agronomy

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Mixtures of Forage Species as Pasture for Dairy Ewes in a Mediterranean Environment

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Abstract: In Sicilian forage systems, the introduction of native self-seeding annual legumes can be beneficial in low-input farming. Intercropping would be a valuable strategy for implementing pasture resources in Sicilian forage systems during late spring. The aim of this study was to evaluate the effects on ewes' milk production of continuous grazing with two different mixtures (i) sulla (*Sulla coronarium* L.), burr medic (*Medicago polymorpha* L.), and chicory (*Cichorium intybus* L.) (SuBuCh); and (ii) barrel medic (*Medicago truncatula* Gaertn.), snail medic (*Medicago scutellata* L.), and burr medic (BuSnBa). Twenty lactating ewes were homogeneously divided into four groups of five ewes. Each group was assigned to one of four 1500 m^2 grazing sectors consisting of two replicates of SuBuCh and BuSnBa. Ewes fed with the SuBuCh mixture showed higher milk yield, higher protein (5.17 vs. 4.85%, $p < 0.001$) and casein content (4.02 vs. 3.73%, $p < 0.001$), lower urea content (37.70 vs. 45.38 mg dL^{-1}, $p < 0.001$), and better clotting parameters compared to ewes grazing on the BuSnBa mixture. Finally, ewes in the SuBuCh group showed a smaller decrease in live weight at the end of the grazing period compared to BuSnBa ewes (−2.05 vs. −3.55 kg, respectively), although the difference did not reach a significant level. These preliminary one-year results seem to highlight the promising role of SuBuCh intercrop leading to a potential quantitative/qualitative improvement in grazing resources and the productive performance of grazing ewes in a semi-arid Mediterranean environment. However, it is of note that these outcomes might undergo variations when subjected to a prolonged trial extending beyond three years.

Keywords: forage system; intercropping; meadow; self-seeding; grazing; ewes' milk

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Citation: Di Miceli, G.; Ponte, M.; Dinolfo, L.; Maniaci, G.; Pipi, M.; Gannuscio, R.; Prestigiacomo, S.; Bonanno, A.; Di Grigoli, A. Mixtures of Forage Species as Pasture for Dairy Ewes in a Mediterranean Environment. *Agronomy* **2024**, *14*, 393. https://doi.org/10.3390/agronomy14020393

Academic Editors: Jennifer MacAdam and Katja Klumpp

Received: 7 December 2023
Revised: 10 February 2024
Accepted: 16 February 2024
Published: 18 February 2024

1. Introduction

Forage production in the Mediterranean basin is a key component of livestock systems and rural livelihoods [1]. Of the total ewes' milk production, 44% comes from dairy sheep in the Mediterranean basin, and this production is essential for the economy, the environment, society, and culture [2–4]. However, the small ruminant livestock system faces many challenges. Despite its significant importance, it is still far from being sustainable when animal health, environmental effects, product quality, and profitability are taken into account [5,6]. Furthermore, forage production is affected by a strong seasonality due to hot dry summer climatic conditions that create a peak of availability in spring and a severe shortage in summer and early autumn, with the consequence of a lack of fodder supply at certain times of the year (in terms of quality or quantity) [3,7]. For all these reasons, livestock forage systems in the Mediterranean region need to adapt towards a low-impact and sustainable farming system with the introduction of legume-rich mixtures and drought-tolerant and resilient species and varieties, and the utilization of self-reseeding species to ensure continuous pasture availability.

Among the native perennial forage species, in the Mediterranean basin, a great interest is focused on sulla (*Sulla coronarium* L.) and chicory (*Cichorium intybus* L.). The first one is a short-lived legume that is grown as a two-year forage crop for grazing and hay or silage production, and represents a resource whose potential is well known [8–10].

Chicory, due to its deep taproot structure, is more resistant to water stress than the majority of grasses and legumes. Chicory has a high nutritional value thanks to its high level of minerals, digestibility, and crude protein. It also has a high water content, which can reduce heat stress and water intake by animals. Animal performance can be enhanced by chicory in terms of live weight increase, carcass quality, milk production, and milk composition [11].

As alternatives to perennial forage species in the Mediterranean fodder system, the introduction of native self-seeding annual legumes provides many beneficial effects due to their characteristic of persistence on the same area for several years; moreover, the self-seeding mechanism makes them able to reduce input and to create more sustainably managed small ruminant forage systems. The annual species included in *Medicago* spp., such as *Medicago polymorpha*, *Medicago truncatula*, and *Medicago scutellata*, present excellent self-seeding capacity and adaptability to the Mediterranean area. These legumes can enhance animal health by providing biologically active compounds, such as phytoestrogens, saponins, and tannins, that have various effects on reproduction, digestion, and immunity [12–14]. Despite their great plasticity, that could emphasize their use in a ley farming system or in improved pastures (especially in marginal land) [15,16], unfortunately, this group of species is not yet sufficiently known and cultivated in the Mediterranean basin.

