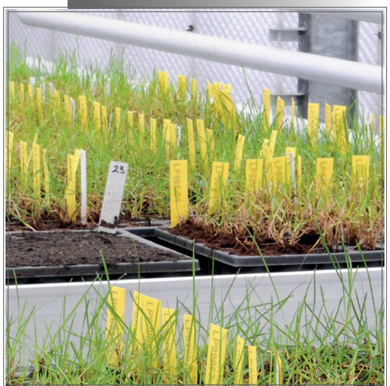

NUTRIHORT

Nutrient management, innovative techniques and nutrient legislation in intensive horticulture for an improved water quality

September 16-18, 2013, Ghent

Book of Abstracts

editors

- Karoline D'Haene
- Bart Vandecasteele
- Raf De Vis
- Sara Crappé
- Danny Callens
- Els Mechant
- Georges Hofman
- Stefaan De Neve

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NUTRIHORT: Nutrient management, innovative techniques and
nutrient legislation in intensive horticulture for an improved water quality
16 - 18 September 2013, Ghent, Belgium

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PREFACE

Background

Growers urgently need to find and implement more sustainable strategies for the intensive production of vegetables, potatoes, flowers and ornamental trees. Plant production in the open field or in greenhouses is challenged by the need to balance high productivity and sometimes late harvests with fewer nutrient losses to the environment. The reasons for this are clear: the nutrient enrichment of soil and water disrupts the natural processes in agro-ecosystems and leads to decreased biodiversity. High concentrations of nitrate or phosphate can cause eutrophication of the surface and coastal water. Leaching of nitrate or phosphate to the groundwater can pose a problem for drinking-water production.

Aims of NUTRIHORT

NUTRIHORT presented the current knowledge of sustainable and innovative techniques in vegetable and ornamental plant production. The conference focused on innovative fertilization, crop residues management, crop rotation, organic matter management and soil quality practices in horticulture. Throughout this conference, the focus was on the conflict between crop quality demands and legislative requirements to protect water quality.

In addition to oral and poster presentations on these topics, working groups during dedicated sessions discussed 1) technical and economic benchmarking of sustainable and innovative cultivation and fertilization techniques in horticulture and 2) the implementation of environmental EU directives in different horticultural regions and opportunities for innovative nutrient legislation to control pollution and improve water quality.

Conference themes

The conference covers the following themes:

- Nutrient legislation in horticulture
- Nitrogen dynamics in relation to soil quality
- Nitrogen mineralization from soil organic matter in horticultural fields
- Good agricultural practices for vegetable crop residues
- Conflict between improving soil organic matter and legislative requirements, e.g. the Nitrates Directive
- Phosphorus, horticulture and the environment
- Conflicts between crop quality and legislative requirements
- Nutrient use efficiency and fertilization advice
- Catch crops and crop rotation alternatives in intensive horticultural production
- Innovative cultivation and fertilization techniques in horticulture
- Recirculation of nutrients in greenhouse horticulture

Committees

Scientific Committee

- Georges Hofman (Ghent University, Belgium)
- Erik Van Bockstaele (Institute for Agricultural and Fisheries Research (ILVO), Belgium)
- Johan Van Waes (Institute for Agricultural and Fisheries Research (ILVO), Belgium)
- Kristiaan Van Laecke (Institute for Agricultural and Fisheries Research (ILVO), Belgium)
- Bart Vandecasteele (Institute for Agricultural and Fisheries Research (ILVO), Belgium)
- Stefaan De Neve (Ghent University, Belgium)
- Bruno Gobin (Vegetable Research Centre East Flanders (PCG) & Research Centre for Ornamental Plants (PCS), Belgium)
- Raf De Vis (Research Station for Vegetable Production (PSKW), Belgium)
- Mia Demeulemeester (Inagro, Belgium)
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- Francesco Tei (University of Perugia, Italy)
- Clive Rahn (PlantNutrition Consulting, UK)
- Wim Voogt (Wageningen UR, the Netherlands)
- Sylvain Pellerin (INRA, France)

Organising Committee

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- Kristiaan Van Laecke (Institute for Agricultural and Fisheries Research (ILVO), Belgium)
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- Raf De Vis (Research Station for Vegetable Production (PSKW), Belgium)
- Mia Demeulemeester (Inagro, Belgium)

CONFERENCE VENUE

Conference venue

E Block
Faculty of Bioscience Engineering
Ghent University

Coupure links 653
9000 Ghent
Belgium

Conference dinner

Salons "Carlos Quinto"

Kammerstraat 20
9000 Gent
Belgium

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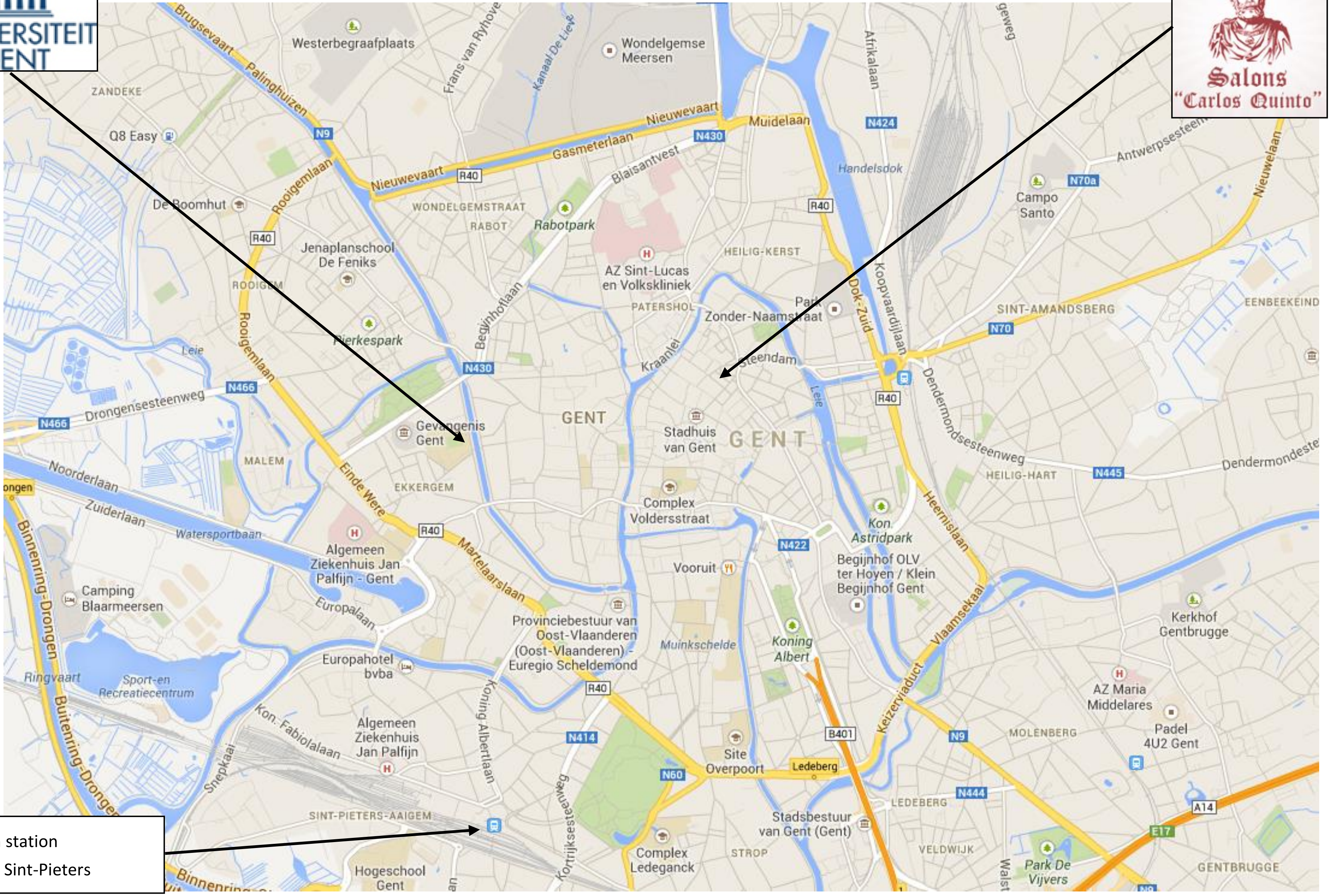
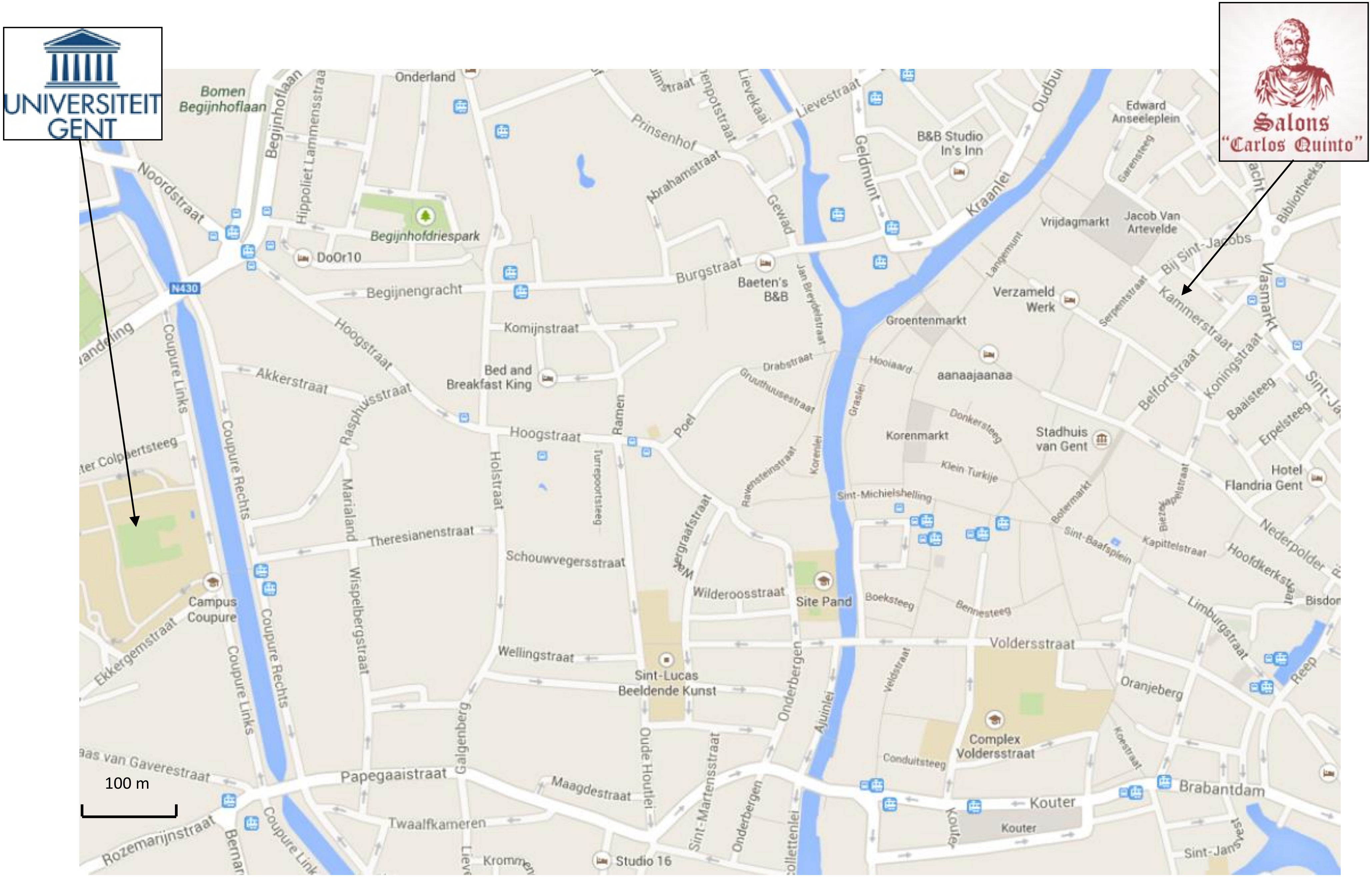
Salons "Carlos Quinto"

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Prinsenhof
Abrahamstraat
Lievekaai
Lievestraat
Geldmunt
Gewad
Jan Breydelstraat
Kraanlei
B&B Studio In's Inn
Edward Anseeleplein
Vrijdagmarkt
Jacob Van Artevelde
Bij Sint-Jacobs
Kammerstraat
Vlasmarkt
Verzameld Werk
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Poel
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Donkersteeg
Korenmarkt
Stadhuis van Gent
Klein Turkije
Hotel Flandria Gent
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Coupure Rechts
Holstraat
Turrepoortsteeg
Ravensteinstraat
Sint-Michielshelling
Botermarkt
Sint-Baafsplein
Kapittelstraat
Hoofdkerkstraat
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Marialand
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Schouwvegersstraat
Wilderoosstraat
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Campus Coupure
Ekkergemstraat
Wispelbergstraat
Wellingstraat
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Onderbergen
Ajuinlei
Veldstraat
Voldersstraat
Oranjeberg
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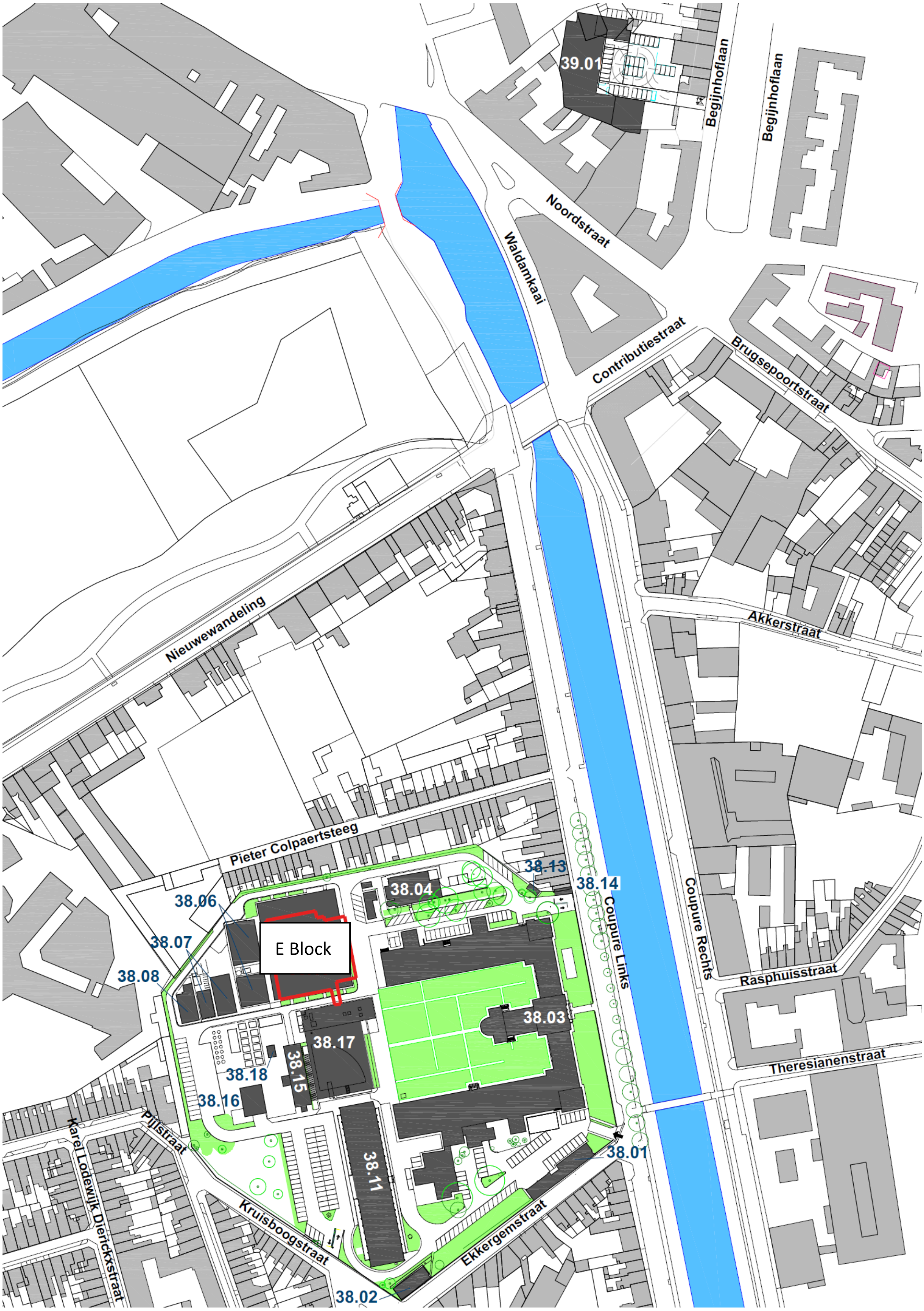

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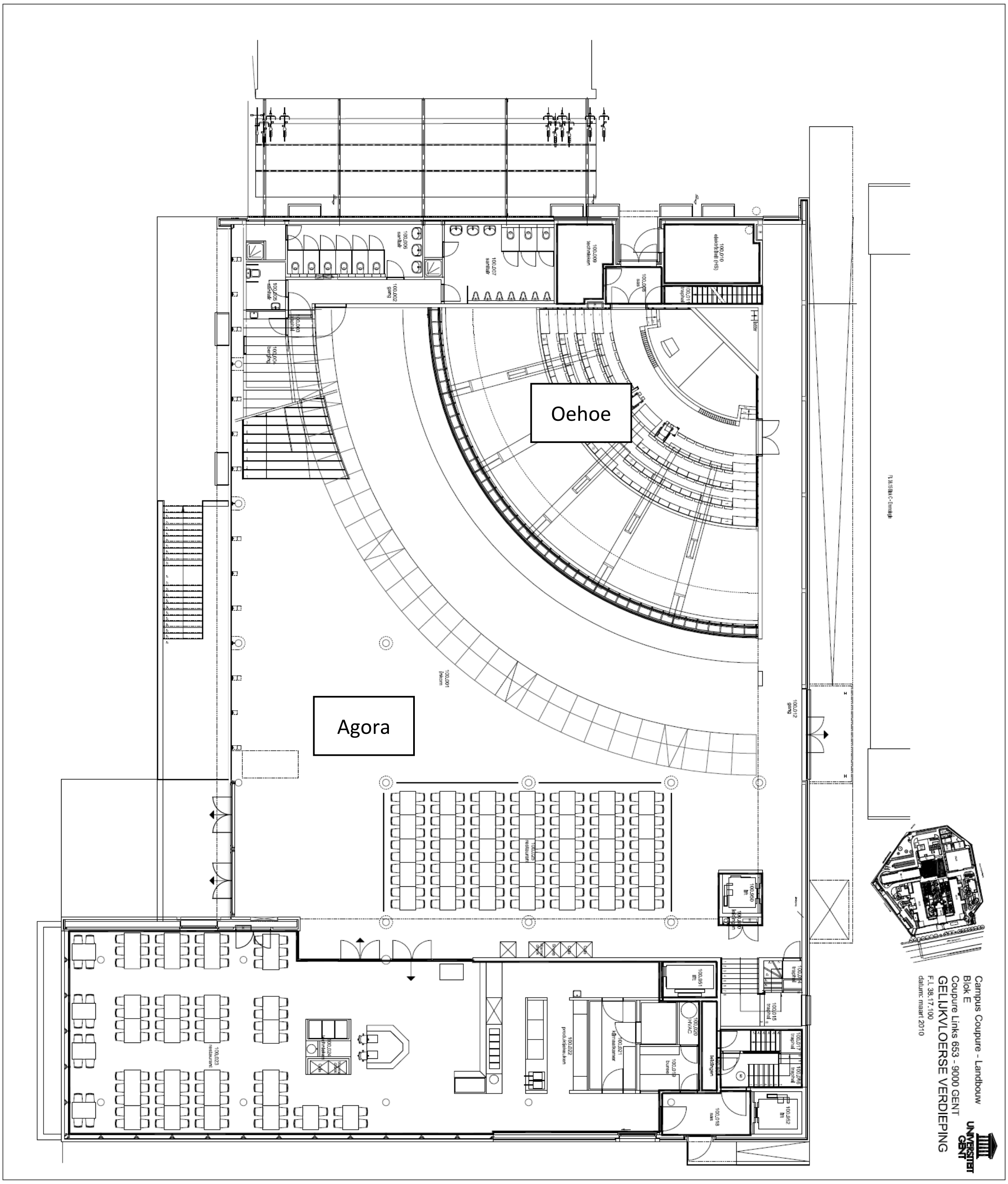

