agronomy

MDPI

Article

How Long Should Grasses of South American Campos Grasslands Rest for Stockpiling Forage?

Marlon Risso Barbosa [1], Martín Durante [1,2], Luciana Marin [3], Fiorella Cazzuli [1], Fernando Luiz Ferreira de Quadros [3,†], Rob M. Dixon [4], Franklin Riet Correa [5] and Martin Jaurena [1,*]

1 Instituto Nacional de Investigación Agropecuaria (INIA), Programa Pasturas y Forrajes, Estación Experimental INIA Tacuarembó, Tacuarembó 45000, Uruguay; marlonrb_1@hotmail.com (M.R.B.); durante.martin@inta.gob.ar (M.D.); fcazzuli@inia.org.uy (F.C.)
2 Instituto Nacional de Tecnología Agropecuaria (INTA), Estación Experimental Agropecuaria Concepción del Uruguay, Concepción del Uruguay 3260, Argentina
3 Laboratório de Ecologia de Pastagens Naturais (LEPAN), Departamento de Zootecnia, Universidade Federal de Santa Maria (UFSM), Santa Maria 97105-900, Brazil; lumarin.zoot@gmail.com (L.M.)
4 Queensland Alliance for Agriculture and Food Innovation (QAAFI), Centre for Animal Science, The University of Queensland, St. Lucia, QLD 4072, Australia; r.dixon2@uq.edu.au
5 Escola de Medicina Veterinária e Zootecnia, Universidade Federal da Bahia, Salvador 49170-110, Brazil; franklinrietcorrea@gmail.com
* Correspondence: mjaurena@inia.org.uy
† Fernando Luiz Ferreira de Quadros has passed away.

Abstract: Stockpiling forage (i.e., deferring grazing) is one way to provide forage for livestock during intervals of low pasture growth, but there are trade-offs as nutrient content declines with increasing forage maturity. Phosphorous (P) concentration, crude protein (CP) content and organic matter digestibility (OMD) were evaluated in two C3 and four C4 grasses native to the South American Campos grasslands. These were: *Bromus auleticus* (BROAUL) and *Nasella neessiana* (NASNEE) as C3 grasses and *Andropogon lateralis* (ANDLAT), *Mnesithea selloana* (MNESEL), *Paspalum dilatatum* (PASDIL), and *Paspalum notatum* (PASNOT) as C4 grasses. The grasses were grown in pots during five stockpiling periods (450, 900, 1350, 1800 and 2250 degree days, approximately 20, 40, 60, 80 and 100 days). As the forage deferment increased, the nutritional value decreased more in C4 than in C3 grasses. Short rest periods (approximately 40 days) are recommended for PASDIL and MNESEL, and medium rest periods (approximately 80 days) for ANDLAT and PASNOT. However, the C3 grasses BROAU and NASNEE maintained high P and CP concentrations and may be the most appropriate option for long rest periods (≥100 days). This information is important to manage different Campos grassland communities for the optimal rest period according to the dominant species.

Keywords: forage deferment; native grasses; phosphorus; protein; digestibility; *Bromus auleticus*; *Nasella neessiana*; *Andropogon lateralis*; *Mnesithea selloana*; *Paspalum dilatatum*; *Paspalum notatum*

Citation: Risso Barbosa, M.; Durante, M.; Marin, L.; Cazzuli, F.; Ferreira de Quadros, F.L.; Dixon, R.M.; Riet Correa, F.; Jaurena, M. How Long Should Grasses of South American Campos Grasslands Rest for Stockpiling Forage?. *Agronomy* **2024**, *14*, 1790. https://doi.org/10.3390/agronomy14081790

Academic Editor: Marisol Berti

Received: 30 June 2024
Revised: 2 August 2024
Accepted: 11 August 2024
Published: 14 August 2024

1. Introduction

Native grasslands are very large ecosystems that occupy 40% of the Earth's surface [1,2]. The dominant form of land use of native grasslands in many parts of the world is through extensive grazing by livestock. In many such systems, livestock graze pasture grows on soils with very low phosphorus (P) contents [3]. For example, in the Centre-East region of South America, native grasslands include the Pampa biome—locally known as "Campos"—which occupies part of Brazil (between 24° S and 35° S latitudes), Uruguay, North-East Argentine and part of Paraguay, with a total surface of approximately 500,000 km^2 [1,4]. These grasslands are used for grazing sheep and cattle [5], and there are opportunities and challenges for the preservation of biodiversity while maintaining or improving livestock productivity. They are dominated by C3 and C4 perennial grass species [6] but with high plant biodiversity with 4864 plant species having been identified [7]. Livestock production systems based on grazing native grasslands must combine a range of management tools and techniques to overcome low forage productivity and quality that can occur during some seasons of the year [4].

A key issue for appropriate grazing management is to control the animal stocking rates in relation to available forage. This is a low-cost approach but with major implications for both forage and animal production [8,9]. Specifically, excluding certain areas from grazing to favor grass growth and increase standing biomass helps to adjust the forage on offer. Grass growth is determined by the accumulation of the energy in the plant and the accumulated growing degree days (GDD) over time is a thermal-based indicator for grass growth [10]. Deferment [11] or "stockpiling" is a common practice and is defined as the postponement or delay of grazing or harvesting to achieve a specific management objective. This technique is generally used to maintain certain grazing intensity during periods of rapid growth and accumulate a reserve of standing biomass for subsequent use during forage deficit periods [12] and, more specifically, to mitigate the effects of seasonal droughts [13] or harsh winters [14].

High climatic variability, particularly in rainfall, in the Campos region [15] increases the risk of excess or lack of standing grass. Optimal grassland management requires farmer decisions to adjust the forage offered to livestock. Forage accumulation in specialized areas such as small paddocks, as opposed to accumulating forage excess throughout all the paddocks, may help reduce energy losses during grazing activities (e.g., due to trampling), allow native plants to seed, and facilitate precision management of the native grassland communities. Grazing deferment is a simple and low-cost technique that enables farmers to cope with the effects of climatic variability since the forage accumulated during the deferment period can supply nutrients for ruminants when needed, especially for key subgroups of animals in the herd and thus enhance animal production [16]. There is usually an inverse relationship between quantity and quality of accumulated standing forage since as the plants grow and mature, and herbage is accumulated, forage quality decreases due to the increase of stem and the presence of dead tissue at the base of tillers [17]. The study of Andrade et al. [18] provides a good example of how to define the best deferment period according to the nutritional value of different cultivated pastures. In this way, farmers have the possibility to manage the forage quantity/quality trade-offs according to their production objectives. These could be achieved through the exclusion of some paddocks in the grassland communities from grazing and later reassuming grazing activities as needed. However, there is little information to decide the optimal deferment period for different communities dominated by C3 or C4 grass species of South America Campos native grasslands, and under various sets of circumstances.