Many farmers recognize the significance of incorporating legumes, sulla, and chicory into forage systems. However, decisions in pasture management and climate conditions, characterized by a progressive increase in global temperatures and extreme climatic events, could have an influence on the quality and quantity of a grass–legume mixture and could compromise the persistence of the pasture component [17].

Concerning pasture management, the intercropping of these species could be a valuable strategy for implementing pasture resources in Mediterranean forage systems. Indeed, a varied pasture composition, including different botanical families, has proved to fulfill the nutritional requirements of small ruminants [18–20].

Simulating the effect of climate change on livestock, in line with the principles of global warming theory [21], a late spring short-term experiment was conducted with the aim of examining specific aspects of ewes' milk quality and production dynamics under continuous grazing conditions in a semi-arid Mediterranean environment under extreme climatic characteristics [22–24].

2. Materials and Methods

2.1. Location, Animals, Experimental Design, and Feeding Treatments

The experiments were conducted during one growing season in 2021–2022 at the experimental farm "Sparacia" (Department of Agricultural, Food and Forest Sciences, University of Palermo, Cammarata, Agrigento, Italy, 37°38′09.0″ N 13°45′46.6″ E, 415 m above sea level), located in a semi-arid, hilly area in western Sicily, approximately 100 km south of Palermo. The soil is a Vertic Haploxerept [25] with a clay texture (62% clay, 33% silt, 5% sand). In 2020, the organic matter content was 0.7%, and the total N was 0.1% determined by the Kjeldahl method. The climate of the experimental site is semiarid Mediterranean, with a mean annual rainfall of 604 mm, concentrated mostly during the autumn–winter period (September–February; 71%), followed by spring (March–May; 23%). There is a dry period from May to September. The mean air temperature is 14.8 °C in autumn, 9.4 °C in winter, and 18.1 °C in spring. The weather data were collected from the Agrometeorology Service Network of the Sicilian Region [26].

Plowing in August and complementary operations in October were carried out on the soil where the previous crop was wheat. The trial began in the second week of May and concluded in the first week of June, as this brief timeframe was identified as suitable for simulating the conditions sought by our study.

The trial involved the study of two intercropping mixtures consisting of (i) sulla (*Sulla coronarium* L., landrace Avorio), burr medic (*Medicago polymorpha* L., var. Protosardo), and chicory (*Cichorium intybus* L., var. Spadona) (SuBuCh); and (ii) barrel medic (*Medicago truncatula* Gaertn., var. Paraggio), snail medic (*Medicago scutellata* L., var. Sava), and burr medic (BuSnBa).

The sowing density utilized for the SuBuCh mixture was 400 germinable seeds per square meter allocated to both sulla and chicory, and 350 for burr medic (seeding rates 35:35:30 for sulla, chicory, and burr medic respectively). Additionally, the sowing density employed for the BuSnBa mixture was 350 germinable seeds per square meter assigned to each of the three species of annual medics present in the mixture (seeding rates 33:33:33).

A total of four adjacent fenced plots, each one covering an area of 1500 m^2, were broadcast-seeded in the middle of January using the two mixtures, and no fertilizers were applied. A randomized block design was adopted with two replications.

Twenty lactating Valle del Belice ewes, which previously and until the beginning of the experimental test were raised on pasture, were divided in 4 balanced groups of 5 ewes based on days in milk (92 days ± 8), milk yield (2110 g ± 162), liveweight (49.2 kg ± 5.3), and Body Condition Score (BCS); each group was assigned to one of four grazing sectors of 1500 m^2, consisting of two replicates of SuBuCh and BuSnBa. The ewes grazed continuously until the end of the trial, which lasted a total of 25 days in May and June 2022. During this period, these groups were allowed to graze on one of the designated plots for 8 h, between the two daily hand-milking sessions (from 08:00 h to 16:00 h). During nighttime, the four groups of ewes were housed in separate straw-bedded pens, each equipped with a water trough, where they received no additional feeding supplement. The experiment protocol had the approval of the Animal Welfare Body of the University of Palermo (2022-UNPA-CLE) that considered not applicable the exigency established by the National Legislative Decree 2014/26, implementing the Directive 2010/63/EU.

