Crude Protein (g kg^{-1} of DM)								
Andropogon	52.4	47.0	62.7	54.0B	0,29	<0.0001	0.0022	0.9411
Massai	85.7	77.3	90.5	84.5A				
Ruzizienses	76.7	73.2	89.1	79.6A				
Means	71.6b	65.8b	80.7a					
Neutral Detergent Fiber (g kg^{-1} of DM)								
Andropogon	727.4	757.5	739.2	741.4A	0.89	<0.0001	0.3949	0.1267
Massai	722.7	729.0	714.2	721.9A				
Ruzizienses	668.9	624.1	621.8	638.2B				
Means	706.0a	703.5a	691.7a					
Acid Detergent Fiber (g kg^{-1} of DM)								
Andropogon	547.6	603.6	533.2	561.6A	1.02	<0.0001	0.1799	0.0570
Massai	538.0	548.2	544.4	543.6A				
Ruzizienses	473.9	434.0	433.1	447.0B				
Means	520.0a	528.6a	503.7a					

Hemicellulose (g kg-1 of DM)								
Andropogon	179.5	153.8	206.3	179.8A	0.44	0.8352	0.1490	0.2218
Massai	184.7	180.7	169.5	178.3A				
Ruzizienses	195.0	169.5	188.7	184.4A				
Means	186.4a	168.0a	188.1a					
Mineral Matter (g kg-1 of DM)								
Andropogon	75.9Ba	58.4Cb	72.7Ba	69.0	0.40	<0.0001	0.0019	0.0005
Massai	121.0Aa	121.3Aa	111.9Ab	118.0				
Ruzizienses	103.7Ab	91.3Bc	113.6Aa	102.9				
Means	100.1	90.3	99.4					

Means followed by different uppercase letters in columns and lowercase letters in rows differ by Tukey's test (P>0.05). [1]sem = Standard Error Means; [2]Grass effect; [3]Sowing form effect; [4]Effect of interaction between grasses and sowing form.

Table 1.Productivity of corn intercropped with three tropical forages subjected to different sowing methods

Mono	Grass	Sowing forms			Means	s.e.m[1]	Int *vs* Mono[2]	*p*-value		
		1L	2L	Spread				Grass[3]	SF[4]	Grass*FP[5]
Productivity (kg ha-1)										
1695.83	Andropogon	3915.6	3550.0	2981.3	3482.29A	114.77	<0.0001	0.7238	0.0281	0.1498
	Massai	4000.0	2758.3	3145.8	3301.39ª					
	Ruziziensis	3416.7	3270.0	3479.2	3388.89ª					
	Means	3777.43a	3193.06b	3202.08b						

Means followed by different uppercase letters in columns by the Scott & Knott test (P>0.05). [1]sem = Standard Error Means; [2]Int vs Mono = Contrast effect between corn in monoculture and corn in intercropping; [3]Grass effect; [4]Sowing form effect; [5]Effect of interaction between grasses and sowing form.

Table 5. Economic evaluation of corn production in sacks ha^{-1} intercropped with tropical grass species and different forms of planting

System	Total Cost (R$)	Production (Sacks ha-1)	Gross Revenue (R$)	Total Cost/Sacks	Breakeven point	Profit (R$)
Milho monocultivo	2,315.00	28	1,406.57	81.95	46	-32.16
Milho+Andropogon 1line	2,511.42	65	3,249.30	38.48	50	11.31
Milho+Andropogon 2line	2,511.42	59	2,945.91	42.45	50	7.34
Milho+Andropogon spread	2,536.42	50	2,473.98	51.05	51	-1.26
Milho+Massai 1line	2,511.42	67	3,319.33	37.67	50	12.12
Milho+Massai 2line	2,541.42	46	2,288.93	55.28	51	-5.49
Milho+Massai spread	2,536.42	52	2,610.49	48.38	51	1.41
Milho+Ruziziensis 1line	2,591.42	57	2,835.29	45.51	52	4.28
Milho+Ruziziensis 2line	2,653.42	55	2,713.56	48.69	53	1.10
Milho+Ruziziensis spread	2,696.42	58	2,887.16	46.50	54	3.29

A sack of corn 60 kg; Corn value was considered the Bovespa quotation in July 2020 R$ 49.79.

level, according to CONAB data, respectively. It is outstanding that the values may have been below the state and national averages because it is an area of poor soil and because it is the first year of cultivation. The findings in this study confirm that corn intercropped with perennial forage grasses, regardless of the sowing method, can be considered an excellent alternative for use in integrated agricultural systems because they do not interfere with the grain crop yield. These results were similar to those found by Guarnieri et al. (2019), who evaluated intercropping of corn with paiaguás grass in different sowing methods, found that intercropping did not interfere with corn productivity, demonstrating the viability of this system.

