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Performance of dairy heifers in a silvopastoral system

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ABSTRACT

The characteristics of the pasture and performance of dairy heifers were evaluated in a silvopastoral system (SPS) established with *Brachiaria decumbens* grass in a consortium with four tree species (105 trees/ha) and in a monoculture system of *Brachiaria decumbens* (MS). Thirty-two paddocks (0.5 ha/paddock) were used, sixteen for each system (SPS and MS). The paddocks were managed under rotational stocking, with seven days occupation and 35 and 45 days of rest during the rainy and dry seasons, respectively. The treatments were distributed in a randomised block design with two repetitions. The heifers used had an initial weight of 200 kg and a variable stocking rate as a function of the herbage allowance of 7.0 kg of DM/100 kg of body weight/day. The forage mass was estimated at each grazing cycle. For each sample, the DM, crude protein and neutral detergent fibre contents were determined as well as the *in vitro* dry matter digestibility (IVDMD). All animals were weighed every 35 days to estimate daily body weight gain and weight production per area. The forage dry mass, stocking rate and herbage allowance were similar between the systems studied, but they varied according to season. Average values of 2031 and 1100 kg/ha/grazing cycle, 1.6 and 0.8 AU (Animal unit = 450 kg of body weight)/ha and 7.2 and 5.0 kg DM/100 kg of body weight were estimated for the rainy and dry seasons, respectively. The values for crude protein content were higher in the SPS in the rainy season, while the NDF and IVDMD did not vary with raising system. The body weight gains per animal and per hectare in the dry season did not vary, but were higher in the SPS during the rainy season in the first and third experimental years. The annual body weight gains were also higher in SPS than in the MS. It was concluded that the SPS is more efficient for rearing dairy heifers than the MS due to the higher body weight gain per heifer and per area.

1. Introduction

In dairy husbandry systems, heifers are an important component in guaranteeing the continuous production of the herd. The rearing phase for heifers, which goes from weaning to the first insemination or mating time, represents a fundamental step in the production system. In the tropics, heifer feeding has been based on the utilisation of grass pastures, which find themselves in the process of degradation soon after establishment due to problems arising from incorrect management associated with reduced soil fertility (Boddey et al., 2004). Advancement in the process of degradation entails a progressive reduction in forage biomass and decreased crude protein content, forage digestibility and, mainly, dry matter consumption by the animals. Inadequate feeding management can result in low daily body weight gains of heifers, which in turn results in an elevated first birth age, lower rates of animal production and decreased economic efficiency of livestock production systems.

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Several authors have suggested that an option available to overcome these problems is the integration of pastures with tree species in silvopastoral systems (Paciullo et al., 2009; Sousa et al., 2010; Yamamoto et al., 2007). Highlighted among the benefits of the utilisation of such system are the following: increased soil fertility and conservation (Power et al., 2003; Sierra et al., 2002), improved thermal comfort for the animal (Tucker et al., 2008), increased quality in forage and animal production (Deinum et al., 1996; Yamamoto et al., 2007) and possibility of income diversification. There are also environmental benefits, such as biodiversity conservation (Pagiola et al., 2004), atmospheric carbon sequestration (Andrade et al., 2008; Soto-Pinto et al., 2010) and the mitigation of greenhouse effect gases (Kaur et al., 2002; Schoeneberger, 2009).

Reaching these benefits in a silvopastoral system depends on the balance among pasture, trees and animal, as competition for growth and production resources, such as radiation, water and nutrients can render the system's sustainability unfeasible. A few important aspects are the tolerance of the forage species to shade and the use of the density and spatial arrangements of the tree species, ensuring it reaches adequate shade for forage development. Most of the studies with tropical grasses have shown a reduction in forage production when shade levels exceed 50% of the incident radiation due to the acute decrease in photosynthetic rates of C_4 route grasses (Devkota et al., 2009; Guenni et al., 2008; Paciullo et al., 2010). However, in moderate shade conditions, there is evidence of the maintenance of or even an increase in forage production when compared to full sun conditions (Baruch and Guenni, 2007), especially in soils naturally poor in nitrogen (Wilson, 1996).