2.2. Sampling and Measurements

2.2.1. Forage Sampling

The experiment encompassed measurements to assess forage availability and quality throughout its duration. To estimate the forage biomass (kg DM ha^{-1}), a sward-cutting technique was applied within each plot, evaluating the amount of forage before and after a grazing period [27–29]. Specifically, the total above-ground biomass was harvested using hand-held equipment, and this approach was consistently executed by the same operator, thereby mitigating the risk of operator-dependent errors. The initial measurements involved selecting two 1 m^2 sample areas and cutting them down to ground level. Continuing throughout the trial, the assessment of forage biomass on offer was conducted on a weekly basis within the continuously grazed plots. Four sampling areas were identified in each sector, consisting of two inside exclusion cages of 2 m^2 and two outside of them. Within a 1 × 1 m survey area, prior to each biomass collection, the height of each species was measured in its natural state (cm), and the overall and specific coverage (%) of study species and weed species were assessed. The aboveground parts were cut and brought to the laboratory in bags. Proportions of botanical groups and plant species within these groups were determined. The fresh weight and dry weight were determined by subjecting samples to a convection oven maintained at a constant temperature of 65 °C until reaching a stable weight, and then weighed. At the conclusion of the experimental trial, an evaluation was conducted to assess the residual forage not grazed by the ewes.

2.2.2. Animal Sampling

The liveweight and BCS of the ewes were measured at the start and end of the trial. The individual milk yield of the two daily milkings was recorded. Three times during the experimental period (on 15 and 27 May, and 10 June), the botanical composition of ingested herbage was assembled using the hand-plucking technique after observing the ewes during the daily grazing period [30,31]. Also, on the same three dates, individual daily milk was sampled.

2.2.3. Forage Analysis and Measurements

After obtaining the measurements, the first data were used to calculate forage biomass availability (A) and grazing intensity percentage (GI%). Availability, determined starting from Linehan's formula (1947) [32], was obtained with Formula (1) [33], and it was assessed at each sampling.

$$A = Y_s + f_L\,(Y_u - Y_s) \tag{1}$$

where:

A = forage biomass availability;
Ys = forage biomass at the start of each grazing period (kg DM ha^{-1});
Yu = forage biomass at the end of each grazing period in the ungrazed area (kg DM ha^{-1});
fL = Linehan's accumulation factor.

The difference between the two values, represented as $(Y_u - Y_s)$, was an estimate of the apparent quantity of forage consumed per unit area. However, it is important to consider that forage growth occurs during grazing, necessitating an adjustment for this factor. The disturbed accumulation cannot be measured directly since it is constantly being influenced by the grazing animal. For this reason, Linehan's accumulation factor was utilized. This factor was obtained using the formula:

$$f_L = (Y_s - Y_e)/(Y_u - Y_s)\cdot((\ln(Y_u/Y_e)/\ln(Y_s/Y_e)) - 1) \tag{2}$$

where Y_e = forage biomass at the end of the grazing period (kg DM ha^{-1}).

f_L is a coefficient used to express production as a fraction of the undisturbed accumulation of forage biomass [28,33], and its use allows for the consideration of the exponential growth of ungrazed sward. After obtaining the availability for each weekly observation, the total forage biomass availability (A_{tot}) of the two intercropping mixtures throughout the entire grazing period was calculated using the following formula:

$$\mathbf{A_{tot}} = \sum_{\mathbf{i=0}}^{\mathbf{n}} \mathbf{A_i} \tag{3}$$

where A_{tot} is the sum of the forage biomass availability values across these observations, n represents the maximum number of observations considered in the summation, i is the index variable range from 0 to n, and A_i is the value of forage biomass at the i-th observation.

Additionally, the GI (%), representing the percentage of pasture utilization by animals during a specific period in relation to the total forage availability in the grazing area, was calculated:

$$GI = (A_{tot} - Y_e)/A_{tot} \times 100 \tag{4}$$

2.2.4. Animal Analysis and Measurements

Samples of total biomass on offer and forage ingested by grazing ewes were analyzed according to AOAC procedures (AOAC, 2005) to establish DM (dry matter) (method 934.01), EE (ether extract) (method 920.39), CP (crude protein) (method 2001.11), and ash (method 942.05). The fibrous parts, as aNDFom (neutral detergent fiber using heat-stable amylase and exclusive of residual ash) (method 2002.04), ADFom (ash free acid detergent fiber) (method 973.18), and ADL (acid detergent lignin) (method 973.18), were defined according to AOAC (2005) and Van Soest et al. (1991) [34]. Non-structural carbohydrates (NSC, %) were assessed as (5):

$$100 - (\text{CP\%} + \text{EE\%} + \text{ash\%} + \text{aNDFom\%}) \tag{5}$$

Milk individual samples collected from animals were examined for protein, casein, fat, lactose, and urea using the infrared method (Combi-foss 6000, Foss Electric, Hillerød, Denmark). Individual milk was also investigated for clotting parameters using a Formagraph instrument (Foss Electric). Then, the following values were measured in 10 mL of milk at 35 °C to which 0.2 mL diluted solution (1.6:100, v/v) of rennet (1:15,000; Chr—Hansen, Parma, Italy) was added: coagulation time (r, min), curd-firming time (k_{20}, min), curd firmness (a_{30}, mm), and curd firmness after twice clotting time (a_{2r}, mm).