The sowing of grasses in one row favored higher grain yield. This result can be associated with lower competition between corn and grass. Paris et al. (2011) observed that the highest corn yield was also registered in the intercropping that the grass was sown in a row. This type of sowing also has an ease handling, favoring lower corn harvest losses, as reported by Pariz et al. (2011) since, spread planting, the corn plant gets smaller. One advantage of forage spread sowing is better distribution of the plant stand; however, in this system, the number of seeds rises up, which can lead to greater competition and later trouble of compromised grain filling in the final stage of development. The choice of sowing method must be well planned, targeting all production system points.

System management has become important for intensive agriculture. The economic analysis of the system is a key point for good strategic planning of the activity. The economic analysis evidenced in this study that sowing in monoculture provided a negative result for the planting system. It can be seen that, to equal the cost of production, it would be necessary to produce around 2760 kg. The cost of bags (60 kg) produced was high in consideration of other production systems.

When adopting the intercropping with andropogon grass, a positive result was observed. However, in the forage production for the second phase of the system, off-season cattle, the structural and nutritional quality of the pasture is compromised, which can cause a reduction in animal performance. Among the intercropping systems, the massai grass sown in one row presented the highest result per sack of corn produced. It must be emphasized that it was possible to generate profit and pay for the implementation of the pasture, maintaining the system's balance; this is a factor of great relevance to reducing degraded pasture areas.

Material and methods

Description of the experimental area

The experiment was carried out in the Forage and Pasture Sector in an area belonging to the Center for Agrarian and Environmental Sciences of the Federal University of Maranhão (CCAA/UFMA) on Campus (IV) in the municipality of Chapadinha, in the eastern Maranhão State, Region of the Baixo Parnaíba, located at 03°44'33'' S of latitude, 43°21'21''W of longitude.

Plant materials

The corn cultivar used was Planalto. Corn sowing was carried out in February 2018, with a spacing of 0.60 m between rows and 0.20 m between plants (0.60 m x 0.20 m), totaling a density of 83,000 plants per hectare. At 15 days after corn germination and emergence, forage sowing was conducted according to the treatments.

Statistical design, treatments, and establishment of cultures

O experimento foi conduzido em delineamento inteiramente casualizado com arranjo fatorial 3 x 3 + 1, sendo três forrageiras: capim-andropogon (*Andropogon gayanus* Kunth cv. Planaltina), capim-massai (*Megathyrsus maximum* cv. Massai) e capim-ruziziensis (*Urochloa ruziziensis*), três formas de semeadura de consórcio com o milho (uma linha, com duas linhas e a lanço) com quatro repetições e o milho em monocultura.

The experiment was led in a total area of 960 m², divided into 40 experimental plots. The soil was classified as Yellow Latosol (Santos *et al*.,2018). Soil samples were taken using an auger at a depth of 0 to 20 cm, and then sent to the Soil Analysis Laboratory to determine chemical characteristics, such as: pH in $CaCl_2$ = 4.6; Al = 1.3, cmmolc/dm³; K = 1.9 cmmol/dm³; Ca = 14 cmmolc/dm³; Mg = 5 cmmolc/dm³; P = 15; S = 6 mg/dm³; base saturation = 33%; and OM = 18 g/kg^{-1}. For preparation, correction, and fertilization of the soil, the plow and leveler harrow were used. The sowing of the species was managed according to their proper treatments.

Soil acidity correction was conducted using the base saturation method, increasing it to 60%, following the recommendation for the corn crop. A dose of 120 kg ha^{-1} of P_2O_5 was applied in the single superphosphate form after soil correction, as base fertilization. For cover fertilization, a dose of 20 kg ha^{-1} of nitrogen in the form of urea and 40 kg ha^{-1} of K_2O in the form of potassium chloride was applied. This dose was divided into two, in which the first application occurred at 35 days after emergence (DAE) and the second at 60 DAE.

Evaluation of productive and nutritious forages

After forages germination, four tillers were chosen in each experimental unit; then, they were marked with colored threads to assess the morphogenic characteristics. The evaluations were performed using a millimeter ruler, and the measurements occurred every seven days during the experimental period. From the information, leaf appearance rate (LAR), leaf elongation rate (LER), stem elongation rate (SER), phyllochron (PHY), leaf senescence rate (LSR), final leaf blade length (FLL), number of live tillers (NLT) and number of live leaves per tiller (NLL) were calculated. In each tiller, forages data were recorded considering the number of leaves, leaf blade length, stem length, and leaf classified according to the stage (expanding, expanded, senescent, and dead).