Available energy (usually measured as digestible energy or metabolizable energy), crude protein (CP) and phosphorus (P) are usually the key nutritional parameters to assess the value of deferred or stockpiled pastures for animal production [3,9,19]. P deficiency often occurs in ruminants grazing native Campos grasslands due to low soil and forage P contents [20]. There is an inverse relationship between the quantity and quality of the accumulated standing forage, and this will determine the optimal grazing rest period to minimize forage nutritional deficiencies. Understanding the responses of accumulated forages under various circumstances in the dominant grass species in Campos grasslands is needed to provide guidance on the optimum deferment periods where energy, protein or P are expected to be the most limiting nutrients [17].

The objective of this study was to evaluate the variation of forage energy, protein and P content in several C3 and C4 grass species often dominant in Campos grasslands as they accumulated biomass through increasing forage deferment periods and to determine in which situations P, CP and energy are likely to be first-limiting as nutrients. Our hypothesis was that some grasses would present a slower decline in these key nutrients as deferment periods increase.

2. Materials and Methods

The experiment was carried out at the Tacuarembó experimental station of the Instituto Nacional de Investigación Agropecuaria (INIA Uruguay), 31°44′18.5″ S; 55°58′47.9″ W, between 8 November 2019 and 14 February 2020. The experiment was a factorial design evaluating six native grass species and five deferment periods, which were grown in open field conditions. The grass species were collected directly from paddocks of basaltic native grasslands: two winter C3 species (*Bromus auleticus*, BROAUL; *Nasella neessiana*, NASNEE) and four summer C4 species (*Andropogon lateralis*, ANDLAT; *Mnesithea selloana*, MNESEL; *Paspalum dilatatum*, PASDIL; *Paspalum notatum*, PASNOT). These species were selected specifically because they are very frequent in the "Campos" Native Grasslands that were characterized by Cruz et al. [6]. A map of the Campos grasslands of South America could be seen in Jaurena et al. (2021) [4].

The substrate used for the culture of the plants is described in Annex 1. Each grass species was established into pots of 12 L (an upper and lower diameter of 30 cm and 20 cm, respectively, and a height of 25 cm) through vegetative propagules established two months before the start of the experiment. A similar set of tillers of each species was transplanted into the central part of individual pots (the center of the pot with approximately 15 cm in diameter). Each pot was fertilized by top-dressing with urea and 7–40 NP that provided 40 kg/ha of N and 10 kg/ha of P_20_5. Each pot was irrigated daily from the soil surface to maintain the soil water content at the minimum level of 70% of the maximum soil water-holding capacity. Thermal sums were calculated by adding degree-days considering mean daily temperatures and a base temperature of 0 °C. The thermal sum began on 8 November 2019 (day 0) when all pots were completely harvested above 5 cm. After that, every 450-degree days (approximately 20 days), the corresponding pots were completely harvested above 5 cm on reaching the thermal accumulation of their respective treatments.

Treatments were applied sequentially, and they all finished on the same date (14 February 2020) when all pots were completely harvested above 5 cm. A completely randomized design was used, in which the five deferment treatments were applied (450, 900, 1350, 1800 and 2250 degree days or approximately 20, 40, 60, 80 and 100 days) in the six grass species in six replicates in a randomized complete block design (180 pots).

The harvested forage samples were manually divided into three morphological components: green leaves, stem and dead tissue. Samples were oven-dried at 60 °C until constant weight to determine the DM yield of components and then the component was bulked into their experimental unit (pot) for subsequent analysis. The total plant DM in the pot was calculated. Each bulked sample (n = 180) was ground using a Wiley mill to pass a 1 mm screen. Phosphorous was determined by sulfuric acid digestion (98% H_2SO_4 and a dilution of 6% after digestion with deionized water) using 200 mg subsamples and then colorimetry, according to Murphy and Riley [21]. Forage CP content was determined with the Dumas method [22] using an elemental analyzer CHN 682 (LECO, St. Joseph, MI, USA) and then multiplying the N values by 6.25 according to AOAC [23]. In situ dry matter digestibility was estimated using a 1 g subsample of each sample, which was placed into polyamide bags of 5 × 5 cm (40 μ porosity) and incubated in the rumen of a fistulated cow grazing C4 grasses for 48 h according to Kosloski et al. [24]. Following extraction from the rumen, the bags were washed with tap water and oven-dried at 110 °C for 8 h, weighed, and DM disappearance calculated. Organic matter content was determined on the samples after incineration at 600 °C for 3 h, and subsequently, organic matter digestibility (OMD) was calculated.

The phosphorous concentration of the species in different periods of deferment was subjected to an analysis of variance using SYSTAT® software, version 12. In this analysis, a mixed model was used in which grass species, deferment treatments and their interactions were used as fixed effects and the replicate as a random effect, considering heterogeneous variances of species. Means of significant effects were considered according to LSD Fischer ($p < 0.05$). Additionally, Pearson correlation coefficients were examined between forage P and thermal sum (°C), green leaf (%), stem (%), dead tissue content (%) and accumulated forage mass (g pot^{-1}) using SYSTAT® software [25].

The temperatures were as expected for the given period of the year, with maximum values of 29 °C and a minimum of 15 °C in February 2020. Maximum, minimum and average (24 h) air temperature by month during the trial is presented in Figure 1.