Shade provides an environment with milder temperatures and, consequently, greater thermal comfort for pasturing animals (Kendall et al., 2006; Tucker et al., 2008). Thermal comfort is important especially for animals of pure European races or mixed European × Zebu races, which are more sensitive to the high temperatures of the tropics than animals of the pure Zebu races (Bennett et al., 1985; Kendall et al., 2006; Nonaka et al., 2008). Similarly, improvement of the nutritional value of the forage under shade, mainly through the increase in crude protein content, may contribute to the improved performance of animals on a pasture diet (Sousa et al., 2010; Yamamoto et al., 2007).

Aside from the potential benefits, few studies have evaluated animal production in silvopastoral systems. The adoption of these systems still depends on research using *in vivo* techniques to evaluate the factors that may influence the efficiency of the different systems. Therefore, the objective of this study was to evaluate the pasture characteristics and the performance of dairy heifers kept on a silvopastoral system and on a monoculture of *Brachiaria decumbens*.

2. Material and methods

2.1. Location and experimental treatments

The experiment took place at *Embrapa Gado de Leite*, in the city of Coronel Pacheco, MG, Brazil, during the period of April 2004 to March 2007. The geographical coordinates are 21°33′22″ South latitude and 43°06′15″ West longitude. The altitude is 410 m. The climate of the region, according to Köppen's classification, fits the Cwa type (mesothermal). The soil in the experimental area is of the Red-Yellow latosol type and is dystrophic with a clayey texture and a wavy relief. The chemical characteristics of the soil as follows: pH in water, 4.61; Available P (Mehlich-1), 4,47 mg dm^{-3}; Al, 0,79 cmolc dm^{-3}; K, 0.11 cmolc dm^{-3}; Ca, 0.33 cmolc dm^{-3}; Mg, 0.12 cmolc dm^{-3}. Climate data were collected from a meteorological station approximately 500 m from the experimental area (Table 1). The treatments consisted of two types of systems for rearing heifers: the silvopastoral system (SPS) and the monoculture system (MS). Both systems used a pasture of *B. decumbens* established in November 1997 in an area of 16 ha (8 ha for each treatment). The treatments were distributed in a randomised block design, with two blocks (4 ha per block) and two replications (paddocks or animals) in each block.

The silvopastoral system was implemented in November 1997, with *B. decumbens* cv. Basilisk grass and the tree legumes *Acacia mangium*, *A. Angustissima* and *Mimosa artemisiana* as well as *Eucalyptus grandis.* At planting, a density of 342 trees per hectare was adopted, with trees arranged in strips with a width of 9 m interspersed with bands of pasture with a width of 30 m. Within the tree strips, a tree spacing of 3 × 3 m was kept between the lines and plants. The tree density in 2007 was estimated at 105 trees per hectare due to mortality and to the selective thinning that occurred. The most representative species of the system between 2004 and 2007 were *E. grandis* and *A. mangium*, which presented, on average, chest-high diameters of 25.5 and 20.0 cm and heights of 21.7 and 14.2 m, respectively.

Before planting in November 1997, and according to the soil analysis, 1.000 kg ha^{-1} of dolomite lime, 600 kg ha^{-1} of Araxá Potash (5% P_2O_5 soluble in citric acid), 25 kg ha^{-1} of simple superphosphate, 100 kg ha^{-1} of potassium chloride and 30 kg ha^{-1} of FTE (fitted trace elements) BR-16 (3.5% zinc, 1.5% boron, 3.5% copper and 0.40% molybdenum) were applied to the soil. For the exclusive *Brachiaria* pasture implementation, regarding soil preparation and the application of soil correction and fertilisers, the same protocol of the SPS was adopted because the areas destined for SPS and MS were contiguous and presented the same inclination and soil type. After planting, the areas with pasture in both systems did not receive additional applications of fertilisers and lime.

Through measurements of photosynthetically active radiation (PAR) taken with the aid of a ceptometer (Decagon, model LP 80) in the entire paddock area, it was possible to verify that in the SPS there was an average shade of 29% of full PAR, considering the strips with and without trees. To obtain a value for average shade, the measurements were taken every 3 m, starting at the tree strip up to the centre of the paddock, so

Table 1
Mean monthly rainfall (mm) and daily air temperature (°C) at the experimental site from 2004 to 2007.