After corn harvesting, forages were evaluated. The tiller population density (TPD) was estimated by counting the live tiller at two points within each plot. A polyvinyl chloride (PVC) framework with dimensions of 0.50 x 0.50 m was used, which was randomly thrown in each plot. After counting, the material contained within the frame was cut; in order to estimate forage production, the samples were cut at the residual height of 20 cm for all grasses. The material was packed in properly identified plastic bags and then sent to the laboratory. The plots were mowed to standardize the plants and start the new growth cycle and later evaluation.

The material was fractionated into the leaf blade, stems (true stems + sheath), and dead material. The fractions were placed in identified paper bags, weighed, and dried in a forced-air circulation oven at 55 °C until reaching constant weight and, then were weighed again. Thus, the leaf production (LP), stem production (SP), dead forage biomass (DFB), and total forage production (TFP) were estimated. The leaf blade/stem ratio (L/S) was determined by dividing the LP/SP.

After drying, the samples were ground in a knife mill using a 1 mm porosity sieve. The values of dry matter - DM (AOAC, 2005, method number 930.15); mineral matter - MM or ash (AOAC, 2005, method number 942.05), crude protein - CP (AOAC, 2005, method number 984.13); ether extract - EE (AOAC, 2005, method number 920.39) were determined based on the Official Methods of Analysis of the Association of Analytical Chemists (AOAC). Whereas, Neutral detergent fiber - NDF (INCT-CA method F-002/1); acid detergent fiber - ADF (INCT-CA method F-004/1) were quantified according to the standard analytical methods of the National Institute of Science and Technology in Animal Science (INCT-CA; Detmann et al. 2012).

Corn productivity evaluation

At 100 days of corn sowing, the harvest was carried out. For corn yield evaluation, a central line was selected as a representative useful area of each plot, with six meters, the ears were threshed, cleaned, placed in plastic bags, and weighed; in order to determining total production by area (plot and hectares), the dimensions between rows were taken into account.

Statistical analysis

Data were submitted to normality tests to attest to the basic prerogatives of analysis of variance. Data referring to the study of grasses and sowing methods were analyzed using the MIXED procedure of the SAS® statistical program (Edition University, SAS Institute Inc., Cary, NC, USA, CODY 2015), using the following statistical model:Model 1:

$Y_{ijk} = \mu + G_i + FP_j + (G \times FP_{ij}) + \varepsilon_{ijk}$,

In which: Y_{ijk} is the dependent variable of the experiment measured in the experimental unit "*k*" of the grass "*i*" and sowing form "*j*"; μ is the general constant; G_i is the effect of the "*i*" grasses; FP_j is the effect of the seeding form "*j*"; G x FP_{ij} is the effect of the interaction between grasses "*i*" and the effect of the seeding form "*j*"; and ε_{ijk} is the effect of random error. The means were obtained by the LSMEANS command with adjustment for the Tukey test, being considered different when p<0.05.

Data referring to the study of corn were performed in a contrast analysis between corn in intercropping and corn in monoculture. For ensuring an orthogonal correlation among treatments, the control was compared to all treatments in the consortium using only one contrast. The results are shown in general as the effect of intercropping between corn and grasses and sowing methods.

Conclusion

Massai and Ruziziensis grasses are an attractive alternative for intercropping in integrated crop-livestock systems to the production of grain and forage. Andropogon grass proved unviable for this system, with low production and forage quality. Sowing forms had not influenced corn and forage productivity. Nevertheless, the system in rows is recommended due to its ease of handling for the crops' implantation.

Acknowledgments

To all the members of the teaching, research and extension group FOPAMA- Forage and Pastures in Maranhão

References

[AOAC] Official Methods of Analysis (2005) Association of Analytical Washington. 17th ed. Washington (USA).

Allaoui H, Guo Y, Choudhary A, Bloemhof J (2018). Sustainable agro-food suplly chain desing using two-stage hybrid multi-objective decision-making approach. Computers and Operations Research. 89:269-384.

Carvalho P, Domiciano LF, Mombach MA, Nascimento HLB, Cabral LS, Sollenberger L (2019) Forage and livestock production in signalgrass pastures growing in monoculture or as a component of integrated crop, livestock and forestry systems. Grass and Forage Science. 1:1-11.

Costa CS, Rodrigues RC, Araújo RA, Cândido MJD, Santos FNS, Rodrigues MM, Costa FO, Silva IR, Alves AA, Lima NM (2017b) Agronomic and nutritional characteristics of Massai grass subjected to deferred grazing and nitrogen fertilization. Semina Ciências Agrárias. 38: 1617-1624.

Costa CS, Rodrigues RC, Santos FNS, Araújo RA, Sousa GOC, Lima JRL, Nunes DRE, Rodrigues MM (2017a) Structural characteristics and chemical composition of andropogon grass pasture managed under different defoliation intensities and rest periods. Revista Brasileira de Saúde e Produção Animal. 18:492-504.