2.3. Statistical Analysis

Data were statistically analyzed using the Minitab® v 19.1.0 and SAS 9.2 software [35]. In the assessment of all data coming from the forage samples collected, all measured variables were assumed to be normally distributed. Proportional variables underwent arcsine transformation for a better fit with the Gaussian distribution. Bartlett's test assessed the homogeneity of variances before combined analyses. Analysis of variance (ANOVA) was conducted based on block randomization in the experimental design. Treatment means of total forage availability, residual, and grazing intensity were compared using Fisher's LSD test at a 5% significance level, while for the averages relating to total cover, specific cover, and the height of the forage species for each treatment, the standard error was calculated. The GLM procedure was used for ewes' live weight and BCS, with forage mixture (FM: SuBuCh and BuSnBa) as a unique factor. For milk yield and composition, with the ewe as the experimental unit, the fixed effects of FM, control day (CD: 1 = 15 May, 2 = 27 May; 3 = 10 June), and replicates (2 levels) were assessed using a MIXED model for repeated measures, with CD as the repeated measure and the ewe as the repeated subject, regarded as a random error term. Interactions were removed from the models because they were not significant. Before analysis, the SCC values were transformed logarithmically ($\log_{10}$). When the effect of forage mixture was considered significant ($p \leq 0.05$), means were compared using p-values adjusted according to the Tukey–Kramer multiple comparison test.

3. Results and Discussion

Livestock systems based on grazing and forage production are strongly influenced by global warming due to reduced precipitation and increased drought on crops. These conditions impact pasture growth, in addition to the direct effects of high temperatures and solar radiation on animals [21]. This study focused on assessing the productive effects of climate change conditions on a group of lactating ewes. The thermo-pluviometric trend at the experiment site posed some challenges to pasture management. Rainfall events, some of which were quite substantial, were concentrated between September and December, causing a delay in seeding. This was followed by a dry period that initially presented difficulties for the development of the forage species under investigation. However, during the late grazing period, some significant rainfall events allowed for a satisfactory development of the pasture. Temperature trends remained consistent with the multi-year thermal pattern. In contrast, in May, temperatures were recorded to be higher than the polyannual average (Figure 1). These conditions provided a 25-day timeframe to assess the forage availability and productivity capabilities of ewes, under natural conditions induced by climate change. Identifying this short time frame is not a drawback but rather essential for simulating the conditions of climate change. The described conditions are specific to this brief period. Anticipating the study phases would prevent the accurate simulation of the desired conditions. Conversely, extending the study beyond this interval would expose animals to unacceptable heat stress and nutrient deficiencies, affecting animal welfare.

