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Pasture Production and Sheep Behavior in Mixed or Adjacent Monocultures Swards in Different Seasons of the Year

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Abstract: Traditionally, forage is grown in mixed (Mi) or monoculture (Mo) pastures. However, there is currently no evaluation of the advantages of these production systems under tropical conditions. The aim of this study was to evaluate forage production and animal behavior in Mi and Mo pastures containing white clover (*Trifolium repens* L.), African star (*Cynodon nlemfuensis* Vanderyst) and Taiwan Napier (*Pennisetum purpureum* Schumach), using a completely randomized design with two treatments (Mo and Mi) and three repetitions during the four seasons of the year. For each repetition and season, three sheep were evaluated for 8 h/d during three consecutive days. The forage produced in Mo and Mi pastures was similar ($p > 0.05$) during the four seasons of the year. Sheep displayed higher ($p < 0.01$) average daily weight gains (ADG) when grazed on Mi than Mo pastures, particularly during summer, autumn and winter, seasons that corresponded to the higher dry matter intake (DMI) ($p < 0.05$), even though sheep spent more time ($p < 0.01$) grazing on Mo pastures, when compared with spring. It was concluded that there is no advantage in forage production when associations of white clover and two tropical grasses are grown in Mo or Mi pastures. However, heavier sheep are obtained from the later as a result of an increase in forage consumption.

Key words: *Trifolium repens*, *Cynodon nlemfuensis*, *Pennisetum purpureum*, grazing behavior, pasture.

1. Introduction

Several studies in recent years have investigated the behavior of grazing ruminants in mixed (Mi) pastures consisting of native grasses, herbaceous plants and shrubs [1, 2], improved grasses and legumes [3-5] and in monoculture (Mo) pastures combining legumes and grasses in temperate regions [6-8].

In Mo pastures, animals spend less time selecting their preferred species, which affects grazing time [9, 10], while in Mi grasslands grazing time is based on a more careful selection of the species, which depends on plant density and availability [9]. These behaviors affect both the use of the pasture and average daily weight gains (ADG).

Furthermore, in Mi pasture and temporal Mo in temperate and semi-arid areas, forage production varies throughout the year due to lower humidity and low temperatures, so that the spring-summer production contrasts with that of autumn-winter [8]. However, competition for space, light and nutrients between forage species occurs only in Mi pastures. On the other hand, in subtropical regions, where one would expect a more stable production throughout the year, Mi grass and legume pastures are combined with tropical species [11]. Therefore, the behavior of

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legume-grass mixes combined with temperate species such as white clover (*Trifolium repens* L.) and tropical grasses such as African star (*Cynodon nlemfuensis* Vanderyst) and Taiwan Napier (*Pennisetum purpureum* Schumach) in Mo or Mi pastures is unknown, as is their potential effect on forage production, sheep grazing behavior and meat production.

The goal of the current study was to evaluate forage production and sheep grazing behavior throughout the year on Mi and Mo pastures using white clover and two tropical grasses.

2. Materials and Methods

All procedures were approved by the Ethics Committee for Animal Experimentation of the University of the State of Morelos, México. All animals were handled according to the principles stated in the 86/609/EEC EC Directive regarding the protection of animals used for experimental and other scientific purposes.

2.1 Experimental Area

The experiment was conducted on a field station located at 18°56′ N and 99°13′ W, at an altitude of 1,510 m above sea level, with a semi-warm climate with summer rain [12] and average annual temperature fluctuating between 16.4 °C and 19.9 °C.

