Effect of an in-season living mulch on leaching of inorganic nitrogen in cauliflower (*Brassica oleracea* L. var. *botrytis*) cropping in Slovenia, Germany and Denmark

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Abstract

Vegetables with a high nitrogen demand such as cauliflower may cause intensive leaching of nitrate to the environment in conventional as well as in organic production. In organic cropping systems, the use of an in-season living mulch may decrease the risk of nitrate leaching after harvest when left growing in the field to the end of the leaching season. The aim of this study was to investigate the effect of growing an in-season living mulch including legumes on the risk of leaching of inorganic nitrogen over winter, and soil nitrogen availability the following spring. Three field experiments were carried out in Slovenia, Germany and Denmark in the frame of the Interveg project (CORE organic II). Evaluation of soil inorganic nitrogen content was done at planting, at harvest, in late autumn and in spring to a depth of 0.6, 0.9 or 1.5 m as well as nitrogen uptake by the biomass. This study reports preliminary results of the first year of experiments on soil inorganic nitrogen. They indicate that living mulches may have a potential to decrease the nitrate leaching risk depending on the design of the cropping system.

Introduction

Production of organic vegetables is thought to be less harmful to the environment compared to conventional cropping. However, leaching losses of nitrate may be high in organic production depending on the composition of the crop rotation and use of catch crops (Thorup-Kristensen et al., 2012). In order to reduce nitrate leaching to the environment, new organic cropping systems have been developed where the main crop is intercropped with an in-season living mulch. The idea is to better exploit ecosystem services by use of the living mulch for example by attracting beneficial insects, suppressing weeds, increasing biodiversity and decreasing nitrate losses (Kremen and Miles, 2012). However, the question is if nitrate losses can be reduced while maintaining crop yields of, for example, a short-seasoned and high nitrogen (N) demanding crop such as cauliflower (*Brassica oleracea* L. var. *botrytis*) and if N fertilizer levels may be reduced when employing a living mulch including legumes. The aim of this study was to investigate the effect of growing an in-season living mulch including legumes on leaching of inorganic N in new intercropping systems for organic cauliflower production in Slovenia, Germany and Denmark. The study represents the first year preliminary results of the experiments carried out in the frame of the Interveg (Core Organic II Era-Net) project (Canali, 2013).

Material and methods

Experiment Slovenia was carried out at the University Agricultural Centre of the University of Maribor located in Pivola near Hoče (latitude 46°28'N, longitude 15°38'E) in Slovenia. In a randomized block design with two factors (i.e. LM sowing time and crop cultivar) and three replicates, cauliflower was grown within June and October 2012 with white clover (*Trifolium repens* L.) as living mulch, which was sown directly after planting of the cauliflower. Results are reported for the Snow ball cultivar.

Experiment Germany was carried out at the research farm Hessian State Estate Frankenhausen, located at Grebenstein (latitude 51°9'N, longitude 9°4'E) in Germany. In a randomized block design with two factors (i.e. LM introduction strategy comparing the addition and the substitution design, and crop cultivar, comparing the performances of the Chambord and the White ball ones) and three replicates, cauliflower was grown on a Parabrown earth with loess cover between June and September 2012 intercropped with white clover (*Trifolium repens* L.), which was sown 28 days after planting of the cauliflower.

Experiment Denmark was carried out at the Research Centre Aarslev, located at mid Funen (latitude 55°18'N, longitude 10°27'E) in Denmark. In a strip plot design with three factors (i.e. LM presence, crop cultivar and N fertilization dose) and three replicates, cauliflower was grown on a sandy loam soil from the

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31st May until harvest during the period 3-20 August 2012. The design was a substitution design where the rows of living mulch replaced every third row of cauliflower which reduced the crop density by one third. The living mulch was an overwintering grass-clover of *Trifolium repens* L. and *Lolium multiflorum* Lam. that was incorporated in strips or fully incorporated in December 2012 in both systems. The rows of living mulch were cut aboveground and root pruned below ground (0.2 m depth) before planting the cauliflower in May 2013 to control interspecies competition. The plots were fertilized with two levels of dried chicken manure. The amount was adjusted based on the inorganic N in the soil to a total of 240 and 290 kg N ha^{-1}. Results are reported for the Chambord cultivar.

In all three countries, after harvest, the living mulch was left to grow until early spring the following year. Soil samples were taken (to 0.6, 0.9 or 1.5 m depth) to evaluate the inorganic N content at planting, harvest, late autumn, and the following spring depending on the crop rotation of each country. The field experiment was conducted according to standard agronomic practices used by local farmers and to the rules of organic management which exclude the use of inorganic fertilizers or pesticides. Preliminary statistical analysis included analyses of variance (F-test) and multiple comparisons based on the least significant differences (GLM procedure).