Experimental year	Dry season			Rainy season		
	Rainfall	Max. temp.	Min. temp.	Rainfall	Max. temp.	Min. temp.
2004/2005	259	26.0	13.9	1.648	28.7	19.1
2005/2006	262	26.3	14.8	1.138	29.8	18.8
2006/2007	215	26.3	12.9	1.838	29.2	19.3

that after 30 readings per paddock, there was a representative value for the SPS.

2.2. Pasture management

The pastures were divided into 32 paddocks of 0.5 ha each, 16 for each system. Between 2001 and 2003, the pastures were used for non-lactating Holstein × Zebu (Gir) cows with an average live body weight of 480 kg. The pasture management adopted was that of rotational stocking, with an occupation period of five days and a resting period of 40 days, according to the description of Aroeira et al. (2005).

The experiment with rearing heifers began in April 2004 with the inclusion of ten tester animals in each treatment. Each repetition area was pastured by five heifers with a genetic composition ranging from ½ to ¾ Holstein × Zebu, with an initial average body weight of 200 kg. To ensure a herbage allowance of 7.0 kg of forage DM (based on the dry matter of the green pasture) for each 100 kg of body weight per day during the period of paddock occupation, additional animals of the same category were placed and removed from each paddock as needed (variable stocking rate). Whenever the average body weight for the group of experimental animals reached 320 kg (usually between April and May each year), all heifers were replaced by others of 200 kg body weight. The paddocks were managed under rotating stocking, with seven days occupation and 35 and 45 days of rest during the rainy and dry seasons, respectively. The paddocks were provided with a watering place and a trough, thus allowing the ingestion of water and mineral salt at will by the heifers during the entire experimental period.

2.3. Evaluated characteristics

Forage mass was estimated for each grazing cycle from cuts made in the pre-grazing condition. Twenty random samples were collected from each paddock with the aid of a metal frame of 0.5 × 0.5 m. The plants were cut at a height of 5 cm above the soil and were then taken to the laboratory for the separation of green and dead fractions. Each component was weighed and oven dried at 55 °C for the determination of DM.

The dried samples of the green fraction of grass were submitted to analysis for the determination of crude protein content (CP) (AOAC, 1980), neutral detergent fibre (NDF) (Van Soest et al., 1991) and *in vitro* dry matter digestibility (IVDMD) according to the procedures described by Tilley and Terry (1963).

All animals were weighed every 35 days. The daily body weight gain of the test animals was used to estimate the individual performance of the heifers. The number of days the extra animals were kept in the pasture was also recorded. Thus, the data of the test animals and the extra animals, taken together, made it possible to generate estimates of the carrying capacity of the pastures and the body weight production per area.

2.4. Statistical analysis

The procedure used for the analysis of variance was the GLM (General Linear Model) from SAS (SAS Institute, 2001) with the option of repeated measures over time (experimental years). Average values were obtained for each season of the year, and the data were analysed separately by season of the year (the dry season between April and September and rainy season between October and March). Subsequently, we analysed the data from the annual average gain per animal. For the gain per area, the values of the sum of the rainy and dry seasons of the year were analysed. For data relating to pasture (herbage mass and nutritive value), the paddock was considered an experimental unit, with three paddocks (replicates) within each block. For individual body weight gain, the experimental unit was the heifer (ten heifers per treatment), and the weight gain per area was used for two blocks of each system as a repeat. In this case, the experimental unit was constituted by the set of plots of each treatment within each block. The estimated averages through the LSMEANS option were compared by the Tukey test with a probability level of 5%.

3. Results

3.1. Herbage mass and stocking rate

The dry weight of the green forage was not influenced (P > 0.05) by the rearing system (SPS and MS), but it varied with the interaction between rearing system and experimental years for both seasons (Table 2). The values range between 1823 and 2283 kg DM/ha/grazing cycle during rainy season months and between 942 and 1212 kg DM/ha/grazing cycle during drought.

Table 2
Forage mass (kg/ha/grazing cycle) and herbage allowance (kg DM/100 kg body weight/day) in *Brachiaria decumbens* pastures in pre-grazing, according to experimental year, season of the year and grazing system.

