euvrin
European Vegetable Research Institutes Network

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PISA, ITALY

PROCEEDINGS OF THE

3RD WORKSHOP FERTILISATION AND IRRIGATION

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RODNEY B THOMPSON, JANA ZINKERNAGEL

The 3rd Workshop Fertilisation and Irrigation was jointly organized by the EUVRIN Working Group Fertilisation and Irrigation, CREA Research Centre for Vegetable and Ornamental Crops (Council for Agricultural Research and Economics), DAFE Department of Agriculture, Food and Environment (University of Pisa), SOI Società di Ortoflorofrutticoltura Italiana

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ABOUT EUVRIN

EUVRIN is an informal, voluntary organization of research institutes or research institutes departments that specialize in research, development, and extension on vegetable production based within (countries of) the European Union. It was constituted during its first meeting in Brussels on 1 February 2016, attended by representatives of Austria, Belgium, Cyprus, Denmark, Estonia, France, Germany, Italy, Lithuania, Netherlands, Norway, Slovenia, Spain, Sweden, Switzerland and United Kingdom. The current number of research institutes stands to 50 (Membership of and Participants in EUVRIN).

ABOUT THE WORKING GROUP FERTILISATION AND IRRIGATION

This working group provides a forum in which researchers working on diverse aspects of fertilisation and irrigation of vegetable crops can exchange information, experiences and feedback, and develop collaborations. With a wide European membership members' interests cover a wide range of fertilisation and irrigation issues. The general objective is to develop tools and strategies for sustainable nutrient and irrigation management achieved through optimal management strategies. This is being achieved through two general research lines that are applicable to both fertilisation and irrigation which are: (1) determination of accurate recommendations, and (2) monitoring systems to ensure optimal management throughout a crop cycle.

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3RD FERTILISATION AND IRRIGATION WORKSHOP: INTRODUCTION

The members of the WG Fertilisation and Irrigation met for the second time at the research workshop in Bleiswijk, the Netherlands, from 13th to 14th of September 2018. 35 participants from 11 European countries addressed current research topics in five scientific sessions. During excursions to the research facilities of Wageningen University & Research Field Crops and to commercial farms producing in greenhouses and fields, the attending members gained excellent insights into both, vegetable research and commercial production in the Netherlands. With this successful workshop behind, we are looking forward to continuing our work in Pisa this year. The exciting programme in a stimulating environment promises a successful elaboration of new perspectives for our future work.

The Coordinator of the Working Group
Fertilisation and Irrigation
Jana Zinkernagel

3RD FERTILISATION AND IRRIGATION WORKSHOP: PROGRAM

Monday 9 September		
13:00-15:00	*Registration of participants at "Polo Piagge" congress centre*	
15:00-15:15	**Introductory session** **Chair: Daniele Massa**	
10 mins	Welcome speech	Alberto Pardossi - University of Pisa (IT)
5 mins	Roadmap for the workshop	Zinkernagel, J. - Geisenheim University (DE)
15:15-16:30	**Scientific session 1. Fertilisation and irrigation: young minds at work (under 35)** **Chair: Jana Zinkernagel**	
15 mins	Irrigation and fertigation in Flanders	Tavernier, G. - Vegetable Research Centre (PCG) (BE)
15 mins	Evaluation of the yield and quality of processing tomato (*Solanum lycopersicum* L.) cultivated using Variable Rate Technology	Guarise, M. - University of Milan (IT)
15 mins	SuWaNu Europe, a network for effective knowledge transfer on safe and economic wastewater reuse in agriculture	Hisette, N. - Research Station for Vegetable Production (PSKW) (BE)
15 mins	Effects of blue light and molybdenum supplementation on quality of Brassica greens (*Brassica rapa* var. Japonica)	Giro, A. – University of Padova (IT)
16:30-17:15	*Relax session, scientific discussions continue during the coffee break: enjoy colleague presence, share opinions, propose ideas…*	
17:15-18:15	**Scientific session 2. Organic farming & green residues | Posters** **Chair: Michela Farneselli**	
15 mins	Sustainable Intensification and Nitrogen Management in Organic Vegetable Production	Lakkenborg Kristensen, H. - Aarhus University (DK)

15 mins	Cut-and-Carry Systems in Organic Vegetable Production – Solution or Part of the Nitrogen Problem	Katroschan, K.U. - Mecklenburg-Vorpommern Research Centre for Agriculture and Fisheries (DE)
2-3 mins each	Poster presentations	Buono, V. (IT); Ombódi, A. (HU); Orlando, M. (IT); Medrano, E. (ES); Rodríguez Chaves, A. (ES); Farneselli, M. (IT)
Tuesday 10 September		
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15 mins	Irrigation scheduling using a calibrated soil water balance and Sentinel-2 satellite images	Janssens, P. - Soil Service of Belgium (BE)
15 mins	Dynamic Kc-Model based on Eddy Covariance Measurements outperforms Static Model	Zinkernagel, J. - Geisenheim University (DE)
15 mins	Development of the VegSyst-DSS web-based decision support system for vegetable crops to manage irrigation and N fertilization and to calculate the C and N footprints (VS-DSS)	Campillo, C. – Centre for Scientific and Technological Research of Extremadura (CICYTEX) (ES)
15 mins	Nutrient uptake of tomato as affected by rootstock and tomato type	Voogt, W. - Wageningen University & Research Centre (NL)
10:30-11:15	*Relax session, scientific discussions continue during the coffee break: enjoy colleague presence, share opinions, propose ideas…*	
11:15-12:30	**Scientific session 4. Recirculation & reuse** **Chair: Wim Voogt**	
15 mins	Constructed wetlands and bacteria to recover and treat leachates from semi-closed soilless systems in Mediterranean greenhouses	Suárez-Rey, E. – Andalusian Institute of Agricultural Research

		and Training (IFAPA) (ES)
15 mins	Evaluation of the standard nutrient solution of long term soilless grown tomato crops	Voogt, W. - Wageningen University & Research Centre (NL)
15 mins	Recycling of leather waste industry as phosphorous based fertilizers	Grassi, C. – University of Florence (IT)
15 mins	LOCO: a local network for composting	Goovaerts, E. - Research Station for Vegetable Production (PSKW) (BE)
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14:00-16:00	**Scientific session 5. Management techniques e technologies Chair: Giorgio Gianquinto**	
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15 mins	Water supplied and mycorrhizal interaction in a tomato crop growing in a commercial greenhouse	Biel, C. - Institute of Agrifood Research and Technology (IRTA) (ES)
15 mins	Use of a portable analysis system to measure nitrate concentration in nutrient and soil solution and in petiole sap	Thompson, R. - University of Almeria (ES)
15 mins	Irrigation 2.0	De Cuypere T. – Inagro (BE)
15 mins	Integrating Sentinel-2 Imagery with AquaCrop for Dynamic Assessment of Tomato Water Requirements in Southern Italy	Baldi, A.D. – University of Florence (IT)
15 mins	Reference values of reflectance indices for optimal nutrition of processing tomato	Gianquinto, G. – University of Bologna (IT)
16:00-16:45	*Relax session, scientific discussions continue during the coffee break: enjoy colleague presence, share opinions, propose ideas…*	

