Management of vegetable crop residues for reducing nitrate leaching losses in intensive vegetable rotations

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Abstract
Crop residues of field vegetables are often characterized by large amounts of biomass with a high N -content. Even when these are incorporated in autumn, high rates of N mineralization and nitrification still occur causing important N -losses through leaching. Crop residues thus pose a possible threat to maintaining water quality objectives, but at the same time they are a vital link in closing the nutrient and organic matter cycle of soils. Appropriate and sustainable management is needed to fully harness the potential of crop residues. In this research, two fundamentally different management strategies are investigated, namely i) removal of crop residues followed by a useful and profitable application or ii) on-field treatment of crop residues in order to prevent N -losses and maintain soil quality. We here present the preliminary results of these experiments, and more comprehensive results will be presented during the conference.

Introduction
Crop residues constitute an important link in soil nutrient and organic matter cycle and aid in maintaining soil quality and fertility [12, 2]. The combined above- and belowground biomass of crop residues is often greater than the biomass of the harvested crop. Vegetable crop residues take a particular position relative to arable crops due to often large amounts of biomass and high N -content. Economically important vegetable crops such as cauliflowers may leave 50 ton or more of fresh material ha^{-1} as crop residues with a N -content of up to 200 kg N ha^{-1} [9]. Vegetable crop residues are characterized by low C:N ratios [4] and mineralize rapidly [6, 11]. During summer generally more than 80% of N present in cauliflower crop residues will be mineralized within 8 weeks [5]. An important amount of vegetable crops are harvested during late autumn and despite decreasing soil temperatures during autumn, high rates of N mineralization and nitrification still occur [4]. Crop residues may thus lead to considerable N losses through nitrate leaching during winter [3]. Hence crop residues pose a possible threat to maintaining water quality objectives. However, at the same time crop residues are a vital link in closing the nutrient and organic matter cycle of soils. Appropriate and sustainable management is needed to harness the full potential of crop residues [1].

Materials and methods

On field management of crop residues
The field experiments in this research are set up in 'long term' experiments (18 months), and 'short term' experiments (2-6 months), all located in the intensive vegetable growing region in Flanders (Belgium). All field experiments were designed in fully randomized blocks with four replicates.

Long term experiments
Two long term experiments are set up to investigate the effect of alternative crop rotations on soil mineral N -content compared to conventional vegetable crop rotations. The potential of including either non-vegetable crops or cover crops in vegetable crop rotations is assessed. In the long term experiments the vegetable crop residues are treated in a conventional manner, namely left on the field and incorporated. The first alternative crop rotation examines the inclusion of Italian ryegrass (*Lolium*

multiflorum) in cauliflower (*Brassica oleracea var. botrytis*) rotations. Per location two treatments, namely (i) cauliflower – Italian ryegrass (sown in August) and (ii) cauliflower – cauliflower – Italian ryegrass (sown in October) are compared to the conventional cauliflower – cauliflower combination. Following spring one or two cuttings of grass is harvested and removed. The remaining organic material is incorporated and a new cauliflower crop is planted. The field experiments are established at three locations with a different soil texture (sand, sandy loam and loam) in order evaluate the effect of soil texture on nitrate leaching. The second alternative crop rotation examines the use of two cover crops (Italian ryegrass or winter rye (*Secale cereale*) after a cauliflower crop. Similar as for the first alternative rotation two rotations, namely (i) cauliflower – cover crop (sown in August) and (ii) cauliflower – cauliflower – cover crop (sown in October) are compared to a conventional double cauliflower rotation. However in contrast to the first alternative rotation the cover crop will be incorporated during spring instead of harvested. Again three locations with different soil textures (sand, sandy loam and loam) are chosen to take into account the influence of the latter.

Short term experiments
Several crop residue management strategies are assessed through means of short term field experiments. A first set of field experiments assesses the effect of conventional crop residue incorporation compared to no-incorporation or total removal of crop residues for cauliflower, leek (*Allium porrum*) and headed cabbage (*Brassica oleracea convar. capitata var. Alba*). Two cauliflower crops, one headed cabbage crop and one leek crop were established at a sandy loam soil. Another three fields with cauliflower are set up on a sandy soil. Following harvest of crop residues a cover crop (winter rye, Italian ryegrass or black oats (*Avena strigosa*)) was sown and compared to leaving the field fallow. A second set of field experiments examines the effect of three immobilizing materials on N losses. At two fields on a loam and a sandy loam soil cereal straw (12 t ha^{-1}), corn straw residue (12 t ha^{-1}) or immature green waste compost (50 t ha^{-1}) was mixed with cauliflower residues and subsequently incorporated. The three treatments are compared to incorporation of cauliflowers residues without immobilizing materials. The potential of cover crops undersown is evaluated at a third set of field experiments. On a sandy loam soil three cover crops (Italian ryegrass, winter rye or phacelia (*Phacelia tanacetifolia*)) were sown 4 week after planting of a cauliflower crop and compared to a treatment without understorey.

Removal of crop residues
In the crop residue removal scenario we assess the potential of ensilaging or composting of vegetable crop residues followed by reapplication on the field.
Four crop residues (leek, celery, cauliflower and headed cabbage) were mixed with corn straw residues and 42L of fresh material (50/50 vol% composition) was ensilaged in 15L buckets (Agriton) specially designed for this purpose. Before ensilaging, the bulk density, organic matter, dry matter, N - and P -content was measured for the starting materials. In the composting scenario two compost piles (12 m long × 3 m wide) with crop residues of leek or headed cabbage residues, mixed with additional materials, were set up at the end of November in open air on a concrete floor, with a mixture of 20 vol% crop residues, 30 vol% wood chips, 30 vol% bark and, 20 vol% straw. Temperature and CO_2 levels in the composts were monitored and the compost piles were mixed, turned and covered or rewetted when necessary. Before composting bulk density, organic matter, dry matter, N - and P - content was measured for the starting materials and the feedstock mixture.