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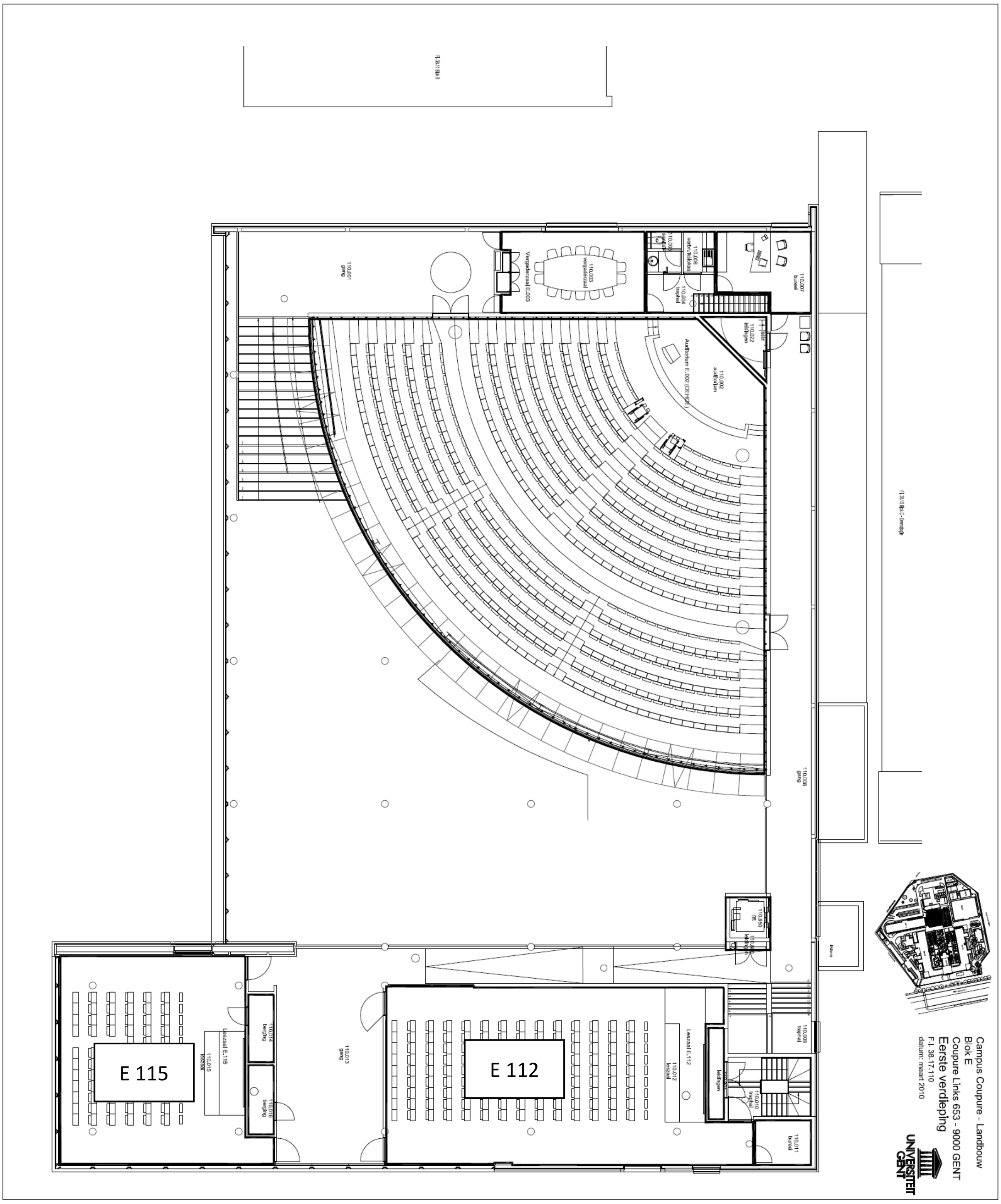

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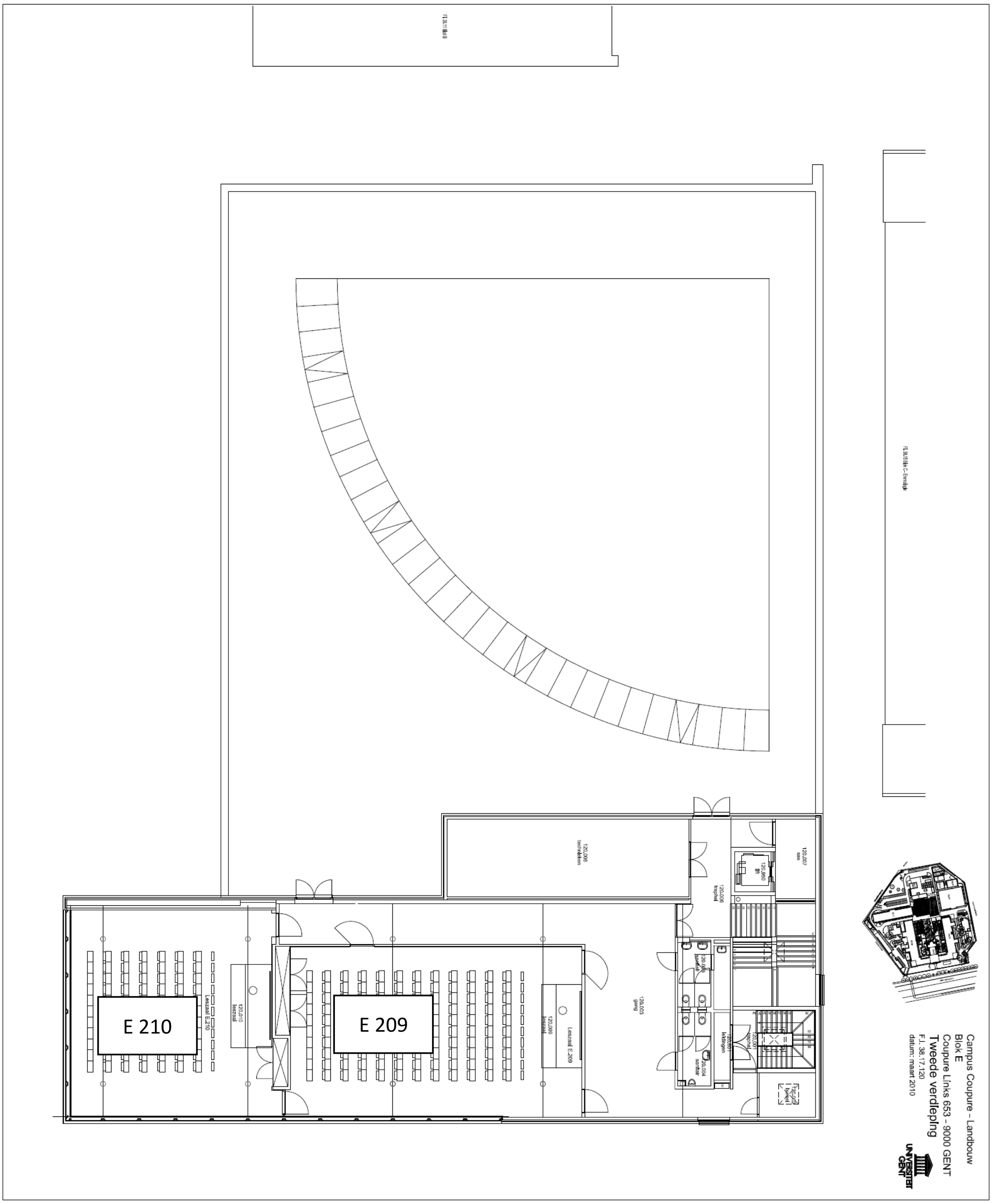

ORAL PRESENTATIONS

(1) Implementation of the Nitrates Directive in the EU: Results overview 2007-2011

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The Nitrates Directive obliges Member States to submit, every four years, a progress report on the implementation of the Directive, including, i.a., water monitoring results, information on nitrate vulnerable zones, and summary of the action programmes. This presentation provides an overview of the implementation of the Nitrates Directive based on the latest reports submitted for the period 2008-2011. It focuses on changes in designation of nitrate vulnerable zones; trends in agricultural pressure; and water monitoring, quality and trends – both at EU and national levels. Although farm practice and – in consequence – water quality are generally improving, there remain 'hotspots' related to intensive agricultural production, which will require greater attention in the future. Pressure from horticultural crops has been identified as a particularly challenging area, which will need to be better addressed in the action programmes. Exchange of best practices, knowledge and experiences is necessary for developing tailored measures minimizing nutrient losses and ensuring high productivity in this field.

(2) The application of the Nitrates Directive to vegetable crops: tools and strategies from NEV2013 for an integrated fertilisation management

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The European Commission DG Environment and the University of Turin (Italy) have organized the NEV2013 Workshop on 'Nitrogen, Environment and Vegetables' for providing support to the implementation of the Nitrates Directive (91/676/EEC). NEV2013 has focused on the critical issues of the Nitrates Directive in vegetable crops in European Countries. NEV2013 covered Nitrogen fertilization management, strategies to improve Nitrogen and water use efficiency, relationship of Nitrogen and other nutrients, Nitrogen effects on product quality, vegetable growing systems and their effect on waters pollution, crop residues management, crop rotation, and monitoring of the environmental pollution caused by Nitrogen losses from vegetable cultural systems. The critical issues of the Nitrates directive for vegetable crop systems of different European Countries were tackled. The outcome indicated that the environmental impact due to the Nitrogen fertilization varies not only from country to country but also locally within the same country or region. There is a striking need for increasing the Nitrogen fertilizer use efficiency for all crops in order to reduce its potential negative effects on the environment and, in the case of vegetable crops, its effects on human health when accumulated as nitrate in the plants. In recent years, numerous research programs have assessed the effects of Nitrogen fertilizer rate, fertilization methods, and Nitrogen fertilizer source on Nitrogen uptake and plant growth of many vegetable species. On this base, tools to determine the Nitrogen losses owing to the different cultivation systems for vegetables and to the different climate and soil conditions have been developed. Their spread implementation can lead to environmental-friendly fertilization strategies, applied taking into consideration the needs and suggestions of researchers, farmers, and consumers, and involving policy makers. As any other cropping system, also vegetable systems need valuable indicators: the tool box of indicators that can be used to sustainably manage fertilization is quite large, while modeling allows for quantifying environmental impacts. Combining indicators, empirical predictions and model predictions into expert systems helps to take decisions about management practices. Future strategies need better connection and data transferring among the actors, from policy makers to scientists, extension service technicians and growers.

(3) The challenges of knowledge transfer in the implementation of the Nitrates Directive

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A previous conference NEV2013 (15-17 April 2013 Turin, Italy) highlighted the risks of N losses from horticultural crops. For EU member states to reduce N losses from horticultural systems and fulfil the requirements of the Nitrates Directive improvements to fertiliser use are needed. The conference concluded that fertiliser management practices could be improved by the use of a range of fertilisation recommendation tools, however the appropriateness of any individual tool, in a given set of circumstances was not always clear.

For horticultural crops there is a need to ensure that quality as well as yield is maintained leading to a tendency for farmers to over-fertilise. The process leading to more optimised fertiliser applications requires efficient two-way delivery of knowledge between the researcher and farmers on the ground. This process is complicated by the needs and agenda of a range of stakeholders which include the policy makers, the regulators, the market represented in the main by supermarkets, many non governmental organisations and fertiliser companies. Additionally the funding required for effective and sustained communication is not always available.

This paper attempts to understand why farmers fail to follow the best practices that are available and how with better knowledge transfer, such practices can not only help to implement the Nitrate Directive but can benefit the farmer and society in a much wider context.

(4) Improved nitrogen management practices for vegetable production

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In intensive vegetable production (IVP), the supply of plant available N often appreciably exceeds crop N requirements resulting in NO_3^- contamination of water bodies. Available methods for improving N management in IVP will be reviewed, with an emphasis on recent developments that enable growers to exploit the increasing technical capacity (e.g. fertigation, drip irrigation) of IVP for precise and responsive N management. An overview will be given of available methods with consideration of suitability to different and changing cropping conditions, and practicality. Improved N management systems will be considered as being (a) soil-based N recommendation systems, (b) crop-based monitoring systems, (c) N balance calculations, (c) decision support systems, and (d) scenario analysis tools.

Soil-based systems consider soil mineral N when determining N fertilizer rates. Crop monitoring can potentially inform of the adequacy of crop N status at given times. However, for each method, there are important considerations. Proximal optical sensors are a promising approach. The N balance considers the various soil N sources. Decision support systems combining N balance calculations with simulations of crop N uptake can provide N fertilizer plans that closely follow crop N needs and consider soil N supply. Scenario analysis tools are relatively complex models used to illustrate consequences of different management practices.

A suggested optimal N management approach is combined prescriptive-corrective management. Prescriptive management being preparation of N fertilizer plans that match N supply to crop N needs while considering soil N supply, and corrective management being monitoring approaches that assesses crop/soil N status to subsequently adjust and optimize N management.

(5) Optical sensors for the ion-selective management of hydroponic nutrient solution quality

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Traditional management practices for maintaining hydroponic solution quality waste considerable volumes of water and fertilizers. In general, hydroponic solutions are created to provide an ideal mixture of nutrients to plants, the quality of which depletes as the plants grow. Because plant nutrient uptake is variable and dependent on many environmental factors, growers cannot know the composition of their nutrient solution without outsourcing expensive lab analysis. Typically, measures of electrical conductivity and pH help growers determine hydroponic solution quality (although crudely) and weak solutions are eventually discharged and replaced. If detailed information describing the composition of a hydroponic solution was readily available to a grower, management practices could be developed such that nutrient solutions are adjusted to replenish ions that are depleted. Ion-Selective (IS) Sensor technologies have been developed in the last few decades and are now realizing market availability. We are characterizing novel IS *Optodes* alongside commercially available IS *Electrodes* in the hydroponic environment to assess the feasibility for use in an automated nutrient management system (HPLC is used to validate measurements). The most suitable technology will be integrated into the design of an online IS Monitoring System. The IS Monitoring System will be tested in custom plant growth chambers at the University of Guelph as we monitor plant nutrient uptake in response to environmental variables with a focus on *light quality and quantity*. Ultimately this system could be used for feedback control of an IS Nutrient Dosing Apparatus that can maintain an ideal nutrient solution composition, continuously.

(6) Management of nitrogen fertilization of fresh vegetable crops at field scale in Wallonia (Belgium) - Combination of soil or crop nitrogen status evaluation and splitting of nitrogen fertilizer application

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Fresh vegetable crops frequently receive high supplies of organic or mineral nitrogen (N) fertilizer leading to quality loss and water or atmosphere pollution. An optimal management of N fertilization of these crops should largely contribute to their productivity and to reduce environmental risks. Based on previous research to the set-up of provisional N recommendations, several field trials with increasing N fertilizer rate and including split rates have been conducted on loam soil in Wallonia (Belgium) from 2005 to 2010 aiming to improve N efficiency of four crops (carrot, escarole, Welsh onion and curled-leaved endive). For arbitrary application dates of split N rates, results have not shown any difference between split and non-split N rates for carrot and escarole. For Welsh onion and fine curled-leaved endive the results show an advantage to split N, regarding yield as well as nitrate concentration in leaves at harvest. Soil mineral N residues at harvest were also lowered. For these two crops, tools to assess crop N status were tested for their ability to decide on the best time for split N rate application aiming to improve N use efficiency. Tools are based either on leaf chlorophyll content assessed with a chlorophyll meter or on shoots nitrate concentration assessed by colorimetry. For each tool, discrimination in readings appeared between increasing N rates. Moreover, optimal periods for a second N application were determined through good correlations between total plant N content or N-uptake and the values of the "plant-based" tools. For these identified periods, tool values have been plotted against the Nitrogen Nutrition Index (NNI) and threshold values for both tools have been identified, but are still to be validated for further implementation in practice.

(7) Row application of fertilizers, manure and manure fractions to increase nutrient use efficiency

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Fertilizers and slurries are valuable products to provide nutrients to crops. However, nutrient use efficiencies are low due to large application rates. Legislation limits application rates in order to minimize losses to the environment.

Slurries can be separated into a solid and liquid fraction. This creates opportunities for innovative techniques such as row applications of the nitrogen (N) rich liquid fraction. In our research row applications, both as basic fertilization before planting and as side dressing after planting, of mineral fertilizers, slurries and treated products were compared with broadcast applications and a blank on different soil types and locations in potatoes from 2010 to 2012. A precision GPS system was used both with fertilization and with planting to increase the time window for manure and fertilizer applications. This enables planting to be done after and separately from the basic manure application and the additional fertilizer can be applied as row application some time after planting.

Row applications of mineral phosphate fertilizers containing small amounts of N improved potato yields and caused a large shift in the size distribution towards larger tubers on soils characterized by Dutch fertilizer recommendations as sufficient on phosphorus (P) fertility. Row applications thereby improve the P-use efficiency. Positive results on row application were mainly found on young, calcareous clay soils where P availability could be limiting at early stages of crop growth, especially with cold spring temperatures or dry conditions. A shift in the size distribution towards larger tubers was also found for a pre-planted row application of slurry at a high application rate but not for row applications of side dressings of N-fertilizers. At low N application rates, row applications of side dressings of liquid N-fertilizers had a higher N-use efficiency compared to broadcast application of CAN at the same amount of N.

(8) Soil erosion in vegetable production – Solution approaches

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Soil erosion by water is a widespread problem throughout the world. In recent years, there have been more frequent, heavy rainfall events in temperate zones, affecting many regions in Europe. Areas with intensive vegetable or crop production are especially at risk. In Southwest Germany, a highly intensive vegetable production region, on- and off-site damages by soil erosion will be witnessed more frequently due to extreme weather events resulting from climate change and use of heavy machinery and soil compaction. To manage this problem in vegetable cultivation, two different strategies to reduce soil erosion were tested: Soil cover by fabrics and strip-tillage. Covering the white cabbage plants (Brassica oleracea convar. capitata var. alba) with non-woven fabrics, such as fleece or nets, could function as an erosion control measure. Soil losses of fleece covered area were reduced about 90 % and in net covered plots soil losses were reduced about 72 % compared to the uncovered control treatment. Strip-tillage is a conservation tillage technique, which is well established in corn and sugar beet production. For vegetable production, only a limited number of studies exist. In this technique, crop residues from the previous culture remain on the soil surface. In autumn, the strips were prepared with a GPS-RTK based strip-tillage machine. The straw residues between the strips remained undisturbed on the soil surface. Spring white cabbage was transplanted with a modified planting machine. Rainfall simulation to determine soil losses showed significant lower soil losses in strip-tillage plots (20 g m^{-2}) compared to plots managed by mouldboard plough (110 g m^{-2}). Different nitrogen fertilization techniques, band-placed and broadcast application, were tested. Soil mineral nitrogen contents and total nitrogen content in plants indicate that the nitrogen availability in strip-till system is sufficient, which shows that the different application techniques have no significant effect on cabbage yield. Generally, strip-tillage has a high potential to protect against erosion and is suitable for cabbage cultivation. Cabbage yields in strip-tillage systems are comparable to yield levels in mouldboard ploughing systems.

(9) Minerals and wastewater treatment products effectively increase P sorption capacity in acidic sandy soils.

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As a result of decades of excessive phosphorus fertilization, most acidic sandy soils in Flanders (Belgium) and the Netherlands are phosphorus (P) saturated. Many of these soils are under intensive vegetable rotations. This saturation entails a risk of significant P leaching to groundwater resulting in environmental problems. A study was undertaken to test several soil amendments in terms of their potential for increasing P sorption capacity of the soil, with a view to decreasing the risk of P leaching.

In this study eight amendments, including five minerals (olivine, biotite, zeolite, gypsum and bauxite), one waste water treatment residual (dried Fe-sludge) and 2 amendments designed for P fixation in water (Phoslock® and Sachtofer) were evaluated for their ability to fix P in soil with different P level, by assessing P leaching in incubation experiments.

The preliminary results showed that all amendments reduced P leaching to varying degrees, and the success depended on the amount of product applied and the pre-treatment of the product (for the minerals). This research opens perspectives for combating P leaching losses in a relatively simple and cheap way.

(10) Sustainable nutrient management in soil-less culture in Dutch greenhouse horticulture

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Since the expansion of soil-less culture in the Netherlands in the mid-eighties of the previous century, emission of nutrients and plant protection products (PPP’s) used in the root environment was considered as a huge problem. Eventually, the government and growers organisations reached an agreement which aimed at reducing the N, P and PPP emissions. For soil-less culture, reuse of drain water or closed growing systems became obligatory. Recently, the regulation changed by shifting the focus on reaching emission targets for N rather reaching 100 % closure of the systems. Yet, recirculation is still the key issue for reaching the goal of zero emission by 2027. These closed systems will potentially lead to substantial reduction of mineral leaching to the environment, however, they require adequate water quality and nutrient management. Moreover, satisfactory disinfection to control root diseases and removal of organic components is needed. In practice, substantial loss of water and minerals still occurs occasionally, when growers decide to flush the system and drainage water is partially discharged to the surface water or sewage system, causing emission of nutrients and PPP’s. There are several reasons for growers to discharge e.g. accumulation of Na, mismanagement in EC or pH or nutrient supply, and serious problems with soil borne diseases or growth inhibition. This paper will give an overview of the state of the art of systems for nutrient solution recycling, and the requirements for water treatment, water quality and nutrient supply and strategies to obtain the highest efficiencies for nutrient and water use.

(11) Quantification of nutrient rich wastewater flows in soilless greenhouse cultivations

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Despite far-reaching recirculation of nutrient solutions, important nutrient enrichment of surface water is still frequently observed near greenhouses with soilless cultures of vegetables and ornamental plants. In order to quantify nutrient rich wastewater flows, 13 farms with greenhouse vegetable or ornamental crops are monitored intensively during a 2-year-period. Results of the first year (2012) show that only 25% of the soilless cultivation systems is completely closed and 92% of the farms where nutrient rich wastewater was generated, produced less than 50m³ per hectare. Only 1 farm produced up to 435m³ waste water due to frequent discharge of nutrient water because of accumulation of sodium. Important causes for the generation of nutrient rich wastewater are i)removal of nutrient water because of imbalance of nutrient elements, e.g. sodium and ii) wash water of filter systems. Imbalance of nutrient elements can be prevented when water of high quality i.e. containing little ballast salts is used. Therefore, rain water is advised as the best water source for recirculation systems. Recirculation of wash water is possible but in most situations requires a sedimentation step. The amounts of wash water can also be reduced by use of new techniques such as ECA-technology and SAF-filters. If a drainage system is placed beneath the greenhouse construction this drainage water can contain higher nutrient concentrations due to leakage of the recirculation system or historical enrichment of the soil by previous cultivation systems. Annual drainage water volumes can reach up to 100 m³ per hectare. Consequently, discharge of this drainage water can lead to important enrichment of the surface water. Based on the monitoring results, growers are advised on good fertigation techniques to prevent or significantly reduce the production of nutrient rich waste water flows.