16:45-18:30	**Session 6. Getting EU projects, what works and what doesn't - our experiences** **Chair: Rodney B. Thompson**	
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1 h	Round table	
20 min	General conclusions/ future activities	
20:00	***Social Dinner***	
Wednesday 11 September		
8:00-17:00	**Technical tour**	
8:30	Leave Pisa by bus	

ORAL PRESENTATIONS (ALPHABETICAL ORDER)

Integrating Sentinel-2 Imagery with AquaCrop for Dynamic Assessment of Tomato Water Requirements in Southern Italy

Baldi Ada[1], Dalla Marta Anna[1], Chirico Giovanni Battista[2], Falanga Bolognesi Salvatore[3], Mancini Marco[1], D'Urso Guido[2], Orlandini Simone[1], De Michele Carlo[3], and Altobelli Filiberto[4]*

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Abstract

The state of the art suggests that significant reductions in irrigation volumes at farm level can be achieved by assessing crop water requirements through the combination of crop satellite images and a crop growth model. Satellite images provide information of the current state of the crop canopy, and crop models simulate the biophysical processes of the growing crop. Based on this hypothesis, a research study was conducted with open field tomato (*Solanum lycopersaicum* L.) in order to: (i) Evaluate the capability of Sentinel-2 imagery to assess tomato canopy growth and its crop water requirements; and (ii) explore the possibility to predict crop water requirements by assimilating the canopy cover estimated by Sentinel-2 imagery into the AquaCrop model. The study area was in Campania, a region in the south west of Italy, characterized by a typical Mediterranean

climate, where field campaigns were conducted in the 2017 and 2018 growing seasons with processing tomato. Crop water use and irrigation requirements were estimated by means of three different methods: (i) the AquaCrop model; (ii) an irrigation advisory service based on Sentinel-2 imagery known as IRRISAT, and (iii) assimilating the canopy cover estimated by Sentinel-2 imagery into AquaCrop model. Sentinel-2 imagery proved to be effective for monitoring canopy growth of tomato crops in open field and for predicting irrigation water requirements during the mid-season stage of the crop, when the canopy is fully developed. The integration of the Sentinel-2 imagery with a crop growth model can improve the estimation of crop irrigation water requirement in the early developmental stage of the crop, when soil evaporation is an appreciable part of crop evapotranspiration.

This study was part of the OPERA project, financed under the ERA-NET Cofund WaterWorks2015 Call.

Irrigation management and mycorrhizal interaction in a tomato crop growing in a commercial greenhouse

Biel Carmen[1], Camprubí Amelia[1], Castañer Cristina[1], Agustí Nuria[1], Riudavets Jordi[1], and Calvet Cinta[1]*

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Abstract

Water and fertilization surplus in vegetable production have an environmental impact. Inoculation with endomycorrhizal fungi can enhance plant water uptake and phosphorus availability to the plant that permit to save irrigation water and fertilizers. The aim of this work is to study the interaction between water supplied by irrigation and mycorrhizal inoculation into tomato on crop production response. In a commercial greenhouse located in Mataró (Barcelona, Spain), a 2 x 2 factorial essay were set: 2 irrigation and 2 mycorrhizal treatments. The irrigation factor has two levels: FARM that is the normal grower water management and SENSOR where irrigation dose is modulated by soil water content measured by GS3 (Decagon, USA) capacitative sensors at 20 and 40 cm depth. The mycorrhizal factor has two levels: plants inoculated at transplant (M) and non-inoculated plants (No M). The experimental design consisted in 3 blocks with 4 treatments and 24 plants in each elementary plot. Water meters in each treatment were also installed. The tomato cultivar was Riesling and the rootstock is Silex. The distance between plants was 0.25 m and 1.8 m between rows. Irrigation water was distributed by 1.5 $L.h^{-1}$ integrated drippers. Once a week irrigation dose was calculated from the nearest meteorological station data and modulated by soil water content

evolution. Production as fruit weight and number in 6 plants per elementary plot was measured.

Preliminary results showed that to maintain the threshold level of 80% of the soil available water content the SENSOR_M treatment plants has been irrigated with fewer amount of water compared with SENSOR-No M. The fruit weight and quality are similar between treatments.

This project received funding from Operational Group (European Innovation Partnership for Agricultural productivity and Sustainability).

Development of the VegSyst-DSS web-based decision support system for vegetable crops to manage irrigation and N fertilization and to calculate the C and N footprints (VS-DSS)

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Abstract

Vegetable production in Spain is characterized by a water scarcity and environmental problems associated with irrigation and nitrogen (N) fertilizer use. The lack of effective tools to optimize irrigation and N fertilization are greatly responsible of these issues. To optimize irrigation and N fertilizer management in vegetable production, this study proposes developing a prescriptive-corrective management system based on the preparation of plans of crop-specific recommendations, and the use of monitoring approaches to identify and make the required adjustments in fertigation scheduling to ensure optimal management. Model-based decision support systems (DSSs) are ideal tools for prescriptive management. In this study, the new version of the decision support system VegSyst-DSS will be developed, based on the VegSyst simulation model. For

irrigation management, relatively simple and cheap soil moisture sensors will be used, and for N management, a combination of monitoring approaches with on-farm measurements will be used determining nitrate with ion-selective electrodes and measuring different indexes, using a leaf chlorophyll meter. All tools (both, for planning and monitoring) are simple, easy to use, and promptly provide data thereby permitting rapid adjustments. VegSyst-DSS will be developed for various important field vegetable crops (processing tomato and pepper, lettuce and broccoli). For greenhouse vegetable crops, the existing recommendation system for irrigation and N will be extended by including other macro and micro elements as P, K, Ca and Mg. An additional feature will be the calculation of C and N footprint to evaluate the environmental impact of a given set of management practices. The new VegSyst-DSS will provide an important contribution to developing an optimal irrigation and N management of field vegetable crops, thereby reducing the environmental footprint.

