Root biomass and carbon storage in differently managed multispecies temporary grasslands

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Abstract

Species-rich grasslands may potentially increase carbon (C) storage in soil, and an experiment was established to investigate C storage in highly productive temporary multi-species grasslands. Plots were established with three mixtures: 1) a herb mixture containing salad burnet (*Sanguisorba minor* L.), fenugreek (*Trogonella foenum-gruecum*), chicory (*Chicorium intybus* L.), caraway (*Carum carvi* L.), birdsfoot trefoil (*Lotus corniculatus* L.), chervil (*Anthriscus cerefolium* L.), plantain (*Plantago lanceolata* L.), lucerne (*Medicago sativa* L.) and melilot (*Melilotus officinalis*), 2) 50% of the herb mixture and 50% of a white clover (*Trifolium repens* L.) - perennial ryegrass (*Lolium perenne* L.) mixture, and 3) 5% of the herb mixture and 95% of the white clover-ryegrass mixture. Management factors were number of cuts per year and fertilizer application. Aboveground biomass increased considerably with increasing content of herbs and with fertilizer application in plots with a 4-cut strategy. With a 6-cut strategy without fertilizer, herbs had no effect on the aboveground biomass. In the herb mixture, biomass of small roots was lower than in mixtures with white clover and ryegrass. There was a tendency towards increased biomass in the large root fraction with increasing herb content. The experiment indicated increased CO_2 evolution following cultivation of multispecies grasslands.

Keywords: multispecies mixtures, herbs, white clover, ryegrass, root, CO_2 emission

Introduction

In grasslands most C originates from roots and total allocated C increases with plant species richness (Adair *et al.*, 2009). The larger roots seem to be more important than small roots in enhancement of the C pools (Rasmussen *et al.*, 2010). However, the storage of C in soils depends on both the inputs and the decomposition rate, which is especially important in farming systems with frequent grassland cultivation. We investigated above and belowground biomass in differently managed multispecies mixtures and CO_2 emission upon grassland cultivation.

Materials and methods

A plot experiment was established with three mixtures: 1) a herb mixture containing salad burnet, fenugreek, chicory, caraway, birdsfoot trefoil, chervil, plantain, lucerne and melilot; 2) 50% of the herb mixture and 50% of a white clover-perennial ryegrass mixture; and 3) 5% of the herb mixture and 95% of the white clover-ryegrass mixture. Also, some herbs were established in pure stands. All mixtures were managed with 4 or 6 cuts per year, with and without fertilizer application (200 kg N ha^{-1}via cattle slurry) for the 4-cut system. The pure stand was managed with 4 cuts and without fertilizer. In the spring of the third production year, aboveground biomass was determined by harvesting plots of 1.5 × 12 m, and belowground biomass was determined by wet sieving of eight soil samples per plot from three depths (0–10, 10–20 and 20–50 cm) sampled with an 8.75 cm inner-diameter auger. Furthermore, CO_2 release following simulated cultivation was investigated in an incubation experiment for soils from 0–10 and 10–20 cm depths.

Results and discussion

Aboveground biomass increased considerably with increasing content of herbs in the mixture and also with fertilizer application in plots with a 4-cut strategy (Table 1). With a 6-cut strategy, aboveground biomass was much depressed compared to the 4-cut strategy; in the previous years this depression was only noticed in the 100% herb mixture (Mortensen *et al*., 2012). The herb mixture was dominated by lucerne, most pronounced without fertilizer, and caraway, most pronounced with fertilizer application.

Table 1. Aboveground biomass and botanical composition of swards with different herb seeding rates, manure application and cutting frequency in spring cut. Biomass values with different letters are statistically different ($P < 0.05$). Annual biomass production in Mortensen *et al*. (2012)

Herbs in mix	Manure applied	Cuts per year	Biomass t DM ha^{-1}	Ryegrass	White Clover	Lucerne	Caraway	Chicory	Salad burnet	Plantain	Birdsfoot trefoil	Unsown
				Proportion of dry weight (%)[1]								
5%	0 N	4	2.6^{d}	61	32	4	3	0	0	0	0	0
50%	0 N	4	3.6^{c}	34	10	40	14	1	0	0	0	0
100%	0 N	4	4.7^{b}	0	0	77	17	1	2	0	1	2
5%	200 N	4	3.2^{cd}	74	22	0	5	0	0	0	0	0
50%	200 N	4	4.4^{b}	37	7	26	30	0	0	0	0	1
100%	200 N	4	5.9^{a}	0	0	30	67	1	1	0	0	1
5%	0 N	6	1.8^{e}	59	39	0	0	0	0	0	0	2
50%	0 N	6	1.7^{e}	61	33	0	3	0	0	1	0	2
100%	0 N	6	1.6^{e}	0	0	15	39	5	8	6	8	20

[1]Chervil, melilot and fenugreek were not present at all.

