COST ACTION FA1204

3rd COST Action FA1204 Annual Conference

Vegetable Grafting and the Rhizosphere

14 – 16 September 2015, Berlin, Germany

Programme and Book of Abstracts

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Welcome Note

Dear Participants of the 3rd Annual Conference, COST Action 1204 Vegetable Grafting,

We wish you a very warm welcome to the Dahlem Campus of the Humboldt University in Berlin. Certainly, the main goal of this meeting is to follow the COST Action topic: Vegetable Grafting. In recent decades, fruiting vegetable consumption has been increasing in Germany from 60 kg per capita a year in the sixties up to 90 kg today. Tomato is Germany's most beloved vegetable. Currently, we consume 26 kg per capita a year, among this quantity 7 kg is consumed fresh. However, most vegetables we consume are imported and our production area is relatively small when compared to Southern European countries. We grow about 600 ha mostly under protected cultivation. Most of these plants are grafted: tomato at 80%, pepper at 5%, and cucumber at 95%. Since grafting has a wide potential in research, several research centers in Germany are considering grafting either as a topic for applied research to help the growers or as a tool for basic research.

Our last annual meeting in Carcavelos (Portugal) was dedicated to Innovation in Vegetable Grafting for Sustainability. This year for the 3rd annual meeting we decided to focus mainly on the root environment, aka the rhizosphere. This is the space that surrounds the roots and is of particular importance for the rootstock and thus, the scion's growth and development. It is in this space where the cohabitation and interaction of the rootstock with soil-borne microorganisms occurs. So far, and to a large extent, this environment and relationship remains neglected. We want to stress this topic during the conference particularly with the invited lectures.

We thank all individuals that were invited for their willingness to come and contribute to this meeting, adding even more to its excitement and success. We also thank the Life Science Faculty at the Albrecht Thaer Institute for hosting us and supporting this meeting. A particular thanks to Profs. Uwe Schmidt, Carmen Büttner, and Christian Ulrichs for opening their rooms and offering their facilities, and to Gabriele Buddruss and Renate Junge for making us feel at home.

Now, we wish all participants to feel comfortable and enjoy not only the lectures but the follow-up discussions during the breaks, the various visits to different locations and companies, and particularly the fellowship of old and new friends. We also hope that the 3rd Annual Meeting follows in the tradition and example of the preceding Annual Meetings and stimulates the spirit of togetherness and exchange, especially between different research areas, new friends, and collaborative projects.

Have a good time, Berlin 14 September 2015

On behalf of the local organizer committee:
Rita Grosch
Dietmar Schwarz
Marina Korn

Committees

Local Organizing Committee (Germany)

Rita Grosch, Leibniz Institute of Vegetable and Ornamental Crops (IGZ)

Marina Korn, Leibniz Institute of Vegetable and Ornamental Crops (IGZ)

Dietmar Schwarz, Leibniz Institute of Vegetable and Ornamental Crops (IGZ)

