Grass-legume mixtures: a novel approach to forage production in Ethiopia

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Abstract

Ethiopia has the highest livestock numbers in Africa, and a large part of the population depends fully or partly on cattle for their livelihoods. The country experiences high rates of soil erosion due to degradation of cropland and rangelands, and overgrazing is a serious problem. In this paper, we report results from the first two harvests of two field experiments established in June 2021 at two different highland locations in Ethiopia: Hawassa in the south, and Bahir Dar in the north. Four species; two legumes (*Desmodium intortum* and *Stylosanthes guianensis*) and two grasses (*Brachiaria* hybrid 'Cayman' and *Panicum maximum* 'Mombasa') were sown in monocultures and various mixtures in a simplex design. Dry matter yields and botanical composition from each cut were recorded. The first harvest was taken around 100 days after establishment, while the second harvest was taken during the drought period, i.e. in January 2022 at Hawassa and in March 2022 at Bahir Dar. The difference between monoculture and mixture community performances varied in magnitude from site to site and across harvests; we found evidence of positive interactions between grasses and legumes at Hawassa. These preliminary results show that grass-legume mixtures using tropical species have some potential under Ethiopian conditions.

Keywords: grasses, legumes, monocultures, mixtures, productivity, Africa

Introduction

The livestock numbers in Ethiopia are among the highest in the world and almost all farmers hold some cattle or other livestock (Bachewe *et al.*, 2018). Most of the feed for the livestock is derived from free grazing on overgrazed rangeland and from crop residues. This aggravates the ever-rising problems with soil erosion and soil degradation. Cultivation of forage for livestock is still not very common or widespread in Ethiopia, and the number and variety of forage species used is limited. The adoption of forage legumes by farmers is also minimal (Muir *et al.*, 2014). A shift towards more intensive cut-and-carry feeding, using improved forage species for feed production, could counteract soil degradation. More yielding and better-quality livestock feed than communal grazing on crop residues or rangeland can alleviate the grazing pressure on land used for food crops. Positive mixing effects of grasses and legumes have been found in numerous studies under temperate conditions, e.g. Finn *et al.* (2013), but has not been studied extensively under tropical conditions (Muir *et al.*, 2014). In the current study, we examine the performance of improved grass and legume species. We report on results from the first two harvests of monocultures and various mixtures of grasses and legumes grown at two sites in Ethiopia.

Materials and methods

Field experiments were established at the end of June 2021 in Bahir Dar on a silty loam soil, pH 5.56 (10°30'N, 37°29'E, 1972 m a.s.l.) in the north and Hawassa on a loam, pH 6.63 (7°30'N, 38°28'E, 1660 m a.s.l.) in the south of Ethiopia. At each site, monocultures, and mixtures of two, three and four species were sown in a simplex design (Cornell, 2002) in a total of 60 plots (3×7 m^2). The species were the grasses *Brachiaria* hybrid 'Cayman' and *Panicum maximum* 'Mombasa', and the legumes *Desmodium intortum* 'Greenleaf 'and *Stylosanthes guianensis* 'Ubon'. In addition to monocultures, mixtures of two, three and four species varied to include both equal and unbalanced proportions, i.e. one species dominated the

mixture. The plots were fertilised with 100 kg DAP ha^{-1}, i.e.19 kg N, 16.5 kg P and 7 kg S ha^{-1} at sowing. No fertilisers were distributed after establishment. The species *S. guianensis* did not establish well at either site. All plots were weeded manually after establishment. Plots were harvested manually after ca. 100 days in mid-October 2021 at both sites. The second cut was taken 17 January 2022 at Hawassa, and 28 March 2022 at Bahir Dar, during their respective drought seasons. All biomass (sward height ca 7 cm) in the central 2×2 m^2 of the plots was weighed fresh, and a sub sample of 1 kg was weighed fresh, and then air dried at ambient temperatures to stable weight for determination of dry matter (DM) yield. To adjust for the non-establishment of *S. guianensis*, monocultures of this species were omitted from the statistical analysis, and the proportions of other species in mixtures that included *S. guianensis* were recalibrated to sum to 1. For each harvest by site combination, the DM yield was modelled as a function of the (adjusted) sown proportions and species interactions, following the diversity-Interactions modelling approach (Kirwan *et al.*, 2009).

