



Choose Local: Dung Addition from Native Herbivores Can Produce Substantial Positive Effects on the Growth of Native Grasses Compared to Livestock Dung

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Abstract

Livestock grazing and dung deposition can increase soil nutrients, contributing to the dominance of exotic species. Recent research suggests that native herbivore grazing has positive effects on native vegetation and soil health. However, little is known about the effects of native herbivore dung on plant growth and its potential implications for the restoration of degraded grasslands. This study examined the effects of dung addition from a native herbivore, kangaroo (*Macropus giganteus*), and ruminant livestock, sheep (*Ovis aries*), on biomass production and nutrient uptake of the native perennial wallaby grass (*Rytidosperma auriculatum*) and the annual exotic wild oat (*Avena barbata*), two of the most abundant grasses from the temperate grasslands of southern Australia. We conducted a glasshouse experiment, adding each type of dung to each plant species grown without competition in pots containing soil with a nutrient composition similar to that of old fields. Kangaroo dung produced higher wallaby grass aboveground biomass than other treatments and less wild oat aboveground biomass than the control. Kangaroo dung affected nutrient uptake but not nutrient concentration. Sheep dung had no effect. We demonstrated that native herbivores and livestock dung can have different effects on the biomass of native and invasive grasses. The higher nutrient uptake in wallaby grass appeared to be a consequence of the higher biomass production, suggesting that the effects produced by kangaroo dung could be related to its chemical and biological characteristics rather than its nutrient composition. Incorporating native herbivores' dung or facilitating their presence can improve restoration outcomes in degraded grasslands.

Keywords Dung · Native grasses · Exotic invasion · Biomass production · *Rytidosperma auriculatum* · *Avena barbata*

1 Introduction

Temperate grasslands are valuable ecosystems that have been severely impacted and modified by humans (Hautier et al. 2015). They provide forage resources for livestock grazing and essential ecosystem services such as water supply and flow regulation, carbon sequestration, soil erosion control, and pollination (Bengtsson et al. 2019). Despite their importance, the continuous agricultural expansion has substantially reduced the extension of natural grasslands worldwide (Corbin and D'Antonio 2004; Hoekstra et al. 2005). Thus, the conservation and restoration of native grasslands are paramount.

Grazing is considered one of the main drivers of floristic and edaphic changes, and thus, all of its manifold impacts need to be considered in the management of grasslands for the conservation of native vegetation (HilleRisLambers et al. 2010; Zemmrich et al. 2010; Eldridge et al. 2018). In managed grasslands, the positive effects of livestock grazing on soil fertility have been vastly studied (Lai and Kumar 2020; Rayne and Aula 2020). However, the presence of livestock in natural and semi-natural grasslands is often related to negative impacts on soils and the loss of biodiversity (Kimball and Schiffman 2003; Blumenthal et al. 2017). In contrast, native herbivores have been associated with positive effects on soil health and native vegetation (Hobbs 1996; van der Wal et al. 2004; Eldridge et al. 2017). These contrasting effects produced by livestock and native herbivores are likely to be influenced by their coevolution with vegetation and grasslands site-specific characteristics (Hobbs 1996; Forbes et al. 2019). A better understanding of the responses of grassland species to the various effects of grazing is essential for the conservation of native vegetation.

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The activity of grazers encompasses several effects beyond defoliation, including dung deposition, which can influence the chemical and biological properties of soil, leading to changes in vegetation composition (Bardgett and Wardle 2003; Filazzola et al. 2020). The addition of dung represents a substantial input of nutrients that can modify nutrients and biological processes in soils, thus affecting vegetation (Peco et al. 2006; Nichols et al. 2016). Most grazers recycle a high portion of the nutrients they consumed through their dung and urine, which in the case of cattle could be as high as 80% for nitrogen (Wachendorf et al. 2008). Dung decomposition reduces the time and increases the rates at which nutrients, especially nitrogen (N), potassium (K), and phosphorus (P) become available to plants compared to plant residue decomposition (Bloor 2015; Milotić and Hoffmann 2016). The subsequent changes in soil chemical, physical, and biological properties can lead to indirect effects on nutrient cycling that can affect vegetation communities (Yoshitake et al. 2014). These effects will largely depend on the composition of grazers and the vegetation communities they feed from (Liu et al. 2018). The high nutrient content in livestock dung can alter the trade-offs in species resource-ratio requirements, favoring the dominance of species with elevated responses to nutrient increases like invasive annual graminoids (Davis et al. 2000; Harpole et al. 2016; Pearson et al. 2018). Conversely, native herbivores dung, from European ungulates and African large herbivores, facilitates the redistribution of nutrients and can have profound positive effects on native vegetation (Hobbs 1996; van der Wal et al. 2004; van der Waal et al. 2011). Yet, several herbivore groups and ecosystems remain to be studied.