(12) Improving irrigation and nitrogen management in California leafy greens production

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The Salinas Valley, located on the coast of central California, is the most intensive leafy greens production region of North America. Lettuce, broccoli, cauliflower, celery and spinach production occur nearly year around, with two or more crops produced annually in most fields. This intensive cropping schedule minimizes the use of catch crops. Consequently, nitrate loss from vegetable fields represents a serious threat to environmental water quality. In more than a decade of N management research we have collected extensive data on N cycling in this vegetable production system, and have developed and demonstrated improved irrigation and fertilization practices that reduce environmental N loading. To aid in the adoption of these more efficient practices an on-line tool, called CropManage, has been developed. The software estimates irrigation and N fertilizer requirements on a field-by-field basis. The grower provides baseline information (field location, soil type and planting date), and inputs fertilizer and irrigation data as the crop progresses. The N fertilizer algorithm generates recommendations based on the crop N uptake requirement, current soil NO_3-N status, and estimated soil N mineralization. The irrigation scheduling algorithm uses real-time reference evapotranspiration data, crop coefficients based on the planting configuration, and soil water holding characteristics to estimate the appropriate irrigation interval and volume of water to apply. CropManage was evaluated by growers in 10 commercial lettuce fields in 2012, and their assessments have been used to improve the functionality of the tool.

(13) Anoxic Moving-Bed BioReactor (MBBR) and phosphate filter as a robust end-of-pipe purification strategy for horticulture

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Throughout Europe, the wide application of soluble fertilizers gives rise to a wastewater-related nutrient problem in the greenhouse industry. When ‘closing the loop’ with the aid of water and nutrient management strategies is impossible, only an end-of-pipe solution remains to solve this global environmental problem. In this paper, the development of a combined system comprising an anoxic Moving Bed BioReactor (MBBR) and a phosphate adsorption filter was studied as a possible alternative for the disposal of nutrient-rich wastewater on grassland. The most important operational parameters of these purification technologies have been examined in detail with the aim to guarantee a high nutrient removal efficiency. For the anoxic MBBR process, the removal efficiency during winter operation and the influence of the type of carbon source was thoroughly investigated. For the optimal operation of the phosphate chemisorption process main attention was paid to the influence of the influent pH and the introduction of intermittent periods of rest, in order to maximize the adsorptive capacity of the iron grains.

(14) Strategies to control nitrate leaching in irrigated agricultural systems and their effects on crop yield: a comparative meta-analysis

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Nitrate leaching (NL) is an important N loss process in irrigated agriculture that imposes a cost on the farmer and the environment. A meta-analysis of published experimental results from agricultural irrigated systems was conducted to identify those strategies that have proven effective at reducing NL and to quantify the scale of reduction that can be achieved. Forty-four scientific articles were identified which investigated four main strategies (water and fertilizer management, use of cover crops and fertilizer technology) creating a database with 279 observations on NL and 166 on crop yield. Management practices that adjust water application to crop needs reduced NL by a mean of 80% without a reduction in crop yield. Improved fertilizer management reduced NL by 40% and the best relationship between yield and NL was obtained when applying the recommended fertilizer rate. Replacing a fallow with a non-legume cover crop reduced NL by 50% while using a legume did not have any effect on NL. Improved fertilizer technology was the least effective of the selected strategies at reducing NL. Overall, we recommend a sequential approach in which the primary approaches used should be optimization of water and fertilizer management. More innovative methods including the use of cover crops and improved fertilizer technologies may offer additional reductions in NL, but may not always result in a net financial benefit. Ultimately, the costs and benefits of NL reducing strategies should be assessed for a specific system, to ensure the best choice is made for the farmer and the environment.

(15) Optimization of N fertilisation through fertigation and green manuring: case studies in processing tomato

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In conventional cropping systems fertigation with drip irrigation represents an efficient tool to optimize vegetable crop nutrition and limit nitrogen pollution to the environment. In fact this technique allows to split and adjust the rate according to crop requirements during the growth cycle, to localize the fertilizers and thus to improve N use efficiency.

In organic systems green manure crops can have a strategic role both to reduce the risk of nitrate leaching and to supply N for a subsequent cash crop so improving the environmental sustainability and self-sufficiency of the system.

Recently, there has been an increased interest in fertigation in organic agriculture due to the availability of reliable water soluble organic fertilizers as well as in cover crops in conventional agriculture mainly due to a rise in the price of fertilisers and to the increased awareness of environmental issues. As a consequence, within a sound strategy for a conservative horticulture, fertigation and green manure crops could be suggested as complementary tools in order to guarantee both adequate vegetable crops N nutrition and environmental benefits.

Nitrogen dynamics in crop-soil system when fertigation, green manuring and fertigation+green manuring were applied in processing tomato is discussed on the basis of published and unpublished evidences from field experiments carried out in the last decade in Central Italy. Particular attention is given to N leaching risk as affected by fertigation frequency, green manuring by legumes and grass species as pure stands or mixtures, and green manures coupled with fertigation.

(16) Nitrogen management by use of in-season living mulch in organic cauliflower production

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Consumers expect that the production of organic vegetables is less harmful to the environment compared to conventional vegetable cropping. However, vegetables with a high nitrogen demand such as cauliflower may cause intensive leaching of nitrate to natural waters. In addition, organic growers face difficulties in providing adequate amounts of organic fertiliser in order to attain high yields. In organic cropping systems, the use of an in-season living mulch may decrease the need for fertiliser and the risk of nitrate leaching. It may also improve nitrogen nutrition for next season's crop. The aim of this study was to investigate the effect of growing an in-season living mulch of grass-clover on cauliflower yields, nitrate leaching over winter, and soil nitrogen availability the following spring. A field experiment was performed on a sandy loam soil using two cultivars of cauliflower and with or without grass-clover as living mulch. The mulch was sown in rows between the rows of cauliflower, and two levels of fertilisation (dried chicken manure) were applied. Plant samples were taken for evaluation of yields, biomass and nitrogen content. Evaluation of inorganic N-content in the soil was done at planting, at harvest, in late autumn and in spring by taking soil samples to a depth of 1.5 m. Results show that high yields of cauliflower can be maintained, whereas no effects on nitrate leaching could be observed in a cropping system with an in-season living mulch of grass-clover.

(17) Spatial and temporal variability of rooting characteristics and catch crop effectiveness

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Growing catch crops is an effective measure for reducing nitrate-N leaching during autumn and winter. In this study we investigated 1) how effective different catch crop types are over time, 2) how deep they can extract N with their rooting system and 3) the effect of field conditions. The two catch crops under investigation were Italian ryegrass (*Lolium multiflorum* Lam.) and white mustard (*Sinapis alba* L.). They were sown the 29th of August 2008 at three different locations (headland, normal and wet conditions) in a sandy loam field plot (Terric Anthrosol) in Merelbeke (Belgium) on wheat stubble. At each location, a randomised block design was established with three replicates. Apart from the catch crops, there was a third treatment with bare plots. Mineral N in the soil profile (0-90 or 0-210 cm) and above and below ground biomass parameters were measured in September, October, November and February. N-uptake in October was higher for white mustard than for ryegrass because of the fast early crop development. This difference had disappeared in November. The nitrate-N content in the 0-90 cm soil profile (residual N) did not change between October and November for white mustard and fallow, but decreased for ryegrass in that period. The maximum rooting depth for both crop types was 50-60 cm, except for the headland where, depending on the precise location, the crops could only extract N from the 0-25 or 0-45 cm top soil. Remineralisation from white mustard in winter was demonstrated.

(18) Strategies to reduce nitrogen leaching by summer catch crop in vegetable greenhouse of North China

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Continuing monoculture, excessive fertilization and irrigation has led to high risk of the dominant nitrogen (N) leaching in the greenhouse. Control N fertilizer input is one of the efficient strategies to reduce N leaching, however, the high manure application and N mineralization is difficult to avoid total N leaching. In the study, catch crop was introduced into vegetable greenhouse as a biological tool to reduce N loss in China. Although root growth was not deeper and stronger than the cereal field, the effects of N extraction by aboveground of catch crop from the soil was significant, with N uptake of 150-180 kg N ha^{-1} in aboveground part and soil N_{min} in the soil profile of 0-180cm decreased by 303-343 kg N ha^{-1}. The analysis of ^{15}N isotopic technique implied that N immobilization from N_{min} to organic N contributed to the difference between the reduction of residual soil N_{min} and N uptake. Catch crop planting significantly increased organic N content and the ratio of dissolved organic nitrogen (DON) to dissolved total N in 0-60 cm soil depth, which accounted for 20-30% of the total soluble nitrogen. Nitrate leaching was dominant in vegetable field with high N_{min} residue and selecting some special catch crop, i.e. sorghum, maybe significantly in inhibiting the process of ammonium transforming to nitrate through biological nitrification. Our study highlights the need for considering both N_{min} and DON to account for the strategies of catch crops to control N leaching, which is a critical requirement for efficient vegetable production while avoiding environmental damage.

(19) Why do we have to increase P use efficiency and recycling in cropping systems?

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Phosphorus (P) is an essential, non substitutable nutrient for plants. Moderate P deficiency limits yield by reducing leaf growth, light interception and photosynthesis. In soils, P availability for living organisms is limited because it is strongly bound to soil particles. Since the end of the second world war, agricultural soils from western Europe have received large amounts of P as mineral and organic fertilisers. Today, the P content in soils is often above the minimum requirement for maximum yield. When overused, P can be a major water pollutant triggering eutrophication. Moreover, mineral P fertilisers derive from phosphate rock, which is a non-renewable resource whose future scarcity, decreasing quality and increasing cost threatens agricultural production and food security. Europe has very limited phosphate rock reserves, and depends on imports from a small number of countries, leaving it exposed to geopolitical issues. These emerging issues strengthen the need for a more sustainable use of P in agricultural systems, including more efficient use and recycling.

(20) Phosphorous placement for bulb onions – rates and distances

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In the production of direct sown bulb onions it is normal practice to place a starter fertilizer close to the seeds at sowing. However, in some cases the distance between the starter fertilizer and the seeds becomes too short resulting in salt stress and reduced seedling emergence. The objectives of this experiment were to examine the influence of various fertilizer types, fertilizer rates, and distances between fertilizer and seeds on seedling emergence and plant production. At sowing of bulb onions in early spring in five years 2008-2012, a range of P and NP fertilizers were tested alone or in combination. The treatments resulted in large differences in plant emergence and size of plant seedlings. Starter fertilizers containing N applied in the highest amount and close to the seeds resulted in seedling damages and reduced emergence percentage. The damage was less severe when the amount of starter fertilizer was reduced or when the distance between fertilizer and seeds was increased. Placement of starter fertilizers without N close to the seeds showed less damaging effects. Placement of 44 kg P per ha in a distance of 4-5 cm resulted in high yield. Reduced yield was obtained when the P rate was reduced and when the distance between fertilizer and seeds was larger than 5 cm or especially when the fertilizer was placed close to the seeds. Combining low P amounts close to the seeds and higher P amounts in 4-5 cm distance of the seeds increased the plant production, especially in moist soils.

(21) The phosphorus cycle in North-West European agricultural soils

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Phosphorus (P) concentrations in NW European surface waters generally exceed ecological thresholds. The Nitrates Directive and the Water Framework Directive have asked EU Member States to address this problem. The resulting monitoring networks and P concentration standards differ widely between Member States. Because agriculture is considered to have a large impact on the surface water P concentrations, the diffuse P losses from soils with high P contents are targeted. Attempts have been made to reduce the soil P concentration under the threshold above which P losses increase exponentially. However, agro-economic interests should also be taken into account. A target zone of soil P concentrations with optimum crop yields and limited P losses can be defined. In order to reach or stay in this target zone, fertilisation recommendations should be adapted to include the risk for P losses. Soil P application standards are ideally differentiated to soil P concentrations. In this way, soils with large P concentrations should receive less P in order to reduce the P losses and soils with small P concentrations can receive more P to ensure satisfactory crop yields.

(22) The effect of different fertilizer types on soil P conditions, crop yield and P leaching potential

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A history of excessive fertilization in Flanders' intensively managed agriculture, causes severe nitrogen (N) and phosphorus (P) losses to water bodies. The local government took action from the 1990s onwards, by introducing restrictions to N and P fertilizer use. These restrictions also limit the supply of organic matter to the soil, while the soil organic matter level of many agricultural soils is suboptimal in Flanders. Moreover, P is an immobile nutrient and P fertilizer efficiency is low as only a minor part is directly available for plant up-take. We compared the effect of three compost types, cattle slurry, farmyard manure and mineral fertilizers on crop yield, soil organic carbon content, P availability, P export and P leaching in a long-term field experiment with arable, vegetable and fodder crops. Organic fertilizer doses were calculated every year for equal C input, and were always combined with mineral NPK. Total N supply fulfilled the demands of the crops and total P input was set equal to 100kg P_2O_5/ha.yr. As expected, farmyard manure and compost are the best options to enhance the total organic carbon level of the soil. Cattle slurry and mineral fertilizers tended to produce lower crop yields. P plant availability increased in the farmyard manure treatment, but did not lead to extra P export. Probably the soil delivers already sufficient P to the crops, and increasing P availability is not necessary. In a column leaching experiment in unsaturated conditions based on soil samples of this field experiment, increased potential P leaching was observed in the farmyard manure treatment. We conclude that evolution in soil organic carbon level and P plant availability, but also potential P leaching is dependent on organic fertilizer type. Compost shows to be an interesting product, as it can gradually increase TOC level, without increasing potential P leaching losses. Moreover compost has a positive effect on crop yield.

(23) A more trustworthy P recommendation by implementing the intensity, buffering capacity, quantity concept into agricultural practice

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The basis of current fertilization recommendations as a function of soil P status was established mostly in the 1950's – 1960's. To establish the soil P status, dozens of different soil P tests have been developed and were tested in many field trials. Up to now almost everywhere a single soil test is used which differs between countries and regions. The last decades the agro-economic environment has altered; environmental protection has become a topic and P resources proved exhaustible. This requires a more precise P fertilization recommendation that makes better use of the state of the art regarding soil chemical knowledge and laboratory methods (e.g. increased precision and decreased duration and costs of analyses but with minimal cost increases for the farmer). Though, replacing existing soil tests and recommendations would imply a very significant effort with respect to introducing new tests and recommendations by fertilization trials in practice. However, with a more mechanistic approach less field testing is required to develop an improved recommendation system than based on an empirical approach. We have used a soil chemical approach to study and predict the dynamic behaviour of P release by the soil as a result of P removal (P uptake by the crop). With a at least two soil parameters (P-Al and P-$CaCl_2$) it was possible to describe what is directly available for plant uptake (P intensity), the capacity of the soil to replenish this directly available P by the soil when P is removed (or added) to the soil (the P buffer capacity) and what is the total capacity for P replenishment (P quantity). We will describe the stepwise introduction of the intensity, buffering capacity, and quantity concept into agricultural practice, and into proposed legislative measurements in the Netherlands.

(24) Future fertilizer legislation will require adapted nutrient management strategies in German vegetable production

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In the framework of implementing the EU Nitrates Directive in Germany, the German fertilization legislation is under consideration. It is to be expected that after the amendment of the Fertilization Ordinance growers will have to cope with stricter rules regarding nitrogen (N) fertilization. To identify management strategies suited for the new legislation we used scenario calculations with agro-ecosystem models. Not surprisingly, the model results indicated that the highest N losses occurred when crops with high amounts of harvest residues were grown in autumn and most of the residue N was lost overwinter. The most promising model strategies included the use of winter catch crops. We tested these strategies in field experiments with three catch crops at three sites in three years. Our experimental results indicated that on average catch crop strategies do not solve the problem of high N losses in intensive field vegetable production systems.

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

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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 experimental set-up of the project, results will be presented during the conference.

(26) Integrated nitrogen management – a strategy to improve nitrogen efficiency in intensive field vegetable production

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Nitrogen use efficiency is low in regions with intensive field vegetable production. Weak points involved in low N use efficiency are (i) poor root growth, (ii) large amounts of N left in the field in crop residues and (iii) excessive N fertilisation, due to quality standard demands of the market. We conducted field experiments to identify the most effective measures to improve N use efficiency and to develop integrated N management strategies in field vegetable production. In this contribution, effects of the combination of prediction of N fertiliser demand, crop rotation and crop residue management on vegetable yield and quality, N balances and nitrate leaching are assessed. Based on the results achieved under experimental field conditions, model calculations were performed to evaluate the effects of the implementation of integrated N management strategies in farmers practice on a regional scale (vegetable growing area of Palatinate). Results show that accurate prediction of N fertiliser demand is a prerequisite to grow vegetables in an environmentally friendly way. Nevertheless, yearly N leaching losses are still too high from the environmental point of view. Accurate fertilisation has to be combined with the inclusion of cover crops in the rotation to further reduce N leaching. Export of crop residues should be adopted with caution, particularly due to the fact that export of crop residues also negatively affects soil humus content. Our results indicate effective measures to improve N use efficiency in agriculture and may be used as a basis to develop integrated N management strategies in vegetable production.

(27) KNS[1] – Based advisory system proves to be a useful tool in reducing residual nitrate content of horticultural soils in the fall

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The past 15 years practical research considering nitrate uptake of different horticulture crops led to an adaptation of the German KNS (Kulturbegleitenden N_{min} Sollwerte-System) advisory system to Flemish circumstances. Between 2006 and 2011 this Flemish advisory system was validated on 60 different fields spread over Flanders. On those 60 fields two different fertilization strategies were applied. One part of the field received nitrogen fertilization following the advisory system. Here soil samples before and during the culture were used in order to determine the given nitrogen doses. Depending on the culture, nitrogen fertilization was applied in a number of different fractions and nitrogen doses were always based on the analysis of a soil sample. On the other part of the field, the farmer was asked to fertilize his crop according to his own insights. The selection of cooperating farmers was done by the Flemish research centres (practical agricultural research in open air horticulture) and was based on the care and precision of farmers' fertilization practices. Only farmers already using 'good agricultural practices' were allowed. On both parts of every field nitrate content in the soil and obtained yields were closely surveyed. From the results of the comparison a number of conclusions can be drawn:

- Farmers applied larger N–fertilizer doses compared to the KNS-system.
- Average residual nitrate content in the fall was higher on the fields fertilized by the farmers.
- Both farmers and practice centres struggled to achieve the legally obliged residual nitrate content of 90 kg NO_3-N in their soils (soil layer between 0 and 90 cm depth) during the fall.
- On 11 of the 60 fields the farmers achieved higher yields.

[1] KNS (Kulturbegleitende N-min – sollwerte)–system, developed by IGZ (Institut fur gemuse und zierpflanzenbau) and DLR (Dienstleistungszentren landlicher raum) Rheinland - Pfalz, republished and digitalized by IGZ and named N-expert.

(28) Strong effect of compost and reduced tillage on C dynamics but not on N dynamics in a vegetable cropping system

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Organic matter supply by compost and the way it is incorporated are important issues for sustaining soil quality in horticulture. Our research question was how compost application and reduced tillage would affect soil N dynamics and fertilizer N availability. To this end a multiyear field trial on a sandy loam soil with a vegetable crop rotation was set up. Soil tillage in spring was executed either with a moldboard plough or with an Actisol cultivator designed for non-inversion soil tillage. Farm compost was applied each autumn, starting in 2008, at 3 different rates, i.e. 0, 15 and 45 Mg per hectare. In 2011 leek (*Allium porrum*) was cultivated as test crop. Top mineral N dressing (0, 30 or 60 kg N ha^{-1}) eight weeks after planting was added as a third factor. After three years significant differences between treatments were observed with respect to pH, total organic C and hot water extractable C content in the 0-10 cm soil layer. Only a few significant differences in N dynamics between treatments were registered. Residual N at the end of the growing season only varied due to differences in top mineral N dressing. The resulting higher C stocks did not appear to affect the risk of nitrate leaching

(29) Fertilization of flower bulbs and hardy nursery stock in open field production in the Netherlands

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A substantial part of flower bulbs and nursery stock crops in the Netherlands are grown on sandy soils. In these regions the European quality standards for groundwater and surface waters are often exceeded. Therefore in 2006 new legislation was introduced with application standards for N, P and animal manure. These restrictions necessitates growers to implement measures that increase the efficiency of applied nutrients and in addition reduce the risk of leaching.

The nutrient need of crops as well as measures to reduce leaching and effects on soil fertility are discussed. Also the adoption rate by growers will be presented and if relevant how this rate can be increased. Special attention will be paid to soil organic matter management.