2.2 Swards

The Mi grassland was established in February on 82 m^2 (10 m × 8.2 m) and was prepared in rows spaced 0.8 m apart in which the following species were homogeneously combined: African star, Taiwan Napier and white clover. The planting densities were 2.0 tons/ha and 2.5 tons/ha of vegetative material for the African star and Taiwan grasses, respectively, and 7 kg/ha of white clover seed [13]. For the African star grass, three guides per row were distributed, for Taiwan Napier, 10 30 cm reeds per row were horizontally planted and for the white clover, 2 g of seed spread proportionally per row were used. A dose of 100-150-20 of N, P_2O_5 and K_2O was applied to both pastures, dividing N and P in four equal parts applied one month before starting the spring, summer, autumn and winter grazing, while 100% of potassium was applied in the first fertilization. The sources used were urea, triple superphosphate and potassium nitrate, respectively. For two months, weeds were manually eliminated every 15 d and sprinkler irrigation was conducted for 6 h a day twice a week, until a week before the start of sheep grazing for each season. Irrigation was suspended during the rainy season (June to September).

The Mo pasture was established on 82 m^2 (10 m × 8.2 m) with the three species used in Mi, but each species was planted in adjacent 10 m × 2.73 m (27.3 m^2) strips. Planting date, fertilization, weed control and irrigation were similar to those used in Mi pasture.

2.3 Animals

Two groups of 18 Saint Croix sheep were used. Animals in the first group, used for the spring (May) and summer (August) evaluations, were five months old females and weighed an average of 32.4 ± 0.37 kg, while sheep in the second group, evaluated in autumn (November) and winter (February), were eight months old and weighed an average of 34.6 ± 0.21 kg. All animals were identified with numbers painted on their sides and were adapted to the grazing area for one month before initiating the experiment.

2.4 Experimental Procedure

The surface per treatment was 246 m^2, which included three repetitions of 82 m^2 each, in a completely randomized design with two treatments (Mi and Mo).

Three sheep were randomly assigned per repetition in order to avoid altering their grazing behavior [14]. Each sheep was considered an experimental unit, and a total of nine experimental units per treatment were

evaluated.

Sheep were evaluated on the pastures for 8 h a day for three consecutive days with free access to water in accord to the methodology validated by Lin *et al.* [15], and were then placed in the stables without food for the rest of the day. The same operation was carried out in spring, summer, autumn and winter and the animals within each repetition were kept together and physically isolated by an electric wire fence.

2.5 Variable Measurements

2.5.1 Swards

Sward biomass in dry matter (DM) (82 kg/m^2) was determined 3 d before the evaluation period on consecutive days. For this, plants were manipulated to have an average height of 15 cm (white clover), 25 cm (African star) and 40 cm (Taiwan Napier). Furthermore, the amount of residual forage was assessed 1 d after the end of the evaluation period by randomly establishing a quadrant (35 cm × 35 cm) twice in Mi and twice in each Mo, and cutting forage at ground level [16, 17]. The samples were dried in an oven at 60 °C for 48 h.

The amount of supplied and residual forage was estimated in kg/ha, and for the Mo pasture, the quantities for each Mo were added together. An electronic scale with a capacity of 5 kg and an accuracy of 1 g was used to determine the weight of the forage samples. The amount of supplied and residual forage from each pasture was then transformed to obtain the percentage value.

During times of the year when the pastures were not used, they were grazed at a severity of 5 cm, to allow the growth of tender sprouts and prevent lignification and aging.

2.5.2 Animals

The DM requirements were 1.2 kg/head/day in the spring-autumn and 1.3 kg/head/day in the summer-winter, which corresponds to the recommendation of the nutrient requirement tables [18] for replacement animals with a live weight of 30 kg and 35 kg, respectively. The forage produced in each season was assessed to determine whether the DM requirements of the three sheep from each repetition were met.

The ADG in kilogram was calculated by comparing sheep weight at the end of the evaluation period to the baseline weight 3 d before. Sheep weight was measured using an electronic scale with a capacity of 40 kg and a precision of 1 g.

Sheep behavior was recorded by three observers (one for each repetition) who remained at least 10 m from the pastures so as not to alter the animals' behavior. Focal observation was conducted for 5 min/h from 8:00 to 15:00 representing observation of 120 min/repetition/day, recording the time spent on each of the behaviors (i.e., grazing, ruminating, lying, walking and standing) to obtain the average time (in minutes) spent on each behavior over the 480 min of measured activity (8 h/d for three consecutive days).