The addition of dung to soils may also affect substantially seed germination and plant growth (Milotić and Hoffmann 2017). Responses to dung addition can vary among species and depend on the biology of the animal producing the dung (Milotić and Hoffmann 2016). Dung chemical compounds can be beneficial by promoting the production of secondary metabolites that improve antioxidant activity and the health of plants (Baghdadi et al. 2018). Dung can also contain concentrations of phytotoxic compounds such as phenols and fatty acids that can affect germination and seedling growth (Milotić and Hoffmann 2016). Moreover, dung nutrients become available to plants at different rates depending on the diet of herbivores and their digestive physiology (Sitters et al. 2014; Milotić and Hoffmann 2016; Dhiman et al. 2021). In turn, plants have different nutrient requirements and/or absorption efficiencies depending on their physiology (Padgett and Allen 1999; Chapman et al. 2014). Dung also contains microorganisms that could potentially favor the establishment and growth of plants or become pathogens (Bardgett and van der Putten 2014; Qi et al. 2019).

Thus, herbivores with different digestive physiologies could produce dung with species-specific effects on plant growth and development (Jørgensen and Jensen 1997; Dai 2000). For instance, cattle (ruminant) and horse (non-ruminant) dung have been reported to produce different effects on seed germination (Milotić and Hoffmann 2016) and plant growth (Milotić and Hoffmann 2017) for graminoid species with different life strategies. However, there is still much to be explored concerning the effects of dung on grasses (Bloor 2015), especially in scenarios where native herbivores are non-ruminant (Dai 2000).

Assessing the effects of dung deposition in semi-natural grasslands, where livestock and native grazers coexist, could strengthen our insight into the effects of grazing and improve its management for native vegetation conservation. Livestock grazing is often employed to manage plant communities with the intention of maintaining species richness and reducing the presence of invasive species with high levels of productivity (Bailey et al. 2019). Moreover, some management practices consider the exclusion of native herbivores to avoid losing young plants in restoration projects (Freeman and Pobke 2021). However, there is growing evidence concerning the negative effects of livestock grazing on native vegetation (Kimball and Schiffman 2003; Beever et al. 2006; Blumenthal et al. 2017; Filazzola et al. 2020). Furthermore, recent research has noticed that native herbivores produce positive effects on native plant richness, soil health, and productivity (Eldridge et al. 2021; Flojgaard et al. 2018; Travers et al. 2018; Snape et al. 2021; Hawkins and Zeglin 2022). Contrasting the effects of native herbivores and livestock dung on native vegetation could provide new insight into the relationship between native herbivores and native vegetation, which can benefit the establishment and growth of native vegetation in grasslands. Management and restoration projects could benefit from such information, by limiting or promoting the presence of native herbivores or by using their dung as fertilizer. This study focuses on the temperate grasslands of southern Australia, an ecosystem characterized by dominant perennial tussock grasses (*Austrostipa*, *Rytidosperma*, and *Themeda*) that have been severely affected by invasive species, mainly annual grasses (Lenz and Facelli 2005). We asked what is the effect of native herbivores and livestock dung on the growth of grasses and how it differs depending on dung type. We conducted a glasshouse experiment that simulated the soils rich in nutrients found in restoration projects at old fields (former farmlands). We assessed the effects of the addition of dung from gray kangaroo (*Macropus giganteus*) and sheep (*Ovis aries*) on the growth of the perennial native wallaby grass (*Rytidosperma auriculatum*) and the annual invasive wild oat (*Avena barbata*). Sheep dung is a rich source of nutrients that can reduce acidification and enhance soil nutrition (Rolando et al. 2018; Teixeira et al. 2019). Little is known about kangaroo dung composition, properties, or effects on soils.