(30) An integrated model for the management of nitrogen fertilization in leafy vegetables

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Optimal nitrogen (N) supply is crucial for high yield, produce quality and crop sustainability of leafy vegetables. In spinach (*Spinacia oleracea* L.), N availability in the root zone is positively correlated with biomass production, tissue minerals and antioxidants content, and other commercial quality attributes such as leaf colour and wrinkledness. An erroneous N supply may cause crop N deficiency or overfertilization, which in turn results in waste of fertilizers with increased production costs and environmental impact. Nevertheless, growers very often supply N at constant rate based on empirical protocols, without taking into consideration climate variables and crop rotations. During a four-year long study (2007-2011), we assembled, calibrated and validated an integrated model (DSS, decision support system) that simulates N concentration in the root zone (daily basis) and gives information on the amount of N that should be delivered to the crop for maintaining the desired (i.e. optimal) N mineral content in the root zone. Simulations run on the basis of climate parameters, chemical-physical soil characteristics, and crop characteristics. Main outputs of the DSS are: crop cumulated biomass and N uptake, soil water balance and nitrogen balance. The DSS was tested on spinach grown in open field, in sandy-loam soil, under Mediterranean climate conditions. A significant linear correlation was found between simulated and measured data. The DSS was effective to support the management of N fertilization: in some cases, it allowed a reduced N supply in comparison to standard protocols applied by local growers, with no significant reduction in yield and quality.

(31) Nitrate nitrogen residues, soil mineral nitrogen balance and nitrogen fertilizer recommendation in vegetable fields in Flanders

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In vegetable crops, an accurate nitrogen fertilization based on soil analysis is essential, both to optimize crop yields and to reduce nitrate residues after the crop and nitrate leaching during winter. The nitrate residue in autumn is determined by several factors. Crop N requirements and N uptake patterns play a significant role, as well as N stocks at the start of the cropping period, N mineralization from soil organic matter and plant residues and N fertilization. The calculation of soil mineral N balances taking into account the different N inputs and outputs in a crop can be very useful to detect the possible causes of excess nitrate-N residues after the crop. In this study, the major bottlenecks of vegetable growing in Flanders in terms of N fertilization and nitrate-N residues are discussed, based on the calculation of soil mineral N balances in three different vegetable fields with cauliflower and leek.

(32) Soilless cultivation of outdoor horticultural crops in The Netherlands to reduce nitrogen emissions

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Many horticultural crops in open field production in The Netherlands do not meet the demands of the EU Water Framework Directive and EU Nitrates Directive mainly because of too high nutrient emissions. No solutions are available within the conventional cultivation systems to reduce nutrient emissions sufficiently while maintaining financial returns and crop quality. Addionally, growers have difficulties to manage their crops e.g. to comply with new market requirements, to have sufficient labour available or manage soil borne pest and diseases. Therefore, new soilless cultivation systems are being developed and tested for various horticultural crops (lettuce, leek, cabbage, strawberry, apple, blue berry, flower bulbs and tree nursery crops). A structured design method was used. First, an analysis was made of the conventional cultivation systems. Secondly, a brief of requirements was set up for all crops. Thirdly, various crop specific systems were designed, selected, engineered and tested on a small scale during several years. The sustainability and profitability of the selected systems are assessed in detail on all sustainability aspects (Planet, People, Profit). Almost all crops can be grown on a system without soil. Most promising systems are: deep flow systems for lettuce, leek and cabbage; NFT systems for strawberry and systems with substrate in pots, gutters or troughs for flower bulbs, tree nursery crops and fruit crops. The profitability and sustainability of the systems is currently under investigation, some first results are shown. Some leading growers have already installed prototypes of these new systems on their own farms.

(33) Opportunities provided by the European Innovation Partnership "Agricultural Productivity and Sustainability" and its Operational Groups

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European Innovation Partnerships (EIPs) are a new approach to EU research and innovation. EIPs are challenge-driven, focusing on societal benefits and a rapid modernisation of the associated sectors and markets. EIPs streamline, simplify and better coordinate existing instruments and initiatives and complement them with new actions where necessary. This should make it easier for partners to co-operate and achieve better and faster results compared to what exists already. Therefore, they build upon relevant existing tools and actions.

The agricultural EIP aims to foster a competitive and sustainable agriculture and forestry sector that 'achieves more from less' input and works in harmony with the environment. It will contribute to ensuring a steady supply of food, feed and biomaterials, both existing and new ones, working in harmony with the essential natural resources on which farming depends. For achieving this aim, the EIP needs to build bridges between research and practice.

The innovation model under the agricultural EIP goes beyond speeding up the transfer from laboratory to practice through diffusion of new scientific knowledge (referred to as the "linear innovation model"). The EIP adheres to the "interactive innovation model" which focuses on forming partnerships -using bottom-up approaches and linking farmers, advisors, researchers, businesses, and other actors in Operational Groups. This will generate new insights and ideas and mould existing tacit knowledge into focused solutions that are quicker put into practice. Such an approach will stimulate innovation from all sides and will help to target the research agenda.

Operational Groups will bring together farmers, researchers, advisors, businesses, NGOs and other actors to implement innovative projects pursuing the objectives of the EIP for Agricultural Productivity and Sustainability. Operational Groups can be supported by various funding sources.

Rural Development Policy and the Union Research and Innovation Framework "Horizon 2020" will provide particular opportunities for setting up Operational Groups in the period 2014-2020 and incentivize interested actors who engage in actions on developing, testing and applying innovative approaches. The two policies complement each other in giving emphasis to different objectives and main target groups. In addition, Rural Development Programmes are normally applied within a specific programme region, whilst research policy must go beyond this scale by co-funding innovative actions at the cross-regional, cross-border, or EU-level. Other policies, such as Cohesion and Education Policy, might offer additional opportunities.

(34) Benchmark study on innovative techniques and strategies for reduction of nutrient losses in horticulture

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Open field or greenhouse production of vegetables and ornamental plants is challenging because of the need to balance high productivity and sometimes late harvests with reducing nutrient losses to the environment. Growers urgently need to find and implement more sustainable strategies for the intensive production of vegetables, potatoes, flowers and ornamental trees. On request of the European Commission - DG Environment, a consortium of research institutes and extension research centers in Flanders (ILVO, UGent, Inagro, PCS, PCG and PSKW) performed a benchmark study to evaluate innovative techniques for nutrient management in horticulture in Flanders and other regions in Belgium, The Netherlands, France, Spain, Italy, Germany, Denmark, Switzerland and Poland. The benchmark focuses on the current knowledge of sustainable and innovative techniques of vegetable and ornamental plant production. The techniques are related to both conventional and organic agriculture, are used both for vegetables and ornamentals, and do include applications for all horticultural systems (open air and greenhouse, in soil and soilless). The selected techniques focus on innovative fertilization, crop residues management, crop rotation, organic matter management and soil quality practices in horticulture. The necessary information was gathered by visits to the selected regions. The benchmark resulted in an overview of promising techniques on this subject compiled in a report with fact sheets on cultivation and fertilization techniques for vegetable and ornamental plant production. The position of Flanders relative to other European regions concerning the implementation degree is assessed as well. For new techniques ready for implementation, we evaluated the applicability and the economic and technical feasibility for Flanders. These results will be used for an action plan for horticulture in Flanders.

(35) Benchmark study on nutrient legislation for horticultural crops in some European countries

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A benchmark study on nutrient legislation for horticultural crops in some European countries has been done by a consortium of Flemish institutes involved in nutrient management of horticultural crops. Therefore, the members of the consortium visited horticultural institutes and contacted persons responsible for nutrient legislation in a selection of EU countries and Switzerland. By filling out a questionnaire and discussions with the responsible researchers and governmental people, the members of the consortium got well documented information of the nutrient legislation in these countries. This paper gives a summary of the different nutrient legislations for horticultural crops in the various countries. It ends up with points of discussion with the aim to clarify some points in the various legislations as well as to come up with ideas about harmonisation where obvious.

(36) Facing the nutrient challenge in the vegetable sector

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The very close relationship between agriculture and water is replicated as much in horticulture as in livestock and arable farming. However, EU Member States and the Commission have paid rather more attention to livestock over the two decades since the introduction of the nitrates directive largely because of its scale and concentration. The vegetable and fruit sectors are also concentrated, albeit to a lesser degree, and increasingly specialised, both of which traits generally combine to increase environmental imbalances if not addressed. The well-known challenges facing fruit and vegetables are water consumption and plant protection product use; rather less is the issue of water pollution with nutrients. Partly, this is due to the enormity of the other two although the relatively low input cost of the fertilizer relative to other costs is an important, if currently diminishing, factor. In any event, as progress is made on other aspects of the agriculture water relationship, it is time to examine the obligations and possibilities provided by EU legislation and policy in the vegetable sector.

First and foremost, the nitrates directive provides basic tools for addressing nutrient use. The various aspects of the code of good practice such as land application rules and conditions near water courses, uniformity of fertilizers applications, crop rotations, winter cover and the prevention of water pollution from run-off and the downward movement beyond the reach of crop roots in irrigation systems are all relevant. While many codes were designed with large cultures and livestock in mind, there are horticultural practices that differ in their intensity and need to be addressed in codes.

When translated into action programmes applicable to areas draining into waters polluted or at risk of becoming polluted, significant issues going beyond those of the codes include greater attention to the nitrogen supply to crops from soil and all nitrogen sources especially given the high nutrient need of vegetables, which might result in applications in excess. Another factor to consider is the shallow rooting of many vegetables, which makes it likely that nutrients may be out of reach for new roots. The use of catch crops is extremely relevant. Indeed, in developing aspects of action programmes relevant to vegetables, it will be necessary in coming years to pay particular attention so that horticultural areas do not become "black-spots of stubborn resistance" in the search for improved water quality.

Additional to the nitrates directive, it is useful also to look at what obligations and possibilities could emanate from the water framework directive. Furthermore, and most importantly, the current round of CAP reform will bring further challenges, not least in terms of the eventual outcome of the greening component and the possibilities under both rural development and the operational programmes for the horticultural sector.

(37) Nitrates Directive in Flanders' horticulture: towards nutrient management through participation

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In the first decade, measures taken to implement the Nitrates Directive in Flanders were mainly focused on livestock breeding. Impact on horticulture in this stage was very limited. With the introduction of the nitrate residue instrument (NO_3-N measurement in autumn in the soil up to 90 cm depth), however, horticulture was pushed to implement environmental aspects in their nutrient management. Since water quality remained insufficient, the focus of the action programs shifted towards measures targeting more directly on improving water quality. From this moment on also greenhouse horticulture has taken up responsibility in close cooperation with the government. This collaboration was the basis for further alliance in preparation of the current action program. The participatory approach has initiated research initiatives on different aspects of horticulture and several demonstration activities. Participation of the stakeholders has introduced also changes in legislation. Specific fertilization standards where defined for vegetables according to their nitrogen uptake capacity, replacing general values. Furthermore, since 2013 fertilization on vegetable crops is only allowed when based upon fertilization advices. Changes in nitrate management policy have had their effects. The mean nitrate residue on vegetable crops has dropped 36% since 2007. Nevertheless it's too early to draw conclusions on the enhanced participatory approach in the current action program. However, it's already clear that this strategy creates a higher level of awareness among horticulturists regarding the effect of nutrient management on water quality, and facilitates acceptance of stricter regulation in order to meet the objectives set in the Nitrates Directive.

(38) Emission control of soil nitrogen content in water protection areas in Baden-Württemberg, Germany

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Vegetable production in water protection areas in Baden-Württemberg (BW) is subject to regulations according to the decree SchALVO (Schutzgebiets- und Ausgleichsverordnung). To remediate groundwater consistent constraints in addition to the existing standards of good agricultural practice are imposed. It fulfils the Water Framework Directive (WFD) as 'additional program of measures'. SchALVO is compulsory in water production domains with 359.500 hectare in agricultural use. The constraints depend on soil type, altitude, distance to water sources and the nitrate concentration of groundwater in three classes (normal area <35-50, problem-area 35-50, remediation area >50 mg NO_3 L^{-1}). Measures in vegetable cropping include fertilizer use; crop choice; dates for establishing catch crops; time windows for tillage; and others. Residual soil nitrate-N is monitored in 0-90 cm between October 15th and November 15th. Farmers get financial compensation for meeting a threshold of 45 kg N ha^{-1}. SchALVO was amended in 2001 and monitoring was restricted to areas at risk (problem- and remediation areas) which resulted in an increase of residual nitrate-N. Since 2006 the residual nitrate-N reaches a level of 70 to 80 kg N ha^{-1}. For 2011 a detailed analysis of nitrate-N residues on 141 vegetable growing sites was done and results presented. Generally the effect of measures according to SchALVO is influenced by site specific characteristics as well as weather conditions. The results of the monitoring program are used to check compliance with the requirements and are a valuable instrument for the extension services to derive recommendations for vegetable farmers. Additionally SchALVO measures provide valuable experience to implement voluntary measures according to WFD in horticultural practice in BW.

(39) Nitrate-leaching from container grown nursery crops on a closed culture system in open air

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Belgian tree nurseries often use a closed culture system with plantcontainers in open air. Although runoff is captured and stored, excessive rainfall might necessitate overflow to surface water. Hence, the EU Nitrates Directive (91/676/EEG) limiting NO_3-concentration to 50 mg/l indirectly applies on NO_3-concentration in the drain storage basin. To ascertain if standard practice on nurseries answers to the Directive, representative data on NO_3-leaching from containers are needed. Therefore, experiments were conducted on a containerfield with lysimeters allowing collection and monthly analysis of drain (i.e. water passing through and around containers). Experiments covering one growing season of *Prunus laurocerasus* “Otto Luycken”, *Fagus sylvatica*, *Lonicera nitida* “Maigrün”, *Thuja plicata* “Atrovirens” or *Viburnum tinus* were repeated over five years to reckon with climatic variations influencing plant growth and drain characteristics. As controlled released fertilizers (CRF) are generally used, different brands of CRF were applied at recommended doses. Despite varying growing conditions, water-drain fluctuated around 33% of total water-input. NO_3-leaching averaged 14% of total NO_3-input and never exceeded 30%. Based on these numbers and taking into account the applied NO_3-concentration, average water-input and field coverage (to estimate runoff of unpolluted water), growers are now able to predict the NO_3-concentration in their drain storage basin. Experiments demonstrated that most Belgian tree nurseries with a closed culture system in open air are able to produce high quality plants without violating the EU Nitrates Directive. In addition, results provide background for substantiated advice to growers and future experiments on reducing NO_3-leaching.

POSTER PRESENTATIONS

(40) In Line Roller Crimper technology in organic vegetables production to mitigate nitrate leaching risk

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The use of the In Line Roller Crimper (ILRC) technology to terminate cover crops could reduce nitrate leaching risk in vegetable cropping systems. Two 2-year field experiments were carried out, growing zucchini after rolled cover crops (barley and common vetch in central and southern Italy, respectively). In central Italy no cover crop, green manure and in-line till/roller crimped barley were compared on zucchini yield, yield quality, weed control and N dynamic in the soil–plant system. Zucchini cultivated by the ILRC yielded 69% more than the crop preceded by the green manure and similarly to the control. Yield quality did not differ among the treatments. Weed above ground biomass was lower than the control in the green manure and in the ILRC treatments. The N use efficiency in the ILRC treatment was twice as high in comparison with the control treatment and 29% higher compared with the green manure treatment. In southern Italy, the effects of vetch management strategies as green manure (GM), using a roller-crimper (RC) and different organic fertilizers (municipal solid waste compost, anaerobic digestate and a commercial organic fertilizer) on organic zucchini yield and quality were investigated. The vetch cover crop increased marketable zucchini yield by 26.6% compared to the fallow (FA) treatment, indicating that using this fertility building crop could reduce the off-farm N fertilizer input. Averaging over two years of the experiment, the marketable zucchini yield increased when RC mulch and GM were used. The concentrations of mineral N in the soil at harvest were 19, 27 and 28 mg kg^{-1} for the RC, FA, and GM treatments, respectively. Research findings suggest that ILRC technology was able to increase the zucchini N utilization efficiency in both the experiments, and to mitigate the risk of nitrate leaching.

(41) Use of textile and organic waste as a substrates for soilless cultivation of greenhouse tomato

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Research on the effect of organic substrates made of textile waste (wool and cotton), supplemented with coconut fiber, sawdust or flax shives, on the yield and chemical composition of greenhouse tomato variety Growdena grown in greenhouses in a prolonged cycle, was carried out in the years 2009 - 2010. Growing media made from textile waste and organic wool differed from almost all of the studied physical properties as compared to rockwool slabs. The organic substrates had higher bulk density (bulk density of the organic substrate was 105 kg/m3, while rockwool had only 62 kg/m3), a lower water content at full saturation (pF 0.0) and greater at higher potentials of 1.5 pF and 2.0 pF. The porosity of the organic substrates was only slightly less than the total porosity of the rockwool and it was higher than 90%. The substrate type had no significant effect on growth, development and yield of tomato plants. Nutritional status of N, K, Ca and Mg in all tested substrates was at a similar level, while the content of P, Fe, Mn, Cu and B was significantly higher in the leaves of plants grown in rockwool.

(42) Method using gas chromatography mass spectrometry (GC-MS) for analysis of nitrate and nitrite in vegetables

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Accurate analytical methods are very important to detect the contents of chemical substances in vegetables and fruit. There is particular interest in nitrate and nitrite, due to their possible benefits and harm on human health. The aim of this research is to modify the method of measurement of nitrate and nitrite by GC-MS for use in vegetables. Many procedures are available to measure nitrate (NO_3) and nitrite (NO_2). Some examples are: capillary electrophoresis, spectrophotometry using the Griess reaction, various HPLC methods and different types of isotope dilution GC-MS: with electron ionisation by nitration of mesitylene, and with chemical ionisation by derivatisation with pentafluorobenzyl bromide. However, some of these methods are mostly used in research on human health, to measure nitrate and nitrite in human biological fluids such as plasma or urine. Methods developed for analysis of vegetable samples often give variable results, for example due to interference from coloured compounds in the plant material. Therefore, we tried to modify the GC-MS method using pentafluorobenzyl bromide and chemical ionisation to optimise it for analysis of nitrate and nitrite in vegetable samples. Experiments were carried out to maximise peak area, in particular for nitrate. Factors that were tested were gas pressure, derivatisation reaction time and temperature, duration of nitrogen flushing, time of vortex after adding toluene during sample preparation, and amount of water added to separate the phases. The modified method was used to analyse contents of nitrate and nitrite in samples from a range of different vegetables.

(43) The Flemish approach to reduce nutrient losses from soilless horticulture: legislation to practice

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Since the manure decree of December 22th 2006, soilless horticulture growers have to take measures to prevent nutrient leakage to the environment. Monthly data from fresh surface water monitoring stations in areas with high concentrations of soilless horticulture however kept showing typically high concentrations of nitrates in summer, initially coming from soilless horticulture.

In 2009 the Flemish Land Agency started visiting greenhouses with soilless horticulture (approx. 1,000 in Flanders) to monitor sources of nitrate leakage and to stimulate growers to take necessary measures to reduce nutrient losses. Nitrate concentrations are measured in surface water courses with colorimetric test strips showing concentrations from 10 – 500 mg/l NO_3^-. During the visit growers are immediately confronted with actual nitrate concentrations in different water flows. Although the strips give only an indication of the amount of nitrates in the water flow, this technique has proven to be highly suitable to enhance the grower´s awareness. In dialogue with the grower achievable solutions are proposed and discussed and the timing for implementation is agreed and checked. Several causes of nutrient leakage in greenhouses with soilless horticulture have been discovered since 2009. The used approach to reduce nutrient losses from soilless horticulture has recently resulted in great reductions in measured nitrate concentrations in some fresh surface water monitoring stations. On the poster the way of working will be presented, as well as different problems of nutrient leakage, reactions of horticulture growers and results.

(44) Improvement of N efficiency in vegetable crops to fulfil the demands of water framework directive

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In Baden-Württemberg, Germany, the national monitoring (2009) according to the water framework directive identified 23 water bodies as vulnerable zones for which 14 zones will not reach the "good quantitative status and good chemical status of the groundwater" until 2015. Agricultural and horticultural land use was designated for being the main contributor exceeding the threshold of 50 mg nitrate L^{-1}. Besides existing national and state specific action plans (DüV, MEKA, SchALVO[1]) this enforces additional requirements to reduce nitrate input to fulfil the requirements of the water framework directive. Therefore the state horticultural college Heidelberg successfully established a three-year-project to improve nitrogen efficiency of vegetable crops in three of the vulnerable zones (Rhein-Neckar, Hockenheim-Walldorf and Bruchsal).

With the active cooperation of farmers, horticultural extension services and administration, a sustainable nitrate management system will be developed and integrates several measures into the farms' crop rotation.

This includes an economic an ecological evaluation of measures and their acceptance in practice. Finally this concept will be transferred to other vegetable growing areas in Baden-Württemberg. Main components of the project are: exact field trials in three pilot farms; 28 actively engaged farmers in a working group; analysis of farm and field based nitrogen balances.

Representative data of one pilot farm will be presented and discussed. In this field trail N-fertilization was calculated by using the software application N-expert (IGZ) and crop rotation was changed. Nitrogen supply could be reduced up to 50 kg N ha^{-1} in carrot crops without yield reduction. N-Expert improves fertilizer management by better matching N supply to crops needs. Replacing the vegetable crop during winter by greening significantly reduced N-content in the soil (0-90 cm) This treatment will be economically evaluated. These current results have already led the farmer to reorganize his fertilization on farm level.

The progress of the project can be tracked on the advice platform www.beratung-im-gartenbau.de/WRRL.

[1] action programmes of Baden-Württemberg: DÜV = Düngeverordnung, MEKA = Marktentlastungs- und Kulturlandschaftsausgleich, SchALVO = Schutzgebiets- und Ausgleichs-Verordnung für Wasserschutzgebiete

(45) Coordination centre for extension services for sustainable fertilization

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Flanders has a difficult task to achieve the European nitrate directive. European legislation states that nitrate concentration in surface and ground waters may not exceed 50 mg NO_3^-/l. Therefore, the 'Coordination centre for extension services for sustainable fertilization' (CVBB) was founded by the authorized practice centres and professional organizations as supporting measure to the Manure Action Plan 4 of Flanders to reduce the concentrations of nitrates. The employees of CVBB follow a network of reference parcels, offer individual counselling to farmers and organize water quality groups (WKG) in Flanders.