Irrigation 2.0

De Cuypere Tim[1], Pollet Sabien[1], Huits Dominique[1], Coudron Willem[2], De Swaef Tom[2], Lootens Peter[2], Gobin Anne[3], and Boeckaert Charlotte[4]

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Abstract

Water availability and water use efficiency are increasing challenges for Flemish farmers and horticulturists. This is especially the case for crops with a high-water requirement such as potato, cauliflower and spinach. To achieve this, the project "*Irrigation 2.0*" aims to familiarize growers with scientifically sound irrigation practices and assist them to determine which fields should be prioritized for irrigation and how much water should be applied to those fields. The study is also investigating the possibility of re-using reclaimed water from households and the potato and vegetable processing industry for irrigation purposes.

Various potato, cauliflower and spinach fields throughout Flanders are being monitored with soil moisture sensors, satellite images, and with periodic soil and crop sampling. With these techniques, the soil moisture status and the crop water deficits are being investigated. The data on current water availability and crop growth will be used to calibrate a crop growth model that has been specifically developed for irrigation purposes (Aquacrop). This will allow us to predict the water needs of the crop more precisely, so that irrigation can be carried out more efficiently.

To gain insight into the feasibility of using treated wastewater for irrigation, the effect of frequent irrigation with re-used water will be investigated on yield and product quality, and on the long-term effects on the soil. Finally, all this information will be included in a user-friendly online platform in which the irrigation requirements at field level will be visualized, together with information on the possible supplies of alternative water resources in a given area. Through informing growers of the feasibility of using these alternative water resources, a more sustainable use of irrigation water in Flanders will be promoted.

New modelling for soil water relations and N soil dynamics of the DSS GesCoN

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Abstract

From its first release in 2015, the *GesCoN* DSS for managing fertigation in open field grown vegetable crops has been tested under several processing tomato commercial fields. Among the simulation approaches of the DSS, the modelling used for water relations and N dynamics into the soil has been benchmarked during the 2016 and 2017 seasons against direct measurements of soil water content, crop growth and N uptake. To assess the accuracy of the DSS in soil moisture predictions, a series of capacitance multiple depths sensors were used to provide near-continuous measurements within the soil profile most interested by plant roots, along with some gravimetric direct measurements of soil water content throughout the crop cycle. N plant uptake through the crop cycle was also used to assess the DSS accuracy in the prediction of the available N soil content. Following the comparison tests among measured and simulated data, a new approach has been developed for modelling water that also affects plant growth and N uptake. This research describes this approach along with the 2018 season results of the in-soil/on-crop direct measurements as performed in 2016-2017 seasons. Soil water content was satisfactorily predicted by the DSS and efficiently maintained in the range of optimal water availability for the processing tomato crop. In the validation trial, 36 irrigations were scheduled providing a seasonal volume

of 454 mm, against a cumulated effective evapotranspiration of 387 mm. The DSS proved to adequately estimate soil moisture content, total aboveground dry weight accumulation and total N uptake of the crop thus resulting able to predict water and N crop needs during the season. The DSS allowed an equilibrated crop growth in terms of quantity and quality, at the highest levels for this crop.

Reference values of reflectance indices for optimal nutrition of processing tomato

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Abstract

The management of N fertilization through a method called "dynamic optimisation of nitrogen supply" requires the assessment of crop nitrogen status throughout the growing season. Proximal optical sensors such as leaf chlorophyll meters and canopy reflectance sensors are promising tools to monitor crop N status, but a prerequisite is the determination of reference values for optimal crop N status. A procedure for the calculation of reference values for SPAD 502 chlorophyll meter (Minolta Camera Co. Ltd., Japan) and a handheld Multispectral Radiometer (MSR5/87/16R ,CropScan Inc. Rochester, MN, USA), was set using data obtained in a trial on processing tomato (cv. Perfectpeel) conducted in 2003 at the Experimental Farm of the University of Padova at Legnaro, Italy (44°47' N; 12°06' E; 8 m a.s.l.). The trial was included in a long-term experiment on nitrogen fertilization carried out on different soil types. The experiment was carried out on 108 vegetation boxes of 4 m^2 area (2x2 m) and 0.8 m depth. According to a randomised complete block design with 3 replicates, 6 increasing rates of N (0, 30, 60, 160, 200 and 260 kg N ha^{-1}) were factorially combined with 3 soil types (clay, silty-loamy, sandy), in either presence or absence of residues of the previous wheat crop. Optical sensors

measurements were carried out at 2-7 days-interval. At harvest, fruits were collected and weighed. Linear-plateau equations were developed for calculating the relationships between optical sensors readings and relative tomato yield. The abscissa of the break-point in the linear-plateau regressions was defined 'Threshold Value' (TV) and represents the limit below which a reduction in yield occurs. During workshop this procedure will be proposed and discussed.

Effects of blue light and molybdenum supplementation on quality of Brassica greens (*Brassica rapa* var. Japonica)

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Abstract

Nowadays, consumers are more self-conscious about the relationship between nutrition and health. *Brassica* ssp. such as Moutarde rouge (*Brassica rapa* L. *nipposinica* group) was chosen either for its taste or for its positive effects on human health. Molybdenum (Mo) is an essential element in human diet and *Brassica* ssp. could be fortified with Mo increasing their nutraceutical properties. Blue light supplementation can boost growth and absorption of nutrient and, at the same time, it increases the accumulation of active compounds such as polyphenols. Moutarde rouge (MR) were sown (4,000-5,000 seeds m^{-2}) directly on polystyrene panels (0.56x0.36 m) containing perlite. Plants were cultivated hydroponically (floating system) using 18 tanks of 50 L (0.40x0.60x0.32 m) divided in two cultivation modules of nine tanks each. From March 2019 to June 2019, three cultivation cycles were performed in a greenhouse-tunnel and four LED lamps were turned on to supplement light during sunlight, 30 µmol s^{-1} of blue light (467 nm) above (1 m height) the cultivation module (2x2 m). Three different concentrations of sodium molybdenum (0; 0.1; 1 g L^{-1}) were added to the nutrient solutions in a randomized experimental design. Yield changed among cycles: 1.28 to 1.39 kg m^{-2} at 1°cycle, 1.20 to

1.29 kg m^{-2} at 2° cycle and 1.45 to 1.95 at 3° cycle and water use efficiency (WUE) varied significantly during the seasons. The two factors (Mo and light) did not affect biomass, dry matter of leaves (7 %) and °Brix; no significant variations were observed for polyphenols (total phenol and anthocyanin) and pigments (chlorophylls and carotenoids) or chroma. Plants treated with sodium molybdenum showed higher Mo concentration highlighting the biofortification opportunity with this micro-nutrient. Quality of MR was not affected overall by the concentrations of molybdenum used for the fortification and no interaction between light and molybdenum were observed during the cultivation.