2 Materials and Methods

2.1 Resources

To conduct the glasshouse experiment, the Plant Research Centre of the University of Adelaide provided sterilized loamy soil rich in nutrients that mimicked the composition and texture of old-field soils from the Mediterranean-type climate region of South Australia, “rich soil” hereafter (Table 1). A local plant nursery (Seeding Natives) donated wallaby grass seeds for the experiment, while wild oat seeds were obtained from Para Woodlands Nature Reserve (34.6420° S, 138.8147° E), former farmland currently managed for native grassy woodlands restoration. At this site, pulse grazing by sheep is used to attempt weed control, and wild kangaroos graze freely. We collected fresh kangaroo and sheep dung samples at Para Woodlands in spring, just before starting the experiment. A random subsample of 250 g for each type of dung was homogenized and sent for chemical analyses at CSBP laboratories (Bibra Lake, WA, www.csbp-fertilisers.com.au). Sheep dung presented higher concentrations of N, K, and P, while kangaroo dung presented higher iron (Fe) and zinc (Zn) concentrations (Table 2).

2.2 Species

Two of the most abundant native and invasive species in the temperate grasslands in southern Australia are wallaby grass and wild oat respectively. The former is a slow-growing perennial grass adapted to droughts and soils with low nutrient availability that has a low response to P and N fertilizers

Table 1 Soil physicochemical properties from the sterilized loamy-rich soil that mimicked the composition and texture of old-field soils and from a soil sample from Para Woodlands taken in 2021. Data provided by CSBP laboratories (Bibra Lake, WA, www.csbp-fertilisers.com.au)

Parameter	Units	Loamy-rich soil	Para Woodland sample
Color		DKGR	
Gravel	%	0	0
Texture		1.0	3
Ammonium (NH ₄ ⁺) N	Kg ⁻¹	95	9.17
Nitrate (NO ₃ ⁻) N	kg ⁻¹	140	40.83
P Colwell	kg ⁻¹	58	38.83
K Colwell	kg ⁻¹	283	1003.5
Sulfur (S)	kg ⁻¹	118.0	6.42
Organic carbon (C)	%	1.31	3.93
Conductivity	dS/m	0.519	0.18
pH level (CaCl ₂)		5.0	5.95
pH level (H ₂ O)		5.7	6.65

Table 2 Kangaroo and sheep dung nutrients composition. CSBP laboratories (Bibra Lake, WA, www.csbp-fertilisers.com.au)

Parameter	Units	Kangaroo dung	Sheep dung
Total N	%	1.79	2.98
Compost total B	kg ⁻¹	13.3	31.1
Compost total Ca	%	1.69	2.51
Compost total Cu	kg ⁻¹	21.24	27.04
Compost total Fe	kg ⁻¹	3639.3	1840.02
Compost total K	%	0.7	1.1
Compost total Mg	%	0.44	0.86
Compost total Mn	kg ⁻¹	277.62	336.21
Compost total Na	%	0.15	0.35
Compost total P	%	0.42	0.95
Compost total S	%	0.22	0.35
Compost total Zn	kg ⁻¹	83.66	64.53

compared to wild oats (Waddell et al. 2016; Mitchell et al. 2019; McIntyre et al. 2022; Ba and Facelli 2022). This species is used as a grazing pasture (McIntyre et al. 2022) and is commonly used in restoration projects (Jellinek et al. 2020). The latter is an annual invasive grass from central Asia and the Mediterranean Basin, associated with higher fertility soils in southern Australia, such as old fields (Lenz and Facelli 2005). Previous glasshouse studies reported a faster response of wild oat to higher nutrients in old-field soil than wallaby grass, which is consistent with the rapid response to resources that annual species have (Smith et al. 2018).

2.3 Experimental Design

We conducted a fully factorial experiment in a glasshouse from 13/08 to 21/10 in 2020. We prepared 60 pots (r: 4.5 cm, h 12.5 cm) filled with rich soil and watered them before sowing. We allocated 30 pots to each species and each pot received 14 seeds of the corresponding species. We applied three dung treatments to the pots: kangaroo dung, sheep dung, and dung-free control treatment, each replicated 10 times. Previous to application, dung samples from each species were crushed and homogenized. Dung application consisted of adding 10 g kangaroo or sheep dung distributed over the surface of the pots. Pots were located in an unheated greenhouse without artificial light at the Benham building, Adelaide, Australia (34.918°N, 138.6047°E).