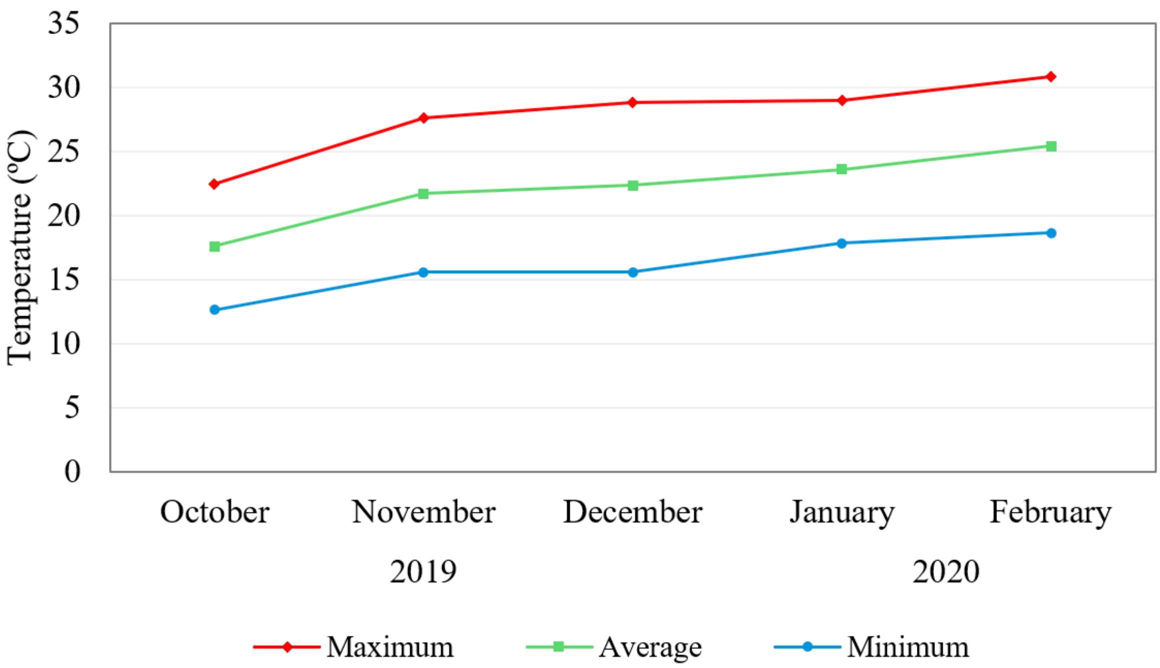

Figure 1. Minimum, maximum, and average air temperature during a trial in which six native grassland species were harvested at different degree-day accumulation.

3. Results

A statistical interaction between species and deferment period was detected ($p < 0.05$) on forage P (Figure 2). C3 grasses always had higher P concentrations than C4 grasses. In intermediate deferment periods (900 and 1350 thermal degree-days), BROAU presented the highest P (Figure 2A), while in the NASNEE, there were no differences in P across the deferment periods (Figure 2B). All the C4 grasses demonstrated declining forage P concentrations through the accumulation periods, but there was evidence of two different patterns. From 450 to 900 thermal-degree days, there was a similar decline in all grasses. However, from 1350 to 2250-degree days, ANDLAT (Figure 2C) and PASNOT (Figure 2D) tended to plateau, whereas MNESEL and PASDIL (Figure 2E,F) continued to decline in P concentrations.

C4 grass P concentrations showed strong negative correlations with both forage accumulation and thermal sums (duration of deferment period), as well as strong positive correlations with green leaf content for PASNOT and PASDIL (Table 1). In contrast, C3 species did not present any strong correlation between forage P concentrations and thermal sums or the sward components.

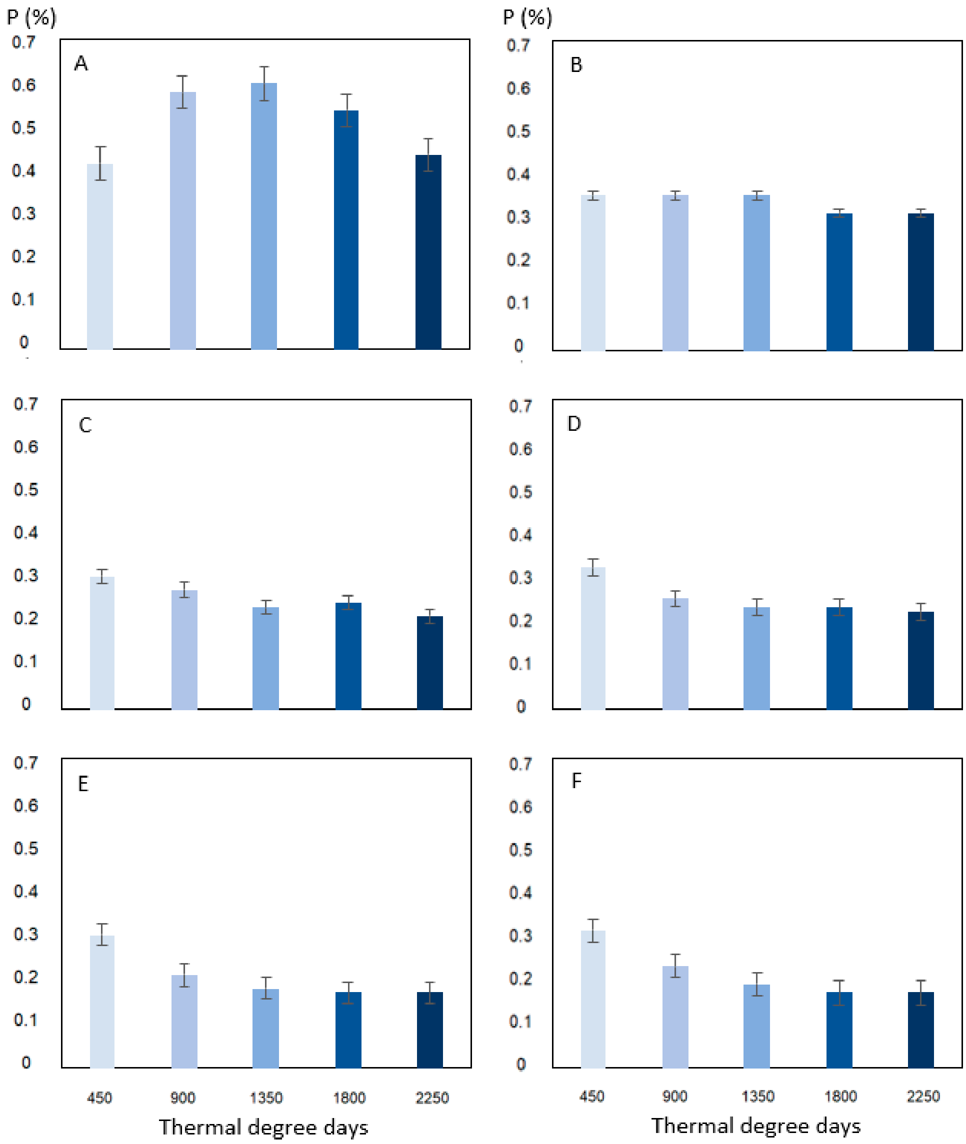

Figure 2. Phosphorus forage (P) content (%) of six native grass species in relation to the accumulation of thermal sum from 450 to 2250 degree days (°C-days). (**A**) *Bromus auleticus*; (**B**) *Nasella neessiana*; (**C**) *Andropogon lateralis*; (**D**) *Paspalum notatum*; (**E**) *Mnesithea selloana*; and (**F**) *Paspalum dilatatum*. Bars represent the standard error means (SEM).