LOCO; a local network for composting

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Abstract

In the rural development project LOCO we strive to upgrade waste streams of companies into durable compost. By creating local produced compost we can reach a win- win situation. Waste streams from companies can be upgraded into sustainable compost production and spread local for achieving a resilient and fertile soil. Composting asks for a right ratio of carbon and nitrogen. We strive to a C/N ratio of 25-35/1. To reach this, materials must be added on a volume based ratio of 60 % of brown and 40 % of green materials. When all these materials can be delivered at company level we speak of farm composting. Usually there is only one type of stream available at company level .In the LOCO network we bring several stakeholders together such as horticultural farms, tree nurseries, nature organizations and a vegetable & fruit auction or food processing companies. Composting is a controlled breakdown and building up process of organic matter by micro organisms in aerobic conditions. A monitoring and registration system is needed for changing a waste stream into raw material. Frequent measurements of temperature, CO_2 and moisture are crucial to steer the composting process. First results showed that the dimensions of the wood ships have an important influence on the frequency of turning the heap and adding small fractions of green material during the first stage of the composting process gives no negative effects. The aim is to reach a VLACO quality label, which is the standard in Flanders. Beside the practical part of composting, specific attention goes

to the administrative and legislative process. The main issue is that an environmental permission is needed when external material is supplied. This permission demands strict conditions to avoid leaching out of elements towards the environment. Registrations of waste streams transport are needed on governmental level. This seems a bottleneck for different stakeholders. It seems to turn out that stakeholders also need support when implementing a required quality handbook. If circular use of waste streams from agriculture is promoted by government, local composting can contribute, but in that case some bottlenecks must be solved first.

Recycling of leather waste industry as phosphorous based fertilizers

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Abstract

In a context of sustainable agriculture, the use of leather waste as fertilizer is part of the concept of the circular economy, which is being promoted by the European Union to enhance the reuse and recycling of materials. Leather industries produce a large amount of waste products that, if treated with the eco-friendly vegetable tanning method (Cr (VI) free), can be used as organic fertilizers as they are rich in organic N and C compared to manure and compost. We studied the agronomic performances of a fertilizer (Vegetable Tanned Leather Waste-VTLW) obtained by hydrolysing vegetable tanned leather scrap with sulphuric acid and then solidified by adding natural soft rock phosphate. Performance of VTLW was evaluated against other mineral, organic and inorganic fertilizers in pot experiment on six vegetable crops: brown-mustard (*Brassica oleracea* L.), chick pea (*Cicer arietinum* L.), chicory (*Cichorium intybus* L.), pea (*Pisum sativum* L.), tomato (*Solanum Licopersicum* L.), fava bean (*Vicia faba* L.). Periodically, morphological data were measured with the aim of monitoring the development of the plants. At the end of the crop cycle production, yield was determined. This study showed that VTLW fertilizer enabled good plant growth and production and a slow release of nutrients with a positive effect on soil chemical properties. The results suggest that VTLW could be used as

organic fertilizer in agricultural systems to assist with sustaining healthy soils.

This research was supported by the project “AgrinMec - Produzione di fertilizzante per AGRicoltura biologica: automazione del ciclo tramite Innovative parti MECcaniche” and was co-financed under Tuscany ERDF ROP 2014 - 2020 - POR-CReO FESR 2014 – 2020 RD&I Call 2.

Evaluation of the yield and quality of processing tomato (*Solanum lycopersicum* L.) cultivated using Variable Rate Technology

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Abstract

The management of irrigation and fertilization is fundamental to improve crop yield and quality. Furthermore, the application of variable amounts of water and nutrients at field scale can efficiently improve the environmental sustainability. PA (Precision Agriculture) is a production system that promotes variable management practices within field scale, using new tools and sources of information provided by modern technologies (Variable Rate Technology).

Processing tomato is an important field crop in Italy, Lombardy is its third main producer. Tomato is one of the most demanding crops in water, and nutrients deficiencies can badly affect its quality parameters.

The aim of this work is to evaluate the yield and the quality of processing tomato cultivated using the most recent precision farming techniques for irrigation and fertilizer applications.

Solanum lycopersicum (L.) variety Pietra Rossa F1 was grown in open field during 2019. The field (0.5 ha) was divided into three parcels based on soil texture, one parcel with sandy soil, one with clay soil and one as control.

Water and nutrients were supplied by fertigation using drip irrigation system; irrigation shifts, and the amounts of nutrients were balanced according to soil hydraulic capacity. Chlorophyll *a* fluorescence related parameter was measured in leaves during the cultivation period (May-August) in order to evaluate the efficiency of the photosystem II (PSII). Moreover, to evaluate the quality of tomato fruit, °Brix, pH, titratable acidity and colour of fruit were measured at the harvest.

The yield was higher in the control parcel (134.08 t/ha) and lower in the parcel 1 (101.83 t/ha). pH and titratable acidity did not show differences among the parcels, and values ranged between 4.8 and 5.2 for pH, and between 2.8 and 4.2 meq AC/kg for titratable acidity. °Brix and colour value of tomato fruit were similar among the parcels.

SuWaNu Europe, a network for effective knowledge transfer on safe and economic wastewater reuse in agriculture

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Abstract

Reclaimed water has a strong potential for complementing conventional water resources. Water reuse is especially relevant in agriculture as this is one of the main water consumers. Water reuse has several benefits for farmers: lower cost compared to other solutions (e.g. desalination), reliability of supply regardless of season, climatic conditions and associated water restrictions, and nutrients contribution of the treated wastewater that can supplement or replace conventional fertilizers. SuWaNu Europe (Sustainable Water treatment and Nutrient reuse options - https://suwanu-europe.eu/) is a thematic network that intends to bridge the current innovation gaps and to achieve an effective implementation of reuse solutions in agriculture. It aims to summarize, share and present existing and upcoming knowledge and skills in the field of water reuse in agriculture to the relevant stakeholders such as farmers and farming advisory groups. SuWaNu Europe will also create regional working groups for the development of action plans. These action plans will set strategies at regional level with the objective of boosting innovation in the agricultural and water sectors, improving best practice development and identifying the most appropriate channels to reach stakeholders. In addition to this, dissemination and training will create the capacity and competencies needed to implement these results.