Total root biomass (small and large roots at all depths) was not significantly affected by treatments or by species type in the pure stand experiment (Figure 1). However, in specific size classes and depths differences appeared. Thus, in the 100% herb mixture the biomass of small roots (<8 mm) in the top layer were significantly lower ($P < 0.001$) than in mixtures with white clover and ryegrass, and similarly the root biomass in this fraction was lower without fertilizer application ($P < 0.01$). The biomass of large roots (>8 mm) in mixtures with herbs showed considerable variation probably as a result of more taproots and there was a non-significant tendency towards increased biomass in the large root fraction with increasing herb content. This was probably related to the high contents of lucerne and caraway both having significantly larger root biomass in 10–20 and 20–50 cm in the pure stand plots of these species.

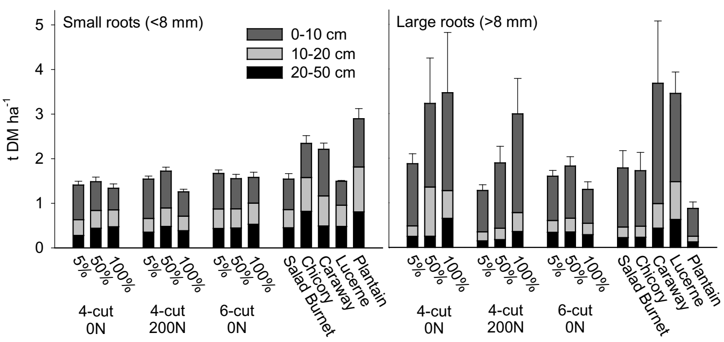

Figure 1. Root biomass at different depth of swards with different herb seeding rate (5, 50 or 100%), manure application (0 or 200N) and cutting frequency (4- or 6-cut) and of selected species in pure stand in a separate experiment. Error bars: SE

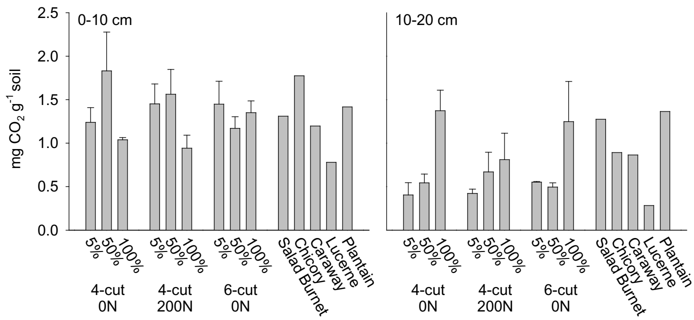

Figure 2. Accumulated CO_2 evolved from soil during incubation at 20ºC for 97 days. Error bars: SE. Unreplicated results for soil from plots with species in pure stand

Release of CO_2 during incubation following simulated cultivation showed significantly ($P < 0.001$) higher mineralization in the topsoil compared to 10–20 cm (Figure 2), indicating larger C deposition in this layer of the grassland soil where a huge part of root biomass was also present. There was no effect of fertilization and cutting management on CO_2 release following cultivation, but in the 10–20 cm layer CO_2 evolution from the soil of the 100% herb mixture was significantly increased compared to the mixtures with grass-clover ($P < 0.05$). This indicates that at least in the plough layer (0–20 cm) the extra C sequestered by temporary multispecies grasslands may to some extent be accompanied by increased mineralization following cultivation.

Conclusions

In the present experiment, inclusion of herb species in grasslands was shown to increase yield stability (Mortensen *et al*., 2012). Furthermore, the results presented here have indicated some potential of species known to have deeper and denser rooting systems to increase belowground biomass, an important asset for C sequestration in grasslands. However, in mixed cropping systems with temporary grassland it is important to know if differences in root composition affect the rate of decomposition of soil organic matter upon cultivation to evaluate the net C storage of the cropping system. This experiment gave an indication of increased CO_2 evolution following cultivation of multispecies grasslands, but this needs further investigation over longer time periods and with focus also on soil below the plough layer.

References

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