Grazing behavior was considered when sheep kept their head down to eat the forage [19]. Ruminating consisted of jaw movements indicating regurgitation and chewing, considered in both, when animals were lying or standing [19]; walking was defined as slow locomotion [19]; lying sheep were reclined or lay on their sternum [20]; standing sheep were those that remained still without grazing or ruminating.

2.6 Statistical Analyses

The data were analyzed using the SAS procedure [21], by means of a completely randomized design, in which treatments, times and treatment × time were considered fixed variables and replicates, random. The least square means (LS means) were compared using the adjusted Tukey's test. To fulfill the normality assumption, the fragmentation data were transformed to Sine Arc, and the results were expressed as LS means and standard error of means (SEM) expressed in the original units of measure.

3. Results

3.1 Swards

Results showed that Mo produced similar ($p > 0.05$) amount of forage as Mi, with no difference ($p > 0.05$) among the seasons of the year (Table 1).

The amount of forage supplied by each pasture in all seasons yielded surpluses, so that the sheep met the DM requirements of 10.8 kg/three heads/day during the 3 d of occupation in spring and autumn, and the requirements of 11.7 kg/three sheep/day for summer and winter.

The amount of residual forage was similar ($p > 0.05$) between Mi and Mo across all seasons, which resulted in a similar DM consumption between treatments. However, a greater DM intake (DMI) was observed from summer to winter in contrast with spring (Table 1).

3.2 Animals

The ADG was higher ($p < 0.01$) in Mi than Mo, particularly during summer, autumn and winter, in comparison with spring (Table 1). In contrast, the time spent grazing was higher in Mo than Mi, particularly during summer, autumn and winter ($p < 0.01$). Walking activity was also higher ($p < 0.01$) during the summer and autumn seasons in comparison with winter and spring, while sheep lay for more time during the autumn ($p < 0.05$) in comparison with the rest of the year. In contrast, no effect ($p > 0.01$) was found between treatments or season of the year in the time spent ruminating and vocalization frequencies (Table 2).

4. Discussion

The similar forage production observed in Mo and Mi associations could be due to the fact that establishing the species separately does not eliminate the competition among them, and competition intra- and inter-species happens anyway. In Mi, one might expect white clover to increase DM production due to the effect of nitrogen (N) [22]; however, this was not the case: the shade provided by the grass leaves may trigger competition for light. Grass plants grow taller than clover [13] and clover plants may be eliminated from the pasture. The greater the shade, the less efficient the photosynthesis [23].

On the other hand, the competition between grasses affected the Taiwan Napier, which presents a vertical leaf growth pattern. This is in contrast to African star, whose leaves grow horizontally, thus allowing them to receive more sunlight for photosynthesis [24]. Furthermore, the Taiwan Napier in this study was not allowed to grow more than 40 cm in order for sheep to have complete access to the plant, leaving them with fewer leaves.

Another possible effect of associating white clover with tropical grasses is because tropical grasses are C4 plants, which are more efficient at harnessing solar energy for photosynthesis, they yield greater growth and production relative to legumes (C3), displacing these in the pasture [25, 26]. The proportion of grasses has been shown to be greater than that of legumes in Mi pastures as time passes [27].

Although there are reports in the literature regarding pastures mixing white clover with temperate grasses such as perennial ryegrass, both in Mi [28] and Mo [29, 30] as well as the tropical grasses used in the current study mixed with tropical legumes [11], no reports were found of pastures combining white clover with tropical grasses.

The forage distribution in strips (Mo) made it easier for the sheep to choose the order and time devoted to each species.

The amount of prairie forage was always enough for the sheep, because it was handled under irrigation conditions and temperature was the only variable fluctuating through the year, which did not affect the amount of forage produced.

