Trade-offs between milk production potential, tannin content and plant diversity depend on grassland mixtures

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Abstract

Temporary grasslands are crucial for addressing dairy cow sector challenges, including milk production, methane emissions mitigation, and biodiversity enhancement. In this study conducted in Frick, Switzerland, we investigated four distinct temporary grassland mixtures, replicated across 16 plots. These mixtures comprised: 1) pure grasses, 2) a combination of grasses and legumes, 3) a combination of grasses and tannin-rich plants, and 4) a combination of grasses and plants rich in essential oils. Over the course of six grazing rotations in 2022, our research encompassed botanical surveys and vegetation chemical analyses for each mixture. We calculated three pivotal variables: the potential milk production for a hypothetical dairy cow, the plant species diversity, and the condensed tannin content. Principal component analyses (PCA) were employed for each mixture to highlight the trade-offs among these variables. Grass mixture correlated potential milk production with species diversity. Essential-oil mixture correlated milk production to tannin content. Grass-legume and tannin mixtures traded species diversity for tannin content. These findings underscore the importance of designing specific temporary grassland mixtures at the plot and farm scale to effectively address the predominant challenges facing the dairy cow sector.

Keywords: multi-species grassland, plant secondary metabolites, temporary grassland, ecosystem services, organic agriculture

Introduction

Temporary grasslands play a pivotal role in addressing challenges in the dairy cow sector, such as achieving optimal milk production, mitigating methane emissions, and promoting biodiversity. Yet, our understanding of the relationships among these characteristics remains limited, particularly in the context of organic grassland systems. The trade-off between grassland productivity and species diversity has been strongly debated. In sown grasslands, this relation is mostly positive: multi-species grasslands tend to yield higher biomass (Baker *et al*., 2023), and have the potential to result in higher milk yields (Schaub *et al*., 2020). Diversity in species and functional groups (grasses, legumes, forbs) influences these outcomes, while condensed tannins (CT) offer promise in methane mitigation while having a negligible impact on milk production (Herremans *et al*., 2020). However, the connection between plant diversity and CT content remains understudied. It is reasonable to expect that this relationship largely depends on the composition of sown species and the presence of weed species. If sown species are tannin-rich, weeds may boost species diversity but dilute tannin content; conversely, in tannin-poor grasslands, weeds may increase CT content. Therefore, we propose that the correlations between milk production potential, species diversity, and CT content depend on the sown grassland mixtures.

Materials and methods

We conducted this study from April to October 2022 in Frick, Switzerland (47°30'51"N 8°01'26"E), investigating four distinct temporary grassland mixtures, replicated in four plots each (16 plots total). The swards were established in 2021 with seed mixtures encompassing: 1) pure grasses (mixture G), 2) a combination of grasses and legumes (L), 3) a combination of grasses and tannin-rich forbs and legumes (T), and 4) a combination of grasses and forbs rich in essential oils (EO) (Table 1). Across six rotations in 2022, botanical surveys and chemical analyses of vegetation were performed for each plot. For every rotation, we calculated three key variables: the potential milk production of a theoretical dairy cow (kg ha^{-1}), based on INRA (2010) equations; the plant species diversity; and the condensed tannin content (g kg^{-1} DM). Finally, we conducted a principal component analysis (PCA) for each grassland mixture to investigate the correlations between potential milk production, plant species diversity, and condensed tannin content.

Table 1. Functional composition of the four grassland mixtures [Grasses; Legumes; Forbs].

	G	L	T	EO
Number of species	[4; 0; 0]	[4; 3; 0]	[4; 1; 3]	[4; 0; 6]
Proportion (%)	[100; 0; 0]	[50; 50; 0]	[50; 12; 38]	[60; 0; 40]

Results and discussion

In the four PCA, the two first dimensions explained more than 70% of the variability, so we focused our analysis on these dimensions only. The results showed three distinct trade-off profiles dependent on grassland mixtures (Figure 1).

Mixture G exhibited a positive correlation between milk production and species diversity, while CT content was uncorrelated to these variables. This correlation could be due to the inclusion of dicotylous weed species is the grassland like white clover or dandelion (up to 67% of biomass), which increased the diversity and exhibits greater drought resistance compared to the sown grass species (Haughey *et al*., 2018). The lack of correlation with CT content may be due to the generally low presence of tannin-rich species in this mixture.