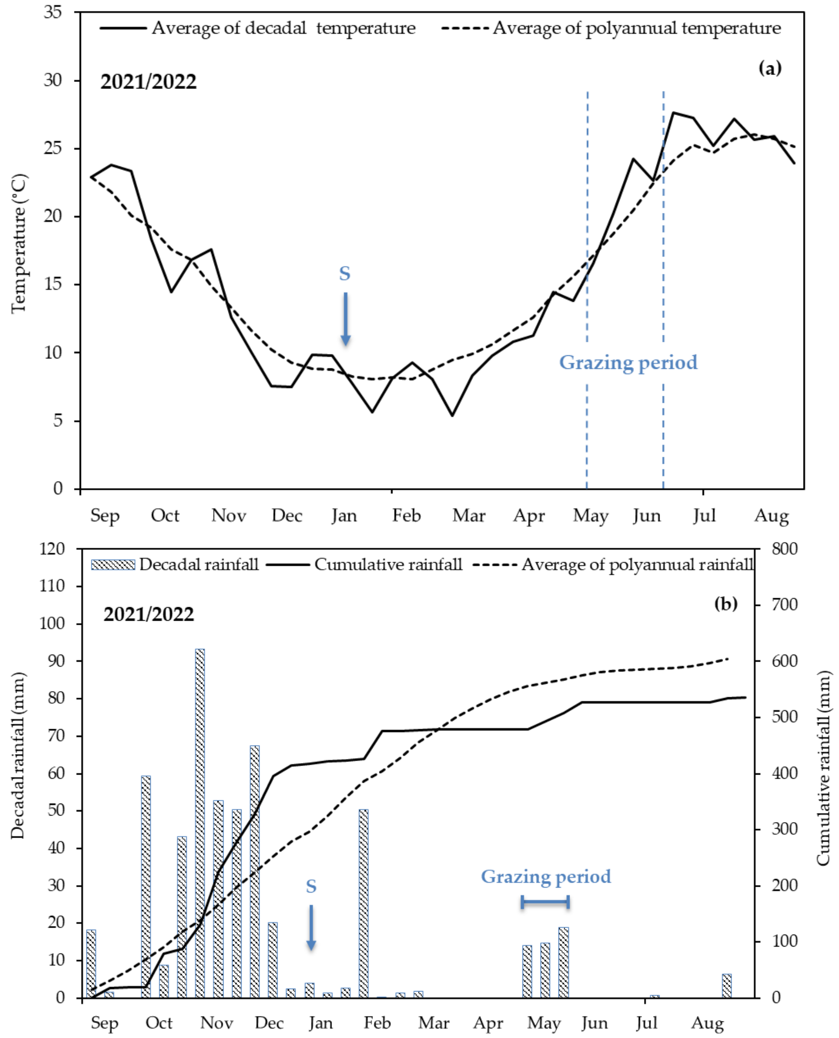

Figure 1. Decadal air temperature (**a**) and decadal accumulated rainfall (**b**) at the experimental site during the 2021–2022 growing seasons; the 30-year average temperatures and accumulated rainfall are also included. Major events are plotted (S = sowing and the grazing period).

3.1. Total and Specific Coverage Analysis

Having an accurate assessment of on-farm pasture cover is a crucial aspect of profitable dairy farm management. The evaluation of the height of the plants and the overall and specific coverage of forage species mixtures in late spring represents a critical aspect to obtain precise information on the production of high-quality forage. Despite the overall coverage showing high percentages, specific coverage allowed us to highlight differences in the prevalence of individual species (Table 1). While at the beginning of the trial, in SuBuCh, sulla and burr medic reach similar values of specific coverage (37% and 47%, respectively), at the last observation, burr medic, given its precocity [36], is drastically reduced (22%). Chicory, re-evaluated as a potential forage species in the mid-1970s in New Zealand due to its ability to extend the production period of high-quality green fodder under semi-arid conditions [3,37], did not, actually, exhibit this tendency in the present study. The low level of specific coverage showed an underside competitive attitude compared to the other two species in the mixture. This might indicate a low seedling emergence of chicory probably due to unfavorable weather conditions (Figure 1) and a late biological cycle that is not suitable for development within the intercropping. This underscores the importance of considering the production dynamics of different species within a forage mixture. It is possible to highlight how the height of sulla prevails over the other species in the studied mixtures, reaching values of up to 86 cm. Conversely, some species within the Medicago genus exhibit increased resistance to natural grazing by adopting a low growth profile, which is advantageous in the context of natural grazing, as it likely contributes to the plants' ability to withstand grazing pressure more effectively [38]. In BuSnBa, annual medics exhibited a relatively uniform level of specific coverage and height; this homogeneity is probably due to their belonging to the same genus.

Table 1. Total cover (TC) of the two forage mixtures (SuBuCh and BuSnBa), and cover (%) and height (cm) of all the species in the mixtures. Values are mean ± SEM (standard error of mean).

	First Measurement			Second Measurement			Third Measurement		
Forage Mixture	**TC (%)**	**Cover (%)**	**Height (cm)**	**TC (%)**	**Cover (%)**	**Height (cm)**	**TC (%)**	**Cover (%)**	**Height (cm)**
SuBuCh	99 ± 0.6			91 ± 3.8			88 ± 2.6		
Sulla		37 ± 2.6	86 ± 5.2		40 ± 5.4	75 ± 10.4		39 ± 3.5	/
Burr medic		47 ± 2.5	44 ± 6.4		33 ± 3.5	37 ± 4.6		22 ± 2.6	/
Chicory		6 ± 0.8	27 ± 4.4		9 ± 1.8	12 ± 1.8		5 ± 1	/
Weeds		9 ± 1.5			9 ± 1.8			22 ± 3.4	
BuSnBa	94 ± 1.3			93 ± 2.5			90 ± 1.2		
Burr medic		2 ± 2.5	38 ± 6.3		25 ± 1.8	34 ± 1.5		19 ± 0.9	/
Snail medic		24 ± 2.4	35 ± 3.8		26 ± 1.5	27 ± 1.2		27 ± 1.7	/
Barrel medic		26 ± 2.4	33 ± 2.8		30 ± 2.8	27 ± 1.1		32 ± 2	/
Weeds		16 ± 2.2			12 ± 3.1			12 ± 1.6	

3.2. Forage Biomass and Composition

In the fields of agronomy, forage production, and animal husbandry, the accurate assessment of pasture herbage availability, obtained with direct and indirect methods [39], plays a fundamental role, as it has direct implications to the sustainable management of forage resources and livestock feeding. The use of Linehan's accumulation factor (f_L) allowed for the estimation of the quantity of forage available for grazing, considering all those interconnected variables that influence forage accumulation: environmental conditions, seasonal and meteorological variations, water supply, and grazing intensity.