C3 grasses always had greater CP and P than the C4 grasses through the forage accumulation treatments (Figure 3). In these C3 grasses, P tended to remain constant with time, while CP declined similarly in the BROAUL and NASNEE. (Figure 3A,B). Additionally, BROAUL had lower CP/P ratio values (approximately 27) than NASNEE (45–50), but in both grasses, the P and CP were sufficient for animals in slow to moderate growth (>0.2% P and 7% CP). A similar pattern was observed in the change of forage P concentration and CP for C4 species throughout the accumulation period. P and CP were highest in the shortest growth interval (450-degree days) and then declined with time. All the C4 species began with similar forage P concentration (around 0.30%); the ANDLAT and PASNOT (Figure 3C,D) had greater P and CP (10 to 14%CP) by the end of the accumulation period than PASDIL and MNESEL (Figure 3E,F) (CP 8% vs. < 7%; P% > 0.2% vs. < 0.2%). On the other hand, PASDIL, MNESEL and PASNOT presented similar declining trends for both nutrients, while ANDLAT presented the greatest difference between the initial and final CP contents (15% vs. 7% CP, respectively). C4 grasses had similar CP/P ratios throughout the deferment treatments (CP%/P% 30–40), except for ANDLAT, which commenced with a CP/P ratio = 48 and ended with a CP/P ratio = 34.

Table 1. Pearson correlation coefficients of six native grass species between their forage components throughout different forage thermal sums (TS, 450 to 2250 degree day) considering base temperature = 0 °C. * $p < 0.05$. Phosphorous concentration (P); thermal sum (TS); leaves percentage (L); stem percentage (S); dead tissue percentage (D); forage mass (FM).

	B. auleticus					***N. neesiana***				
	TS	L	S	D	FM	TS	L	S	D	FM
P	0.01	0.09	−0.11	−0.06	0.06	−0.32	0.14	−0.19	−0.06	−0.6
TS		−0.88 *	0.26	0.91 *	0.94 *		−0.70 *	0.27	0.65	0.72 *
S			−0.52	−0.98 *	−0.83 *			−0.39	−0.92 *	−0.38
D				0.35	0.17				0.01	0.26
FM					0.88 *					0.26
	A. laterallis					***P. notatum***				
	TS	L	S	D	FM	TS	L	S	D	FM
P	−0.74 *	0.6	−0.39	−0.43	−0.81 *	−0.72 *	0.88 *	−0.71 *	−0.39	−0.80 *
TS		−0.53	0.26	0.67	0.92 *		−0.54	0.27	0.42	0.84 *
S			−0.91 *	−0.24	−0.55			−0.73 *	−0.54	−0.76 *
D				−0.1	0.3				−0.17	0.47
FM					0.56					0.51
	M. selloana					***P. dilatatum***				
	TS	L	S	D	FM	TS	L	S	D	FM
P	−0.85 *	0.61	−0.05	−0.59	−0.81 *	−0.82 *	0.74 *	−0.11	−0.48	−0.80 *
TS		−0.46	−0.23	0.75 *	0.83 *		−0.78 *	−0.16	0.71 *	0.86 *
S			−0.62	−0.39	−0.59			−0.19	−0.65	−0.79 *
D				−0.47	−0.07				−0.59	−0.01
FM					0.61					0.61

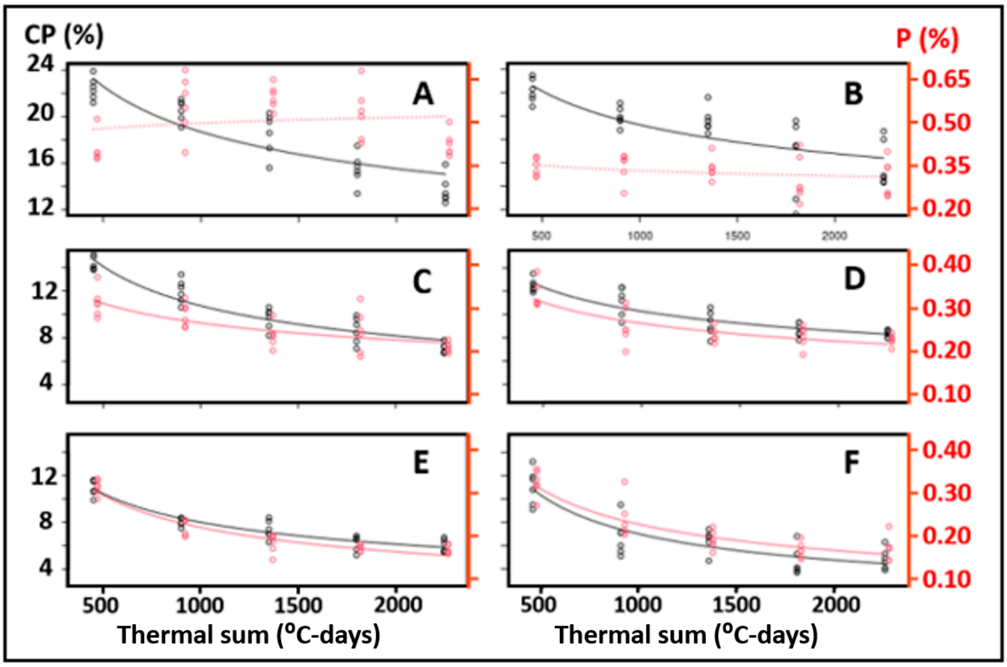

Figure 3. On the right, forage phosphorous content (%P, red line) and on the left, crude protein content (%CP, black line) of six native grassland species by different forage thermal sum ((TS) as °C-days) considering base temperature = 0 °C. (**A**) *Bromus auleticus* %P = 0.346 × $TS^{0.056}$ R^2 = 0.03,

CP = 136.4 × $TS^{-0.304}$ R^2 = 0.77; (**B**) *Nasella neessiana* %P = 0.592 × $TS^{-0.081}$ R^2 = 0.08, CP = 80.2 × $TS^{-0.222}$ R^2 = 0.58; (**C**) *Andropogon lateralis* %P = 1.148 × $TS^{-0.217}$ R^2 = 0.55, CP = 160.3 × $TS^{-0.392}$ R^2 = 0.88; (**D**) *Paspalum notatum* %P = 1.294 × $TS^{-0.235}$ R^2 = 0.66, CP = 62.8 × $TS^{-0.262}$ R^2 = 0.79; (**E**) *Mnesithea selloana* %P = 3.417 × $TS^{-0.401}$ R^2 = 0.90, CP = 113.6 × $TS^{-0.384}$ R^2 = 0.90; and (**F**) *Paspalum dilatatum* %P = 4.018 × $TS^{-0.421}$ R^2 = 0.80, CP = 317.5 × $TS^{-0.553}$ R^2 = 0.77.