2.4 Harvesting and Measurements

We assessed seedling emergence and germination rates for each species separately: for wild oats, 3 days after the first seedling emerged, and for wallaby grass, 3 and 9 days after the first emergence. After 1 month, plants in each pot were

thinned to three individuals to reduce intraspecific competition. Plants were harvested after 10 weeks when wild oats started to flower. Below and aboveground plant parts were dried separately to a constant weight at 65 °C. To assess the effect of dung addition on plant growth, we measured the aboveground biomass, belowground biomass, and total biomass for each pot. We also calculated the biomass ratio by dividing aboveground by belowground biomass. The total biomass was calculated by adding aboveground and belowground biomass. The aboveground nutrient concentration and nutrient uptake (aboveground biomass $\times$ nutrient concentration) of N, K, and P were analyzed for each species separately to explore any potential effects produced by dung addition. The nutrient analysis was conducted by the Australian Precision Ag Laboratory (APAL). We focused our results on the aboveground biomass since rich soils promote the allocation of resources to this part of the plant (Stevens et al. 2010; Nogueira et al. 2018).

2.5 Data Analysis

We conducted statistics tests for each species separately due to differences in life-history traits. Seedling emergence and germination rate were compared between treatments using one-way ANOVA followed by Tukey's HSD test for each species. The same tests were used to compare biomass (aboveground, root, ratio, and total) production, nutrient concentration, and nutrient uptake (N, K, and P) between treatments for wallaby grass. In the case of wild oats, aboveground biomass, nutrient concentration, and nutrient uptake were compared between treatments employing the ANOVA type III test due to the unbalanced number of samples caused by the loss of part of the samples. All statistics were conducted using R v. 4.1.2 (R Core Team, 2021).

3 Results

3.1 Seedling Emergence

Seedling emergence started after 3 days for wild oat and 9 days for wallaby grass, with no significant differences between dung treatments (Supplementary material). The

germination rate of wild oats was higher than 85% for all treatments. The germination rate of Wallaby grass was lower than 50% 3 days after emergence and presented a small increase after 9 days. Only pots with sheep dung presented a germination rate of wallaby grass higher than 50% (Table 3).

3.2 Biomass Production

The addition of kangaroo dung to wallaby grass resulted in significantly higher aboveground, belowground, and total biomass than the control treatment and the addition of sheep dung ($P < 0.001$, Fig. 1a, Table 4). In the case of wild oats, the addition of kangaroo dung resulted in significantly lower aboveground biomass than the control treatment ($P < 0.05$, Fig. 1b, Table 4). The addition of sheep dung had no significant effects on any of the plant species (Table 4). Further detail of biomass production for both species can be found in the Supplementary material.

3.3 Nutrient Uptake

The aboveground nutrient concentrations and uptake varied across species and treatments (Supplementary material). In the case of wallaby grass, there were no significant differences between the concentration of nutrients among treatments. The uptake of N, K, and phosphorous by wallaby grass was the highest in pots with kangaroo dung. The nutrient concentration and uptake by wild oat pots did not differ among treatments (Table 5).

4 Discussion

Wallaby grass and wild oats biomass production responded in unexpected ways to the addition of dung. We expected that the addition of dung, particularly the nutrient-rich sheep dung, would trigger an increase in growth in wild oat, which is documented as responding to increased nutrient availability (Ba and Facelli 2022). We also expected a minor response, if any from, wallaby grass which is less responsive to nutrient additions

Table 3 Germination rate and mean $\pm$ SE number of individuals of wild oat and wallaby grass emerged after 3 and 9 days, 10 samples per treatment. ANOVA statistics: not significant (ns)

Plant species	Variable	Days	Control	Kangaroo	Sheep
Wild oat	Number of individuals emerged (ns)	3	12.6 $\pm$ 2.76	12.5 $\pm$ 2.01	12 $\pm$ 1.05
	Germination rate (%)	3	90	89.29	85.71
Wallaby grass	Number of individuals emerged (ns)	3	5.8 $\pm$ 1.32	5.7 $\pm$ 2.26	6.5 $\pm$ 1.78
	Germination rate (ns)	3	41.43%	40.7%	46.42%
	Emergent number of individuals (ns)	9	6.8 $\pm$ 1.4	6.10 $\pm$ 2.42	7.70 $\pm$ 1.25
	Germination rate (%)	9	48.57	43.57 b	55