WKG is a voluntary meeting group where farmers and CVBB discuss the nitrate concentrations from the official measuring points for water quality. The aim is to exchange information, reveal possible causes of high nitrate concentrations and solve them. The eventual objective of these WKGs is to improve water quality by next Manure Action Plan (MAP).

At each measurement point and further upstream, CVBB measure the nitrate content with a rapid test and a reflectometer. Through this detailed sampling, CVBB can map out the evolution of the nitrate concentration in the surface and ground waters.

(46) Optimalisation of fertilisation in vegetable crops to reduce nitrate residues and nitrate leaching to surface- and groundwater

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The legally provided standard of 90 kg NO_3/ha in the soil between the 1^{st} of October and the 15^{th} of November is a bottleneck for the vegetable crop production in Flanders. This project, subsidized by the Department of sustainable agriculture (ADLO), aims to reach innovative fertilization techniques to growers, in order to reduce the nitrate residue on field level. Three strategies to reduce the nitrate residue are demonstrated in different field trials. First of all, it is important that the applied fertilization is based on the nutrient need of the crop. Secondly, row application of fertilizers, close to the roots of the plant, increases the efficiency of nitrogen uptake. Also the use of slow release fertilizers (with nitrification inhibitors and urea or ammonium based fertilizers) reduces the nitrogen leaching and increases the nitrogen use efficiency. And third, some vegetables can have profit of a small gift of phosphorus fertilizer at the beginning of the crop period.

For crops with a long cultivation period, it is recommended to fractionate the fertilization. By applying only the amount of N that can be taken up by the plant nitrogen leaching is decreased. With row application of fertilizers, the nutrients are only deposed in the soil where the roots can absorb it and the required amount of fertilizers can be reduced by 20%. An application of a small amount of phosphorus fertilizers (25 kg P_2O_5/ha en 14 kg N/ha) at planting, close to the roots of the young plant, achieve a better development of the rooting system. The efficiency of nutrient uptake increases, leading to significantly higher yields (up to 20 % higher piece weight) of some vegetable crops. Especially leafy vegetables (endive and celery) grown during springtime. The results of the trials are communicated to the growers by way of guided visits at the field trials and by organising study moments.

(47) Sensitivity of optical sensors to crop N status of a tomato crop

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Optical sensors are a promising monitoring approach to assess crop N status. Their use *in situ* and in real time provides the potential for N fertiliser application to be rapidly adjusted to crop N status. This is particularly the case where high frequency drip irrigation and fertigation are used together, as is being increasingly done in horticultural production, such as in the greenhouse based vegetable production system of the south-eastern (SE) Mediterranean coast of Spain. Canopy reflectance has been previously been evaluated with various cereal crops, but little work has been reported with vegetable crops. This work examined the use of canopy reflectance to assess crop N status of a tomato crop grown with drip irrigation and fertigation, and which received complete nutrient solutions in all irrigations. Four different N concentrations were applied from 28 Days After Transplanting (DAT) until the end of the crop. Reflectance measurements were made weekly from 25 DAT on. Reflectance measured as the Normalized Difference Vegetation Index (NDVI) was strongly related to the Nitrogen Nutrition Index (NNI). Three different linear relationships described the relationship between NDVI and NNI for three different phases of the crop which covered the period from 43 DAT to the end of the crop.

(48) Sensitivity of optical sensors to crop N status of a melon crop

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Optical sensors are a promising monitoring approach to assess crop N status. Their use *in situ* and in real time provides the potential for N fertiliser application to be rapidly adjusted to crop N status. This is particularly the case where high frequency drip irrigation and fertigation are used together, as is being increasingly done in horticultural production, such as in the greenhouse based vegetable production system of the south-eastern (SE) Mediterranean coast of Spain. Canopy reflectance has been previously been evaluated with various cereal crops, but little work has been reported with vegetable crops. This work examined the use of canopy reflectance to assess crop N status of a melon crop grown with drip irrigation and fertigation, and which received complete nutrient solutions in all irrigations. Four different N concentrations were applied from 23 Days After Transplanting (DAT) until the end of the crop. Reflectance measurements were made weekly from 36 DAT on. Reflectance measured as the Normalized Difference Vegetation Index (NDVI) was strongly related to the Nitrogen Nutrition Index (NNI). Three different linear relationships described the relationship between NDVI and NNI for three different phases of the crop which covered the period from 36 DAT to the end of the crop.

(49) Life cycle assessment of broadcast and fertigation fertilization systems in open field cauliflower production in Flanders, Belgium

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Current farming practices in Belgium use large amounts of inorganic fertilizers to attain high yield and quality. This practice results in an exceedance of the residual soil nitrate threshold value of 90 kg/ha. Lowering the nitrogen application rate however does not yet give sufficient guaranties to uphold the demanding standards. An experiment has been set up to monitor and evaluate the influence of two fertilizer application rates (high – low) and two strategies (broadcast – fertigation) on the growth, yield and quality of a cauliflower crop, and the amount of nitrate leaching to soil and surface water. Regarding productivity, there was no difference between the broadcast and fertigation application of fertilizer. With current pressure on the environment however more objectives come into consideration. A life cycle analysis (LCA) focuses for each fertilization treatment on the differences in input loads and their corresponding environmental impacts in terms of different categories : resource depletion, global warming, toxicity, acidification and eutrophication. A higher nitrogen application rate resulted in an overall higher impact in all categories. For the effect of fertilizer strategy, the relation is not straight forward and effects should be looked at per category.

(50) Reducing P_2O_5-leaching from container grown nursery stock: potential of lower P_2O_5-input and Humifirst

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After nitrogen, phosphorus recently came into the spotlight for its detrimental effects on (surface) water and environment. Because nutrient-leaching is an important issue for container grown crops on closed culture systems in open air, possibilities to reduce P_2O_5-drain in tree nursery should be explored. One option is to simply decrease P_2O_5-input, another to ameliorate substrate buffer-capacity and nutrient-availability by adding Humifirst, an organic matter concentrate of humic and fulvic acids. In 2011 and 2012, *Prunus laurocerasus* "Otto Luycken" was fertilized with a recommended dose of [1] standard controlled released fertilizer ("CRF", *e.g.* Basacote 16-8-12), [2] CRF-formulation with lowered P_2O_5-content ("CRF-lowP", *e.g.* Basacote Native 14-3-19) or [3] "CRF-lowP" plus Humifirst ("CRF-lowP+HF", WG or liquid). Containers were placed in lysimeters allowing measurement, collection and monthly analysis of drain (*i.e.* water passing through and around containers). After one growing season NO_3- en P_2O_5-balance was calculated and plant quality evaluated. Contradicting results were found between experiments. In 2011, "CRF-lowP" reduced both NO_3- and P_2O_5-leaching but had negative effects on plant quality. Adding Humifirst ("CRF-lowP+HF") ameliorated plant quality but P_2O_5-drain unexpectedly exceeded that of "CRF". In 2012, however, plant quality was acceptable for all fertilization methods and the sequence for P_2O_5- and NO_3-leaching was "CRF" > "CRF-lowP" > "CRF-lowP+HF" and "CRF-lowP" > "CRF-lowP+HF" > "CRF" respectively. In conclusion: although both lowering P_2O_5-input and adding Humifirst have potential to reduce P_2O_5-leaching while producing qualitative *P. laurocerasus*, present results urge caution on increasing NO_3-leaching and necessitate further experiments under varying abiotic conditions and with various nursery crops.

(51) NO_3-leaching from *Azalea indica* on containerfields: effect of current fertigation strategies

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From June to October/November, *Azalea indica* (*Rhododendron simsii*) is grown on containerfields in open air and daily fertigated. Consequently, runoff is high in both quantity and nutrient-concentration. When runoff is discharged into surface water, the EU Nitrates Directive (91/676/EEG) limits NO_3-concentration to 50 mg/l. To ascertain if high-quality *A. indica* can be grown within this Directive, representative data on NO_3-leaching are needed. During one outdoor season (June to October), *A. indica* cv. Sachsenstern was grown under three fertigation strategies: [1] excessive (daily at 8 a.m.; EC = 1.5-2.0 mS/cm), [2] practice-based (daily at 8 a.m.; EC = 0.8-1.0-1.5 mS/cm, according substrate analysis) and [3] adapted (frequency according radiation sum of 1500 J/cm²; EC = 0.8-1.0-1.5 mS/cm, according substrate analysis). Containers were placed in lysimeters allowing measurement, collection and two-weekly analysis of drain (*i.e.* water passing through and around containers). Plant quality was determined after the outdoor season. Although total NO_3-drain was proportional to NO_3-input (excessive > practice-based > adapted), plant quality was acceptable for all strategies. Unfortunately, NO_3-concentration of drain always exceeded 50 mg/l. In conclusion, *A. indica* growers applying current fertigation strategies can only meet the EU Nitrates Directive when drain is recirculated (*i.e.* closed culture system) or adequately diluted with rainwater before overflow to surface water. Consequently, further research on improving fertigation strategies is recommended so that NO_3-leaching from *A. indica* can be reduced without loss of plant-quality. Luckily, results indicate that there is still room left for such improvement.

(52) Nutrition and water management in the integrated production of Emilia Romagna region (Italy)

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The Emilia-Romagna Region (ERR) (Italy) is an important agriculture area in Europe with about 72,845 farms and 1,064,214 hectares invested. The most important horticultural crops are fruit crops (67,454 ha), and vegetables (55,626 ha). The ERR started in the seventies promoting integrated agriculture. From early 90s specific guidelines for Integrated Production (IP) of several crops were developed. They are yearly updated and currently applied on more than 67% of vegetable and fruit crops.

Nutrition and irrigation are two of the aspects included in the guidelines. 'Nutritional balance' is foreseen to be calculated for fertilization but for small orchards and many vegetable crops a simplified method has been studied and specific guidelines developed. Farmers can easily adapt these guideline to their production, soil fertility and rainfalls and rotation. For example on lettuce it was possible to reduce the nitrogen amount distributed per hectare from 180-200 Kg to 100-120 Kg.

The management of irrigation is evaluated also in relation to fertilization to reach the highest efficiency for both techniques. On this concern ERR promoted the implementation of several tools to support farmers for irrigation according to water availability (rainfall, rivers level, ground-water level) and water balance along the irrigation period (e.g., spring-summer). Nowadays specific advices are supplied weekly (provincial bulletins) on all regional territory and a new web-system (IRRINET) has been developed by ERR in cooperation with CER. About 12,000 are IRRINET users (about 25% of the total irrigated surface in the region).

(53) Soilless culture of hardy nursery stock in the Netherlands

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The extent of nursery stock in the Netherlands amounts to 17,000 ha of which 1,000 ha is grown in pot or container. A major challenge is to meet the European water requirements of the Nitrate and Water frame work directives. The European Commission demands substantial steps for improving the water quality before 2015.

One possible solution is the development of innovative soilless culture growing systems aiming at minimalizing the emission of nutrients and crop protection chemicals.

New systems, e.g. gutters, pot-in-pot and growing plants in big containers are developed and tested in close cooperation with growers. The challenge is to meet the water requirements as set by the government and at the same time the aim of the growers which is the production of trees in a profitable way.

Examples will be presented of the different systems in comparison with open field production. Aspects discussed are the nutrient and water use efficiency as well as economics.

(54) Assessment of root distribution by combining observations of the trench profile method with root length observations

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Optimal nitrogen fertilization to horticultural crops critically depends on synchrony and synlocation of N supply and N uptake, and hence requires good knowledge of how root systems develop over time. Root length density (RLD) is a parameter which is difficult to measure, but crucial to estimate water and nutrient uptake by plants in model-based advisory systems for N fertilization. Current methods to estimate the RLD distribution in the root zone are often time consuming and are restricted to one or two dimensions. In this study a novel approach is presented to characterize the 3-D root length distribution by supplementing data of the 3-D distribution of root intersections with data of root length density from a limited number of soil cores. The trench profile method (counting root intersections in a trench profile) was complemented with root length observations on a minimal number of soil cores to translate root intersection density into root length density. The approach was tested in the field on leek and cauliflower and involved multiple root observations over the growing cycle. 3D-root length density functions were fitted to the data yielding parameters that can be used in soil-plant models. For cauliflower, horizontal root intersection counting was done and resulted in R^2 between 0.63 and 0.96. A similar protocol was used for leek, the only difference being that root intersection were counted in vertical planes. An R^2 of 0.67 was obtained using this novel method in leek.

(55) In search of the optimal N fertigation dose for 'Conference' pear trees

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Fertigation is the dispersion of fertilizers trough an irrigation system and allows a precise distribution of the nutrients in the root zone. Fertigation is often used in combination with drip irrigation in 'Conference' pear tree in Belgium and the Netherlands to maximize fruit yield. To optimize the efficiency of the N fertigation, the fertigation can be applied at the end of the vegetative growing period at the beginning of fruit maturing. This way vegetative growth of the pear tree is minimized while fruit yield is maximized. In search for the optimal N fertigation strategy this study discusses the effect of three different fertigation doses (0, 25 kg N, 50 kg N), applied six weeks before harvest, in a humid and a dry irrigation treatment. The experiment was conducted in three different fruit orchards with varying soil profiles and plating systems in two successive years (2008-2009). Fertigation with 25 to 50 kg N resulted in a 20 % higher fruit yield in two of the three orchards independently from the irrigation regime. Water stress induced yield decline and increased the risk of an excessive N residue in autumn. The study proves the necessity of N during fruit maturing but also discusses the risks accompanied with excessive N fertilization.

(56) Soil microbial fertility in olive orchards managed by a set of sustainable agricultural practices

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In conventional olive growing, the frequent tillage has reduced soil organic matter content. Recently, soil conservation is becoming a priority in management strategies of rural areas due to the awareness of the deterioration of this natural resource and of the difficulty of its recovery in short periods (i.e. cross compliance concept in European Union). Therefore, the conventional agronomic practices should evolve to a more sustainable olive management to improve soil quality and water saving. A better understanding of soil ecology could lead to identify agricultural management practices that support and stimulate soil organisms for beneficial purposes in agriculture. The aim of this study was to evaluate the effects of sustainable practices (grass cover and pruning residues recycling) on soil quality in a Mediterranean olive orchard. The trials were carried out in a mature olive grove (Olea europaea L. – cv Maiatica) located in Basilicata Region (Southern Italy) and managed according to two different soil management systems: the sustainable treatment (ST) and the conventional treatment (CT). Soil microbiological quality in the two systems was monitored by both microbiological cultural-dependent and molecular methods. In the ST olive orchard, soil microbiota showed a higher complexity and metabolic diversity. The adoption of 'innovative', sustainable, agricultural practices had positive effects on soil microbiota and its biodiversity which can influence soil fertility and plant growth by increasing nutrients availability and turnover. The results of this study encourage the use of sustainable agricultural practices able to enhance soil fertility and promote good-quality fruit production without detrimental effects on water and soil resources.

(57) Influence of harvest time on fructan content in the tubers of *Helianthus tuberosus* L.

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The influence of harvest time on fructan (fructooligosaccharides and inulin) content of different varieties of Helianthus tuberosus have been investigated in this study. The determination of quantity of inulin in the tubers harvested during three years period from 2010 until 2012 was done. The extraction of fructooligosacharides was carried out with 95 % (v/v) ethanol used as a solvent. Inulin from tubers of Helianthus tuberosus was extracted by treatment with hot distilled water. The extraction efficiency of inulin and fructooligosacharides was followed by TLC analysis. The fructan content in the extracts obtained from the tubers was determined by the spectrophotometric method based on the Seliwanoff reaction with resorcinol and by HPLC-RID method. It was found that a similar amount of inulin and fructooligosacharides (45-53% of dry weight) was observed in the middle early varieties harvested 21-26 weeks after plantation and in the late variety harvested 29-33 weeks after planting. From the obtained results, we can conclude that the tubers of both varieties of Helianthus tuberosus harvested in autumn 2011 contain the highest amount of fructans (50-69 % of dry weight).

(58) Influence of fertilisation and cultivation methods on the yield and essential oil content of thyme (*Thymus vulgaris* L.)

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The information in the literature concerning the influence of nutrient supply on the yield of biomass and essential oil of plants belonging to the Lamiaceae, in particular thyme, is very contradictory. However, it is well known that the quantity of fertilisers and their composition may influence not only the biomass and essential oil, but also the vitality and the hibernation of thyme. Therefore, a field experiment with the cv. 'Deutscher Winter' was carried out in order to investigate the effects of fertilisation during a three- years-cultivation period. Five treatments were applied ('standard fertilisation without N fertilisation', with 'double amount of N fertilisation', with 'double amount of K', 'covered with fleece', and with 'double plant density') and their effects on the content of essential oil, thymol, yield of thyme (dried leaves, leaf fraction on the plants), and influence on hibernation were analysed. The highest yield was recorded in the treatments 'covered with fleece' and at the 'double plant density with standard fertilisation' in average of the three years. The lowest yield of leaf drugs was determined in treatment 'without N-fertiliser', the highest at the 'double plant density'. The amount of essential oil was highest in the treatment 'double plant density', whereas the lowest essential oil quantity was determined when twice the quantity of N was applied. The content of thymol was highest in the treatment standard fertilisation without N-fertiliser. Concerning the vitality and effect on hibernation best results were determined in the treatments without N-fertilisation and covering with fleece. These results confirm the theory that nitrogen has a negative effect on the content of essential oil and its components as well as the vitality of the plants during the winter season.

(59) Optimisation of the SUSON strategy as a method for sustainable fertilisation in glasshouse butterhead lettuce

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The SUSON fertilization strategy (acronym for 'SUstained low SOil mineral N content'), was presented by Bleyaert et al. in 2007. Instead of standard basic dressing at planting up to some disputable and high target level, SUSON tries to maintain soil nitrogen content just above, but very close to a fixed low threshold level, therefore applying fertigation during the cultivation period, based on frequent soil analysis. Frequent experiments in various growing seasons and various soil types showed a threshold level of 60 kg/ha N in winter and of 90 kg/ha N in summer could guarantee the production of heavy lettuce of good quality. Compared to standard fertilization at planting, the SUSON strategy yielded an average reduction of 22.0 % for both fertilizer use and for nitrogen content in the 0-90 cm soil layer. However, the procedure of adjusting soil nitrogen content only at downward trespassing of the threshold level, and adjusting up to a level of 50 % above the threshold level showed some disadvantages: frequent measurement of soil N is necessary, and high fertilizer concentrations needed for overhead fertigation can cause necrotic burns in sunny periods. Therefore, a new working procedure was tested out for spring and summer periods: from planting on, nitrogen fertilizer was continuously added to the irrigation water, at a low concentration of 1.8 dS/m. Experiments in spring period proved this adaptation to yield excellent lettuce heads, on the condition that each fertigation turn of 4 L/m² was preceded and followed by irrigation with respectively 0.5 L/m² and 1.0 L/m² of pure water. Increase of the fertigation concentration to 2.2 dS/m could not increase lettuce head weight. However, postponing fertigation to start only at head formation did cause lower head weights.

(60) Fertigation and winter cover crops as complementary tools for the N nutrition of processing tomato

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Fertigation can allow both to match fertiliser application and N crop requirements at any crop growth phase and to improve the fertilisation efficiency by localization close to the roots. Cover crops are a powerful tool for N management and for limiting the risk of N leaching. Within a sound strategy for a conservative horticulture, fertigation and winter cover crops could be suggested as complementary tools in order to guarantee both adequate vegetable crops N nutrition and environmental benefits. A 2-year field experiment was carried out on processing tomato fertilised by different methods: green manuring of winter cover crops (i.e. hairy vetch and barley as pure stands or mixtures), fertigation, green manures+fertigation. Pure vetch cover crop was able to supply a considerable amount of nitrogen to match N requirement of a subsequent crop of processing tomato, without significant differences with fertigation, applied alone or in combination with winter cover crops. Pure vetch green manure showed a low risk of N leaching during tomato crop cycle but it was poorly effective in reducing the N leaching during the fall-winter period. Incorporation of cover crops with high C/N as pure barley and mixture barley-vetch, although supplied very low amount of N for a subsequent tomato crop, contributed to fix N into the soil and it reduced the environmental impact related to the mobility of nitrogen along the soil profile during fall-winter period and crop fertigation.

(61) DEMETER: Sustainable and integrated soil management to reduce environmental effects

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Flemish and Dutch agricultural land management is characterized by a structural surplus of nutrients. At the same time, there is strong evidence that different processes of soil degradation are intensifying and spreading, including loss of soil organic matter. The rationale of the DEMETER project is that insights in sustainable nutrient and soil organic matter management can be translated into practical recommendations to farmers by offering them a decision support tool that will simultaneously consider both aspects of soil management.

A decision support tool (DST), which delivers advice on nutrient management (N and P balances) and carbon evolution in the soil (Roth-C) has been developed recently. To enhance the success of the DST, the tool works with a limited input and a user-friendly interface. The DST will be tested and fine-tuned based on the experiences and recommendations of 80 Flemish and Dutch farmers in the period 2013-2015. Soil and manure samples of all farms will be analyzed in order to give deliberate recommendations on sustainable soil and nutrient management. Afterwards, the application of sustainable soil management will be evaluated through additional measurements.