The organic matter digestibility (OMD%) of all species was high at the start of the experiment for both C3 and C4 grasses ranging from 68–74% and declining at various rates depending on species (Figure 4). In all species, the OMD% declined more slowly than CP (Figure 4). There was a small decrease in BROAUL and PASNOT, a constant-medium decrease in NASNEE and ANDLAT, and a large decrease in PASDIL and MNESEL through the deferment periods. At the conclusion of the experiment, the OMD% values of the species were 70, 67, 59, 65, 67 and 55% for A, B, C, D, E and F, respectively. The changes in the OMD/P ratios in the six species through the deferment periods could be described as two different patterns. First, the OMD/P ratio did not change markedly in the C3 grasses BROAUL and NASNEE and the C4 grass ANDLAT, with ratios of 170, 200 and 260 OMD%/P%, respectively. Second, in the C4 grasses PASNOT, PASDIL and MNESEL, this ratio increased by approx. 50%, averaging 210 and 320 OMD/P at 450 and 2250 thermal degree-days, respectively.

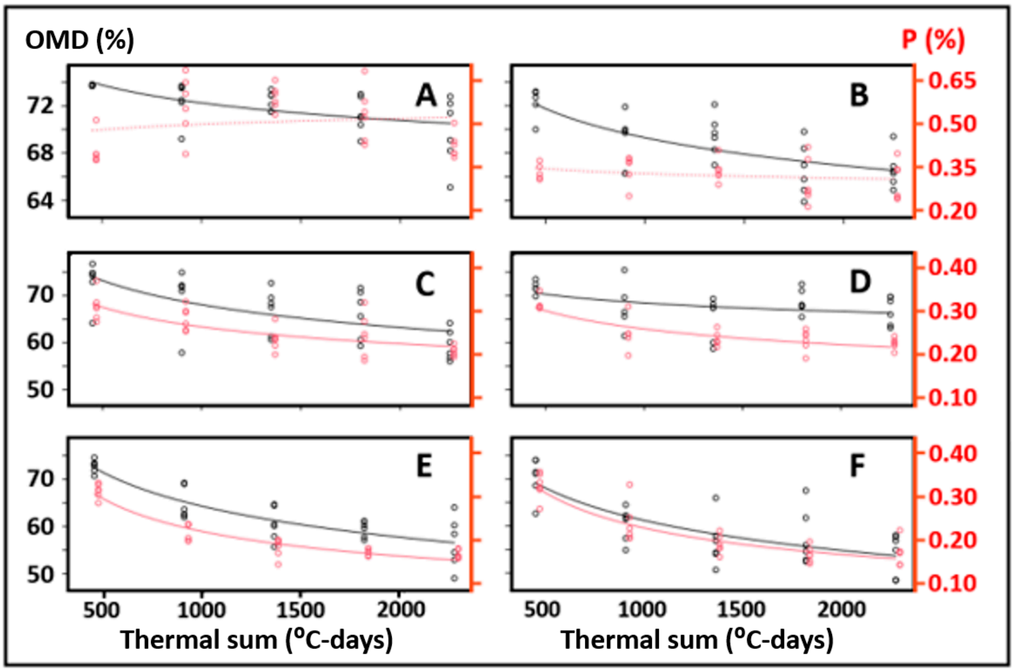

Figure 4. Forage phosphorous content (%P, red line) and digestibility of organic matter (%OMD, black line) of six native grassland species by different forage thermal sum (°C-days) considering base temperature = 0 °C. (**A**) *Bromus auleticus* %P = 0.346 × $TS^{0.056}$ R^2 = 0.03, Dig = 88.8 × $TS^{-0.304}$ R^2 = 0.36; (**B**) *Nasella neessiana* %P = 0.592 × $TS^{-0.081}$ R^2 = 0.08, Dig = 88.8 × $TS^{-0.030}$ R^2 = 0.52; (**C**) *Andropogon lateralis* %P = 1.148 × $TS^{-0.217}$ R^2 = 0.55, Dig = 117.0 × $TS^{-0.084}$ R^2 = 0.43; (**D**) *Paspalum notatum* %P = 1.294 × $TS^{-0.235}$ R^2 = 0.66, Dig = 81.5 × $TS^{-0.031}$ R^2 = 0.14; (**E**) *Mnesithea selloana* %P = 3.417 × $TS^{-0.401}$ R^2 = 0.90, Dig = 144.0 × $TS^{-0.121}$ R^2 = 0.76; and (**F**) *Paspalum dilatatum* %P = 4.018 × $TS^{-0.421}$ R^2 = 0.80, Dig = 138.9 × $TS^{-0.121}$ R^2 = 0.59.

4. Discussion

The deferment accumulation period had different effects on the nutritive value of the grasses. Specifically, across all species, the greatest decrease in nutritive value through the accumulation periods was in CP (42%), followed by P (21%), and lastly in OMD (10%). The patterns of decrease in nutritional value were similar to those reported by McIvor [26] in seasonally dry tropical northeast Australia when forage that had accumulated from the beginning to the end of the rainy season reduced by 41%, 26% and 7% for CP, P and OMD, respectively. The duration of the rest period affected the ratio of P/CP and P/energy content of the forage. However, if using minimum values for the requirement of CP (7%CP) and P (0.2%P), then only BROAUL, NASNEE, ANDLAT, and PASNOT fell below minimum requirements at 100 days of forage deferment. The ratio of various nutrients is important but so are the actual values to determine the limiting nutrient.