The increase in ADG and decrease in DMI observed in Mi pastures, might seem contradictory. However, the structure of the Mi sward might limit the

Table 1 Forage production, sheep weight gains and consumption under mixed or monoculture pastures during different seasons of the year (LS means ± SEM).

	Treatments			Time					$p > F$		
	Mixed	Monoculture	SEM	1	2	3	4	SEM	Treatment	Time	Interaction treatment /time
Offered forage (ton/ha—3 d)	2.44	3.04	0.35	2.16	1.62	3.20	2.74	0.38	NS	NS	NS
Residual forage (ton/ha—3 d)	1.32	1.49	0.21	1.26	1.46	1.63	1.27	0.23	NS	NS	NS
ADG/ewe (kg/d)	0.41b	0.23a	0.02	0.17a	0.23b	0.28b	0.24b	0.01	++	++	++
DMI/ewe (kg/d)	1.10	1.45	0.24	0.88a	1.36b	1.45b	1.35b	0.1	NS	++	+

Mixed: sward associating white clover, African star and Taiwan Napier; monoculture: adjacent swards of white clover, African star and Taiwan Napier; 1, 2, 3, 4: spring, summer, autumn and winter, respectively; +: $p < 0.05$, ++: $p < 0.01$, NS: non-significant; ADG: average daily weight gains; DMI: dry matter intake; LS means: least square means; SEM: standard error of means; a, b: means within a row with different letters, differ statistically.

Table 2 Behavioral activities in sheep, managed under mixed or monoculture pastures during different seasons of the year (LS means ± SEM).

	Treatments			Time					$p > F$		
	Mixed	Monoculture	SEM	1*	2*	3*	4*	SEM	Treatment	Time	Interaction treatment /time
Grazing	35.98[a]	42.41b	1.38	27.20a	42.11b	45.48b	41.98b	1.60	++	++	++
Ruminating	7.93	6.28	0.60	6.17	7.89	6.91	7.44	0.76	NS	NS	NS
Lying	11.1b	6.3a	0.95	8.5a	8.67a	11.07b	6.69a	1.09	++	+	++
Vocalizing	0.62	0.36	0.28	0.87	0.44	0.39	0.26	0.28	NS	NS	NS
Walking	24.11	24.70	0.78	21.17a	28.44b	27.74b	20.28a	1.03	NS	++	++

Mixed: sward associating white clover, African star and Taiwan Napier; Monoculture: adjacent swards of white clover, African star and Taiwan Napier; 1, 2, 3, 4: spring, summer, autumn and winter, respectively; +: $p < 0.05$, ++: $p < 0.01$, NS: non-significant; LS means: least square means; SEM: standard error of means; a, b: means within a row with different letters, differ statistically.

*Reported in average time (in minutes)/animal spent on each behavior over the 480 min of measured activity (8 h/d for three consecutive days).

animals' displacements, facilitating the selection of preferred forage species in a single place, reducing grazing time. Another non-exclusive explanation could be that mixtures of legumes and grasses brings in N to the latter, which makes them more succulent, increase their protein content making them more appetizing [31]. Furthermore, multispecies, generally reduces the invasion of weeds, which could be reflected in the greater consumption [32], perhaps due to a larger bite size, which may compensate for longer grazing times with smaller bite size demonstrated as a regulator of intake [33].

The fact that the Taiwan Napier was the tallest (40 cm) may have allowed the sheep to protect themselves from the sun, which may have favored lying behavior in Mo, using the edge of the tall grass barrier as shade. Although not measured, it was observed that sheep would lie in its shade in order to maintain a more comfortable temperature.

When the preferred species presented a creeping growth archetype, as was the case for white clover, sheep were forced to spend more time walking to graze it and meet their requirements in Mo, which may have affected their behavior (grazing and lying) during grazing. According to Harvey *et al.* [30], sheep spend more time grazing white clover when it is 3 cm tall.

5. Conclusions

In conclusion, Mo pastures combining white clover with two tropical grasses favored legume grazing is more productive and yields heavier animals than when associated under Mi conditions.

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