At the workshop, the decision support tool will be presented and an overview of the first recommendations generated by the DST will be given. The diversity of the participating farms will be presented (farm type, intention of farmers, …) and the results of the samples taken on the farms. The experiences of the farmers during the first growing season will be reported.

Demeter is a LIFE+ project. The LIFE+ programme finances projects that contribute to the development and implementation of environmental policy and legislation.

(62) Soil organic matter management within the legal constraints of the fertilization laws – BOPACT field trial

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Almost all soil and crop management practices have implications for soil organic matter (SOM) but the most obvious way for increasing the SOM content is by using organic fertilizers such as animal manures or compost. However, legislative restrictions related to the nitrate directive limit the use of fertilizers and consequently may constrain the built-up of stable SOM. Therefore, in the spring of 2010 a long term field experiment (BOPACT) was established at ILVO to investigate if the SOM can be increased within the legal constraints of the Manure Decree using slurry and the application of good agricultural practices (cover crops, straw incorporation) and, if not, if this goal can be reached with an extra dose of compost without increasing N leaching. The experiment has a strip split plot design with three factors and four replications. The factors are 1) slurry application (cattle vs pig slurry), 2) tillage practices (ploughing vs non-inversion tillage), and 3) compost application (0 vs 2 ton C/ha.year). The trial has a 4-year rotation with maize, potato, summer barley and leek, with cover crops during winter periods. After three years, the change in SOM content (0-30 cm) was significantly ($p<0.05$) higher for cattle slurry compared to pig slurry and for compost application compared to no compost amendment. Moreover, in 2012 the hot-water extractable carbon was significantly ($p<0.01$) higher in the compost plots than in the non-amended plots. An extra compost amendment did not increase the postharvest mineral N content in soil which could be leached over winter. As the experiment is still ongoing, we will continue to monitor the SOM evolution and nutrient dynamics.

(63) Recent evolution and trends in the soil fertility of Flemish vegetable fields (1998-2012)

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The Soil Service of Belgium (SSB, spin-off of the KU Leuven) formulates each year thousands of fertilization recommendations based on soil analyses. Soil samples are taken in the ploughing layer (0-23 cm) in order to determine the overall soil fertility (pH, C, P, K, Mg, Ca, Na). Liming and fertilization recommendations are then calculated by the BEMEX expert system. In the last 15 years (1989 - 2011), SSB determined the soil fertility of more than 65 000 soil samples from fields with typical vegetable rotations. The samples originated from the whole of Flanders, but especially from the sandy-loam and sandy soils in West-Flanders (the major vegetable-growing area in Flanders). Fertilization recommendations were calculated mainly for Brussels sprouts, leek, cauliflower, spinach and carrots. In this contribution, the statistics and trends of the soil fertility are discussed for cauliflower and leek.

(64) Potential of alternative crop rotations for reducing nitrate leaching losses in intensive vegetable rotations

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Intensive field vegetable production is an important economic sector in Flanders. Several vegetable crops are harvested in a vegetative stage when high daily N uptake rates are achieved leaving behind soils with considerable N content. Vegetable crop residues take a particular position relative to arable crops due to often large amounts of biomass with a high N content left behind on the field. Vegetable crop residues have been found to mineralize rapidly even at low soil temperatures. These factors cause intensive vegetable rotations to be prone to nitrate leaching during winter. In order to obtain water quality objectives set by the nitrate directive three field experiments are set up to evaluate the potential of alternative crop rotations to reduce nitrate leaching during winter. The first alternative crop rotation examines the inclusion of Italian ryegrass (*Lolium multiflorum*) in cauliflower (*Brassica oleracea var. botrytis*) rotations. During the following spring the grass is harvested and a new cauliflower crop is planted. The second alternative crop rotation examines the use of two cover crops (Italian ryegrass or winter wheat *(Secale cereale*)) after a cauliflower crop. However in contrast to the first alternative rotation the cover crop will be incorporated during spring instead of harvested. Both alternative rotations are compared with a standard cauliflower – cauliflower rotation. The vegetable crop residues are treated in a conventional manner, namely being left on the field and incorporated. Results and findings of the first season will be presented at the symposium.

(65) Risk assessment of nitrate leaching in autumn after incorporation of catch crops in spring

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In Flanders, the current environmental policy allows farmers to apply manure after harvest of winter cereals at a maximum rate of 60 kg N ha^{-1}, if a catch crop is sown before September. The N uptake by the catch crop is assumed to prevent nitrate leaching during autumn and winter. After incorporation of the catch crop, its easily decomposable N is mineralized and is expected to become available for the next spring crop. N mineralization was measured through incubation experiments at 15°C for white mustard (*Sinapsis alba*), Italian ryegrass (*Lolium multiflorum*), black oat (*Avena strigosa*) and a grass-clover mixture (*Lolium perenne*, *Trifolium repens*, *Trifolium pratense*). The relative amount of N mineralized after 3 months was negatively correlated with the C:N-ratio of the catch crops. Immobilization was important and long lasting for black oat and to a lesser extent for white mustard. N release from these catch crops could therefore occur late in the season and thus delay the risk of nitrate leaching. To assess effects of sowing date and manure application rates, soil mineral N content in summer and autumn will be monitored for corn grown after catch crop incorporation in spring. Both black oat and white mustard were sown on 2 dates and pig slurry was applied at 3 different rates. Fallow treatments were included. Soil mineral N content and aboveground N were determined before incorporation in April. Mineral N profiles will be used to assess whether delayed risks of nitrate leaching exist with these specific catch crops.

(66) Organic matter fractions and N mineralization in vegetable cropped sandy soils

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Soil organic nitrogen mineralization rates and possible predictors thereof were investigated for vegetable growing soils in Belgium. Soil organic matter (SOM) was fractionated into sand (>53µm) and silt+clay (<53µm) fractions. The latter fraction was further separated into 6% NaOCl-oxidation labile (6% NaOCl-ox) and resistant N and C and subsequently into 10% HF extractable (mineral bound) and resistant (recalcitrant) N and C. The N mineralization turnover rate (% of soil N year-1) correlated with several of the investigated N or C fractions and stepwise linear regression confirmed that the 6% NaOCl-ox N was the best predictor. However, the small R^2 (0.42) of the regression model suggests that soil parameters other than the soil fractions isolated here would be required to explain the significant residual variation in N mineralization rate. A next step could be to look for alternative SOM fractionations capable of isolating bio-available N. However, it would appear that the observed relationships between N fractions and N mineralization may not be causal but indirect. The number of vegetable crops per rotation did not influence N mineralization but it did influence 6%NaOCl-ox N, probably as an effect of differences in crop residues returned and organic manure supply. However, the nature of this relation between management, SOM quality and N mineralization is not clear. Explanation of correlations between N mineralization and presumed bio-available N fractions, like the 6% NaOCl-ox N, requires further mechanistic elucidation of the N mineralization process.

(67) Long term effect of organic fertilization strategies on soil fertility, N dynamics and crop yield

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Litter manure, leguminous cover crops and compost are commonly used in organic crop production to fulfill nutrient requirements as well as to maintain and enhance soil fertility. A long term fertilization trial was started in 2003 on the organic experimental farm of inagro. In this trial the effect of the supply of a high level of organic matter (i.e. use of litter manure and compost) was compared to the supply of a very low level of organic matter (i.e. use of only slurry and organic commercial fertilizer). Fertilization is based on crop requirements and treatments have an equal total nitrogen (N) or effective N supply. The trial has a randomized block design with four replicates. The crop rotation on the trial field was wheat with cover crop clover, cabbage, potato, grass-clover, leek and carrots. Each year fertilizer N availability, mineral N in the soil profile, soil organic carbon as well as crop quality and crop yield were assessed. As total N supply was equal between different treatments, application of slurry and commercial fertilizer resulted in some years in a higher effective N supply. However the crop yield did not increase whereas the N residue highly increased. The N release of the leguminous crops seemed to have an important influence on N supply and crop yield. Furthermore use of only slurry slightly decreased the soil carbon content over the past ten years. Use of municipal waste compost increased soil carbon content significantly. Soil carbon content slightly increased after fertilization with farm compost or livestock manure.

(68) Less organic matter input reduces nitrate leaching and crop yield on a sandy soil in the Netherlands

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Organic matter in soils fulfills vital functions in many ways for food production. However, organic matter can give uncontrolled release of nitrogen leading to high nitrogen leaching to groundwater in periods without crop uptake. On sandy soils in the Southeast of the Netherlands, this is one of the reasons of exceeding the standards of the EU Nitrate directive. When no organic matter is applied with organic manure, less nitrogen is available for leaching to groundwater. The question is if crop yields and soil quality remain stable without external organic matter input. This is tested on an experimental farm since 2001 in an intensive arable and vegetable rotation. A comparison is made between fields with regular organic matter input from crop residues, animal manure and compost (system REG, effective organic matter, (EOM) input about 1600 kg/ha) and fields with minimal organic matter input from crop residues only (system MIN, EOM input about 900 kg/ha). In system MIN, the nitrate content in groundwater was on average 21 mg/l lower (2005-2008) than system REG. Since 2007, crop yields tend to be lower in system MIN up to 6% in 2011. The reason of lower yields is unclear. Nitrogen and phosphorus uptake of the crops were equal in all years and no clear differences were observed in soil parameters. Uncertain is how effects in the long term on leaching, yield levels and soil quality will develop. Therefore, the research is continued in the next years.

(69) Plant nutritional status and susceptibility to necrotrophic pathogens: just a question of nitrogen?

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Hundreds of reports have mentioned the influence of fertilization, especially N fertilization, on a crop's susceptibility to a fungal pathogen, including horticultural crops. However both high or low N inputs can be favorable to diseases, depending on the host-pathogen model, leading to the hypothesis that the plant N status is not necessarily a good indicator to the understanding of the mechanisms of plant defense and/or pathogenicity of the micro-organisms. We hypothesized that other components of the primary metabolism, notably sugars, could have a tighter link with the outcome of diseases caused by netrotrophic pathogens. Eleven experiments on tomato (*Lycopersicum esculentum*), four on lettuce (*Lactuca sativa*), and two on strawberry (*Fragaria* x *ananassa*) are presented, conducted at various N fertilization levels, and inoculated with either *Botrytis cinerea* or *Sclerotinia sclerotiorum.* Statistically, the closest interactions between plant primary metabolites and susceptibility to pathogens are found with plant sugar contents. However, the sugars identified in different plant-host interactions are not the same. We discuss the implication of these findings for the management of lettuce and tomato fertilization.

(70) Removing vegetable crop residues for composting and ensilaging: effects on N, P and organic matter

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The crop residues of vegetables may have a high nitrogen (N) content. These residues often remain on the field after harvest and may lead to nitrogen leaching. Besides having an adverse effect on water quality, such losses of N do not fit within sustainable agriculture practices, where the optimal maintenance and use of nutrients is crucial. However, crop residues are important for phosphorus (P) and organic matter cycling. This study investigates the extent of preventing N loss by removing crop residues, followed by composting or ensilaging. Removal of organic matter and P is assessed as well. Crop residues of cabbage were harvested with common available machinery. For composting, wood chips and bark were mixed with crop residues of corn maize, white cabbage or leek for a good compost composition. Crop residues of white cabbage, celery, cauliflower or leek were mixed in a 50/50 volume ratio with corn maize stover. Ensilage conserves the nutrients for reuse on the field after the winter or for other applications. Feedstock materials, composts and silage were analysed for chemical characterisation. The effects of compost and ensilaging on the N-mineralisation in the soil will be evaluated using an incubation experiment. Also the economic and technical feasibility will be assessed based on the availability of adequate tools, labour and transport costs for the removal of crops.

(71) Nitrate leaching from vegetable crop residues and the fate of N during composting of leek residues

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To reduce nitrate leaching, fertilizer inputs can be limited and fertilizer use efficiency increased. However, these strategies may not be sufficient to reduce nitrate leaching from crops that have a high N content in the crop residues, such as leek, broccoli and other cabbage crops. The crop residues are necessary for production of marketable products, and management of these residues may be required to sufficiently reduce nitrate leaching to fulfil environmental goals. Crop residue management may be incorporation or not, or collection and treatment elsewhere.

In two field experiments, crop residues of leek and broccoli were applied early November both on top and incorporated into the soil to. Degradation of the residues and the fate of N were studied. The residues decomposed quickly: one month after application almost half of the N content was released. In March, 20-60% of the N content was leached to soil layers below 90 cm. Incorporation of the residues increased the rate of degradation and increased nitrate leaching.

Composting of leek residues was studied outdoors on a concrete floor. Residues were mixed with young, immature woody compost in a 1:1 and 2:1 ratio (w:w). The mixtures were placed on a 20 cm layer of woody compost, covered with a sheet and mixed six times. Negligible amounts of N or P leached. During composting, organic matter decreased with 20%, and 8-16% of the N content was lost to the air. Collecting crop residues and composting may reduce N leaching, but increases N losses in gaseous form.

(72) Crop response of leek on fertilizer N from raw and composted chicken manure in organic horticulture

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Organic chicken manure as a by-product of organic meat and egg production has to be destined to fields with a certified organic production. Chicken manure is a nutrient-rich, fast acting organic fertilizer. A high application rate may cause salt stress for a young crop. Stricter P-supply legislative standards will strongly limit the application rate in the near future. Involving chicken manure in a mixture for composting or just mixing it with compost results in a product with a different nature and nutrient composition. Fertilizer N availability was assessed for a set of raw and 'composted' chicken manure products and the resulting N dynamics in soil and crop N response were examined. The field trial had a completely randomized block design with four replicates and leek (*Allium porrum*) as a test crop. Mineral N stock in the soil profile and plant N uptake were assessed. N balances were calculated to express N release from soil organic matter. Low N availability was observed from pure compost products. High fertilizer N availability directly after application of raw chicken manure products clearly caused a priming effect, i.e. an additional N release from soil organic matter. Higher fertilizer N availability affected N uptake and crop quality. However, it did not result in a substantial yield increase. N release from soil organic matter clearly was a major source of plant available N in this organic cropping system. Differences in soil fertility between blocks highly affected crop N uptake and yield potential.

(73) In situ management of vegetable crop residues for reducing nitrate leaching losses in intensive vegetable rotations

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Vegetable crop residues constitute an important link in the soil nutrient and organic carbon cycle and aid in maintaining soil quality and fertility. However during autumn large amounts of N are released by vegetable crop residues causing important N-losses through leaching. Crop residues thus pose a possible threat to meeting water quality objectives, while at the same time being a vital link in closing the nutrient and organic matter cycle of soils. A set of field experiments was set up to evaluate following on-field crop residue management strategies: (i) conventional incorporation of crop residues, (ii) leaving the crop residues untouched on the field and (iii) total removal of crop residues. The field experiments were performed with crop residues of cauliflower (*Brassica oleracea* var. *botrytis*), leek (*Allium porrum*) and headed cabbage (*Brassica oleracea convar. capitata var. Alba*). Soil samples were taken monthly in three layers: 0-30 cm, 30-60 cm, 60-90 cm. Crop residue biomass and N-content were determined before the winter period to assess N-uptake and after winter period to asses N-loss due to decomposition. Total soil mineral N content was generally higher following incorporation of vegetable crop residues compared to leaving them untouched on the field or to total removal. Crop residues left untouched appeared to continue taking up N from the soil, thus further depleting the soil mineral N. More results will be presented at the symposium.

(74) Evolution of nitrogen from crop residues in lysimeters with N^{15} in two cultural systems

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Under climatic conditions in Brittany, we studied the evolution of nitrogen from crop residues in lysimeters. Two types of crop residues (cauliflowers and artichokes) were labelled with N^{15} in the experiment with two different crop rotations: (i) cauliflower followed by potato, (ii) cauliflower followed by artichoke. The N^{15} labelled crop residues were incorporated in the soil. Nitrogen was subsequently measured in the different crops (taken up and harvested), in the soil and in the leached water.

The N-uptake by crops depends on the type of residue and the succeeding crops. After 3 and 6 years, less than 5% of residual N was leached. The most important part remained in the soil: 64% N of cauliflower residue in cauliflower/potato rotation and 90% N of artichoke residue in cauliflower/ artichoke rotation. The part of residual N which was exported represented 33 % for the cauliflower/potato rotation and 6% for the cauliflower/artichoke rotation. In the cauliflower/potato rotation about 30% of N residue of cauliflower was absorbed by potato and 18% by cauliflower the two crops after cauliflower residue incorporation. After two years only 2-3% of the residual N was absorbed by crops. In cauliflower/ artichoke rotation 2 - 6 % N which came from artichoke residue were absorbed by the crops in the rotation. These results allow to define the part that crop residues play in the N balance in the North Finistère rotations.

(75) Effects of vermicomposts on tomato yield and soil fertility under different Irrigation levels in greenhouse

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The effects of Vermicompost (EM) on tomato yield and soil nutrient status (soil organic matter, nitrogen (N), phosphorus (P) and potassium (K)) under three irrigation levels (50-60% of field capacity-L, 60-70% of field capacity-M, 70-80% of field capacity-H) in greenhouse was assessed and compared with conventional compost (as chick composts (CM) and horse composts (HM)) and chemical fertilizers (CF). Additionally a control treatment was included (CK). Under 60-70% of field capacity, higher yields and Vitamin C content were obtained in EM. The average soil organic matter content under different irrigation quantity in EM was 17% and 13% lower than that in CM and HM treatments, but 13% and 10% higher than that in CF and CK treatments. EM resulted in the highest available nitrogen content under 70-80% of field capacity on 67 d after planting. The average available P contents over all irrigation levels in CM and EM were also higher than the other treatments. The available K over all irrigation levels through the whole plant growth stage was lined as CM> HM> CF> EM> CK. The effect of the different irrigation levels on the available nutrients content differed with the fertilization and plant growth stage. The effects of EM on crop yield and soil fertility were controlled by soil water. Therefore, more in-depth study of the mechanism is still needed prior to its application on a large scale.

(76) Pelletized legume plants as fertilizer for vegetables in organic farming

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Effect of pelletized organic fertilizer Ekofert K produced from biomass of red clover has been studied in organic cultivation of celeriac. Fertilizer was preplant applied in doses equivalent to 120, 180 and 240 kg N/ha. The effectiveness of organic fertilizer were compared with mineral fertilization of 100 kg N/ha and control treatment. Nutrients content was measured in soil horizons of 0-30 cm, 30-60 cm and 60-90 cm. Organic fertilizer (Ekofert K) in all applied doses significantly increased plant biomass (19.6-35.5%) and marketable yield (21.5-33.9%) compared to the control treatment, but in relation to mineral N fertilization only the rates of 180 and 240 kg N/ha resulted in significant yield increase (16.3-19.0%). Effectiveness of organic fertilizer applied at 120 kg N/ha was comparable to mineral fertilization.

The highest N-NO_3 content was recorded in topsoil horizon at 5 weeks after fertilizer incorporation to soil. For organic fertilizer and mineral treatments it was 53.6 to 76.3 and for control 38.3 mg N-NO_3/dm^3. The nitrogen uptake in following growing period gradually diminished to 20.6-31.0 mg N-NO_3/ha in topsoil horizon. Compared to the control, however, the highest difference of N-content in soil (10 mg N-NO_3/ha) showed in the treatments with highest rate of organic fertilizer (240 kg N/ha). In subsoil horizon (30-60 cm) the highest N-content was recorded after 8 weeks of celeriac growth and then decreased to a slightly lower level than in the first weeks of plant growth. The only exception was organic fertilizer applied at 240 kg N/ha, where N-content in soil increased to 24.3 mg N-NO_3/dm^3. The amount of nitrogen leached from the highest rate of organic fertilizer application to the soil horizon of 90 cm was only 6 mg N-NO_3/dm^3 higher than this from the control object.

(77) Alternative substrates for overcoming transplanted stress of ornamental plants

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Ornamental plants are subjected to environmental stress when transplanted due to the different chemical and physical characteristics of soil and pot substrates. The main object of this work was to assess the effect of different pot substrates on plant response after transplant, with the final aim of improving plant adaptation to the new root environment and cultivation sustainability. A two-year-long experiment (2011-2012) was carried out in open field. Treatments were: i] a typical mixed cultivation substrate (peat 50% V:V, coconut fiber 20% V:V, pumice 30% V:V) commonly used by growers in the area of Pistoia (Tuscany, Italy) as a control; ii] control substrate blended with 2 g/L of Luquasorb®, a superabsorbent polymer of potassium polyacrylate used for improving water retention in the substrate ; and iii] control substrate in which 20% V:V peat fraction was substituted with urban compost. Treatments were applied to different species, *Rosa* spp. (cv. 'The Fairy') and *Abelia* x *grandiflora*, in a typical two-factor randomized block design. Plant destructive analyses were conducted to assess the main biometric parameters at the end of the nursery period while non-destructive analyses were conducted after transplant. The Luquasorb®-substrate showed the best results in terms of plant growth and development as assessed just before transplant. No significant differences were observed during the successive period after transplant among the different treatments. The use of Luquasorb® can be a valuable strategy to improve the ability of nursery plants to overcome transplant stress but further research is required.