Results and conclusions

Overall the levels of soil inorganic N at harvest were in the range of 34-106 kg N ha^{-1} when comparing the top soils (0-0.9, 0-0.6 and 0-1 m soil layer) for Slovenia (Table 1), Germany (Table 2) and Denmark (results not shown). At the end of the leaching season the following spring the amounts were in the range of 38-82 kg N ha^{-1}. Cauliflower is known to cause leaching levels of up to 300 kg N ha^{-1} or more due to a high amount of soil inorganic N and crop residue N left in the field at harvest. Compared to such levels, the leaching potential was low in the three organic systems in Slovenia, Germany and Denmark. This was confirmed by the measurements of soil inorganic N in late autumn (results not shown). However, the potential N leaching was still of a significant size in all three organic systems (Table 1-3), which was confirmed by the amount of 35-50 kg N ha^{-1} present in the 1-1.5 m soil layer, which may be considered as the bottom of the root zone of cauliflower, in the Danish experiment at the end of the leaching season (data not shown).

In Slovenia (Table 1), at harvest, the living mulch tended to decrease soil inorganic N in the 0-0.9 m soil layer from 91 to 53 kg N ha^{-1}, but at the end of the leaching season the following spring, this difference had disappeared. In Germany (Table 2), at the end of the leaching season, the addition design tended to have a 8-9 kg N ha^{-1} lower content of soil inorganic N, whereas the substitution design had a 7-12 kg N ha^{-1} higher content compared to the sole cropping system for the two cultivars. At the end of the leaching season in Denmark (Table 3), the soil inorganic nitrogen content tended to be 7-14 kg N ha^{-1} lower in the intercropped system compared to the sole cropped system for the two fertilizer levels.

Table 1: The soil inorganic N content in the 0-0.9 m soil layer under cauliflower without or with living mulch (addition design) in Slovenia.

Treatment	Harvest 0-0.9 m (kg N_{inorg} ha^{-1})	End of leaching season 0-0.9 m (kg N_{inorg} ha^{-1})
No LM	91	77
LM	53	82
	n.s	n.s.

Note: No LM = sole crop system; LM = crop+living mulch system; n.s. = not significant.

Table 2: The soil inorganic N content in the 0-0.6 or 0-0.9 m soil layer under two cultivars of cauliflower without (control) or with living mulch (addition and substitution design) in Germany.

Cultivar	Treatment	Design	Harvest 0-0.6 m (kg N_{inorg} ha^{-1})	End of leaching season 0-0.9 m (kg N_{inorg} ha^{-1})
Chambord	No LM	Control	51	48
	LM	Addition	45	40
	LM	Substitution	34	60
White ball	No LM	Control	41	47
	LM	Addition	50	38
	LM	Substitution	79	54
			n.s.	n.s.

Note: No LM = sole crop system; LM = crop+living mulch system; n.s. = not significant.

Table 3: The soil inorganic N content in the 0-1.5 m soil layer under cauliflower without or with living mulch (substitution design) grown at two fertilizer levels in Denmark.

Treatment	Harvest 0-1.5 m soil layer (kg N_{inorg} ha^{-1})	End of leaching season 0-1.5 m soil layer (kg N_{inorg} ha^{-1})
No LM, 240	95	116
No LM, 290	94	126
LM, 240	106	102
LM, 290	94	119
	n.s.	n.s.

Note: No LM = sole crop system; LM = crop+living mulch system; 240 = fertilized by 240 kg N ha^{-1}; 290 = fertilized by 290 kg N ha^{-1}; n.s. = not significant.

Discussion

Overall, the results indicate that the continued presence of the living mulch in the field over winter compared to bare soil after the sole crop may reduce the soil mineral N content during the leaching season and, consequently, contribute to lower the nitrate leaching risk from the cauliflower systems. However, the German results indicate that the effect depends on the design chosen for the introduction of the living mulch into the cropping system. In Germany, the substitution design, where a row of living mulch replaced a row of crop (lower crop plant density), tended to increase leaching. This may be due to a lower N uptake ability of the living mulch compared to the cauliflower that was replaced. In contrast, the addition design, where the living mulch was introduced in-between the rows of cauliflower (same crop plant density), tended to reduce leaching. This was probably due to an overall increase of the uptake capacity for N of the entire plant stand of crops and living mulch.

Further analyses of the results of this study are needed. Still, they point to new perspectives of the importance of the cropping system design for the introduction of living mulches into organic production of high N demanding crops.

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