Experimental year	Rainy season		Dry season	
	Silvopastoral	Monoculture	Silvopastoral	Monoculture
Dry mass of green forage				
2004/2005	2124a	2283a	1212a	1155a
2005/2006	1823Bb	2025Ab	942b	1090a
2006/2007	1927ab	2004b	1211Aab	997Ba
Herbage allowance				
2004/2005	7.3	7.5	5.5	5.2
2005/2006	7.0	7.1	5.3	5.0
2006/2007	7.2	7.1	5.0	5.0

Means followed by different letters, for each season of the year and parameters, capital in the row compare rearing system and small in the column compare experimental year, are different (P < 0.05) by Tukey test.

Table 3
Crude protein and neutral detergent fibre contents (% of dry matter) in *Brachiaria decumbens* pasture in the rainy and dry seasons, according to experimental year.

Experimental year	Crude protein		Neutral detergent fibre	
	Rainy season	Dry season	Rainy season	Dry season
2004/2005	8.9a	7.2	74.7a	71.3
2005/2006	8.2b	7.2	66.6b	70.2
2006/2007	8.6ab	7.5	74.7a	70.9

Means followed by different letters, in the same column, are different ($P<0.05$) by the Tukey test.

During the rainy season, the highest herbage mass was observed in the first experimental year, which decreased in the second year and increased from the second to the third experimental years. In the dry season, the herbage mass in MS did not vary with the year; in the SPS, the lowest value was observed in the second experimental year.

Between the systems evaluated, the values for herbage mass were similar, with the exception of the second year in the rainy season when the mass in the MS was greater and of the third year in the dry season when the highest value was obtained by the SPS.

The stocking rates varied between 0.8 and 1.6 AU/ha, corresponding to 1.2 and 2.4 heifers/ha, respectively, depending on the season and the experimental year. The rates were similar between systems for both seasons of the year, with the exception of the second and third experimental years of the dry season, when the rates were higher in the MS and SPS, respectively. The herbage allowance did not vary between rearing systems, independently of the experimental year and season. During the rainy season, the average value (7.2% of PV) was close to the predicted value (7.0% of PV) for pasture management. In the dry season, the herbage allowance, which was below the predicted value, was influenced mainly by the reduction of herbage mass in both systems due to weather conditions (Table 1).

3.2. Nutritive value

The CP and NDF contents of the pasture varied ($P<0.05$) with experimental year (Table 3). In general, the CP and NDF contents were higher the first and third experimental years during the rainy season, but did not vary significantly in the dry season. The rearing system influenced ($P<0.05$) the CP content only in the rainy season and did not present any effect ($P>0.05$) on NDF content and on IVDMD. A higher CP content was observed in the SPS (8.8%) than in the MS (7.8%) during the rainy season. In the dry season, the average value of CP was 7.1%. The average values of NDF and IVDMD were 71.0 and 54.8% in the rainy season and 71.5 and 51.3% in the dry season, respectively.

3.3. Animal production

The body weight gains per animal and per hectare during the dry season did not vary ($P>0.05$) with rearing system (Table 4). However, during the rainy season, the body weight gain per heifer and per hectare obtained in the SPS were higher ($P<0.05$) than in the MS in the first and the third experimental years. In the second year, the difference in gain between systems did not reach significance ($P>0.05$), although a tendency towards higher values was observed for the silvopastoral system.

No statistical interactions (rearing system × experimental year) were verified for mean annual weight gain. There were isolated effects ($P<0.05$) of rearing system and experimental year when annual gains were analysed. The average body weight gain per animal was higher ($P<0.05$) in the SPS (512 g/day) than in MS (452 g/day). The body weight gain was also higher in the first year (521 g/day) than in the second (446 g/day) year. In the third year, the body weight gain (479 g/day) was intermediate compared to the others. Likewise, the annual gain per area, considering the sum of gains in each season, was higher in the SPS (355 kg/ha) than in MS (317 kg/ha) as well as in the first than in the second year. In the third year, the gain (332 kg/ha) was simultaneously equal to the others.

4. Discussion

4.1. Herbage mass and stocking rate

Similarity in the herbage mass for the two systems during most of the experimental period indicates that shade provided by trees in the SPS did not affect pasture growth. A few studies have shown that shade percentages of up to 30–40% did not affect the grass growth as long as the forage was moderately tolerant to shade (Paciullo et al., 2010; Sousa et al., 2010). This factor explains the similarity in values between the two rearing systems, as the average shade for the silvopastoral system was 29% in relation to the conditions under full sunlight. The tolerance of *B. decumbens* to moderate shade is the result of

Table 4
Average daily gain (g/animal) and gain per area (kg/ha), according to rearing system and experimental year, in the rainy and dry seasons.

