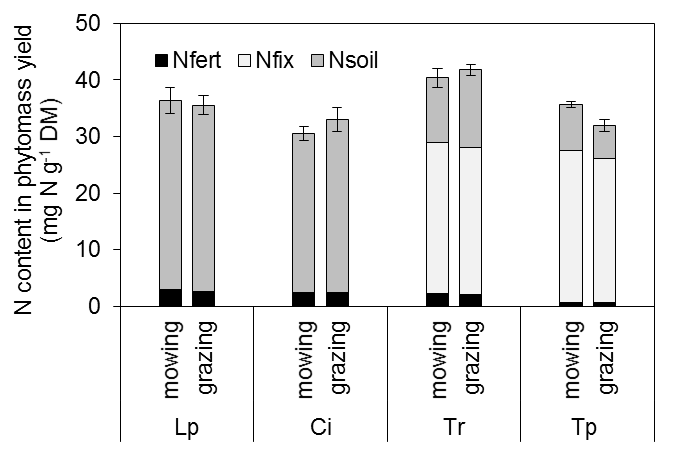
Mixtures provided similar benefits to nitrogen yield under grazing and under mowing  
  
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Abstract  
  
Previous studies showed benefits of mixing species with complementary characteristics related to nitrogen (N) capture on phytomass and N yields of mown grassland. Grazing instead of mowing may impact soil properties and the interactions between plant species. This study aimed at determining whether grazing modifies the benefits of mixtures on N yield compared to mowing. The design included N2 fixing and non-fixing species, as well as shallow- and deep-rooting species. *Lolium perenne* monoculture and mixtures with *Cichorium intybus*, or/and *Trifolium repens* and *T. pratense* were compared under grazing or mowing for their N yield and capture of fertilizer and atmospheric N. Mixtures of the N2 fixing and the non-fixing species yielded as much N as the *L. perenne* monoculture fertilized with 2.4 times more N, showing the tremendous benefit of mixtures for N efficiency. The addition of the deep-rooting *C. intybus* did not lead to a significantly larger N capture. The benefits of the mixtures on N yield were similar under grazing and mowing. Grazing did not modify the proportion of N derived from fertilizer and symbiotic fixation in the plants. We conclude that grass-legume mixtures are effective in improving N efficiency under both mowing and grazing.  
  
Keywords: multispecies swards, mixture effect, nitrogen yield, grazing  
  
Introduction  
  
Recent studies showed that mixing grasses and legumes clearly benefits phytomass and nitrogen (N) yields in fertilized swards managed under mowing (Suter *et al*., 2015). Complementarity between N2 fixing and non-fixing species (Nyfeler *et al*., 2011), as well as temporal and vertical niche differentiation are processes involved in the mixture effects benefiting productivity and nutrient capture of multispecies swards (Husse *et al*., 2017). But grazing may modify these processes as compared to mowing by its effects on plant growth, nutrient availability and spatial redistribution in the soil, as well as on soil compaction (Bilotta *et al*., 2007). The effects of mixing grass, forb and legume species on nutrient capture might therefore differ markedly under grazing and mowing. On the other hand, data from a previous study indicated that the relative advantage for phytomass production of a four-species grass-legume mixture as compared to a *Lolium perenne* monoculture was similar when grazed and when cut (Collins *et al*., 2014). The objective of our study was to determine whether grazing modifies the benefits of multispecies swards on N yield as compared to mowing.  
  