Costa Júnior NB, Baldissera TC, Pinto CE, Garagorry FC, Moraes A, Carvalho PCF (2019) Public policies for low carbon emission agriculture foster beef cattle production in southern Brazil. Land Use Policy. 80(1):269–273.

Detmann E, Souza MA, Valadares Filho SC, Queiroz AC, Berchielli TT, Saliba EOE, Cabral LS, Pina DS, Ladeira MM, Azevedo JAG (2012). Métodos para análise de alimentos. (INCT - Ciência animal). Viçosa: Universidade Federal de Viçosa. 214p.

Detmann E, Valente ÉE, Batista ED, Huhtanen P (2014) An evaluation of the performance and efficiency of nitrogen utilization in cattle fed tropical grass pastures with supplementation. Liv Sci. 162:141-153. DOI: 10.1016/j.livsci.2014.01.029

Dias MBC, Costa KAP, Severiano EC, Bilego U, Furtini Neto AE, Almeida DP, Brand SC, Lourival V (2020) Brachiaria and Panicum maximum in an integrated crop-livestock system and a second-crop corn system in succession with soybean. J Agric Sci. p.1-12.

Dias MBC, Costa KAP, Severiano EC, Bilego U, Lourival V, Souza WF, Oliveira IP, Silva ACG (2021) Cattle performance with Brachiaria and Panicum maximum forages in an integrated crop-livestock system. Afr J Range Forage Sci. p.1-14.

Guarnieri A, Costa KAP, Severianos EC, Silva AG, Oliveira SS, Santos, CB (2019) Agronomic and productive characteristics of maize and Paiaguas palisadegrass in integrated production systems. Semina: Ciências Agrárias. 40(3):1185-1198.

Kamble SS, Gunasekaran A, Gawankar SA (2020) Achieving sustainable performance in a data-drive agriculture suplly chain: A review for research and applicantions. Internacional. J Production Economics. 219:179-194.

Kichel AN, Costa JAA, Almeida RG, Paulino VT (2014). Sistemas de integração lavoura pecuária floresta (ILPF): experiências no Brasil. Boletim da Indústria Animal. 71: 94-105.

Lazzarini I, Detmann E, Sampaio CB, Paulino MF, Valadares Filho SC, Souza MA, Oliveira FA (2009) Dinâmicas de trânsito e degradação da fibra em detergente neutro em bovinos alimentados com forragem tropical de baixa qualidade e compostos nitrogenados. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 61:635-647.

Lopes MN, Cândido MJD, Pompeu RCFF, Silva RG, Carneiro MSS, Morais Neto LB, Carvalho TCF (2019) Biomass components and structure of massai grass fertilized with nitrogen and grazed by sheep. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 71(4): 1411-1420.

Lopes MN, Cândido MJD, Pompeu RCFF, Silva RGD, Lopes JWB, Fernandes FRB, Bezerra FML (2013) Fluxo de biomassa em capim-massai durante o estabelecimento e rebrotação com e sem adubação nitrogenada. Revista Ceres. 60(3): 363-371.

Matthew C, Assuero SG, Black CK, Hamilton NRS (1999) Tiller dynamics of grazed swards. Moraes A, Nabinger C, Carvalho, PCF., et al. (Eds.) Grassland ecophysiology and grazing ecology. p.109-133.

Oliveira SS, Costa KAP, Souza WF, Santos CB, Teixeira DA, Costa V (2020) Production and quality of the silage of sorghum intercropped with Paiaguas palisadegrass in different forage systems and at different maturity stages. Animal Production Science. 60(5): 694-704.

Pariz CM, Andreotti M, Bergamischine AF, Buzetti S, Costa NR, Cavallini MC (2011) Produção, composição bromatológica e índice de clorofila de braquiárias após o consórcio com milho. Archivos Zootecnia. 60:1041-1052.

Rodrigues RC, Sousa TVR, Melo MAA, Araújo JS, Lana RP, Costa CS, Oliveira ME, Parente MOM, Sampaio IBM (2014) Agronomic, morphogenic and structural characteristics of tropical forage grasses in northeast Brazil. Tropical Grasslands – Forrajes Tropicales. 2:214−222.

Santos HG, Jacomine PKT, Anjos LHC, Oliveira VA, Lumbreras JF, Coelho MR, Almeida JA, Araujo Filho KC, Oliveira JB, Cunha TJF (2018) Sistema Brasileiro de Classificação de Solos, 5. ed. Brasília, DF:Embrapa Solos.

Van Soest PJ (1994) Nutritional ecology of the ruminant. p.476, Cornell University Press, New York.