(78) New biodegradable agro-fleece for soil mulching in organic vegetable production

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In field experiments the usefulness of a new organic biodegradable agro-fleece Covelana K was studied in celeriac (*Apium graveolens* L. *rapaceum*) cultivation. The influence of organic agro-fleece on yield, nutrient availability and weeds compensation was compared with 3 types of control objects: non-covered, non-covered but mineral fertilized (100 kg N per ha) and mulched with fresh red clover biomass. Organic agro-fleece had a positive impact on plant development and celeriac yield. Compare to the non-covered object organic agro-fleece significantly increased yield (23%) and share of large roots in marketable yield. The greatest impact on plant development and celeriac yield was obtained by soil mulching with fresh red clover biomass. In relation to organic agro-fleece cover yield increase was higher by 28%. Soil mulching with biodegradable agro-fleece Covelana K eliminated weed problems during the entire growing period. During the first weeks of the celeriac growing period soil mulching with organic agro-fleece depleted nitrate nitrogen in the topsoil horizon (0-30 cm) by 42%, partly due to nitrogen immobilization by soil microorganisms. But in the following weeks of the growing period the rate of nutrients release from organic matter of agro-fleece was higher than plant uptake, so some increase of nitrogen content in the soil was recorded. In objects mulched with red clover decomposition of fresh biomass released a considerable amount of nitrogen and decrease of soil nitrogen content was only 7%.

(79) Effect of different rates of nitrogen fertilization on vegetative development and productivity of cape gooseberry (*Physalis peruviana* L)

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The main goal of the present study was to establish the influence of different level of nitrogen fertilizer on the morphological and physiological behavior of cape gooseberry plants and on the quantity and quality of the obtained fruits. Experiments were carried out with two varieties. Five rate of ammonium nitrate fertilizer (34, 27% N) – 0, 70, 140, 210 and 280 N $kg.ha^{-1}$ were applied in three times – ⅓ before planting soil preparing and the remainder was divided into two and used in two stages of development - beginning of flowering and twenty days later. Plants from different variants were grown on the same level of 160 $kg.ha^{-1}$ P_2O_5 and 120 $kg.ha^{-1}$ K_2O applied in autumn plowing. The morphological behavior in dynamic in three phases of mass flowering, beginning and mass fruiting were measured. Parameters of leaf-gas exchange were analyzed. Uptake of nitrogen, phosphorus and potassium from vegetative part and with fruits, necessary to forming 1000 kg fruits were calculated. The rate of 210 $kg.ha^{-1}$ N causes most highly vegetative development of stem and leaves and also of total vegetative weight. Lower doses of 70 and 140 $kg.ha^{-1}$ N influenced on formation of the highest yield. Regression interaction between nitrogen rate and productivity was established. Content of vitamin C, total sugar, pectin and acid were changed in limited extent.

(80) Effects of some organic fertilizers on growth of grapevines infested with *Xiphinema index*

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Effects of some organic fertilizers on growth of grapevines are reviewed, focusing on its potential for managing the nematode vector of GFLV - *Xiphinema* index. Pot experiments were carried out at the Agricultural University of Plovdiv, Bulgaria in 2004, 2007 and 2010 with - *Vitis vinifera* L. cv. "Cabernet Sauvignon" grafted on rootstock SO4, ungrafted "Palieri" and *Vitis vinifera* L. cv. "Rubin" grafted on rootstock SO4 respectively. Dry extract of green algae *Chlorella vulgaris*, humic fertilizer "Humustim" and highly concentrated liquid fertilizer "Humusil" were tested. Plant height, root length, fresh and dry weight of the plants, average based on repetitions and variations were determined at the end of the experiment.
The results show that in comparative aspect *Chlorella vulgaris* and "Humusil" significantly have the best effects on both plant growth and suppression of ectoparasitic nematode X. index while "Humustim" has a moderate effect. The beneficial effect of microalgae *Chlorella vulgaris* and liquid fertilizer "Humusil" is due to increased plant immunity and improves soil health.

(81) Effect of nitrogen source on soil nitrate concentration and yield, and quality of intermediate-day onions

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The effect of nitrogen source application, broadcast onto the planting bed during the growing phase, on soil nitrate concentration, soil pH, yield, and quality of intermediate-day onions was evaluated in a field experiment in southern Portugal. In addition, the soil potential for providing nitrate-N to the crop along the growing season was also monitored. The field trial consisted of six treatments of different combinations of ammonium nitrate (17% NH_4-N + 17% NO_3-N) (AN) and ammonium sulphate (20.5 % NH_4-N and 60% SO_3) (AS) as fertilizers. Soil NO_3-N and soil pH were measured at 0, 47, 76, 95, and 124 days after transplanting (DAT). Nitrogen source did not significantly affect the soil nitrate concentration, commercial yield, bulb dry weight, soluble solids or pH. AS-AS application as compared with AN-AN led to a significantly decrease in soil pH. The nitrate release through the mineralization of organic matter began in the first 47 DAT and occurred throughout the growing season. At 0 to 10 cm soil depth from 0 to 47 DAT, nitrate concentration increased by 14.8 mg kg^{-1}. A significant amount of N uptake was provided by the soil, achieving a high commercial yield of 7.52 kg m^{-2} in the treatment without nitrogen application and 9.05 kg m^{-2} where N (45kg N/ha) was applied.

(82) Influence of foliar fertilization on the nutrient uptake of zucchini squash (*Cucurbita pepo* L. var. *giromontia*)

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Fertilization has an important role in the absorption of macronutrients, their content in different plant parts and formation of the yield. Zucchini squash are vegetable crops "responsive" of fertilization due to rapid accumulation of vegetative mass and realizing significant yield in a relatively short period of harvest. The maximum production of vegetative mass is related to the maximum biological nutrient uptake.

The main aim of this study was to investigate the influence of various complex foliar fertilizers on the nutrient uptake of zucchini squash. The experiments were carried out during the period 2007-2009, on Experimental Field of Department of Horticulture at the Agricultural University of Plovdiv, Bulgaria. Variety Izobilna F1 was used for the experiments. The field experiments were done by randomized block design with four replications. Complex foliar fertilizers Fitona 3, Hortigrow and Humustimin in three concentrations, separately and in background on soil fertilization $N_{16}P_{16}K_{16}$ were used. The content of N, P_2O_5 and K_2O in stem, leaf, and fruits were determined. Linear relationship between the amount of vegetative mass and nutrient uptake and between yield and nutrient uptake determined high values of correlation coefficients.

The results of this experiment indicate that foliar fertilization with complex foliar fertilizers Fitona 3, Hortigrow and Humustim influence the mineral composition of the formed biomass, which affects the biological nutrient uptake. Formed total biomass and nutrient uptake was greatest after fertilization $N_{16}R_{16}K_{16}$ + Humustim followed by $N_{16}R_{16}K_{16}$ + Hortigrow $N_{16}R_{16}K_{16}$ and Fitona. Plants absorb most potassium and nitrogen and less phosphorus. A similar trend was found in export nutrients through fruits.

(83) Survey activities in the area of Sestu (southern Sardinia) aimed at defining the agronomic techniques to reduce the nitrate pollution

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The horticultural reality in the Sestu district is characterized by a high intensity of growing cycles. The rapid succession of growing cycles and the single-crop regime applied by most farms has over the years led to the worsening of soil fertility and the quality of ground water, thus underscoring the need to adopt sustainable farming practices. Three cultivation cycles of lettuce were performed, in each cycle three different fertilization regimes were compared to determine their effect on production and the release of nitrates. The control fertilization provided manure management following normal usage in the district, distributing in the first cycle a 12-12-17 granular ternary compound at the time of the transplant and in the second cycle the same compound followed by fertilization with a 20-20-20 soluble fertilizer. The second fertilizer regime provided a split distribution of a 15-10-30 soluble compound, in accordance with crop absorption rhythms (Bianco and Pimpini 1990), The third fertilizer regime provided use of slow-release fertilizers based on leonardite and gluconic acid (FertireV), in liquid form: basic Glucohumate at the time of transplant and Glucohumate nitrogen during the cycle. The fertilization technique normally adopted by farms in the Sestu horticultural district determine the higher amount of nitrate leaching compared to thesis 2 and 3. The nitrogen split distribution in accordance with crop absorption rhythms led to equal results in production with respect to the control thesis and reduced losses of nitrates by leaching. The use of slow-release fertilizers led to minor losses of nitrates by leaching compared to the control and produced significantly better crops than the other theses only in the summer cycle.

(84) Organic vegetable crop production needs careful interpretation of nitrogen recommendations

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In conventional vegetable crop production nitrogen (N) advice systems based on N measurements during the growing season are more and more used or even obliged by legislation. We wanted to test whether these advice systems are also convenient for organic vegetable crop production? In this trial leek (*Allium porrum*) was planted end of June 2012 one month after a one year old grass-clover sward was mowed and mechanically destroyed. Before planting leek was fertilized either with 25 ton/ha manure or 35 ton/ha compost. Eight weeks after planting only small differences in nitrogen availability were measured. Based on these measurements, three rates of organic commercial fertilizer were applied ten weeks after planting on both plots corresponding to (1) the standard advice (100 kg N/ha), (2) the adopted 'organic' advice (50 kg N/ha) and (3) a blank (0 kg N/ha). A seventh plot which was not fertilized at all was added as a reference plot. Either with manure as with compost, total leek yield was higher when commercial fertilizer was applied. Although no differences were measured between 100 or 50 kg N/ha whereas N residue increased using the standard advice of 100 kg N/ha. Standard N advice seemed not reliable in organic leek production. The measurement of mineral N availability in the soil during growth is useful on condition that advice is given based on good knowledge of actual crop and soil condition and previous field history.

(85) Documenting and environmental adjusting the KNS and other fertilizer systems in horticulture

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This project consists of four major parts. The first part of the project is based on the translation of the KNS-advice system principles to the Flemish situation. The current system of KNS has some limitations, such as mineralization, production levels, and distribution of nitrogen during the growing system. Therefore the Flemish figures of N uptake, level of N uptake, latent N residue and rooting depth will be pooled and integrated in the system. The translation of KNS to the Flemish situation combined with optimal sampling intervals will determine the optimum amounts of fertilizer. As last step optimal sampling intervals will be determined.

The second part of the project will inventory common fertilizer advice systems in Belgium, such as N-index and KEMA advice system, and improvements will be formulated.

The third part consists of a conceptual compare of the inventoried systems from part one and two. As final part the inventoried systems will be validated and documented for horticulture in Flanders. For this, fertilization experiments will be used.

(86) Canopy reflection-based N sidedress system for leeks

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In The Netherlands, leeks are grown primarily on the sandy soils of Limburg and Noord-Brabant. The risk of N leaching is high, because leeks are fertilized with high levels of N, of which a large part is applied in the form of manure. The goal of our work was to increase N use efficiency of leeks. It was hypothesized that N use efficiency can be increased by synchronizing N input with N demand. Experiments were conducted in 2001-2002 and 2012. Measurements included biomass production, LAI, N uptake, light interception, and canopy reflection. Canopy reflection was measured with a Cropscan reflectance meter in all years and, additionally, with an airborne camera in 2012. Experiments consisted of two types of treatments: grower's practice, and sidedress method. In the sidedress treatments, N was applied before planting and at three monthly intervals. The amount of N applied at each of the three sidedress application was set equal to the N uptake that could be expected during the next month under average weather. The expected N uptake was determined using a crop growth model. Input to the model included current crop LAI and long-term average weather for the location. Results showed that yields in the sidedress treatments were identical to yields in the sidedress treatments, while N use was lower by 85-90 kg N ha^{-1} in the sidedress treatments. As expected, canopy reflection measured with Cropscan correlated well with airborne measurements. In conclusion, a canopy reflection-based N sidedress system for leeks is available. The system can be scaled up to large areas through the use of airborne imaging.

(87) Split nitrogen fertilization and in row application in the potato crop

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Residual soil nitrate after the harvest of potatoes is often too high. Nitrogen (N) efficiency of potatoes is low. This is among other things due to the poorly developed root system of the plants. N uptake by potatoes from soil layers deeper than 60 cm is poor and plant roots in adjacent rows overlap barely. By means of fertilization in the row, the fertilizer is better positioned (near the seed potato). This should lead to a better utilization of the given nitrate and a lower residual soil nitrate while maintaining yield and quality. Another efficient method is to give about 70% of the total need by planting and the other 30% 6 weeks after planting. This should also lead to a better utilization of the given N with less risk of nitrate leaching in spring by heavy precipitation. In the framework of the project "Bring N to the potato to utilize N more efficient" (financed by the Flemish Government), 5 field trials were set up in 2012. On this fields, the use of fertilization in the row in potatoes was demonstrated whether or not in combination with splitting in to 2 gifts. Some trials showed that nitrate fertilization in the row was clearly positive and that a lower N fertilization with this method was sufficient while maintaining yield. In other locations this technique gave little or no added value. On 4 locations was explicitly focused on splitting of the N-fertilisation. Split application proved in 2012 often its usefulness.

(88) Dynamics of integrated organic and mineral nitrogen applications and their impact on crop performance

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Field experiments were conducted to evaluate the effects of integrated organic and mineral fertilization through drip irrigation (fertigation) on nitrogen and water use efficiencies by maize and bean grown on a sandy soil. Fertilization treatments were: (a) 120 kg N/fed (fed= 4200 m^2) and 20kg N/fed for maize and bean, respectively, were applied to the soil through fertigation either in mineral form (ammonium nitrate), organic form (chicken manure extract) or mixtures of organic and mineral fertilizers by the proportions: 75 % organic + 25 % mineral; 50 % organic + 50 % mineral and 25 % organic + 75 % mineral, and (b) the same fertilization treatments as in (a) plus a supplement addition of 50 L/fed of humic substances (Hu).

Increasing the mineral content in fertilizer mixtures had a positive effect on the yield of both maize and bean. The highest yield was realized with the plants that received the fertilizer mixture 75 % mineral + 25 % organic. Addition of Hu with the 100 % mineral fertilization further increased the yield of the two crops. Applying mixtures of mineral-organic fertilizers increased nutrient content in plants more than the sole application of either. In most cases mixing humic substances with fertilizers had positive effects on nutrient content compared to treatments without humic substances.

Nitrogen use efficiency (NUE expressed as kg yield/kg N) increased with increasing the mineral content in the fertilizer mixtures. Highest values were realized with the plants that received the fertilizer mixture 75 % mineral + 25 % organic.

Increasing the mineral content in fertilizers mixtures had a positive effect on values of irrigation water use efficiency (WUE expressed as kg yield/m^3 water) recording 0.76 kg m^{-3} and 0.79 kg m^{-3} for maize grain and bean seeds respectively; both were realized with the plants that received the fertilizer mixture 75 % mineral + 25 % organic.

TECHNICAL TOURS

PCS - Destelbergen

The Research Centre for Ornamental Plants PCS is situated in Destelbergen (Flanders), right in the heart of the growing region for ornamental plants. PCS carries out applied scientific research and more practice-oriented research. At both levels the research is done thematically in each of the five PCS-departments: nursery stock and landscape gardening, azalea, potted plants, bedding and season plants, and cut flowers.

Important research themes are water and fertilisation, plant protection, energy, assortment, and cultivation techniques (including growth & flowering regulation and quality & postharvest properties of ornamentals). At present, environmental protection has become a very important issue including trials in closed culture systems (in which water and fertilizers are recycled to prevent nutrient leaching into the subsoil and surface water) and minimization of the use of chemicals. Integrated cultivation and integrated pest management (IPM) are also important aspects of this research. In this context, PCS developed an observation and warning system for pests and diseases in nursery stock and a program for guided control in greenhouse cultures.

Within PCS, there is an important engagement to disseminate information and organise educational activities. Knowledge transfer is realized by articles in journals for ornamental growers as well as scientific journals and by the organisation of study meetings, lectures, visits, etc.

During the Nutrihort-excursion you will be able to take a close look at our current experiments related to nutrient management.

Water and nutrient balance for container grown shrubs

Long term lysimeter-experiment where a water and nutrient balance is established for different crops during their outdoor growing season. The experiment started in 2008 to determine the effect of controlled release fertilizer (CRF) on nitrate-leaching. Although the experiment is repeated yearly ever since, the focus of the trial has slowly shifted to the effect of organic fertilizers and the addition of Humifirst on P-leaching. At present, the effect of a lowered P-input on nutrient-leaching and plant quality is under trial for Prunus laurocerasus ‘Otto Luycken’ and Spiraea japonica ‘Firelight’.

Soil fertility and cover crops

Although the effect of soil ameliorators, like Humifirst and PRP sol, has already been examined in other horticultural or agricultural sectors, information is lacking on their effect on chemical soil properties and their effectiveness in soil-bound tree nursery. In 2012, a two-year experiment was started with Fagus sylvatica. The effect of Humifirst and PRP sol on soil fertility is examined for six different fertilization treatments. Green compost, anorganic P or a combination of both is used for basic fertilization. Special attention is given to different techniques for P-analysis of soil-samples and to the possibilities to reduce P-input without loss of plant quality.

Reduction of nutrient leaching from container grown plants on a closed culture system in open air

Trial to demonstrate the effect of different fertilization techniques on nutrient leaching and plant quality. For Hebe, three fertilization strategies are compared: only CRF, CRF as basic fertilization plus additional fertigation (i.e. liquid fertilization applied together with irrigation) and CRF as basic fertilization plus an additional foliar fertilizer. For Azalea, that is traditionally fertigated, three different fertigation-frequencies are compared: daily on a fixed time, based on radiation sum and based on radiation sum plus rainfall. In addition, the effect of foliar fertilizer is also examined in Azalea.

Utility research of new water disinfection systems

The optimal way to reduce nutrient leaching from substrate-grown ornamentals in the greenhouse is to close the water cycle. To obtain this, good disinfection systems of drain water are essential. Four systems (chlorine dioxide units, hydrogen peroxides, copper ions and electrochemical activation) are used in an experimental set-up with various ornamental crops (including Hedera helix, Antirrhinum, Pelargonium and Calibrachoa). Their effect on diseases, water quality and reusability as well as on plant quality is monitored and measured.

Constructed wetland

Our demonstrative constructed wetland illustrates how drain water can be adequately treated before discharge to surface water. Nutrient-concentration is measured before and after the wetland. Since 2013, a pilot installation of an additional P-filter to reduce P-concentration to the limit for discharge to surface water is tested.

In addition to the experiments at PCS, many trials are conducted in situ on fields and in greenhouses of ornamental growers. These trials include optimization and demonstration of the KNS-fertilization advice system for soil-bound horticulture, monitoring of nutrient leaching on containerfields, inventory of soil fertility in nursery stock, determining the influence of sustainable fertilization techniques on plant quality of garden chrysanthemums and tuberous begonia, and monitoring nitrate leaching in the subsoil from the culture of garden chrysanthemums.

The operating costs of PCS are financed by government and industry. The most important funds are given by the Flemish Community, IWT (Institute for the Promotion of Innovation by Science and Technology in Flanders), the Province of East Flanders, the Provincial Chamber of Agriculture of East Flanders, Boerenbond (the Belgian Farmers Union), AVBS (the Belgian Ornamental Growers Federation), KMLP (the Royal Agricultural and Botanical Society – organizer of the Floralies of Ghent), KBC Banking & Insurance and the voluntary contributions of growers.

PCG – Vegetable Research Centre East Flanders - Kruishoutem

The PCG is situated in Kruishoutem, near Ghent. It is a nonprofit organization that was founded in 1977 and consists of several research units, each with their own specialties. The main research units are: open air crops, covered conventional crops, sheltered organic farming, irrigation and waste water management and sensory analysis. Within the first 3 units, research is mainly focused on fertilization, crop protection, technical features and varieties. A good cooperation between the various research units ensures that PCG is equipped with a wide range of knowledge and experience that reaches the stakeholders through various channels such as professional journals, meetings, field trial visits, our website and monthly newsletter.

PCG also has a laboratory for analysis of soil samples. Soil samples are taken and analyzed for different purposes, this can be for research purposes in trials, as base for fertilization advice, or in terms of the residual nitrate campaign organized by the government during fall.

Research is done on all kind of vegetables and herbs, with a focus on leek, cauliflower and leafy vegetables. At PCG we have 8 hectares available, open air and sheltered, but several trials are also taking place on location, on fields we rent from commercial growers.

The activities at PCG are mainly financed by project funding (IWT, ADLO, Interreg,…), but also by subsidies from the Flemish government and the province East-Flanders. Each year, a certain amount of trials are requested by private companies. The results of these trials are mostly confidential. As the research centre is GEP accredited, we perform several tests in terms of approval of new crop protection products.

In the following text, a brief overview of the ongoing research concerning fertilization management is given. All of this research will be explained and demonstrated during the technical tour.

EcoFERT: development of a web application for 'Just on time' N-fertilization in vegetables

The manure action programme (MAP 4, the Flemish implementation of the European nitrate Directive) contains a specific regulation for the residual nitrate in soils. Every year, from October 1 until November 15, the Flemish government monitors the residual nitrate on some randomly chosen arable fields in Flanders. The residual nitrate should be below 90 kg NO_3/ha in the 0-90 cm layer. A lot of farmers and horticulturists experience difficulties to keep the residual nitrate on their fields below this threshold value. Especially crops as leek, cauliflower and potatoes face difficulties: only 30-35% of the fields, where one of these crops is cultivated, comply with this threshold value. Nowadays, the fertilization advice is based on the expected nitrogen uptake, this is an average uptake for optimal growth and optimal weather conditions.

During the EcoFERT project, we want to refine this static model to a dynamic model taking into account parcel specific parameters such as: mineralization, growth performance, root depth and spread, precipitation and temperature. This EcoFERT model, that consists of a crop growth model and a soil model, is yet calibrated for leek and cauliflower.

This year, the partners perform field trials in order to calibrate the growth model for other crops. At the research centre in Kruishoutem we are doing this for lettuce, endive, cauliflower and leek. During cultivation crop growth parameters (amount of leaves, weight, soil coverage and specific leaf area) are measured. Also nitrate and dry matter content of leaves and other plant parts are determined. To validate the soil model, several soil samples are taken several times during the growth period.