Materials and methods  
  
Rotational grazing with heifers and mowing (management types) were compared on five sward types in a split-plot design, with the sward type as main plot and the management type as subplot. This design is especially powerful for testing the interaction between management type and sward type. The subplots under mowing were cut at the start of each grazing period. The five sward types were: 1) monoculture of *Lolium perenne* (MonoLp), 2) mixture of Lp and *Cichorium intybus* (LpCi, 2/3 Lp + 1/3 Ci), 3) mixture of Lp, *Trifolium repens* and *Trifolium pratense* (LpTrTp, 2/3 Lp + 1/6 Tr + 1/6 Tp), 4) mixture of Lp, Ci, Tr and Tp (LpCiTrTp, 2/3 Lp + 1/9 of each of the other species), and 5) monoculture of Lp fertilized with 2.4 times more N than the other sward types (MonoLp\_HN, fertilization of 350 kg N ha-1 year-1). The four species were selected for their differences in N2 fixing ability and rooting depth (non-fixing: Lp and Ci, fixing: Tr and Tp, shallow-rooting: Lp and Tr, deep-rooting Ci and Tp). In the grazed plots, the yield was estimated by measuring the height of the swards before and after grazing with a rising plate meter (83 measurements per plot). The N derived from fertilizer application (Nfert) and symbiotic N2 fixation in Tr and Tp (Nfix) were measured using 15N-labelled fertilizer applied on subplots. The N derived from the soil (Nsoil) was calculated as the difference between the total N content and the sum of Nfix and Nfert. The data were analysed by ANOVA.  
  
Results and discussion  
  
The dry matter yields of the LpTrTp and the LpCiTrTp mixtures were significantly larger than those of the MonoLp sward (+47% on average over the grazing and mowing management; Table 1). This difference was +78% for the total N yield. These two mixtures even equalled the yield of the highly fertilized *L. perenne* monoculture (MonoLp\_HN). This confirms the tremendous benefit of grass-legume mixtures as compared to grass monocultures in terms of N efficiency. The interaction between the sward and the management types was not significant for either dry matter or total N yield (Table 1), which shows that the benefit of the mixtures on dry matter and N yield was similar under grazing and mowing. The addition of the deep-rooting *C. intybus* in the swards did not lead to a significantly larger N capture (LpCi versus MonoLp, and LpCiTrTp versus LpTrTp), indicating that the observed mixture effect on N yield was mainly due to symbiotic N2 fixation and not to vertical niche differences in N uptake from the soil.

Table 1. Effect of the sward types on the dry matter and the total nitrogen yield. The data are the average of 3 experimental years. The average of both management types is shown as the interaction between sward and management types is not significant. SE: standard error of the mean. Means followed by a common letter are not different at the 5% level (Duncan MRT).

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Sward type | N fertilisation  (kg N ha-1 yr-1) | Dry matter yield  (kg ha-1 yr-1) | | | Total N yield  (kg ha-1 yr-1) | | |
| Monoculture MonoLp | 145 | 4.7 | a | | 118 | a | |
| Mixture LpCi | 145 | 5.7 | b | | 142 | a | |
| Mixture LpTrTp | 145 | 6.8 | c | | 206 | b | |
| Mixture LpCiTrTp | 145 | 7.0 | c | | 213 | b | |
| Monoculture MonoLp\_HN | 350 | 6.7 | c | | 225 | b | |
| SE |  | 0.4 |  | | 13 |  | |
| *P*-value ANOVA | | | | | | | |
| Sward type |  | <0.05 | |  | <0.01 | |  |
| Management type |  | <0.01 | |  | <0.01 | |  |
| Interaction |  | 0.88 | |  | 0.67 | |  |

In each of the four species of the LpCiTrTp mixture, the total N content in the harvested phytomass, as well as its components (Nfert, Nsoil and Nfix), were similar under grazing and mowing (Figure 1). Thus, although grazing induced compaction of the upper soil layer (0-6 cm soil depth; data not shown), it did not modify the ratio of N derived from symbiotic fixation, fertilizer or the soil in the different species. The absence of a negative effect of grazing on symbiotic N2 fixation by legumes probably contributed to the similar mixture effects under the two managements.

Figure 1. Nitrogen content in the harvested phytomass of each species of the mixture with *L. perenne* (Lp), *C. intybus* (Ci), *T. repens* (Tr) and *T. pratense* (Tp) managed under mowing or grazing. Total N content is divided in N derived from the fertilizer (Nfert), N derived from N2 fixation (Nfix) and N derived from the soil (Nsoil). The data show the mean of two regrowths and the error bars the standard error of the mean.

Conclusion  
  
As compared to a *L. perenne* monoculture, the benefits of multispecies swards on phytomass and N yield were equally impressive under grazing and mowing. We conclude that grass-legume mixtures are effective for improving N efficiency under both mowing and grazing.

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