The rate of decline in the nutritional value of forage as the rest period increased was much slower in C3 than in C4 grasses. The values of CP, P or OMD were the same or higher in C3 grasses rested for 2250-degree days (approximately 100 days) compared to C4 grasses rested for only 450-degree days (approximately 20 days). The decrease in the nutritional value of C3 grasses when increasing the rest period from 450 to 2250-degree days was 38, 3 and 7%, but in C4 grasses, they were 47, 39 and 14, for CP, P and OMD, respectively. McDowell [27] suggested that mineral supplementation is, in general, less important than energy or protein supplementation, where the latter is deficient or limiting for animal growth. The rapid decrease of C4 grasses' nutritional value (as represented by OMD, CP and P) can be related to its advancing maturity, lower proportions of green leaves, and greater dilution of minerals as plant growth has developed significantly. However, in C3 grasses there was less DM growth and hence lesser dilution of the nutrients in forage.

These results suggest that only when C4 grasses are dominant in native grasslands and accumulating forage of high nutritional quality are supplements of protein and phosphorus likely to lead to responses in livestock. The N/P ratios in the present experiment were 5.5–8.7 in C3 grasses and 5.5–6.4 in C4 grasses did not exceed the ratio of 10:1 suggested by McIvor [28] as a minimum threshold for response in livestock. In addition, the CP/MJ ME decreased slowly during the accumulation period, but only in the C4 grasses PASDIL and MNESEL was it reduced to 6.1, lower than the CP/MJ ME ratio of 7 suggested by Dixon et al. [29] as a severe crude protein deficit. Specifically, the duration of the rest period and the type of C4 grasses provide opportunities to analyze the possible responses to crude protein, P or energy supplements in Campos grasslands.

P content declined with greater accumulation periods, particularly on C4 species, which were rapidly growing and maturing. Three different patterns of P content evolution throughout the accumulation period were observed. The first pattern was observed for C3 grass species, which presented no relevant changes regardless of the forage accumulation period of 100 days. The second pattern was found in ANDLAT and PASNOT, which showed a decline of approximately 30% of their initial value which could be differed up to 80 days. The third pattern was observed in PASDIL and MNESEL, where P content declined by approximately half their initial value which could be differed only to 40 days. Grings et al. [30] have argued that the forage live tissues of plants begin with high P content, and then these levels decrease as growth evolves and tissues mature. This was consistent with the slowing of DM growth in the C4 grasses but not in the C3 grasses in the present study. Regardless, although this experiment was not conducted under grazing, the results contribute new information to suggest the likelihood of responses to supplementary phosphorus and the relation with protein and energy for the different native species and accumulated forage from spring to summer.

Despite the functional plant type, C3 grass species tend to accumulate less forage DM, resulting in a simpler plant structure, less fibrous tissue, and more leaf that comprises the component of the sward with generally the greatest concentrations of nutrients [17]. Both C3 species, but most especially BROAU, lost both CP and OMD (from 20% to 12% Figure 3) as the accumulation period advanced, yet P concentration remained virtually unchanged. In Campos grasslands with soil P deficiency, the use of paddocks dominated with C3 grasses, or their introduction by overseeding, could be used to stockpile forage for animals with higher phosphorus demand.

Forage P content and animal P supplementation cannot be considered in isolation from the CP and OMD of the forages. The CP of all grass species evaluated in this study were similar to those values reported in the literature, especially in these species of the Campos grasslands [31–33]. It is important to highlight that almost all forage deferments had CP contents of at least 6% CP, the exceptions being for MNESEL and PASDIL at long accumulation periods. This is the minimum diet protein for proper rumen function of animals in maintenance or low levels of production [34,35]. This reinforces the concept that the native Campos grasslands have a capacity for producing adequate quality stockpiled forage, although the length of the deferment needs to be considered in relation to the nutrient quality and the amount of DM required.

The leaf is the morphological plant component with the greatest nutrient concentration [17,36]. Coincidentally, all the C4 species, particularly PANOT and PASDIL, presented a strong correlation between the green leaf percentage and P content. In addition, stem percentage and P concentration presented a strong negative correlation, especially in PASNOT. This is explained by the fact that stems (lower quality components) increase their proportion as accumulation time increases, thus decreasing overall P content. Since the accumulation period took place during summer, the individual grasses entered a senescent state; this was confirmed by a strong and negative correlation between green leaf and dead tissue content.

CP and OMD behaved similarly, always being greatest at the shortest accumulation periods (450-degree days). OMD values were similar to those reported by Heringer and Jacques [32] and Azambuja et al. [37] in native grasslands during spring and summer. According to Hacker and Minson [38], the OMD drop throughout the accumulation period could be explained by the plant's phenologic evolution in terms of the increase in the cell wall and its lignification. Similarly, Lemaire and Belanger [17] reported a decrease in OMD and CP content throughout the development and growth of plants, while Insua et al. [39] identified a linear decline in digestibility with an increase in tall fescue leaf plant height. Thus, when planning a forage deferment in Campos grasslands dominated by C4 grasses, the decision as to which time to start grazing must be considered to avoid long accumulation rest periods in swards dominated by MNESEL and PASDIL.

When we analyzed the relative nutritional deficit as proposed by Baudracco et al. [40] we found different situations according to species and the thermal sum accumulation. First, BROAU always exceeded minimum P content with respect to the relative requirements of OMD and CP [41]; therefore, it could be an excellent option as a P supplement by direct grazing of long deferment periods. On the other hand, the other C3 grass, NASNEE, exhibited more balanced PC/P and OMD/P ratios with respect to the requirements of young cattle. C4 species, despite their lower P and CP contents, presented nutritional values in terms of CP/P and OMD/P ratios, and actual CP and P contents were more suitable for lighter calves using short periods of deferment from grazing. Only in ANDLAT was a long deferment period suitable.

The information obtained in this study may be used to identify paddocks for stockpiling forage on livestock farms of the Campos grasslands. However, the fact that the plants were grown in pots with a single substrate was inevitably associated with limitations. First, across the Campos grasslands, there is wide variation in the soils and in their available P and N that will have large effects on forage CP and P concentrations. The present study can, at best, provide only a broad picture. Second, selective grazing by livestock in all grazing systems, but especially in the heterogenous Campos grasslands, results in diets that do not necessarily represent the proportions of plant species or of plant components on offer in the pasture; selection of preferred species and the higher-quality plant components such as green leaf. Such factors need to be considered for on-farm management.