Irrigation scheduling using a calibrated soil water balance and Sentinel-2 satellite images

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Abstract

Irrigation is gaining importance in Belgium in vegetables, potatoes and fruit crops. Soil water balances are known to be efficient to foresee irrigation need of crops. In Belgium, yearly, nearly 200 fields are monitored by the Soil Service of Belgium with a calibrated soil water balance. Participating farmers receive a weekly update of their forecasted irrigation need. Crop evapotranspiration up to 10 days ahead is calculated using ECMWF weather predictions of air humidity, temperature and cloud cover, using the penman-montheith approach. Unproductive rainfall events and capillary rise due to shallow ground water tables demand calibration of the soil water balance. Calibration is done by gravimetric soil moisture sampling in combination with assembly of the water retention characteristics. Soil samples on all fields are collected on a monthly basis. In every field were irrigation is scheduled a monitoring zone is defined where the recurring soil samples are collected. Since 2018 Sentinel-2 images are used to indicate the monitoring zone in every field. NDVI images, assembled previously in dry periods, are discussed with farmers to identify the optimal location of the monitoring zone. This way the farmer is assured that the monitoring zone is representative for his entire field, just as the corresponding irrigation

advice. Some farmers even succeed in adjusting the irrigation dose based on the variability in water stress over the field. Aim of this advisory program is a maximal economic revenue of farmers irrigation activities. Close communication with the farmer is judged to be essential to achieve this.

Cut-and-Carry Systems in Organic Vegetable Production – Apparent Net N Mineralization of Soil Surface Applied and Incorporated Grass-Clover Cuttings

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Abstract

In organic farming, leguminous green manure crops play an important role as N source. Main disadvantages of legume green manuring are, however, that the amount of fixed N_2 can vary considerably depending on weather conditions, species, agronomic management, soil mineral N etc. and that the N accumulated in green manure crops is in general not flexibly available in time and space. Thus, the N supply for succeeding vegetable crops is highly variable and hardly controllable. Furthermore, since vegetable production systems mainly lack livestock, forage green manure crops like grass-clover swards are mainly mulched. Mulching, however, is well known to result in substantially lower N_2 fixation rates compared to the removal of cut herbage. Cutting and removal of herbage followed by its application to vegetable crops, either as surface mulch or by soil incorporation before planting, would increase the N input by N_2 fixation and provide a higher spatial ´degree of freedom´ of fixed N. Four field experiments were carried out to quantify the apparent net N mineralization of grass-clover based cut-and-carry biomass. Experiment I and II comprised a crop sequence of fennel

(silage) and leek (freshly cut herbage). Experiment III and IV were carried out with leek and broccoli, respectively. Organic fertilizer treatments (hair meal pellets) were included as control. Grain crops (barley, oat) were grown in the year subsequent to vegetables to quantify residual effects of the amendments. Apparent net N mineralization in the year of application amounted on average to approximately 15% and 30% if cut-and-carry biomass was surface mulched and soil incorporated, respectively. Apparent net N mineralization of the hair meal fertilizer averaged 41%. Residual effects approximated on average to 2.5% of N applied in the previous year, tending to be higher for cut-and-carry biomass compared to the organic fertilizer.

Sustainable Intensification and Nitrogen Management in Organic Vegetable Production

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Abstract

The global agenda as stated in the UN sustainability goals and by the EAT-Lancet Commission asks for high and efficient food production in a sustainable way. The goal is a substantial reduction of the impact on climate, environment and biodiversity. A major part of the solution to the global challenges is a significant increase of vegetable consumption. This asks for implementation of sustainable intensification and an advancement of nitrogen management in organic farming production of open-field vegetables to achieve high yielding systems, while nitrate leaching is limited. For example, controlled traffic farming increased crop yields by 27-70 %, root abundance 2-25 times and nitrogen availability in spring by 2-41 kg N ha^{-1} compared to random traffic in three vegetables tested in Denmark. Accordingly, a 5-year crop rotation trial was designed with the aim to further implement sustainable intensification in organic vegetable production including double cropping, plant-based fertilizers, catch crops, green manures and controlled traffic farming. The system was compared to a more standard organic crop rotation fertilized by liquid manure. Crop growth, plant and soil nitrogen pools, potential nitrogen mineralization, soil enzymatic activity and leaching potential were studied in two years. Results showed that yields calculated per area were maintained for each crop and increased for the season in the double cropping system. Effects on soil

nitrogen availability and leaching potential were ambiguous. Potential mineralization increased by more than 15% and soil dehydrogenase and β-glucosidase activity by more than 20% in the double cropping system compared to the standard system across the five fields in the crop rotation. In conclusion, yields and soil fertility increased in the double cropping system. However, at future implementation at farms attention is needed to the winter plant cover to avoid increase of leaching losses in this system based on sustainable intensification.

Constructed wetlands and bacteria to recover and treat leachates from semi-closed soilless systems in Mediterranean greenhouses

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Abstract

In Almeria (SE Spain), there are 3000 ha of soilless horticultural crops, most of them designed as open systems where leachates are not recovered. It is therefore necessary to reuse and treat these effluents to avoid groundwater pollution. Following the implementation of Nitrate Directive (The Council of the European Communities, 1991), in Europe many areas affected by $N–NO_3^-$ pollution have been designed as Nitrate Vulnerable Zones (NVZs). In NVZs an action program is laid down with several measures for the purpose of tackling $N–NO_3^-$ loss from agriculture and husbandry. The discharge of drainage water from soilless culture, which generally contains high $N–NO_3^-$concentration, is not compatible at all with the rules established in NVZs. The CLEANLEACH technology was a result of the CLEANLEACH project funded by the EU (program ECOINNOVATION ECO/12/332862). The initial purpose of this system was to treat leachates from ornamentals nurseries. Treatment consists of a filtration through constructed wetlands to stimulate anaerobic denitrification processes. In the context of an EU funded project (FERTINNOWA), the CLEANLEACH technology was used to treat leachates from semi-closed soilless horticultural crops in Almeria. This technology was set up to denitrify leachates from the semi-closed system and also, to use halophyte plants to check the sodium chloride uptake potential of

different plant species. Results seem to show a good efficiency of the denitrification processes with a 90% $N–NO_3^-$ reduction. Regarding the performance of the halophyte plants the Na^+ reduction was around 40%. More research is needed to select the best crop species to increase the desalination efficiency.