Results and discussion

The modelled yields differed clearly between the two sites. In the 1st harvest, the yields in Hawassa were approximately three times higher than those in Bahir Dar (Figure 1). This reflects differences in both edaphic and climatic conditions between sites. Bahir Dar has poorer, more acidic soils, and had low rainfall during establishment of the experiment, while Hawassa has richer soils and more rain.

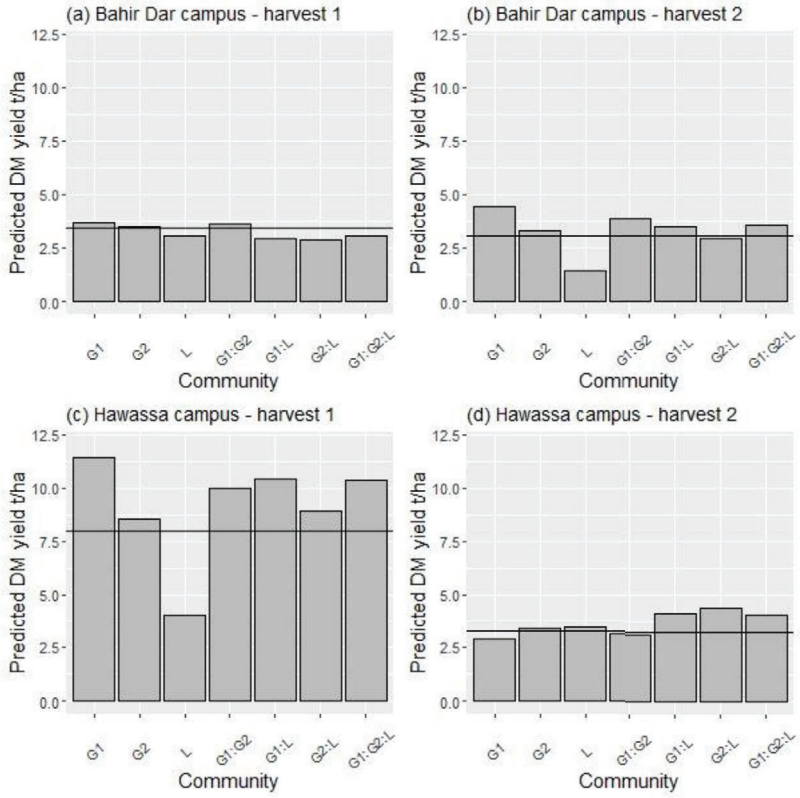

Figure 1. Model predictions of dry matter yield (t ha^{-1}) in 1st and 2nd harvest at Bahir Dar (A and B) and Hawassa (C and D) from monocultures with *P. maximum* (G1), *Brachiaria* hybrid (G2), *D. intortum* (L) and 50:50 mixtures of the two grasses (G1:G2), P. *maximum*: *D. intortum*, (G1:L) and *Brachiaria*:*D. intortum* (G2:L) and the 0.33:0.33:0.33 mixture (G1:G2:L). The horizontal line in each panel shows the average performance of the monocultures.

In the first harvest at Bahir Dar, we found no evidence of differences in modelled DM yield across the species diversity gradient (Figure 1A). In the 2nd harvest we found strong differences in species performances in monoculture (Figure 1B), with the two grasses outperforming the legume species, however, there was no evidence of interspecific species interactions or overyielding in mixtures.

In the first harvest at Hawassa, again strong differences in species performances in monoculture were identified with the similar pattern of the two grasses outperforming the legume species (Figure 1C). At both harvests in Hawassa (Figures 1C and 1D, a positive grass-legume interaction was identified, leading to improved yield of grass-legume mixtures over their respective weighted average monoculture performances.

The growth of *D. intortum* seedlings is relatively slow (Mwangi *et al.*, 2004), which may account for its lower performance in the second harvest at Bahir Dar and the first harvest at Hawassa.

Conclusions

These preliminary results show that mixing grasses with the *D. intortum* legume can potentially increase forage productivity in Ethiopian conditions. An additional benefit of including legumes in tropical productive grasslands may be improved soil health and reductions in land degradation.

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