Experimental year	Rainy season		Dry season	
	Silvopastoral	Monoculture	Silvopastoral	Monoculture
Average daily gain				
2004/2005	722Aa	624Ba	348ab	387a
2005/2006	647ab	563ab	298b	274b
2006/2007	628Ab	515Bb	420a	352ab
Gain per area				
2004/2005	298Aa	256Ba	88	97
2005/2006	242ab	230ab	75	68
2006/2007	258Ab	211Bb	105	89

Means followed by different letters, for each season of the year, capital in the row and the small in the column, are different ($P<0.05$) by Tukey test.

morphophysiological adjustments, such as increases in specific leaf area, leaf elongation rate and the aerial biomass/root biomass relationship, which enables maintained productivity, even in conditions of moderate limited lighting (Dias-Filho, 2000; Guenni et al., 2008; Paciullo et al., 2010).

The results for herbage mass in relation to seasons of the year are in accordance with the reports of Aroeira et al. (2005), who verified that in pastures of *B. decumbens*, the herbage mass varied between 600 and 1.800 kg DM/ha/grazing cycle, with the lowest value obtained in the dry season and the highest in the rainy season. This response pattern shows the strong seasonality in forage production resulting from the low temperature and the water availability observed during the dry period in the region where the study was conducted (Table 1).

The stocking rate obtained in the rainy season can be considered satisfactory when compared to values reported by other authors for *B. decumbens* pastures. The results indicate rates varying between 1.25 and 1.80 AU/ha, depending on pasture management (Aroeira et al., 2005; Paciullo et al., 2009). It is noteworthy that the management adopted in this work predicted low input, as the pastures did not receive fertilisation with nutrients since their establishment and the animals were not supplemented with concentrated feed or forage during the experimental period.

4.2. Nutritive value

The higher CP content of the SPS compared to the MS can be attributed to increases in organic matter degradation and the recycling of nitrogen in the soil in shade conditions (Wilson, 1996). In this context, the highest CP contents in the pasture, which were in shade conditions, could be associated with an increased flow of nitrogen in the soil, especially when the tree component consists of legumes. The higher level of soil organic matter in the 0–10 cm layer in the SPS (2.4%) than in the MS (2.0%) supports this hypothesis.

Although the concentration of CP was higher in the SPS, the NDF and ADF contents did not vary with rearing system. These results are supported in the literature because little or no variation in the levels of the cell wall constituents of forage in the shade has been reported by other authors (Buergler et al., 2006; Kallenbach et al., 2006; Lin et al., 2001; Sousa et al., 2010). Variations in NDF and ADF content seem to be related to the interaction of the shade percentage with the stage of maturity of the plant (Lin et al., 2001; Sousa et al., 2010). In fact, in conditions of elevated shade percentage, plants tend to blanch with the advancement of maturity, which can result in increased fibre content in the forage. Sousa et al. (2007) attributed the increase in ADF content of *B. brizantha*, in response to intense shade (74% of photosynthetically active radiation), to the etiolation of the plant with advancement in age. However, pertinent studies have not detected variations in cell wall constituents when compared to conditions at full sun and moderate shade (Sousa et al., 2010). In this study, the estimates of incident radiation performed in the areas of SPS indicate a 29% average shade in relation to photosynthetically active radiation at full sun. Apparently, this level of shade was insufficient to cause changes in the cell wall constituents of the forage, which would explain the absence of effects due to the rearing system.

It is interesting to observe that the increase in CP content in the pasture under shade had no relationship with the IVDMD coefficients, which remained unaltered due to the rearing system. Some studies do not relate the effect of shade on *in vitro* digestibility (Samarakoon et al., 1990; Sousa et al., 2010), which corroborates the results of this study. Different results from those obtained in this study can also be found in the literature. Under the same cultivation conditions, positive effects of shading were observed over IVDMD for *Setaria sphacelata* and negative effects for *Panicum maximum* (Deinum et al., 1996). Senanayake (1995) reported that the IVDMD of four forage grasses was reduced under intense shade (28% light transmission), but it was increased under moderate shade (64% light transmission) compared to the full sun condition. The varied responses of grasses to shade regarding IVDMD are probably related to differences in shade percentage, forage species and weather conditions.

