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NITROGEN CONSERVATION WITH COVER CROPS: EFFECT OF CN RATIO AND N LOSSES OVER WINTER ON THE POTENTIAL TO SUPPLY SUCCEEDING CROPS

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Abstract: A field trial with different cover crops was carried out in 2018 in Hennef, Germany, to clarify the fate of plant nitrogen over winter. High amounts of nitrogen (up to 100 kg ha^{-1}) were taken up by aboveground plant biomass before winter. Nitrate leaching was avoided in a large scale compared to the untreated control. After winter 10 to 55 % of shoot nitrogen were lost with the highest decline in legumes and the lowest in crucifers. If mulched, losses raised up to 90 %, e.g. for narrow-leaved lupin. Nitrogen losses were slightly lower, when mulch was incorporated by rotary tilling. The CN ratio in stems became wider after winter. Only in leaves the CN ratio was narrow enough to cause an effect on nitrogen supply to the succeeding crop. A trend to higher soil mineral N in spring was only noted in treatments with frost hardy cover crops.

Introduction: In low input systems like organic farming cover crops are not only important to reduce nitrate leaching for ground water protection, but also to preserve nutrients over winter for succeeding crops. While the cover crop potential to reduce nitrate leaching is evident and widely accepted in practice, there is often no empirical evidence for increased nitrogen availability of succeeding crops (Sieling 2019). In warm and wet winters cover crops with a narrow CN ratio may lead to a secondary leaching (Bergkvist et al. 2011) whereas cover crops with a wide CN ratio rather tend to fix nitrogen temporarily. Both can lead to no or even negative effects on N mineralization in spring (Cicek 2015). To work out reasons for this 'nitrogen transfer problem' the loss of nitrogen and the development of the CN ratio of shoot biomass over winter were investigated. Selected cover crops were combined with different crop management (none, mulching and rotary tilling, the latter only for species with low resistance to frost) in the frame of the interdisciplinary on-farm research project Organic Pilot Farms in North-Rhine Westphalia, Germany assuming the following hypothesis: Winter hardy compared with frost susceptible cover crops take up and lose lower amounts of nitrogen over winter resulting also in a narrower CN ratio of residual shoot biomass.

Material and methods: Cover crops of different levels of frost hardiness such as phacelia (*Phacelia tanacetifolia*, cv. Beehappy 12 kg ha^{-1}), oilseed radish (*Raphanus sativus var. Oleiferus* cv. Silentina 25 kg ha^{-1}), turnip rape (*Brassica rapa*, cv. Jupiter 15 kg ha^{-1}), black oat (*Avena strigosa*, cv. Pratex 80 kg ha^{-1}), winter rye (*Secale cereale*, cv. Bonfire 120 kg ha^{-1}), narrow-leaved lupin (*Lupinus angustifolius*, cv. Boruta 120 kg ha^{-1}) and crimson clover (*Trifolium incarnatum*, cv. Linkarus 30 kg ha^{-1}) were sown on 12th of August 2018 as a complete randomized block design with four replications at the organic

experimental farm Wiesengut, Germany (65 m a.s.l., 10,3 °C, 840 mm, silty loam). The previous crop was faba bean (*Vicia faba*) and seedbed preparation was carried out with a rotary harrow after inversion tillage. Due to low rainfall since May 2018 the trial was irrigated twice with 50 mm before and after sowing in August. All cover crops were hoe weeded with additional hand weeding especially in the legumes.