Fig. 1 Aboveground biomass (g) of wallaby grass (**a**) and wild oat (**b**) under different dung treatments (kangaroo, sheep, control). Different letters above a boxplot denote significant differences between treatments (≤ 0.05) using Tukey post hoc test, after one-way ANOVA. Figures created in R

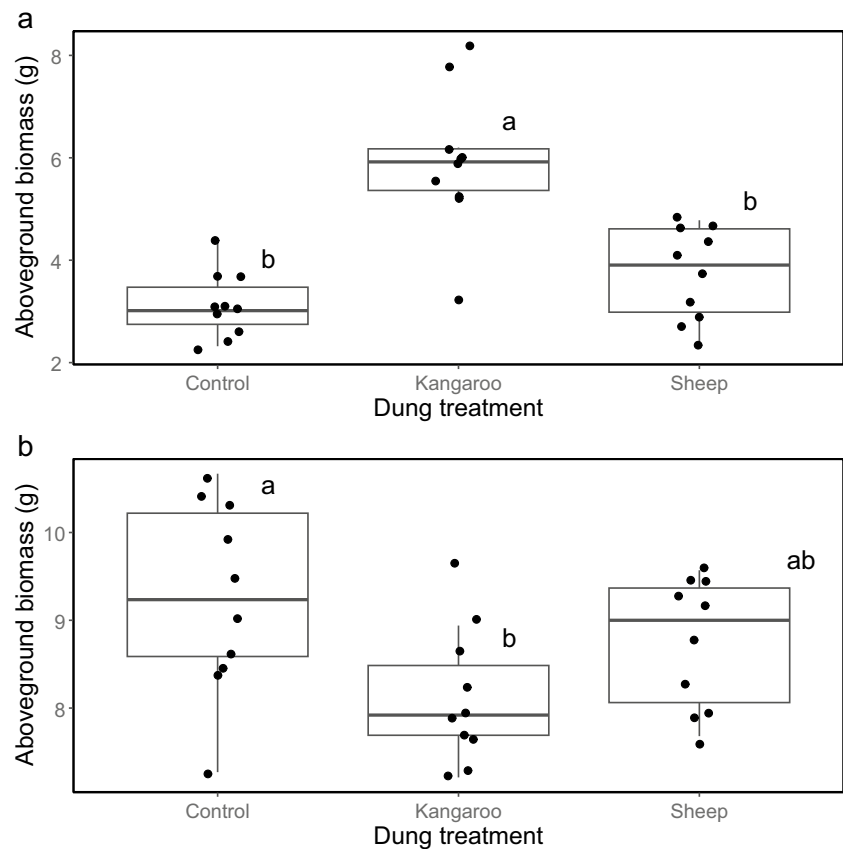


Table 4 Mean $\pm$ SE aboveground biomass (g), root biomass, ratio (aboveground/roots) biomass and total (aboveground + roots) biomass for wild oat and wallaby grass, 10 samples per treatment. ANOVA

statistics: not significant (ns), $P < 0.05$ (*), $P < 0.001$ (***). Post-hoc significant differences between treatments are indicated by letters (a, b, c)

Aboveground biomass				Belowground biomass			
	Control	Kangaroo	Sheep		Control	Kangaroo	Sheep
Wallaby grass ***	$3.12 \pm 0.2a$	$5.92 \pm 0.44b$	$3.75 \pm 0.28ac$	Wallaby grass ***	$2.44 \pm 0.24a$	$3.4 \pm 0.49b$	$2.26 \pm 0.15a$
Wild oat *	$9.27 \pm 0.34a$	$8.12 \pm 0.24b$	$8.75 \pm 0.23ab$	Wild oat (ns)	16.17 ± 1.2	15.25 ± 1.08	14.06 ± 1.05
Biomass ratio				Total biomass			
	Control	Kangaroo	Sheep		Control	Kangaroo	Sheep
Wallaby grass (ns)	1.45 ± 0.217	2.07 ± 0.295	1.73 ± 0.19	Wallaby grass ***	$5.56 \pm 0.29a$	$9.32 \pm 0.53b$	$6.01 \pm 0.35ac$
Wild oat	0.6 ± 0.05	0.57 ± 0.064	0.6 ± 0.05	Wild oat (ns)	25.44 ± 1.45	23.37 ± 1.05	22.81 ± 1.188