Starting from this premise, a comparative analysis of dry matter availability and the overall quantity of residual was conducted between the two forage mixtures, SuBuCh and BuSnBa, revealing no significant differences either in their yields (8221 and 8988 kg ha^{-1}, respectively)or in the residue of the pasture at the end of the grazing period (4103 kg ha^{-1} in SuBuCh and 4658 kg ha^{-1} in BuSnBa) (Table 2). As the grazing period extended into late spring, at the conclusion of the study, significant percentages of senescent plant material were observed in relation to the total residue in both the forage mixtures. Furthermore, the absence of significant differences on GI, with values of 50% in the first mixture and 48% in the second one, suggests that the overall grazing conditions and access to forage resources were similar in both of them. As expected, for both forage sectors used by animals, the total availability of biomass decreased from the beginning to the end of the utilization period, due to animals grazing and, above all, the strong reduction in plant growth due to unfavorable weather conditions, such as high temperatures and the absence of rain (Figure 1). However, a closer examination of forage biomass composition during the trial revealed some interesting observations (Figure 2).

In the SuBuCh mixture, it was observed that sulla exhibited high percentages (37%) of total biomass production thanks to its adaptability to the Mediterranean environment [40,41] (Table 2). Nevertheless, it also underwent a progressive decrease in biomass. This phenomenon underscores the fact that continuous grazing on sulla does not allow sufficient time to accumulate organic material and maximize its production, as it would during a rotational grazing system [42].

Burr medic initially exhibited a small increase in its grazing availability and then decreased, which is likely attributed to the ewes' initial preference for and consumption of sulla. Burr medic initially showed an increase and then decreased, likely due to the fact that, initially, the ewes preferred and consumed sulla. In general, the presence of chicory in terms of quantity was quite low compared to the other species in the mixture. Additionally, it is possible to observe a contrasting trend to previous research works [43,44] for this species, characterized by a progressive reduction in its biomass availability for grazing; indeed, its prevalence remains quite low when considering the overall composition of the mixture.

Table 2. Total forage availability (kg DM ha^{-1}) of the two mixture (SuBuCh and BuSnBa) with their specific composition (%), the residual of forage at the end of the trial (kg DM ha^{-1}), and the grazing intensity (GI).

	Forage Mixtures		
	SuBuCh	**BuSnBa**	**Probabilities**
Total forage availability (kg DM ha^{-1})	8221	8988	<0.05%
Residual (kg DM ha^{-1})	4103 (45%) **	4658 (42%) **	<0.05%
Grazing intensity (%)	50%	48%	<0.05%
SuBuCh mixture			
Sulla (%)	37		
Burr medic (%)	26		
Chicory (%)	5		
Grass weeds (%)	22		
Other weeds (%)	10		
BuSnBa mixture			
Burr medic (%)		22	
Snail medic (%)		26	
Barrel medic (%)		16	
Grass weeds (%)		28	
Other weeds (%)		7	

** Senescent material.

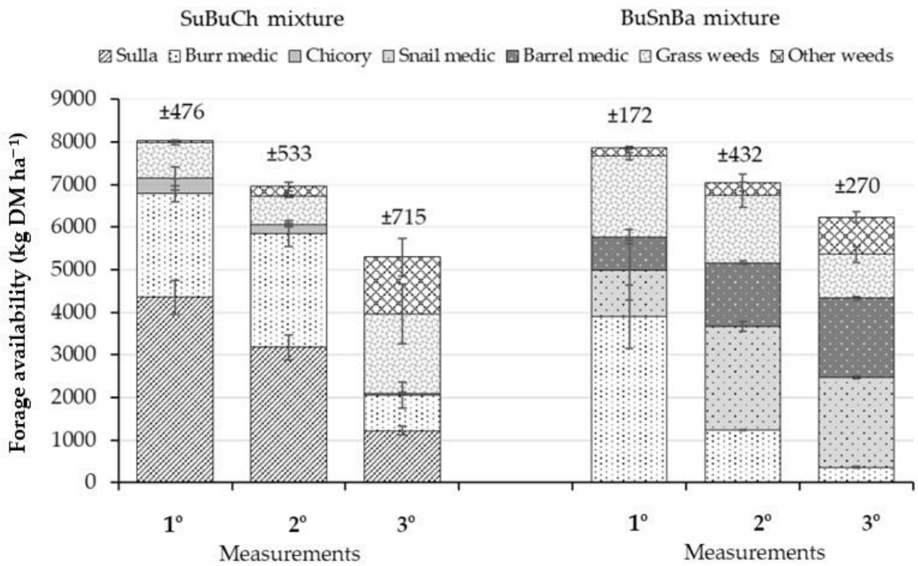

Figure 2. Forage biomass composition (kg DM ha^{-1}) of the two forage mixtures (SuBuCh and BuSnBa) in three different utilizations. Values are mean ± SEM (standard error of mean), while bars represent the SEM for each species.