Soil mineral N was measured monthly after sowing. Shoot biomass, separated into stem and leaves, was harvested shortly before the first frost at 15th of November 2018 and after winter (22nd of February 2019). Immediately after the autumn harvest subplots were either only mulched or mulched and rotary tilled (the latter only for species with low resistance to frost) in contrast to continued growth. To enable measurements after winter in each plot mulched biomass was left on soil surface in a closed net of 2500 cm^2 with 5 mm mesh and two litterbags (600 cm^2, 1 mm mesh) were incorporated into soil at 5 cm depth (only phacelia, oilseed radish, black oat and narrow-leaved lupin). All bags contained mulched biomass equivalent to the surface shoot biomass. Additional mulched biomass (30 g) of oilseed radish, turnip rape, black oat and winter rye was left on soil surface in small litterbags (200 cm^2, 1 mm mesh) to compare decomposition over winter. Samples were taken four times in 21 day intervals with each sampling consisting of five repetitions per culture. To correct the input of soil derived N, biomass stored in litterbags was analysed according to the method described by Jacobs et al. (2011). Data were evaluated by ANOVA followed by the Tukey-Test (α=0.05) using SAS software 9.4.

Results: Nitrogen uptake of cover crops before winter ranged between74 (turnip rape) and 122 kg N ha^{-1} for lupin(Table 1).In contrast nitrogen uptake into root biomass was relatively low with around 20 kg N ha^{-1} (results not sown). Winter hardy cover crops took up lower amounts of nitrogen compared to cover crops with low resistance to frost. Stem elongation of frost hardy species tended to be low resulting in an N uptake domination by leaves except for crimson clover (CC). Similar to cover crops with low resistance against frost, N uptake of crimson clover was balanced between stem and leaves. The CN ratio in leaves was relatively narrow in all cover crops, the CN ratio in stem of cover crops with a low resistance against frost was relatively wide (>30), as expected. Similar to leaves, the narrowest CN ratio in stem was measured in both legumes.

Table 1: Effect of different cover crops on nitrogen uptake into biomass (stem and leaves separated) und CN ratio before winter and after different processing in February on Wiesengut (Tukey-test, HSD (honestly significant difference) α=0.05).

Date	**Parameter**	PH	OR	TR	BO	WR	LUP	CC	*HSD*
15.11.2018	stem (kg N ha^{-1})	44.7	39.2		53.7		38.3	43,6	*n.s.*
	leaves (kg N ha^{-1})	45.7	41.6	73.7	47.9	76.2	84.0	75,7	*19.8*
22.02.2019	stem (kg N ha^{-1})	38.5	38.8	7.3	36.6		28.3		*23.0*
	leaves (kg N ha^{-1})	27.8	33.6	55.7	30.3	57.1	26.2	*66.6	*24.7*
	mulch (kg N ha^{-1})	26.0	38.4	15.0	45.9	36.1	10.9	33.8	*14.1*
	rotary tilled (kg N ha^{-1})	50.2	33.2		60.6		29.1		*14.6*
15.11.2018	stem CN ratio	38.8	38.3		36.9		22.1	17,9	*7.4*
	leaves CN ratio	15.7	14.0	19.0	15.5	19.9	10.6	9.1	*3.2*
22.02.2019	stem CN ratio	36.5	37.6	12.2	47.0		30.3		*9.8*
	leaves CN ratio	12.2	11.2	13.4	25.3	19.6	10.6	*13.1	*4.2*

PH - phacelia, OR - oilseed radish, TR - turnip rape, BO - black oat, WR - winter rye, LUP - narrow-leaved lupin and CC - crimson clover, * = total biomass of CC, no possibility to separate stem and leaves

After winter the amount of nitrogen in shoot biomass was between 10 and 55 % lower than before winter if cover crops were not processed. The highest N-losses occurred in legumes. If mulched, losses raised dramatically, e.g. in narrow-leaved lupin 90 % of the nitrogen uptake was lost till end of February. Nitrogen losses were slightly lower, when mulch was rotary tilled (for phacelia, black oat and narrow-leaved lupin, only on oilseed radish this effect could not be observed). Changes in stem CN ratio over winter were relatively low, only stem CN ratio of narrow-leaved lupin and black oat raised further, and for the latter, the same happened in leaves.

In the additional litterbag trial during the first 21 days no significant difference was observed between species while already 40 % losses of nitrogen occurred (Fig. 1). After 42 days cruciferous cover crops lost another 30 %. In oilseed radish only 10 % N remained after 63 days and turnip rape had degraded completely after 63 days. Grasses, in contrast, still contained about 40 % of the initial N uptake. Differences with respect to frost hardiness were not noted.