Dynamic Kc-Model based on Eddy Covariance Measurements outperforms Static Model

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Abstract

Crop water balance (CWB) commonly schedules the irrigation of open field vegetable crops by estimating the crop water use and balancing it with water inputs. Crop water use is a product of reference evapotranspiration (ET_0) and Kc. Kc represent the crop specific evapotranspiration and alter over the ongoing plant development to represent the natural change in water use. Present CWB approaches often use statically adjusted base points to change Kc. A dynamic adjustment of Kc may offer a more physiologically sound approach to estimate the actual water use and schedule the irrigation of a crop accordingly. In this study, we compare static adjusted with dynamically modelled Kc, obtained by measurements of evapotranspiration via energy and water exchange between crop and atmosphere. Therefore, we cultivated onion in open field trials in Schifferstadt (Germany) and measured Kc with an Eddy-Covariance station in 2017 and 2018. In the cultivation period (March - September) the modelled Kc of the dynamic and static model have been compared by their mean deviation (RMSE) from the measured Kc (n = 74). The adjustment of Kc in the static model was conducted utilizing the BBCH-code of the Geisenheim Irrigation Scheduling. A temperature sum based Gompertz function describes the generation of dynamic Kc.

The results of evapotranspiration measurements show that the dynamic model with an RSME of 0.35 has a better fit to the measured Kc-values than the static adjusted Kc-model with an RSME of 0.49. Therefore, the dynamic Kc-modelling can enhance the water use estimates and facilitate a more demand-driven irrigation scheduling with the CWB.

Use of a portable analysis system to measure nitrate concentration in nutrient and soil solution and in petiole sap

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Abstract

Small portable systems for on-farm nitrate (NO_3^-) analysis could assist vegetable growers to improve crop N management by providing rapid assessment of the NO_3^- concentration ([NO_3^-]) in applied nutrient solution, soil solution and plant petiole sap. The portable LAQUAtwin ion selective electrode system (model B-741T) for measuring [NO_3^-] was evaluated by comparing [NO_3^-] measured with the LAQUAtwin with that measured by a SKALAR San++ segmented flow analyser system in the laboratory on individual samples of the three types solutions. Samples of the three types of solutions were obtained from five different greenhouse-grown vegetable crops (three pepper, two cucumber) in which a range of different N concentrations, ranging from very deficient to very excessive, were applied by fertigation in all irrigations throughout the crops. NO_3^- was leached from the soil before each crop. There were 2010 samples of nutrient solution, 744 samples of soil solution, 1125 samples of sap, and 847 samples of sap that had been diluted (1 in 5 dilution~~)~~ for cucumber and 1 in 10 for pepper). Linear regressions described the relationship between the two measurement systems in the three solutions. For nutrient solution (range, 0-28 m*M*), the relationship between NO_3^- measured with the LAQUAtwin

and in the laboratory was described by y = 0.98x + 0.74; R^2=0.96. For soil solution (range 0-46 m*M*), by y = 0.97x + 1.29, R^2 = 0.97). For undiluted sap (range 0-2600 m*M*) by y = 0.73 + 194.8, R^2 = 0.90. In diluted sap, the slope was much closer to one. An additional study evaluated the effect of sample temperature. There was an inverse linear relationship between temperature and temperature-induced error. The optimal sample temperature was approximately 18°C; at lower temperatures, [NO_3^-] was over-estimated, and at higher temperature, it was under-estimated.

Resource-efficient vegetable production

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Abstract

The increased interest in a vegetable-rich diet provides plenty of opportunities to the Finnish vegetable production. However, the expectations by the consumers and society towards the production methods are changing, and there is a need to increase the sustainability of the production systems. In the project "Resource-efficient vegetable production", performed in co-operation with advisory service and horticultural education, we have proposed a set of tools to increase the sustainability of field vegetable production. The tools are based on our research and general expertise in vegetable production.

According to our view, the following issues should be considered in future vegetable production systems in open field in northern growing conditions:

1. Emphasis on soil quality
2. Crop rotation for better use of soil
3. Soil analysis – basis for balanced nutrition
4. Moderate use of phosphorus fertilizers
5. Nitrogen from green manure
6. Catch crops after early and summer vegetables

7. Alternatives to chemical plant protection
8. Collaboration – key to success.

In relation to plant nutrition, the basis for success is to use only the best field parcels for vegetable cultivation. Good crop rotation and maintenance of soil quality is the prerequisite for ensuring the balanced nutrition. Green manure crops might be increasingly used also in conventional production systems and catch crops utilised more frequently. A thorough soil analysis, including also the micronutrients, is the basis for planning the fertilization. Phosphorus fertilization might be reduced in many fields to avoid accumulation of phosphorus into soil, causing the risk for leaching into waterways. In the presentation, we will outline some research data on the listed issues related to plant nutrition.

Irrigation and fertigation in Flanders

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Abstract

Like other locations in Europe, the region of Flanders (Belgium) has to deal with drought since a couple of years. For 2019 and beyond we expect drought to occur more regularly, because of a rise of temperature, more evaporation, or less rain. To counter these circumstances, farmers need to apply irrigation in an efficient way to minimize water waste. And if farmers can irrigate, it is also important to know the most appropriate systems and which costs are involved.

In Flanders mainly vegetable crops and potatoes are irrigated, often with an inefficient hose reel. To raise awareness among farmers and inform them, we carried out a demonstration trial in which we compare different irrigation techniques (no irrigation, drip irrigation, hose reel) in the crops in Flanders where irrigation is most used: onions, leek and potatoes. With this trial we want to show the farmers that there are other techniques than hose reel irrigation that can be used for watering in a more efficient way. An additional problem of drought is the limited absorption of nutrients by the crop. Therefore, fertigation was included in the trial. By dissolving fertilisers in water in advance, plants can absorb nutrients more easily.

Irrigation is important to ensure yield and quality, but it also involves a cost that is unknown at the start of the season. To meet the farmer's needs, an irrigation tool to estimate the cost per ha and watering session based on cultivation data and the costs of the installation, energy, labour and water supply has been set up. Since irrigation is a costly investment and not always

profitable, this tool allows everyone to easily calculate their irrigation cost and make better decisions on irrigating their crops.

Evaluation of the standard nutrient solution of long term soilless grown tomato crops.