Scientific Committee

Giuseppe Colla, University of Tuscia, Italy

Francisco Perez Alfocea, CEBAS-CSIC, Spain

Dimitrios Savvas, University of Athens, Greece

Working Group Leaders and Co-Leaders

WG 1 Genetic resources and rootstock breeding

Andrew J. Thompson, University of Cranfield, UK

Halit Yetisir, University of Erciyes Melikgazi, Turkey

WG 2 Rootstock-scion interactions and graft compatibility

Jan Henk Venema, University of Groningen, The Netherlands

Ian C. Dodd, Lancaster University, UK

WG 3 Rootstock-mediated resistance to biotic and abiotic stresses

Dietmar Schwarz, Leibniz Institute of Vegetable and Ornamental Crops, Germany

Roni Cohen, ARO, Newe Ya'ar Research Center, Israel

WG 4 Rootstock-mediated improvement of fruit quality

Cherubino Leonardi, University of Catania, Italy

Carmina Gisbert, Polytechnic University of Valencia-COMAV, Spain

Programme

Sunday, September 13, 2015	
All day	Arrivals
Monday, September 14, 2015	
08:00 – 09:00	Registration
9:00 – 13:00	**Session 1 Rhizosphere** **Chair: Marie Torres and Nikolai Velkow**
9:00	• **Welcome (chair of the COST Action; Director of the IGZ)**
9:10	• **Invited lecture. Analysis of Primary and Secondary Plant Metabolites in Root Exudates of *Arabidopsis thaliana* (Katja Witzel, IGZ, Großbeeren) [O-1]**
9:40	• Determination of Heritability of Soil Zinc Deficiency Symptoms in Pepper (*Capsicum annuum* L.) and Mapping for Qtl/Genes Controlling Zinc Efficiency (Pinar,H., Mutlu,N. Keles,D. Ata,A. Büyükalaca,S., Turkey) **[O-2]**
9:55	• Screening of rootstocks able to limit arsenic uptake in melon (Stazi,S.R., Cassaniti,C., Marabottini,R. Allevato,E., Giuffrida, F., Leonardi, C., Italy) **[O-3]**
10:10	• Effect of reciprocal grafting on growth and development of two contrasting potato cultivars differing in nitrogen efficiency (Ulas,F., Yetisir,H., Ulas,A., Turkey) **[O-4]**
10:25	• Response of Cucurbit Breeding Material to Fusarium, Pythium and Meloidogyne spp. (Velkov,N., Masheva,S., Markova,D., Yankova,V., Lazarova, T., Bulgaria) **[O-5]**
10:40	• Grafting in France: A national survey to evaluate the complete picture of the situation (Torres,M., Herouard,C., Fournier,C., France) **[O-6]**
10:55	**Coffee break**
	Chair: Antonio Albacete and Ana Pina
11:15	• **Invited lecture. Microbial community in the rhizopshere (Tomislav Cernava, Techn. Univ. Graz, Austria) [O-7]**
11:45	• Root-to-shoot jasmonic acid signalling under water deficit (de Ollas,C., Arbona,V., Gómez-Cadenas,A., Dodd,I. UK) **[O-8]**
12:00	• Rootstock genotype-mediated variation in xylem sap metabolomite profiles of grafted tomato plants (Albacete,A., Martínez-Andújar,C., Perez-Alfocea,F., Spain) **[O-9]**
12:15	• Rootstock-mediated ABA signalling in salinized tomato (Martinez-Perez,A., Ferrández-Ayela,A., Sánchez-García,A.B., Albacete,A., Thompson,A.J., Pérez,J.M., Pérez-Alfocea,F., Martínez-Andújar, C. Spain) **[O-10]**
12:30	• Unraveling graft compatibility of scion/rootstock interactions in pepper (Penella,C., Pina,A., San Bautista,A., López-Galarza,S., Calatayud,A. Spain) **[O-11]**