Fig. 1: Relative amount of N in shoot biomass of mulched cover crops stored in litterbags (OR - oilseed radish, TR - turnip rape, BO - black oat, WR - winter rye) over 3 months (16.11.18 – 08.02.19) on Wiesengut (Tukey-test, HSD α=0.05).

Soil mineral N in the upper soil layer was high (up to 80 kg N ha^{-1}) in September after harvest of faba beans (Fig. 2). However, all cover crops took up the available nitrogen until November. Thereby Nitrate leaching could be avoided compared to the untreated control (Stumm et al. 2019). After winter, mineralization started to be visible in April, but a significant effect of various cover crops could not be found. A slightly higher nitrogen availability was only observed after hardy cover crops as crimson clover, turnip rape and winter rye.

Fig. 2: Soil mineral N (NO3-N, NH4-N in kg ha^{-1}) in 0-30 cm under different cover crops (CO – control, PH - phacelia, OR - oilseed radish, TR - turnip rape, BO - black oat, WR - winter rye, LUP - narrow-leaved lupin and CC - crimson clover) on Wiesengut (Tukey-test, HSD α=0.05).

Discussion: The potential of cover crops to take up high amounts of nitrogen before winter thus reducing nitrate leaching is well known and could be confirmed under the conditions of organic farming in Rhineland, Germany. Nevertheless, handling of cover crops to conserve nitrogen over winter and to provide nitrogen fertilizer equivalents to succeeding crops is challenging and mainly depends on winter hardiness, CN ratio and residue management as well as on temperature and precipitation (Sieling 2019). The own results showed a clear advantage to minimize N losses especially for frost hardy plants if not mechanically treated (cf. Bergkvist et al. 2011). The narrow CN ratio of hardy plants such as crimson clover, turnip rape and winter rye could give a small note to possibly higher mineralisation in spring. The evaluation of effects on the succeeding summer wheat (*Triticum aestivum*) is in process as well as the repetition of the cover crop trial.

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Image:

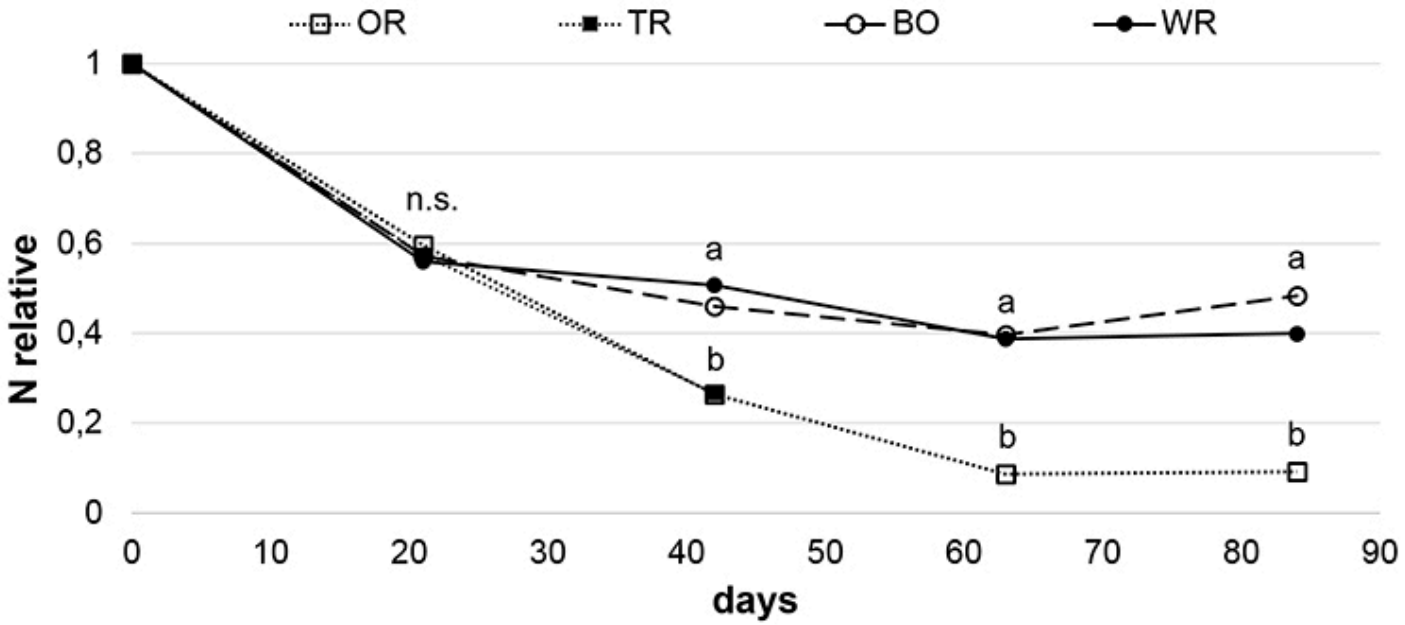
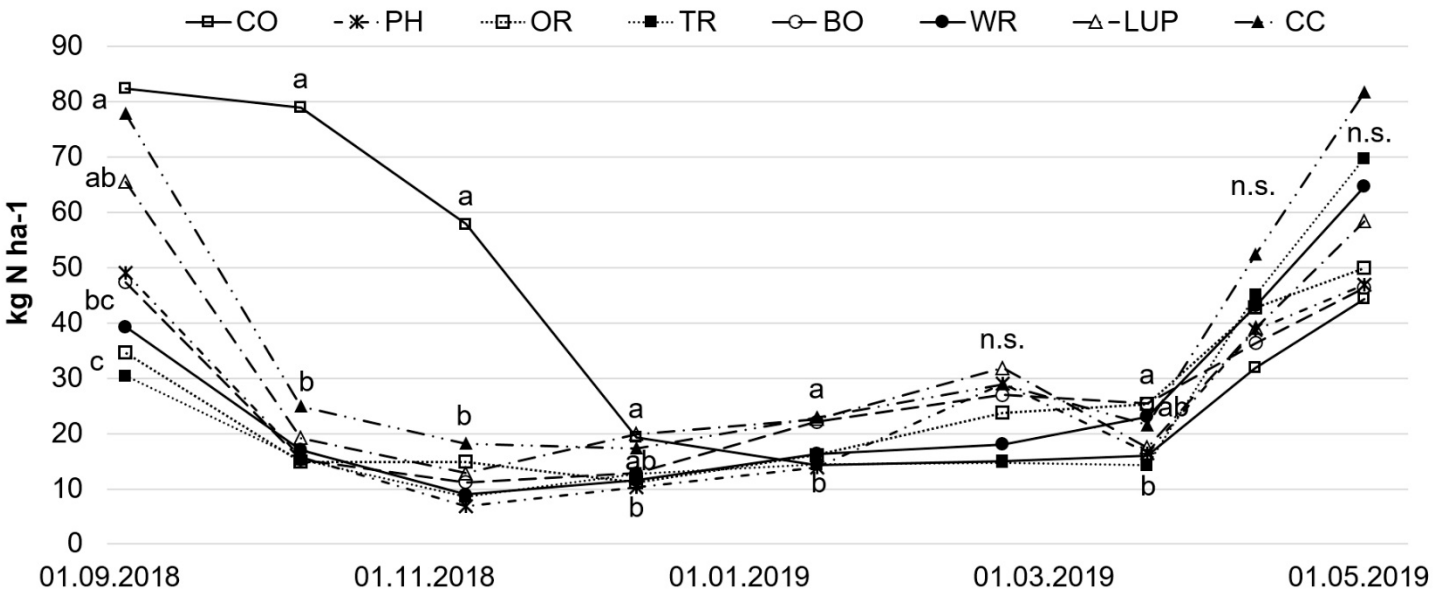


Image 2:



Disclosure of Interest: None Declared

Keywords: CN ratio, cover crops, nitrate leaching, nitrogen supply, succeeding crops