In BuSnBa, it was possible to observe a decline in the percentage prevalence of burr medic compared to the other annual medics. This trend can be interpreted in light of competitive dynamics among different species. The decrease in biomass of burr medic could be attributed to increased grazing pressure due to the species' high palatability to livestock, due to easier chewing (tender stems/stalks/leaves) and a more favorable taste [45]. In the SuBuCh intercropping, the occurrence of weed species in the available forage was consistently high, especially during the last grazing period. This is likely indicative of the cultivated forage species' greater palatability compared to the spontaneous ones. It can be assumed that the forage crops were more heavily consumed, due to a reduction in their prevalence. Moreover, the grass weeds biomass showed a reduction trend in the BuSnBa mixture compared to SuBuCh that might be attributed to the dietary behavior of ewes when offered a monoculture of legumes. This tendency of choosing non-leguminous components could be associated with the ewes' innate nutritional instincts to diversify their diet. A significant point to note is the increase in the quantity of non-grass weed infestations in both associations compared to the initial assessment. This aspect could be the result of reduced competition from forage species due to grazing.

Regarding the chemical composition of the forage, reported in Table 3, moving from the first to the third assessment, for both forage mixtures used by the animals, a general and rapid deterioration of forage quality can be noted, as evidenced by the increase in dry matter and fibrous fractions (aNDFom, ADFom, and ADL), and by the reduction in CP content. Furthermore, the total herbage on offer varied from the forage ingested by lactating ewes. In both forage mixtures used and for the entire grazing period, the ingested forage was lower in fibre fractions (aNDFom, ADFom, and ADL) and higher in CP, with more noticeable differences even as the quality of the forage offered worsened, confirming the better nutritive quality of the herbage ingested by small ruminants than that of the offered forages. Being unable to consume large quantities of fibrous forage, grazing animals are proficient selectors, preferring more palatable and tender fragments rather than the fibrous parts of plants [46,47]; consequently, they consume more of the leaves which, as is known, have better nutritional characteristics than the stems of the plants.

Table 3. Chemical composition (% DM) of total forage on offer (O) and biomass ingested (I) by ewes in the three measurements carried out during the experiment.

	Measurement	Forage on Offer (O)		Biomass Ingested (I)	
		SuBuCh	**BuSnBa**	**SuBuCh**	**BuSnBa**
Dry matter (%)	I	26.7	28.0	26.56	27.5
	II	33.1	37.6	28.60	36.35
	III	39.9	44.4	33.40	38.72
Crude protein (%)	I	16.74	19.48	21.78	20.01
	II	15.52	16.17	19.82	19.45
	III	10.93	7.42	14.50	10.05
Ether extract (%)	I	3.97	3.71	3.35	3.79
	II	3.25	3.35	3.29	3.72
	III	2.29	1.42	3.01	2.33
Ash (%)	I	12.93	9.68	14.09	9.50
	II	14.15	9.99	15.15	8.73
	III	13.45	10.25	14.50	9.22
aNDFom (%)	I	47.34	46.17	26.69	35.62
	II	49.81	51.15	27.82	43.85
	III	54.38	68.61	33.50	52.84
ADFom (%)	I	34.53	34.51	20.99	28.16
	II	42.51	41.37	23.03	33.15
	III	43.85	46.71	25.60	39.13
ADL (%)	I	5.42	4.94	4.38	4.54
	II	8.16	7.76	4.61	6.42
	III	11.03	8.77	6.02	7.23
Non-structural carbohydrates (%)	I	20.25	24.28	34.09	31.08
	II	16.05	16.03	33.92	24.26
	III	18.96	12.30	34.49	25.86

Measurements: I, 16 May; II, 27 May; III, 10 June.