4.3. Animal performance

The lowest body weight gains were observed during the dry season of the year, which can be attributed to the lower CP content of the pasture and, mainly, to the reductions in herbage mass and herbage allowance as a consequence of the decrease in rainfall and air temperature. The reduction of herbage mass during the dry season hampered the maintenance of the daily herbage allowance of 7.0% of the body weight as predicted in the planning for this study. Thus, even though the aim was to maintain a constant herbage allowance, this was not possible during the dry season, when the average allowance decreased to 5.2% of the body weight. The main effect of such a decrease was, most likely, the reduction in dry matter consumption. In fact, Paciullo et al. (2009) found that the forage intake of heifers kept in the same area as this study was reduced from 2.3% of the body weight during the rainy season to 1.6% of the body weight in the dry season due to the reduced herbage mass.

In the first and third experimental years of the rainy season, greater weight gains were observed in the SPS than the MS. Because the herbage mass and herbage allowance varied little between the two rearing systems, it appears that other factors were responsible for this result.

First, the greater CP content in the SPS may have contributed to the improved quality in the diet of heifers in the pasture with trees, thus favouring animal performance. Considering the average DM intake during the rainy season of 2.3% of body weight (Paciullo et al., 2009) and the CP content of the pasture in each system during the rainy season, it is estimated that the heifers in the SPS were able to consume, on average, 607 g/day of CP, while the MS was only 538 g/day. The difference in CP intake by the heifers of the two systems (69 g/day) explains, in part, the best performance in the SPS, even if the IVDMD was the same for both systems.

The second aspect is related to environmental mitigation afforded by the shade of trees in the silvopastoral system, which may have provided better thermal comfort conditions for the development of dairy heifers, especially during the rainy season, when temperatures reached values near 30 °C (Table 1). The fact that animals seek shade, mainly in the summer, highlights the need for the provision of shade (Salla, 2005; Tucker et al., 2008). This is the case even for crossbred animals such as European × Zebu, which, although more heat-tolerant than animals from temperate climates, are more susceptible to the elevated temperatures of the tropics than pure Zebu (Bennett et al., 1985). Shade can decrease the radiant heat charge by 30% or more, allowing the animals to maintain normal behaviour patterns (Blackshaw and Blackshaw, 1994).

The higher annual average gain in SSP may be significant for dairy husbandry systems, considering that the acceleration in growth may contribute to a reduction in the age of first conception and, consequently, of the first calving of the heifers. However, forage scarcity during the dry season reduced the weight gain rates in the systems, requiring management strategies and supplementation if one desires to maintain high levels of weight gain throughout the year. However, forage scarcity during the dry season reduced the weight gain rates in the systems, requiring management strategies and supplementation if one desires to maintain high levels of weight gain throughout the year.

Although most studies with silvopastoral systems in temperate regions show similar animal performance compared to the SPS and MS (Clason and Sharrow, 2000; Hawke, 1991; Kallenbach et al., 2006; Teklehaimanot et al., 2002), the results from this study highlight the potential of silvopastoral systems in providing improvements in animal performance in tropical regions. The marketability of the tree component can also result in additional financial support for rural producers, which is important from the viewpoint of the economic sustainability of the project, besides being a factor of encouragement for the adoption of this technology by farmers. One must consider that the Food and Agriculture Organization recommend the intensification of agricultural exploitation with minimal use of external inputs to property (Steinfeld et al., 2006). These results show the possibility of using silvopastoral practises to increase production to meet the economic criteria and environmental factors that underlie a sustainable system. Also worthy of attention is that sustainable practises are liable to payment as environmental services, among which the silvopastoral system for rearing heifers could be beneficial (Pagiola et al., 2004).

5. Conclusions

The herbage mass in the silvopastoral system with moderate shade was similar to that in the *B. decumbens* pasture in monoculture. The crude protein increased with shading in the silvopastoral system compared to open pasture, but the neutral detergent fibre and *in vitro* dry matter digestibility did not differ. The silvopastoral system was more efficient for rearing dairy heifers than the pasture of *B. decumbens* due to the higher annual weight gain per heifer and per area.

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