In the mixture EO, milk production positively correlates with CT content, while species diversity was uncorrelated to these variables. A closer examination revealed that higher CT contents were associated with high milk production (values above 7 g kg^{-1} CT linked to yields exceeding 1000 kg ha^{-1}), but lower CT contents were associated with both low and high milk production. Samples with the highest CT content in mixture EO had a lower grass proportion, potentially explaining their elevated CT content. However, our calculation for milk production did not counter for the potential effect of CT on protein digestibility nor on palatability, which could lower milk production (Herremans *et al*., 2020).

In mixtures L and T, species diversity showed a negative correlation with CT content, weakly linked to potential milk production. In mixture T, plots with fewer than ten species had an average CT content of 9 g kg^{-1}, compared to 6 g kg^{-1} in plots with over ten species. This indicates that weeds with lower CT contents diluted the high CT content of sown species. Furthermore, in both mixtures, summer drought reduced species diversity but increased CT content in plants, confirming results from other studies (Anuraga *et al*., 1993).

Conclusion

Species composition and functional group ratios, rather than species diversity, are crucial in determining trade-offs between milk production, plant diversity, and CT content in grassland mixtures. Thus, temporary grasslands composition should be considered before assessing ecosystem goods and services.

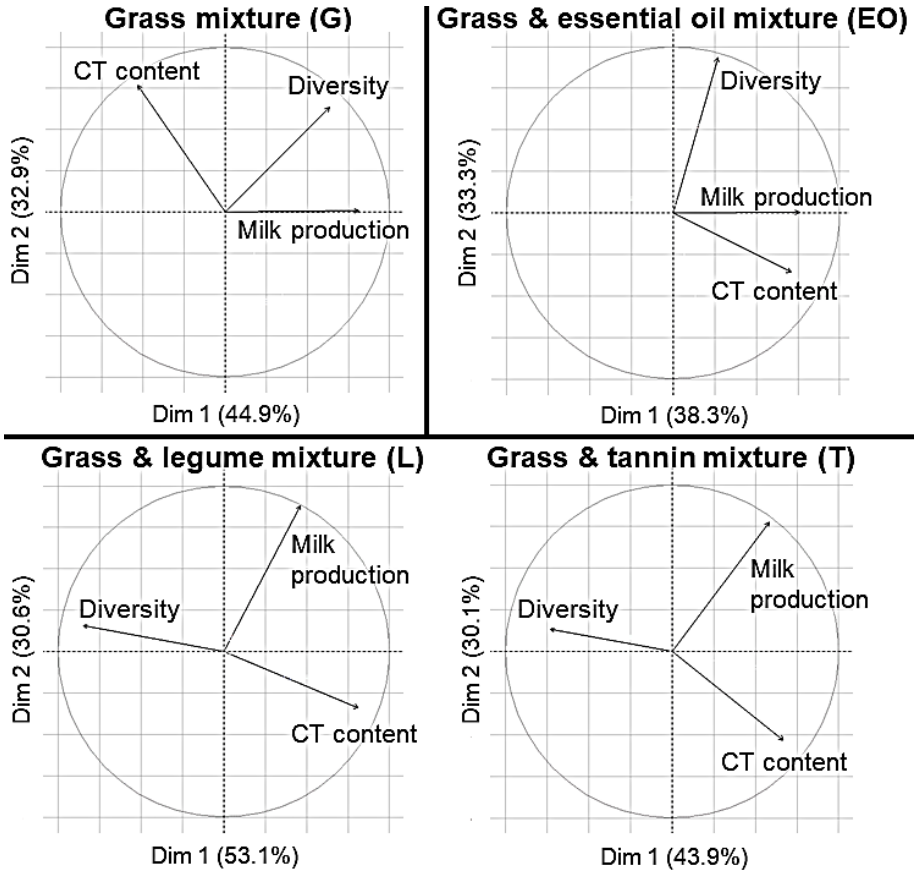

Figure 1. Trade-offs between potential milk production, species diversity and condensed tannin content for each mixture.

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