Plant and soil sampling
General soil properties were determined at all fields before the start of the experiment. During the experiment soil samples were taken monthly with an auger in three layers: 0-30 cm, 30-60 cm, 60-90 cm. These samples were analysed for ammonium-N and nitrate-N after 1 M KCl extraction in order to determine soil mineral N profiles. Crop and crop residue (leaves and stalk) samples were collected at harvest. Four subsamples were taken per treatment. All plant samples were dried, ground and analysed for N and P content.

Results and discussion

Field experiments are still ongoing but some preliminary results are already available. Total mineral N content (N_{min}) was generally greater following incorporation of vegetable crop residues compared to leaving them untouched on the soil surface (Fig. 1), corresponding with results observed in previous studies [8]. Increasing disturbance and incorporation leads to a decreasing residue particle size and thus increases the surface area available for microbial decomposition [10, 7]. More importantly, the crop residues left undisturbed continued to take up N from the soil, further depleting the soil mineral N. Removal of crop residues logically resulted in reduced mineral N concentrations in soil compared to the other options. The overall decrease of soil mineral N with time is a result of leaching of NO_3^--N out of the soil profile.

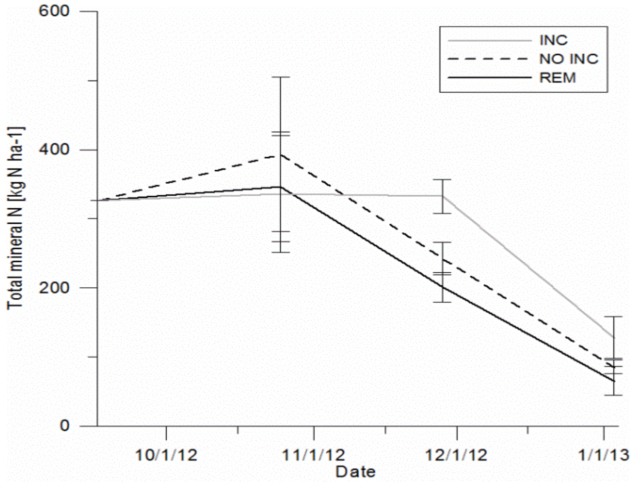

Figure 1 : Mean total mineral N content (N-NH_4^+ + N-NO_3^-) with corresponding standard deviation of the 0 – 90 cm soil layer following a cauliflower crop harvested in September (INC= incorporation crop residues, NO INC= leaving the crop residues behind on the field, REM= removal of crop residues).

Catch crops were undersown in a cauliflower crop to allow the catch crop to be fully developed at harvest of the main crop and facilitate additional N uptake. Due to dry conditions during sowing period growth the catch crops developed poorly. However, first results seem to indicate an effect of Italian ryegrass and phacelia on soil mineral N content (Fig. 2). The winter rye seeds appeared to be of low quality and only limited growth occurred. This may explain the small difference between plots without and with undersown winter rye. Nitrate was the dominant form of inorganic N in all fields.

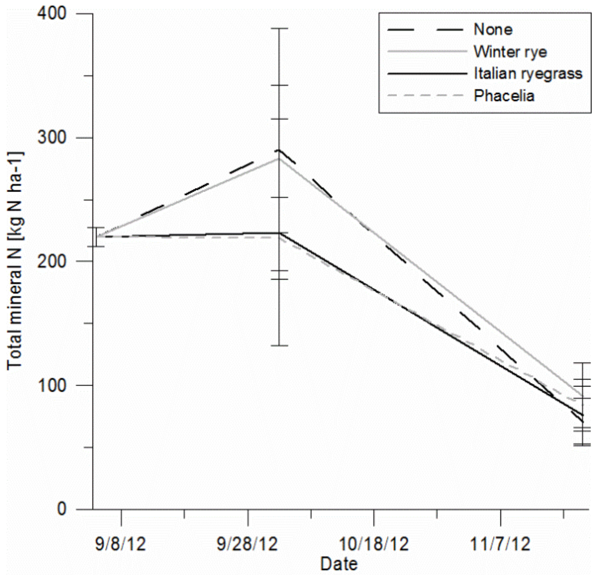

Figure 2 : Mean total mineral N content (N-NH_4^+ + N-NO_3^-) with corresponding standard deviation of the 0 – 90cm soil layer in a cauliflower crop with undersown catch crop.

Clear differences in chemical properties of the silage products were found, with less optimal quality (e.g. pH > 5) for silage based on cauliflower and headed cabbage, the crop residues with the highest water content. For these products, smaller volumes could be compacted in the buckets when the silage started. The silage based on celery had a relatively high NO3-N content and had the best characteristics as fodder.

Conclusion and perspectives

Appropriate crop residue management may contribute to improved soil and water quality, help meet the nitrate directive requirements and possibly imply a new source of valuable organic material for off-field use. Incorporation of crop residues increases total mineral N content and possible risk for nitrate leaching, whereas removal of crop residues lowers total mineral N content. Undersowing catch crops in vegetable fields may aid in preventing nitrate leaching but further investigation is needed. Evaluation of alternative crop rotations, immobilizing materials and potential valorisation of vegetable crop residues through ensilage or composting is currently ongoing and results will be further presented at the symposium.

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Acknowledgments

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