(Waddell et al. 2016; Mitchell et al. 2019; McIntyre et al. 2022). Instead, our results revealed that only kangaroo dung positively affected the biomass production of wallaby grass. Kangaroo dung also produced a negative effect on wild oats, despite the capacity of this species to respond rapidly to increased nutrient availability. Furthermore, neither grasses were affected by sheep dung, which had a higher nutrient concentration than kangaroo dung. Differences in nutrient uptake might be principally related to aboveground biomass production since there were no differences in nutrient concentrations between treatments. Likewise, other studies employing organic fertilizers have not found an increase in nutrient concentration on the aboveground biomass

(Banik et al. 2021; Tshikalange et al. 2022). The absence of changes in nutrient concentrations suggests that the addition of dung could have increased the available nutrients in the soil, thus increasing biomass production (Han et al. 2016; Tshikalange et al. 2022). Differences in proportions of mineral to organic nutrients related to sheep and dung digestive systems could have affected nutrient availability (Sitters and Olde Venterink 2021). However, the nutrient content in soils employed in this study was already high and might have already supplied the nutrient requirements for both species. Hence, the biomass production in our experiment may not be directly related to dung nutrient content, but to dung characteristics that affect plant growth.

Table 5 Nutrients aboveground biomass (g) mean $\pm$ SE uptake for wild oat and wallaby grass for all treatments (eight samples each): wild oat control, wild oat with kangaroo dung, wild oat with sheep dung, wallaby grass control, wallaby grass with kangaroo dung, wal-

laby grass with sheep dung. Number of samples (n). ANOVA statistics: not significant (ns), $P < 0.001$ (***). Post-hoc significant differences between treatments are indicated by letters (a, b, c)

Minerals	Wallaby grass (g)				Wild oats (g)			
	Control (10)	Kangaroo (10)	Sheep (10)	P	Control (5)	Kangaroo (04)	Sheep (7)	P
N concentration (%)	0.96 $\pm$ 0.09	1.02 $\pm$ 0.082	1.01 $\pm$ 0.13	ns	1.18 $\pm$ 0.17	1.12 $\pm$ 0.11	1.15 $\pm$ 0.12	ns
N uptake (mg plant ⁻¹)	2.97 $\pm$ 0.17a	6.06 $\pm$ 0.47b	3.79 $\pm$ 0.32a	***	10.2 $\pm$ 2.09	9.04 $\pm$ 0.74	9.84 $\pm$ 1.37	ns
K concentration (%)	1.73 $\pm$ 0.19	1.62 $\pm$ 0.11	1.67 $\pm$ 0.14	ns	1.4 $\pm$ 0.19	1.58 $\pm$ 0.12	1.55 $\pm$ 0.09	ns
K uptake (mg plant ⁻¹)	5.33 $\pm$ 0.79a	9.56 $\pm$ 2.16b	6.22 $\pm$ 1.41a	***	12.2 $\pm$ 2.31	12.8 $\pm$ 0.56	13.3 $\pm$ 1.51	ns
Phosphorous concentration (%)	0.35 $\pm$ 0.06	0.3 $\pm$ 0.03	0.3 $\pm$ 0.03	ns	0.39 $\pm$ 0.04	0.39 $\pm$ 0.02	0.39 $\pm$ 0.03	ns
Phosphorous uptake (mg plant ⁻¹)	1.06 $\pm$ 0.17a	1.77 $\pm$ 0.4b	1.12 $\pm$ 0.27a	***	3.37 $\pm$ 0.4	3.15 $\pm$ 0.12	3.34 $\pm$ 0.38	ns