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Abstract

The standard nutrient solution for soilless tomatoes, which has been established in the early 80-ies, was evaluated by monitoring the supply, adjustments, nutrient concentrations in the irrigation and drainage during a full cropping cycle (11 months) of tomato crops in rockwool with recirculation in commercial practice. In addition, the uptake was monitored by collection and analysis of biomass.

The uptake concentrations throughout the cropping cycles, calculated from the dataset of supplied quantities of nutrient solution and analysis revealed that there are some typical fluctuations in the uptake ratios of the nutrients, but were not easy to link to specific environmental- or crop-phenotypic features. The only quite clear relationships were found – not surprisingly between the radiation sum and the uptake of K, NO_3 Cl and P and to a less extent for Ca, Mg and SO_4. Clearly the net nutrient uptake has increased dramatically in the current crops compared to 30 years ago, since yields have been almost doubled (from approx. 45 kg/m^2 to almost 90 kg/m^2). It revealed that the net uptake of N, K and P (g/m^2) fitted perfectly with the linear function of uptake versus yield (kg fruits/m^2) published by Sonneveld and Voogt (2009). The evaluation worked out that despite the huge yield

increase, alteration of cropping methods (e.g. high wire system, hanging gutters, recirculation), use of rootstocks and even use of supplemental lighting, hardly affected the general mutual ratios of the macro nutrient uptake by the crop hardly changed. The only change compared to the original standard nutrient solution was a slightly higher K demand. It can be therefore concluded that the recommended Standard Nutrient Solution for soilless tomato is quite independent of the cropping system and cropping conditions.

Nutrient uptake of tomato as affected by rootstock and tomato type

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Abstract

As part of the renewal of the Dutch Fertiliser Recommendation System (BAB) information was needed of the effect of rootstocks and varieties on the nutrient requirements of tomatoes. Three cultivars of tomato: 'Merlice', 'Brioso', 'Sweetelle', being a coarse, normal round and cherry type, respectively, were tested, combined with four rootstocks: non-grafted, 'Stallone', 'Unifort' and 'nr 141'. In a four-month cropping cycle the total nutrient uptake was measured, both by the nutrient depletion method and the total biomass determination method. The results showed that despite the strong differences in phenotype, total yield and total biomass production of the three types, the uptake ratios of macro- and micro elements did not show big variations, except for the K uptake, which was clearly lower with the cherry type. The differences between the rootstocks were almost none existing, except that the stronger rootstocks absorbed more Cl and less P. There were also some minor important differences regarding the micro-elements.

It can be concluded that for the Fertiliser Recommendation System, the aspect of grafting does not have to consider and only some minor adjustments are needed for the variety / type of tomato.

POSTERS (ALPHABETICAL ORDER)

Integration of the CALFERT and GREENFERT software for fertilization management in the framework of a cloud-based Decision Support System (Bluleaf™)

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Abstract

Vegetables cropping systems are based on large application of water and fertilizers, thus requiring new technologies to optimize the irrigation and fertilization management for more 'sustainable' agricultural systems. In the context of 'precision farming', simulation models can be integrated with monitoring tools (plant/soil sensors, hand-held devices, etc.) to design Decision Support Systems (DSS) to be transferred at farm scale for operational use. To reach this goal, advanced digital technologies are increasingly being used to allow 'real-time' data elaboration by means of 'user-friendly' software applications. In Italy, a 'cloud-based' DSS (Bluleaf™) has been developed to support irrigation management by integrating crop models (ET_0 method, FAO Irrigation and drainage paper 56), soil sensors (dielectric probes, tensiometer, etc.) and technological innovations for data acquisition/transmission (e.g. WSN, IoT). Recently, the DSS has been further enhanced to support the fertilization management of vegetable crops by integrating the CAL-FERT and GREEN-FERT simulation tools, originally developed as Excel-based spreadsheets in the framework of the 'AZORT' research project. CAL-FERT aims to support the application of the 'predictive' method for fertilization planning, by simulating soil nutrients' balance through its main components

(mineralization, volatilization, leaching, etc.) on a decadal time-scale. On the other side, GREEN-FERT refers to the so-called 'corrective' method, supporting the calculation of appropriate fertilizers' solutions in relation to soil analytical data, aiming to maintain an 'optimal' nutrient content in the root zone. Both DSS tools are currently under field-testing in real operating conditions: by means of specific Web/App software interfaces (to be accessible by both PC and mobile devices), end-users are enabled to insert site-specific data and model parameters for each management unit, to display detailed model outputs in order to 'design' a specific fertilization plan, to insert the timing and amount of fertilizers applied and to receive a daily update on the current status of crop nutrient balance.

Use of green waste compost in tomato (*Lycopersicon esculentum* Mill.) and cauliflower (*Brassica oleracea* L. var. botrytis): effects of dose and timing of application on crop growth and nitrate leaching

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Abstract

A two-year field experiment was carried out in Central Italy on a spring-summer crop (*Lycopersicon esculentum* Mill.) and an autumn-winter crop (*Brassica oleracea* L. var. botrytis) with the aim to assess the effects of dose and timing of application of green waste compost (GWC) on crop growth and yield, as well as on the potential risks of nitrate leaching. The following treatments were tested on both crops: two doses of GWC (i.e., 10 and 20 t ha^{-1}) and two timing of GWC application for each dose (i.e., spring: 10 _spr and 20_spr; summer: 10 _sum and 20_sum). Two controls were also included without GWC: mineral fertilized control (STD): 200 kg N ha^{-1} for tomato and 150 kg N ha^{-1} for cauliflower; unfertilized control (N0).
Tomato and cauliflower growth and N accumulation were determined fortnightly. The concentration of NO_3-N in the soil solution was measured by suction lysimeters at 0.6 m depth during the growing cycle in both species. Considering the chemical characteristics of GWC, the 10_spr and 10_sum received 180 kg N ha^{-1} and 2.5 t ha^{-1} of organic C, while the 20_spr

and 20_sum received 360 kg N ha^{-1} and 5 t ha^{-1} of organic C. The C/N ratio was 9.4.

The application of GWC right before the transplanting date was inadequate for crop growth independently of species and doses (i.e _spr in tomato and _sum in cauliflower) while applying GWC few months before the transplanting date (i.e., _sum in tomato and _spr in cauliflower) increased the biomass and N accumulation with increasing doses in both species. In all treatments, the application of GWC significantly reduced the NO_3-N concentration in the soil solution, contributing to prevent risks of nitrate leaching. The integrated use of GWC and mineral or organic fertilizer could represent an efficient strategy to reach optimum crop yield while minimizing NO_3-N leaching losses.