The trials consist of 4 treatments: no fertilization, fertilization according to the KNS-system (fractionated fertilization), 40% less fertilization than the KNS-system and 40% more fertilization than the KNS-system. The trials are set up in a randomized block design with 4 replicates.

Mobile gully system

Since several years, the research centre has a mobile gully system in the greenhouse that is mainly used for cultivation of lettuce and herbs. The mobile gully system has a wide range of advantages compared with common soil cultivation. It involves a closed hydro feed system, a more efficient use of space and therefore energy, a shorter processing period, and on top of that it is a less labour intensive and more ergonomic system.

For the mobile gully system, we focus our research on the prevention of tipburn in lettuce regularly in combination with variety trials. At the moment of the visit we will be performing a tipburn prevention trial on salatrio (mix of three different lettuce types).

We also have a non mobile gully system outside. The research on this gully system focusses on the same topics as the research in the greenhouse, with endive being the main crop for research. We will have a closer look to a trial on tipburn prevention in endive on the gully system.

Demo trials: optimal and sustainable fertilization in order to reduce residual nitrogen

The demo trials are three projects that are subsidized by the Flemish government and executed by three research centres for vegetables in Flanders (PCG, Inagro in Beitem and PSKW in Sint-Katelijne-Waver). Different fertilization systems, innovative techniques and possible solutions for the nitrate residue are demonstrated. We will visit the demo trials of PCG in Deinze.

- <u>Optimal and sustainable fertilization with innovative techniques</u>
  Innovative techniques for optimal and sustainable fertilization have been developed during the past years. In the cultivation of leek, head cabbage, carrot, cauliflower and the combined cultivation of spinach and bean, the KNS-system is demonstrated. By giving a fractionated fertilization, the nitrate residue can be reduced.
  Applying a small amount of phosphor at the start of cultivation can affect the nitrate residue and the crop yield as well. Phosphorous stimulates the development of the roots in the beginning of the crop period. This ensures a better uptake of nitrogen and other nutrients. Stronger plants improve the nitrate absorption from the soil, which makes additional fertilization superfluous.
- <u>Sowing cover crops to reduce the nitrate residue</u>
  In this demo trial, several cover crops are tested for their potential to reduce the nitrate residue. The following cover crops are included in the test: white mustard, *Raphanus sativus* subsp. *oleiferus*, phacelia, ryegrass, rye and oats. The effect of different sowing dates (15/08, 01/09 and 15/09) which is very important for reducing the nitrate residue, is also demonstrated in this trial. Certain cover crops must be sown before September to ensure nitrate uptake in fall.
- <u>The KNS (Kulturbegleitende Nmin-Sollwerte)-system and 'effective nitrogen system' in Flanders</u>
  The most recent manure action programme of Flanders (MAP4) has a rather complex regulation in terms of fertilization. It gives farmers the choice to calculate the fertilization norms with total or effective nitrogen. The nitrogen content of organic manure is not 100 % available the first year after application. Therefore, for liquid organic manure, only 60 % of the nitrogen content is taken into account, for solid manure this is 30%. Therefore fertilization norms calculated with both total and effective nitrogen are demonstrated in this trial on head cabbage, to show farmers the possibilities of both systems and the new legislation.

Tomato Masters – The Green House

We will end our technical tour with a visit to an entirely new greenhouse company where the first tomatoes were only harvested this year. Tomato Masters and The Green House are together a new horticultural company runned by the family Vlaemynck. Since more than 30 years, the Vlaemyncks have a greenhouse company in Nevele where they grow tomatoes. In 2011 they became owner of 30 ha land that was intended for greenhouse horticulture purposes which is located near PCG. By the end of December 2012, the brand new greenhouse complex was finished and the first tomato plants were planted. The greenhouse complex covers an area of 10 ha, which is divided in a part of 4 ha with regular glass and a part of 6 ha with diffuse glass. There is possibility to expand the greenhouse surface with another 10 ha in the near future.

The heated greenhouse works with highly innovative techniques in the area of energy management, water consumption and sanitation, waste management and logistics. The company investigated in a cogeneration power system (CHP – combined heat and power) that produces up to 7MW. The greenhouse is equipped with a large capacity for rainwater collection. The tomatoes are sold directly to large customers in consultation with the vegetable auction, this makes a reduction of 'foodmiles' possible.

Inagro - Beitem

Welcome to INAGRO, the Provincial agency for agriculture and horticulture in West-Flanders.

West Flanders is Flanders' ultimate agriculture and horticulture province. It is home to half of all the pigs in Flanders, a third of all cattle and chickens, more than half of all potatoes, and sixty per cent of field grown vegetables. With supply and processing industries combined, the agricultural sector provides about 45.000 jobs, a production value of € 8 billion, and an added value of € 2.6 billion in the province. The production value of agriculture and horticulture in West Flanders equals that of all Walloon provinces together.

In recent decades agricultural practices faced a rapid evolution from traditional family based farming into highly specialized agricultural enterprises. Capital, innovation, mechanisation, specialisation and above all knowledge have become increasingly important. The farmer has evolved to become a well-trained business manager and entrepreneur.

INAGRO is a multidisciplinary research centre working closely with local farmers. Its research and activities are largely based upon relevant problems encountered by farmers in the region and research is highly focused upon practical applicability. Inagro's main activities are practice-oriented research, supplying training and advice to local farmers and the organisation of demonstration days and workshops. The centre was set up in the fifties on the initiative of the Provincial Government, in 2011 becoming a privatised agency of the Province of West Flanders.

Inagro has 6 specialized research units: agriculture, horticulture in open air, greenhouse horticulture, animal production, biological production and an environmental unit who mainly focusses on conciliating intensive agricultural practices with the environmental demands society imposes upon these practices. Inagro also disposes of a BELAC accredited laboratory where soil/water/crop and manure samples are analysed for internal research purposes as well as to facilitate farmers with relevant information. Communication of lab-results to the farmers mostly comprises an (fertilisation) advice or interpretation. At the Inagro campus more than 160 people are employed.

Quality care is the top priority in its operations. All employees work to high quality standards. In many cases, research is conducted using field trials. A large number of the field trials is conducted according to GEP -(good experimental practices) standards.

Inagro disposes of pilot plots on the campus in Beitem as well as spread across West Flanders where practical research is conducted in cooperation with local farmers. Annually about 400 field experiments are conducted by the different research units on the Inagro campus. Conducted research varies from new production techniques to the (independent) evaluation of new products such as varieties of a cultivar, pesticides and fertilizers. In many cases new and innovative practices in agriculture are introduced/evaluated by Inagro, often in cooperation with local and (inter)national partners.

Increasing attention is also being devoted to sustainable practices in (conventional) agriculture. A substantial amount of research is conducted in order to identify cultivation practices conciliating the currently high yields with environmental objectives such as lower nitrate losses and a reduced usage of pesticides.

The scientists at the research centre also give out warnings about impending plagues or diseases. Selective action can then be taken in good time. In the biological trials all chemical pesticides and fertilisers are replaced by natural alternatives or innovative technologies.

N–uptake and fertilisation advice in horticulture

Open air horticulture in Flanders (and elsewhere in Europe) faces a difficult adaptation due to the European nitrate directive. The properties of vegetable cropping demand a high mineral nitrogen content in the soil while the directive states that surface waters must have a nitrate content below 50 mg NO_3^-/l. Nitrate leaching from agricultural soils must therefore remain low.

In order to reduce nitrate leaching from vegetable fields (without reducing high yields), Flemish research centres are progressively investing in advisory systems and fractionated fertilizer gifts trying to supply as much (and no more) fertilizer as needed to the crop, applying when needed.

The ECOfert advisory system aims to provide an improved scientific base for fertilisation advices in open air horticulture. The model based advisory-system extensively describes all relevant processes in plant and soil and is automatically fed with (local) data about the weather. Based upon information given by the farmers, the model provides fertilisation advices on parcel level and remembers all supplied information as well as yields and results of soil analysis conducted. This information is used to evaluate and adapt the model progressively improving its precision. The ECOfert-model is currently being validated, and will soon be used as a scientific base for fertilisation advices given out by all Flemish research centres specializing in horticulture.

Currently a number of fertilisation trials are being conducted at the Inagro campus (and on other research stations in Flanders) in order to supply the model with data about N – uptake and crop properties for the most important vegetables. Each field trial comprises four different treatments. These different treatments are given different target levels for soil mineral N and fertilized accordingly. N fertilization is applied fractionated where the properties of the culture allow it, always following and based upon a soil analysis.

At regular time intervals a number of crop and soil properties (total aboveground biomass, N content, root distribution and depth, specific leaf area and soil coverage) are determined. At harvest, these trials should provide a clear image of crop development, N-uptake and total yield for different fertilization levels. This allows setting the optimal N-fertilization level for the culture (in current weather conditions).

These field trials are conducted in the following crops :

- Early spinach (harvest in July)
- Late spinach (harvest in October)
- Leek (harvest in October – November)
- Early celery (harvest in September)
- Late celery (harvest in November)
- Turnip rooted celery
- Head cabbage (white cabbage)

Innovative fertilisation practices

Researchers at the Inagro campus are well known with local agricultural practices. When problems are encountered, when specific opportunities arise, or when new products appear on the market, experiments are set up to gather vital information in order to contain the problem or evaluate the new opportunity/product.

Currently a number of field trials regarding fertilisation are running at the Inagro campus. A first trial is conducted in spinach harvested in autumn. Here the application of mineral fertilization before sowing is deliberately reduced to be lower than crop demand. By the end of the culture, when mineral nitrogen shortages in the soil start to appear, additional nitrogen is supplied by repeated foliar application (up to 60 kg N/ha will be applied directly on the leaves). This way researchers hope to combine good crop yields with low nitrate contents in the soil at harvest. To reduce damage to the leaves, products with low osmotic value are used for foliar application.

A second trial is conducted in zucchini. In Flanders zucchini is cultivated on elevated rows of soil which are covered in black plastic. A common practice in Flanders is to apply animal manure (and mineral fertilizer) on the field and afterwards heap up the top soil in rows on which the zucchini's are then planted in holes in the plastic. This practice accumulates a large part of the applied fertilizer in the elevated rows. In summer, when conditions get dryer, all soil water in the elevated rows is consumed by the zucchini and soil conditions under the plastic are believed to become too dry to allow N uptake from the rows. In autumn, when the plastic is removed, high concentrations of residual nitrate are measured. A variation in fertiliser applications and doses should provide further information on how best to apply fertilizer in zucchini.

Catch crops

The use of catch crops in autumn is an effective measure reducing nitrate leaching over winter. In order to promote the use of catch crops Inagro organizes a yearly demonstration at which the possibilities of different catch crops are demonstrated. All possible aspects (e.g. optimal sowing density, effect on nematodes, price …) of the different catch crops are considered. This year the demonstration will be organized on near Kortrijk, a drive of about 15 minutes from the Inagro campus. The effect of a catch depends on crop development. In order to realize maximum nitrate uptake, the catch crop has to be sown as early as possible. A good way to demonstrate this importance is to use different sowing dates. The differences between catch crops sown early and late are very useful in convincing local farmers to sow their catch crops as early as possible. Lately different cultivars of the same catch crop appear on the market. This year's demonstration will also evaluate and demonstrate eventual differences between these cultivars.

The demonstration trial is conducted in cooperation with a local farmer. After the field visit a short tour of the company is also foreseen. The company is a large and well equipped company and representative for arable farming and (more extensive) horticulture in Flanders. The company does not hold any cattle or pigs however. The main crops are wheat, potatoes, beans and spinach. Beans and spinach are grown for industrial processing.

ILVO - Plant Sciences Unit – Crop Husbandry and Environment - Merelbeke

The Institute for Agricultural and Fisheries Research (ILVO) is a dynamic, multidisciplinary and future-oriented research institute whose core mission is to work toward sustainable agriculture and fisheries in economic, ecological and social terms. Through this research ILVO accumulates fundamental and applied knowledge which is vital for the improvement of products and production methods, for quality control and the safety of end products, and for the amelioration of policy instruments as a foundation for sector development and agricultural policy for rural areas. Knowledge only becomes valuable once it is shared. Therefore ILVO strives to inform the policymakers, the various industrial sectors and the general public about our projects, future plans, and results.

Supported by four specialized research units, more than 600 committed employees, 9 research sites and an extensive infrastructure, ILVO is ready to address the research questions of the future.

ILVO's four research units are Animal Sciences, Social Sciences, Technology and Food Sciences and Plant Sciences.

Plant Sciences studies agriculture, horticulture, energy crops and ornamentals. Gene characteristics, plant reactions to environmental factors, population diversity, soil characteristics and plant diseases and plagues are a few research topics. Further, the Plant Sciences unit focuses on the breeding of new cultivars and innovations in crop protection and crop husbandry. Plant Sciences' four research areas are Applied Genetics and Breeding, Crop Protection, Growth and Development, and Crop Husbandry and Environment.

Plant Sciences also has a separate Business Unit to develop and market high-quality base material (seeds and grafts), to diagnose plant diseases and plagues, to perform chemical analyses on feed, soil and substrate and to detect and control quarantine organisms.

The research area Crop Husbandry and Environment performs scientific research on plant production on agricultural soils in order to produce optimal crop yield and quality in a sustainable way. The main research topics are:

- Nutrient management and soil organic matter: closing nutrient cycles; organic soil amendments; identifying and transforming organic wastes into valuable products for agricultural use (e.g., farm compost); etc.
- Sustainable soil management: soil quality and disease suppressiveness; soil organic matter; managing nutrient (N, P) losses and use; organic amendments (e.g., farm compost, biochar); tillage practices; etc.
- Crops/crop rotations: cultivation techniques of forage crops, cover crops, energy crops and protein crops (e.g., soya and clover); grassland management; optimizing seed production of grasses, clover and white mustard
- Production/cultivation systems: organic farming; intercropping; use of cover crops; agroforestry; etc.
- Agriculture and Environment: functional biodiversity; ecosystem services; agri-environmental measures; etc.
- Variety research: Value for Cultivation and Use (VCU) of new bred varieties of several agricultural crops (e.g., maize, cereals, grasses, industrial chicory, flax); Distinctness – Uniformity- Stability (DUS) of new bred varieties (e.g., industrial chicory, tuber begonia's)

To address the various research questions within the Crop Husbandry and Environment research area, several short and long term field trials, lab-scale experiments, pot trials, greenhouse experiments, etc. are set up and monitored. Further, researchers can rely on ILVO's laboratory for plant, soil and substrates (Crop Husbandry and Environment research area) which has expertise in the analysis of plant material, mineral soil, potting soil and soil improvers.

Farm compost

Agricultural soils in Belgium are low in organic carbon. One of the strategies used to increase the organic carbon content is applying compost as a source of stabilized organic matter. Moreover, research has shown that adequate use of compost with proper management also provides an array of nutrients to soils, improves water holding capacity and other soil physical properties such as bulk density, penetration resistance and soil aggregation, increases beneficial soil organisms and shows beneficial effects on plant growth.

Compost for this purpose can be prepared at the farm level, which gives the farmer the opportunity to recycle organic residues. Farm compost can contain wood chips and bark, straw, crop residues and surplus grass. However, a successful farm compost preparation depends on the availability of a bulking agent and source of lignin. In cases where wood is scarce at farm level, wood chips may be bought, but they are becoming more expensive due to alternative uses for wood chips, such as for energy production.

ILVO has a composting site and exploits a short-rotation plantation of poplars and willows on an alluvial soil. This provides wood chips for the composting of green waste and crop residues from ILVO's field trials. The Crop Husbandry and Environment research group studies the effect of feedstock composition and process management in small-scale farm composting on compost properties. As compost quality is assessed as well, the ILVO composts are well-characterized. The produced composts are used at ILVO and other research stations for soil management trials, such as the BOPACT, VEGTILCO and TILLMAN-ORG field trials, where the effects of compost application on soil quality and crop productivity are assessed.

Several research projects on the production and application of compost are being executed at the moment. In previous and ongoing projects, the use of chicken manure, crop residues from open field horticulture or other biomass types related to agriculture as feedstock in composting is assessed. Within the EU FP7-project FERTIPLUS, ILVO will determine the influence of biochar addition on compost quality and nutrient losses during storage. Furthermore, lab scale experiments and bioassays with those biochar-blended composts are conducted and the effects on soil quality and crop productivity will be tested in an existing long term field trial. The results of these bioassays, laboratory and field trials will allow for evaluation of nutrient dynamics, enhanced soil health and evaluation of overall soil biodiversity.

In fall 2013, the composting site at ILVO will be considerably expanded. This will facilitate the compost production and will create more opportunities for compost research at ILVO.

BOPACT field trial (NUTRIHORT abstract 62)

The Crop Husbandry and Environment research group relies on several short and long term field experiments to address the various research questions within the field of nutrient and soil management. The BOPACT field trial is one example of such a long term field trial.

The main research question/goal of the field trial is twofold:

1. Can soil quality and disease pressure on slurry fertilized arable land be positively influenced by the soil improving practices compost application and/or non-inverse soil tillage?
2. Can the organic carbon content of the soil be increased within the legal constraints of the fertilization laws using slurry and the application of good agricultural practices (cover crops, straw incorporation) and, if not, can this goal be reached with an extra dose of compost without increasing N and P leaching?

The long term field experiment started in spring 2010. The trial has a 4-year rotation with maize, potato, summer cereal and a vegetable. Cover crops are grown during winter periods. The experiment has a strip split plot design with three factors and four replications. The factors are 1) slurry application (cattle vs. pig slurry, the maximum allowed dose is applied), 2) tillage practices (ploughing vs non-inversion tillage), and 3) compost application (0 vs 2 ton C/ha.year). We monitor nutrient balances, physical and biological soil quality and disease suppression (including plant parasitic nematodes and disease inducing fungi). Preliminary results show that after three years, the change in soil organic carbon content (SOC) (0-30 cm) was significantly ($p < 0.05$) higher for cattle slurry compared to pig slurry and for compost application compared to no compost amendment. Moreover, an extra compost amendment did not increase the risk on N leaching in fall. As the experiment is still ongoing, we will continue to monitor the SOC evolution and nutrient dynamics.

Two ILVO research groups (Crop Husbandry & Environment and Crop Protection) work together for this trial. For the moment, this field trial is used for the EU FP7 projects Catch-C and FERTIPLUS.

TILMAN-ORG field trial 2012-2013

Non-inversion tillage favors soil quality. However, in organic agriculture, where no herbicides are used and external inputs are restricted, non-inversion tillage needs to be optimized by combining it with green manure intercropping. The effect of green manure in a reduced tillage system is currently assessed in a field trial at ILVO (2012-2013). A parallel demonstrative field trial is executed by our partner Inagro, Organic Production Department. This presentation of data has been achieved in TILMAN-ORG (www.tilman-org.net), within the framework of the 1st call on Research within CORE Organic II, with funding from Flanders' Government, ADLO.

In 2012, a split-plot experiment started up including two factors, i.e. green manuring and soil tillage. Leek (*Allium porrum*) followed a green manure crop of grass clover. The grass clover sward was destroyed in three different ways: (gm1) early destruction in March, (gm2) late destruction in May after removal of the first cut, and (gm3) late destruction after repeated mulching without removal of biomass. Destruction was performed mechanically by non-inversion tillage with a cultivator (Actisol) and rotary harrow. Apart from nutrients from this sward, no other fertilization occurred. Soil preparation before planting in June consisted of inversion vs. non-inversion tillage, i.e. either with plough or Actisol.

On all treatments the leek crop developed quite well. Mechanical weed control was performed regularly. Regrowth of grass from the previous green manure crop occurred, especially in non-inversion tillage treatments. After the diagnosis of leek moth (*Acrolepiopsis assectella*), the entire field was treated twice with XenTari® (*Bacillus thuringiensis*) in August. Soil sampling (0 to 10 cm, 10 to 30 cm and 30 to 60 cm) was performed four times, in March, June, August and October. All samples were analyzed for mineral nitrogen and plant available phosphorous (P-$CaCl_2$, 0.01M $CaCl_2$). Measurements of CO_2 emissions from the soil were performed. In October, leek was harvested after crop sampling and yield assessment.

Differences in timing of destruction of the grass-clover green manure crop, with or without removal of the first cut, led to a different nitrogen supply for the following leek crop. In general, early destruction (gm1) led to a higher mineral nitrogen level in the subsoil. Marketable crop yield was consistent with the N amount that was applied with the grass-clover, rather than with the soil mineral nitrogen level. gm3 plots, which showed the highest yield, did not have the highest nitrogen availability during the growing season. Soil nitrogen availability was obviously not the only parameter that affected crop yield. Considering the nitrogen availability in the 0 to 60 cm soil profile, no significant differences were found between both tillage methods. However, in August, the mineral nitrogen content of the top 0 to 10 cm soil layer was relatively higher on non-inversion tillage plots. For marketable crop yield, no significant effects were observed between inversion and non-inversion tillage.

Tuber celery (*Apium graveolens*, var. *rapaceum*) is the test crop in 2013. Farm compost application was included as a third factor obtaining a split-split-plot design. As green manure treatments, the celery crop was fertilized with grass-clover clippings (0, 100 and 200 kg N per ha) harvested in 2012 on the neighboring field and subsequently ensilaged. Youth development visibly differed between tillage practices, in favor of non-inversion tillage.

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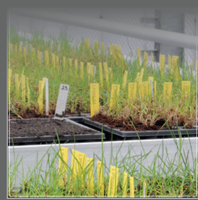


NUTRIHORT
Nutrient management, innovative techniques and nutrient legislation in intensive horticulture for an improved water quality

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Book of Abstracts

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