3.3. Ewes' Milk Production, Live Weight, and BCS

During the experiment, due to the qualitative and quantitative decline in pasture conditions and also the progression of lactation, there was a gradual decrease in milk yield which was less pronounced for SuBuCh (1542, 1462, and 999 g/d on day 1, 2, and 3) than for the BuSnBa group (1306, 1208, and 946 g/d on day 1, 2, and 3); consequently, the SuBuCh ewes produced on average a greater amount of milk, equal to 181 g/day, in comparison with the BuSnBa group (Table 4). This result is probably due to the contribution of sulla forage in the SuBuCh mixture which, as previously seen (Figure 2), was mostly ingested by grazing animals during the experiment. The obtained results confirm the positive effects of fresh sulla forage revealed in previous studies [9,10,40,48]. The milk produced by SuBuCh ewes was also characterized by higher protein and casein percentages, a lower urea content, and better curd firmness measured with a Formagraph (Table 4). Also in this case, this result is attributable to the presence of sulla forage in the SuBuCh mixture, which was provided with an adequate content of condensed tannins able to cause positive effects on the efficiency of use of feed proteins at the rumen level, thereby increasing milk protein and casein content due to the greater allowance of amino acids available at the udder level [49]. Furthermore, the greater presence of more degradable non-fibrous carbohydrates in the ingested biomass of the SuBuCh group probably also contributed to the improvement in milk quality, which improved the balance between energy and nitrogen at the ruminal level by favoring the synthesis of microbial protein [50]. The higher casein and lower urea content of SuBuCh ewes influenced the milk clotting ability measured with a Formagraph, producing firmer curds (a_{30} and a_{2r}, mm). Furthermore, at the end of the grazing period, the ewes of the SuBuCh group, despite having produced a greater quantity of milk, showed a similar reduction in live weight compared to the BuSnBa ewes.

Table 4. Effect of grazed forage mixtures on individual milk yield and composition, coagulation properties, and liveweight and BCS variation.

	SuBuCh	BuSnBa	SEM	Probabilities *p*<
Milk yield (g d^{-1})	1334	1153	52.45	0.0178
Fat (%)	6.17	6.11	0.116	0.7242
Protein (%)	5.17	4.85	0.072	0.0022
Casein (%)	4.02	3.73	0.062	0.0016
Urea (mg dL^{-1})	37.70	45.38	1.379	0.0002
Lactose (%)	4.59	4.67	0.023	0.1187
Somatic cells (log10 n mL^{-1})	5.45	5.17	0.115	0.0910
Coagulation time (r, min)	18.0	17.4	0.457	0.3585
Curd firming time (k_{20}, min)	1.53	1.67	0.095	0.2988
Curd firmness (a_{30}, mm)	57.5	51.2	1.231	0.0007
Curd firmness (a_{2r}, mm)	56.6	49.9	1.561	0.0040
Initial live weight (kg)	49.3	49.0	1.234	0.4607
Initial BCS	3.00	3.00	0.075	0.4545
Weight difference *	−2.05	−3.55	0.353	0.1389
BCS difference *	−0.10	−0.15	0.041	0.3923

SuBuCh = sulla, burr medic, and chicory; BuSnBa = barrel medic, snail medic, and burr medic. SEM = standard error of mean. * Weight and BCS (Body Condition Score) variation from start to finish of the experiment.

4. Conclusions

This study provided an overview of the importance of understanding the complex dynamics of forage species and grazing patterns, with a specific focus on the production of two forage mixtures and their effects on ewes' milk production under climate change conditions. Although the initial production levels were suitable, both forage mixtures showed a gradual deterioration in forage quality throughout the study, characterized by an increase in dry matter and fibrous fractions and a decrease in crude protein content. Moreover, significant amounts of senescent plant material were observed at the end of the grazing period. Ewes demonstrated the ability to discriminate between different parts of plants and selected those that they found tastier or more nutritious. Changes in pasture quality influenced ewes' milk production, resulting in milk with a higher percentage of protein and casein and a lower urea content, attributable to the presence of sulla in the sulla, burr medic, and chicory mixture. The preliminary one-year results obtained seem to highlight the promising role of this intercropping mixture, suggesting a potential quantitative and qualitative improvement in pasture resources and the productive performance of grazing ewes in a semi-arid Mediterranean environment during hot climate conditions. These findings would be highly significant for optimizing the sustainable management of forage resources and animal nutrition. Despite this, the productive performance of intercropping for periods longer than one year remains unexplored. Therefore, future activities will involve the implementation of a long-term trial.

Author Contributions: Conceptualization, G.D.M. and A.D.G.; methodology, G.D.M., A.D.G., and A.B.; software, M.P. (Marialetizia Ponte) and R.G.; validation, M.P. (Marianna Pipi) and G.M.; formal analysis, L.D., S.P.; investigation, M.P. (Marialetizia Ponte), R.G., M.P. (Marianna Pipi), G.M., L.D., and S.P.; writing—original draft preparation, L.D., S.P., G.D.M., A.D.G. and A.B.; supervision, G.D.M. and A.D.G.; funding acquisition, G.D.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by "Ministero dell'agricoltura, della sovranità alimentare e delle foreste", "SFEFA" project, grant number B79C21000370001; The APC was funded by UNIPA-FFR 2023.

Data Availability Statement: The data presented in this study are available on request from the corresponding authors.

Acknowledgments: The authors would like to thank ESA (Ente Sviluppo Agricolo) for organizational support, and Domenico Munì and Luigi Madonia for technical assistance. Additionally, the authors express their gratitude to Roberto Marceddu and Vincenzo Maria Grimaldi for their technical field support.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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