Operational Group on Efficient Use of Water on greenhouse crops

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Abstract

The main objective within the action of this Operational Group was to establish irrigation strategies that minimize water applied on greenhouse grown vegetable crops. This initiative came from the Growers Association 'Grupo La Caña' (South Spain) that searched for effective tools to their growers for using water more efficiently in greenhouse horticultural crops. Then, an Operational Group was started with the participation of other private and public entities (FAECA, CIDAF, Eurocastell, Fundación TECNOVA and IFAPA). In this context, an experiment was set up in a commercial greenhouse with a cherry tomato crop, to evaluate different irrigation strategies both with soil (surface and subsurface drip) and soilless systems**.** For that purpose, six irrigation treatments were established in September 2018 (in soil: conventional surface drip, high-frequency surface drip and subsurface drip; and in soilless: conventional open system, high frequency open system and recirculation system). Low-cost sensors have been developed and installed in the greenhouse, which record real-time data and send it to a web server that compiles and process the data and remotely triggers the different irrigation treatments. Irrigation criteria in each treatment were based on these sensors (electro-tensiometers in soil crops;

VPD and solar radiation sensors in soilless crops). During this first cropping season, the adaptability of these technologies and their efficacy to trigger irrigation have been evaluated. During the second cropping season (2019-2010), the water use efficiency of each irrigation treatment will be evaluated.

Effects of Mycorrhiza Inoculation and Grafting on Sweet Pepper (*Capsicum annuum* L.) under Low-tech Greenhouse Conditions

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Abstract

In order to maintain yield and quality, Hungarian sweet pepper growers are switching over into soilless production even in low-tech unheated greenhouses and tunnels. However, investment costs of soilless production can be too high for some growers. Employment of arbuscular mycorrhizal fungi (AMF) or grafting could be reasonable alternatives to soilless cultivation. Our aim was to determine effects of a commercially available AMF inoculant (Symbivit®) and grafting on sweet pepper under low-tech greenhouse conditions.

The sweet pepper hybrid 'SV9702PP F1' was cultivated for seven months in an unheated greenhouse. Beside the control, three treatments were applied: ungrafted AMF-treated; grafted onto 'Bagi F1' hybrid rootstock; and grafted plus AMF-treated. AMF was applied into the planting holes just before transplanting. The soil type was a sandy loam with 0.8% organic

matter content. Altogether 70 fertigations were employed with a total fertilizer amount of 198 g m^{-2}. SPAD value of leaves, plant stand, yield, above ground plant mass production and root colonisation percentage were determined.

AMF treatment had positive effects on all the aforementioned characteristics, despite the high presence of indigenous populations of AMF in the greenhouse soil. With the applied rootstock/scion combination grafting did not affect most of the measured parameters. SPAD values, mostly measured in the range of 50 to 58 units, were increased by the AMF treatment in periods with lower N doses (0 to 0.8 g N m^{-2} $week^{-1}$). Significant correlation was found between colonisation and above ground plant mass production. AMF treatment increased yield by 18% (from 12.43 to 14.74 kg m^{-2}) due to higher number of fruits. Yield increase was mainly realised during the last third of the harvest period, when the applied nutrient doses were low and temperature conditions were suboptimal. We have concluded that mycorrhizal treatment provides an effective method to increase late season sweet pepper yield in unheated greenhouses.

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Improving green leafy vegetables cultivation with processing waste of horticultural products as source of potential biostimulants

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Abstract

In this work we are interested to improve growth and nutrient uptake of "Romaine" lettuce seedlings (*Lactuca sativa* 'Longifolia') in a floating system under greenhouse conditions. Potato peels and apple residual pulp (e.g. apple pomace: the residue after the extraction of apple juice) were employed as natural biostimulants. Large amounts of organic waste are produced from food processing industries. In particular, the processing waste of fruit and vegetables could be an excellent source of bioactive compounds perceived by consumers as low health risk substances. Skin of organic "Blue Salad" red potatoes and residual of organic "Fuji" apples after squeezing were minced, macerated in deionized water (500 g in 1 L) for 14 and 21 days, in the dark, at room temperature (RT). The aqueous extracts were filtered and properly diluted in water (to 1 or 10 mL L^{-1}). Treatment solutions were sprayed in the morning onto leaves until run-off, every three days for 5 times. Along with plant growth, also the mineral content was significantly affected by the biostimulants. These results represent an interesting and promising possibility of using the waste products of apple and potato processing industry to obtain biostimulants capable of

supporting the growth of agricultural productions, such as vegetables cultured in hydroponic system.

Determination of crop N status using petiole sap analysis in sweet pepper

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Abstract

The suitability of petiole sap NO_3^- concentration ($[NO_3^-]$) analysis for determining crop N status of greenhouse-grown sweet pepper was investigated. Additionally, sufficiency values, that is the concentrations above which crops are not N deficient, were derived. The work was conducted in three different pepper crops in Almeria, Spain, grown in three different autumn-winter cropping cycles in 2014-15, 2016-17 and 2017-18. The crops were grown in soil using drip irrigation and fertigation, receiving complete nutrient solutions in each irrigation (every 1-4 days) throughout the crop. Each crop was grown with five different concentrations of N applied in the nutrient solution, these were very deficient, deficient, conventional, excessive and very excessive N concentrations. Sap was obtained from petioles of the most recently fully expanded leaf, every week in the 2014-15 crop and every two weeks in the 2016-17 and 2017-18 crops. Sap $[NO_3^-]$ was determined in the laboratory using a SKALAR San++ segmented flow analyser. The Nitrogen Nutrition Index (NNI) was used to assess crop N status. Crop N content and hence NNI, using a species-specific critical N curve, were determined from several biomass samplings in each crop. NNI values were then interpolated for each day. All sap $[NO_3^-]$ values for each treatment were related to the corresponding NNI value for that

day. These regression analyses were conducted for the three crops individually and collectively. In all three crops, considering the complete cropping cycle, there was an asymptotic curvi-linear relationship. For the three crops together, the relationship between sap [NO_3^--N] and NNI (n = 220) was described by the polynomial relationship $y = -1E^{-07}x^2 + 0.0005x + 0.5486$, $R^2 = 0.89$. The sufficiency value, estimated by solving the equation for NNI = 1, was 1320 mg $N\text{-}NO_3^-$ L^{-1}