5. Conclusions

As pasture rest periods during spring to summer increased, overall forage quality decreased, especially in C4 grasses. Crude protein presented the greatest decrease in response to longer forage deferment periods, followed by P concentration and with a lesser decline in organic matter digestibility. In C4 grasses, decreases in P to very low levels with longer deferment periods were related to the decline in green leaf content and an increase in forage stem and dead tissue content.

The management of species composition × deferment period is an important tool to manage various grassland communities on-farm. Short rest periods are recommended for *Mnesithea selloana* and *Paspalum dilatatum*, medium rest periods for *Andropogon lateralis* and *Paspalum notatum*, whereas the C3 *Bromus auleticus* and *Nasella neessiana* could be used in long deferment periods.

Author Contributions: M.J. and F.R.C. Conceptualization; M.R.B., M.J., M.D. and L.M. methodology; M.R.B., M.D., F.C. and M.J. formal analysis; M.R.B. and L.M. investigation; F.R.C., M.J. and F.L.F.d.Q. resources; M.R.B., M.J. and M.D. writing original draft preparation; M.R.B., M.J., F.R.C., F.L.F.d.Q. and R.M.D. writing review and editing; M.J. funding acquisition. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by ANII-Uruguay: Project FMV_1_2019_1_155961: Bancos forrajeros: una nueva herramienta para la gestión espacio-temporal de sistemas pastoriles; and Project INIA-Uruguay PA 23: Sistema de apoyo a la toma de decisiones de manejo de campo natural.

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

Acknowledgments: The authors gratefully acknowledge Dennis Poppi for suggestions to review the text.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Pallares, O.R.; Berretta, E.J.; Maraschin, G.E. The South American Campos ecosystem. In *Grasslands of the World*; Suttie, J.M., Reynolds, S.G., Batello, C., Eds.; FAO: Rome, Italy, 2005; Volume 42, pp. 171–219.
2. Gibson, D.J. *Grasses and Grassland Ecology*, 1st ed.; Oxford University Press: Oxford, UK, 2009; 313p.
3. McIvor, J.G.; Guppy, C.; Probert, M.E. Phosphorus requirements of tropical grazing systems: The northern Australian experience. *Plant Soil* **2011**, *349*, 55–67. [CrossRef]
4. Jaurena, M.; Durante, M.; Devincenzi, T.; Savian, J.V.; Bendersky, D.; Moojen, F.G.; Pereira, M.; Soca, P.; Quadros, F.L.F.; Pizzio, R.; et al. Native grasslands at the core: A new paradigm of intensification for the Campos of Southern South America to increase economic and environmental sustainability. *Front. Sustain. Food Syst.* **2021**, *5*, 11. [CrossRef]
5. Mezzalira, J.C.; Carvalho, P.C.d.F.; da Trindade, J.K.; Bremm, C.; Fonseca, L.; do Amaral, M.F.; Reffatti, M.V. Produçao animal e vegetal em pastagem nativa manejada sob diferentes ofertas de forragem por bovinos. *Cienc. Rural* **2012**, *42*, 1264–1270. [CrossRef]
6. Cruz, P.; Lezana, L.; Durante, M.; Jaurena, M.; Figari, M.; Bittencourt, L.; Theau, J.P.; Massa, E.; Viegas, J.; Quadros, F.L.F. A functional classification of 63 common Poaceae in the "Campos" grasslands of South America. *Ecol. Austral.* **2019**, *29*, 239–248. [CrossRef]
7. Andrade, B.O.; Marchesi, E.; Burkart, S.; Setubal, R.B.; Lezama, F.; Perelman, S.; Schneider, A.A.; Trevisan, R.; Overbeck, G.E.; Boldrini, I.I. Vascular plant species richness and distribution in the Río de la Plata grasslands. *Bot. J. Linn. Soc.* **2018**, *188*, 250–256. [CrossRef]
8. Claramunt, M.; Fernández-Foren, A.; Soca, P. Effect of herbage allowance on productive and reproductive responses of primiparous beef cows grazing on Campos grassland. *Anim. Prod. Sci.* **2017**, *58*, 1615–1624. [CrossRef]
9. Poppi, D.P.; Quigley, S.P.; Silva, T.A.C.C.D.; McLennan, S.R. Challenges of beef cattle production from tropical pastures. *Rev. Bras. Zoot.* **2018**, *47*, 1–9. [CrossRef]
10. Ansquer, P.; Al Haj Kahled, R.; Cruz, P.; Theau, J.P.; Thérond, O.; Duru, M. Characterizing and predicting plant phenology in species rich grasslands. *Grass Forage Sci.* **2009**, *64*, 57–70. [CrossRef]
11. Allen, V.G.; Batello, C.; Berretta, E.J.; Hodgson, J.; Kothmann, M.; Li, X.; McIvor, J.; Milne, J.; Morris, C.; Peeters, A.; et al. An international terminology for grazing lands and grazing animals. *Grass Forage Sci.* **2011**, *66*, 2–28. [CrossRef]
12. Derner, J.D.; Augustine, D.J. Adaptive management for drought on rangelands. *Rangelands* **2016**, *38*, 211–215. [CrossRef]
13. Scasta, J.D.; Lalman, D.L.; Henderson, L. Drought mitigation for grazing operations: Matching the animal to the environment. *Rangelands* **2016**, *38*, 204–210. [CrossRef]
14. Berretta, E.J.; Risso, D.F.; Montossi, F.; Pigurina, G. Campos in Uruguay. In *Grassland Ecophysiology and Grazing Ecology*; Lemaire, G., Hodgson, J., Moraes, A., Carvalho, P.C.F., Nabinger, C., Eds.; CAB International: Wallingford, UK, 2000; pp. 377–394. [CrossRef]
15. Giménez, A.; Castaño, J.P.; Baethgen, W.; Lanfranco, B. *Cambio Climático en Uruguay, Posibles Impactos y Medidas de Adaptación en el Sector Agropecuario*; Serie Técnica 151; INIA: Montevideo, Uruguay, 2009; 50p.