Dung chemical and biological characteristics, factors outside the scope of our study, could provide possible explanations for the kangaroo dung effects reported here. Dung micronutrients can increase the production of secondary metabolites that benefit plant health (Bimova and Pokluda 2009; Ibrahim et al. 2013), while dung phytotoxic compounds can affect the initial growth of seedlings (Milotić and Hoffmann 2017). In addition, plant-soil-microbial interactions can play a significant role for plants, as microbes can either favor the establishment of plants or become pathogens for them (Bardgett and van der Putten 2014). The impact of grazing on soil-microbial communities varies between herbivores. Sheep have been shown to cause a negative effect on plant pathogens which affect plant-soil-microbial interactions (Eldridge and Delgado-Baquerizo 2018). These effects could be related to changes in soil pH and nutrient availability caused by trampling and the addition of dung (Ling et al. 2017; Eldridge et al. 2020) but also to the microbial content in dung. Recent research has shown that dung from native herbivores could serve as a dispersal and homogenization vector for soil-microbial communities in grasslands (Hawkins and Zeglin 2022). Furthermore, a few studies have shown that cow dung contains bacteria that promote plant growth due to their capacity to solubilize nutrients (Qi et al. 2019; Bhatt and Maheshwari 2020; Naghizadeh et al. 2022). However, dung can also contain pathogenic fungi and bacteria that negatively affect plant growth (El Barnossi et al. 2020; Semenov et al. 2021). Regarding the plants employed in this study, or closely related ones, glasshouse experiments have shown that alterations in soil-microbial communities affect graminoids biomass production. Ba et al. (2018) reported that soil inoculated with *Rytidosperma caespitosum* roots as a source of microbial inoculum had a positive effect on the total biomass of *R. caespitosum* and a negative one on wild oat total biomass. Similarly, Smith et al. (2018) reported a negative effect on wild oat biomass production in soils inoculated with soil from a remnant native perennial grassland.

Differences in diet and digestive physiology between kangaroos and sheep can provide insight into the chemical and biological composition of dung. Kangaroos and sheep share several

grass species in their diets (Squires 1982) and have similar bacterial flora and anaerobic fungi in the forestomach (Smith 2009). However, macropods' dietary preferences (Taylor 1983; Wilson 1991) and differences in the fermentation processes of rumen and macropods' forestomach (Smith 2009) could result in different chemicals and biological characteristics in dung. Further research concerning microbial communities in dung and soils could provide new insight into mechanisms acting behind fertilization. Possible steps to follow could consider contrasting our results to the addition of sterilized dung, as well as conducting microbial phylogenetic analysis on soils before and after the addition of dung. It must be noted that our results were obtained in conditions of high fertility that simulated the restoration site. Complementing our results with an experiment in soils with lower nutrient contents, adding or not adding the two types of dung could provide a broader insight into the role of dung addition on the growth of these species.

Our results may contribute to improving the management and restoration of semi-natural grasslands. Research in ecosystems like tundra and savannahs has shown that the effects of wildlife dung addition on soil belowground components can significantly impact vegetation (van der Wal et al. 2004; van der Waal et al. 2011; Veldhuis et al. 2018). Favoring the presence of native herbivores may contribute to improving the biomass production of native plants. However, if their presence presents a problem for revegetation, like kangaroos in southern Australia, the allocation of wildlife dung as a fertilizer could be an option to be considered.

5 Conclusions

Our results provide evidence that native herbivores and ruminant livestock dung addition can have different effects on native and exotic grasses. We demonstrated that kangaroo dung could be beneficial for the biomass production of wallaby grass and detrimental for wild oats. In contrast, the addition of sheep dung does not seem to affect the biomass production of wallaby grass or wild oat in soils with high nutrient levels.

However, we could not find the expected evidence linking the effects of dung nutrient content to plant nutrient uptake and growth. Hence, we suggest that other dung properties, such as bio-chemical compounds and the effects of dung microbes on plant-soil microbe interactions, could be responsible for the effects documented. It could then be possible to maintain a controlled presence of kangaroos in restoration sites or add kangaroo dung in their absence to promote native grass establishment and biomass production.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s42729-023-01380-7>.

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Author Contribution DR Guevara-Torres originally conceived the idea. DR Guevara-Torres and JM Facelli contributed to the study design. Material preparation, data collection, and analysis were performed by DR Guevara-Torres. The first draft of the manuscript was written by DR Guevara-Torres, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data Availability The datasets generated during and/or analyzed during the current study are available in the following link to the electronic supplementary material.

Declarations

Competing Interests The authors declare no competing interests.

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