16. Buttolph, L.P.; Coppock, D.L. Influence of deferred grazing on vegetation dynamics and livestock productivity in an Andean pastoral system. *J. Appl. Ecol.* **2004**, *41*, 664–674. [CrossRef]
17. Lemaire, G.; Belanger, G. Allometries in plants as drivers of forage nutritive value: A review. *Agriculture* **2019**, *10*, 5. [CrossRef]
18. Andrade, I.F.; Atkinson, L.G.; Sollenberger, L.E.; Ruegsegger, G.J.; Mislevy, P.; Kalmbacher, R.S. Stockpiling herbaceous tropical legumes for dry season feed in Jamaica. *Trop. Grassl.* **1998**, *32*, 166–172.
19. Karn, J. Phosphorus nutrition of grazing cattle: A review. *Anim Feed Sci. Tech.* **2001**, *89*, 133–153. [CrossRef]
20. Malafaia, P.; Barbosa, J.D.; Brito, M.F.; Souza, V.C.D.; Costa, D.F. A Phosphorus for Cattle and Buffaloes in Brazil: Clinical Signs and Diagnosis of Its Deficiency and Relevance, and Recommended Strategies to Alleviate Issues Observed under Grazing Conditions. *Ruminants* **2023**, *3*, 55–75. [CrossRef]
21. Murphy, J.; Riley, J.P. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta* **1962**, *27*, 31–36. [CrossRef]
22. Wiles, P.G.; Gray, I.K.; Kissling, R.C.; Delahanty, C.; Evers, J.; Greenwood, K.; Grimshaw, K.; Hibbert, M.; Kelly, K.; Luckin, H.; et al. Routine analysis of proteins by Kjeldahl and Dumas methods: Review and interlaboratory study using dairy products. *J. AOAC Int.* **1998**, *81*, 620–632. [CrossRef]
23. AOAC International. *Official Methods of Analysis*, 17th ed.; Association of official Analytical Chemists: Washington, DC, USA, 2000.
24. Kozloski, G.V.; Zilio, E.M.C.; Ongarato, F.; Kuinchtner, B.C.; Saccol, A.G.; Genro, T.C.M.; Oliveira, L.; Faria, B.M.; Cezimbra, I.M.; Quadros, F.L.F. Faecal N excretion as an approach for estimating organic matter intake by free-ranging sheep and cattle. *J. Agric. Sci.* **2018**, *156*, 443–449. [CrossRef]
25. Roberts, D. The statistical program SYSTAT: Wilkinson, L. SYSTAT, The System for Statistics. SYSTAT, Inc. 2902 Central Street, Evanston, IL 60201. *J. Sch. Psychol.* **1987**, *25*, 313–318. [CrossRef]
26. McIvor, J.G. Seasonal changes in dry matter distribution and herbage quality of Urochloa species in north-eastern Queensland. *Aust. J. Exp. Agric.* **1990**, *30*, 523–528. [CrossRef]
27. McDowell, L.R. Feeding minerals to cattle on pasture. *Anim. Feed Sci. Technol.* **1996**, *60*, 247–271. [CrossRef]
28. McIvor, J.G. Seasonal changes in the growth, dry matter distribution and herbage quality of three native grasses in northern Queensland. *Aust. J. Exp. Agric.* **1981**, *21*, 600–609. [CrossRef]
29. Dixon, R.M.; Sullivan, M.T.; O'Connor, S.N.; Mayer, R.J. Diet quality, liveweight change and responses to N supplements by cattle grazing Astrebla spp. (Mitchell grass) pastures in the semi-arid tropics in north-western Queensland, Australia. *Rangel. J.* **2022**, *44*, 97–113. [CrossRef]
30. Grings, E.E.; Haferkamp, M.R.; Heitschmidt, R.K.; Karl, M.G. Mineral dynamics in forages of the Northern Great Plains. *J. Range Manag.* **1996**, *49*, 234–240. [CrossRef]
31. Elejalde, D.A.G.; Nabinger, C.; Pascual, M.G.C.; Ferreira, E.T.; Missio, R.L.; Kunrath, T.R.; Devincenzi, T.; Cardoso, R.R. Quality of the forage apparently consumed by beef calves in natural grassland under fertilization and oversown with cool season forage species. *Rev. Bras. Zoot.* **2012**, *41*, 1360–1368. [CrossRef]
32. Heringer, I.; Jacques, A.V.A. Qualidade da forragem de pastagem nativa sob distintas alternativas de manejo. *Pesq. Agrop. Bras.* **2002**, *37*, 399–406. [CrossRef]
33. Silveira, V.C.P.; Vargas, A.F.D.C.; Oliveira, J.O.R.; Gomes, K.E.; Motta, A.F. Qualidade da pastagem nativa obtida por diferentes métodos de amostragem e em diferentes solos na Apa do Ibirapuitã, Brasil. *Cienc. Rural* **2005**, *35*, 582–588. [CrossRef]
34. Van Soest, P. *Nutritional Ecology of the Ruminant*, 2nd ed.; Cornell University Press: New York, NY, USA, 1989; 528p.
35. Poppi, D.; McLennan, S. Protein and Energy Utilization by Ruminants at pasture. *J. Anim. Sci.* **1995**, *73*, 278–290. [CrossRef]
36. Cano, C.C.P.; Cecato, U.; Canto, M.W.D.; Santos, G.T.D.; Galbeiro, S.; Martins, E.N.; Mira, R.T. Valor nutritivo do capim-Tanzânia (Panicum maximum Jacq. cv. Tanzânia-1) pastejado em diferentes alturas. *Rev. Bras. Zoot.* **2004**, *33*, 1959–1968. [CrossRef]
37. Azambuja Filho, J.C.R.; Carvalho, P.C.F.; Bonnet, O.J.F.; Bastianelli, D.; Jouven, M. Functional classification of feed items in pampa grassland, based on their near-infrared spectrum. *Rangel. Ecol. Manag.* **2020**, *73*, 358–367. [CrossRef]
38. Hacker, J.B.; Minson, D.J. The digestibility of plant parts. *Herb. Abstr.* **1981**, *51*, 459–482.
39. Insua, J.R.; Agnusdei, M.G.; Utsumi, S.A.; Berone, G.D. Morphological, environmental and management factors affecting nutritive value of tall fescue (Lolium arundinaceum). *Crop Pasture Sci.* **2018**, *69*, 1165–1172. [CrossRef]
40. Baudracco, J.; Lopez-Villalobos, N.; Holmes, C.W.; Macdonald, K.A. Effects of stocking rate, supplementation, genotype and their interactions on grazing dairy systems: A review. *N. Z. J. Agric. Res.* **2010**, *53*, 109–133. [CrossRef]
41. Jackson, D.; Rolfe, J.; English, B.; Mathews, R.; Dixon, R.M.; Smith, P.; MacDonald, M. *Phosphorus Management of Beef Cattle in Northern Australia, 1st ed*; Meat and Livestock Australia: Sydney, Australia, 2012; 44p.