12:45	• Inheritance and relationship of important characteristics for determination of graft incompatibility (Irisarri,X., Zhebentyayeva, T., Errea, P., Pina,A. Spain) **[O-12]**
13:00 – 14:00 14:00 – 15:30	**Lunch** Walking tour. The low energy greenhouses (ZINEG) of the HU Berlin
15:30 – 17:00 **15:30** 16:00 16:15 16:30 16:45	**Session 2 Shoot/root interactions** **Chair: Smiljana Goreta Ban and Youssef Rouphael** • **Invited lecture: Phloem transport of proteins and miRNA (Julia Kehr, Univ. Hamburg) [O-13]** • Salinity stress in eggplant can be alleviated by grafting and inoculation with *Serratia marcescens* containing ACC-Deaminase (Turhan,E., Ellialtıoğlu,Ş.Ş., Kıran,S. Alveroğlu,V., Kuşvuran,Ş. Ateş,Ç. Turkey) **[O-14]** • Improving cadmium stress tolerance in tomato by grafting and AMF (Kumar,P., Lucini,L., Rouphael,Y., Cardarelli,M., Kalunke, R.M., Colla, G., Italy) **[O-15]** • Phenotypic Variations in Root Morphology Morphology in *Cucurbita* spp. rootstock genotypes for cucumber under low temperature (Onur Karaağac,O., Özbakir Özer, M., Kar, H., Doğru,M., Yetişir, H. Turkey)[**O-16**] • Tolerance of grafted tomato plants to virus infection (Petrov,N., Balacheva,E., Stoyanova,Z., Rodeva, R. Bulgaria) [**O-17**]
17:00 – 18:30	**Parallel WG Meetings**
19:30	**Boat tour `Berlin at night´** in downtown, starts at Haus der Kulturen der Welt
Tuesday, September 15, 2015	
9:00 – 12:30 **9:00** 9:30 9:45 10:00 10:15 **10:30** 11:00	**Session 3 Plant metabolomics and fruit quality** **Chair: Sevilay Topcu and Dimitrios Savvas** • **Invited lecture. Root engineering for crop improvement using CKX technology Eswarayya Ramireddy, Freie Univ. Berlin, Germany) [O-18]** • Effect of partial root-zone drying on grafted tomato (Branimir U., Dumičić,G., Žanić,K., Goreta-Ban,S. Croatia) [**O-19**] • From Ein Tamar to Berlin: On the complicity of Cucurbita rootstocks (Cohen,R., Edelstein,M., Elkabetz, E., Israel; Grosch,R., Förster,P., Schwarz,D. Germany) **[O-20]** • Rootstock influences tomato quality at different ripening stage (Giuffrida,F., Cassaniti,C., Mazzaglia,A., Ragonese,F., Muratore,G., Leonardi,C. Italy) **[O-21]** • The green colour of the rootstock fruits affect the quality of the scion fruits (Arpaci,S., Tüzel, Y., Aktas,H. Turkey; Schwarz,D. Germany) **[O-22]** **Coffee break** **Chair: Antonella Verzera and Marios Kyriacou** • **Exudation and exchange processes in the rhizosphere (Günter Neumann, Univ. Hohenheim, Stuttgart, Germany) [O-23]**

11:30 11:45 12:00 12:15	• Emerging organic contaminants in fruits of *Cucumis melo* spp. grafted on different rootstocks (Verzera,A., Cincotta,C.F., Tripodi,G. Dima,G., Paratore,A*., Crinò, P.,* Italy) **[O-24]** • Rootstock effect on grafted runner bean yield and fruit quality (Mourão,I., Costa,S., Brito,L.M., Ferreira,M.E., Moura,M.L. Portugal) **[O-25]** • Agronomic and physiological responses of tomato when ABA-deficient plant are used as rootstock (Camps,F. Switzerland; Dodd,I. UK) **[O-26]** • Yield and quality of two melon [*Cucumis melo*] cultivars grafted on four *C. maxima x C. moschata* rootstocks (Soteriou,G.A., Kyriacou,M.C., Cyprus) **[O-27]**
12:30 - 13:30 13:30 – 16:00	Lunch **Walking tour at the Botanical Garden, FU Berlin**
16:00 – 19:00	Meeting of Steering Committee of MC
19:30	**Barbecue at the Dahlem Campus**
Wednesday, September 16, 2015. All day technical visit	
8:00 9:00 10:30 11:30 13:00 14:30 16:00 18:00 20:00 21:30	Leaving from the Best Western Hotel in 12165 Berlin-Steglitz (Albrechtstr. 2) • **Farm Buschmann/Winkelmann** (www.buschmann-winkelmann.de) cucurbitacea (pumpkin), asparagus and blueberry production **Coffee Break** • Leaving • Farm in Raddusch with greenhouse tomato cultivation (www.gemuesering-spreewald.de) **Coffee Break** • Tour through the Spreewald (www.spreewald.de) • Barbecue Leaving the Spreewald Arriving in Berlin
Thursday, September 17, 2015 : Departures	

Poster

Alleviation of Aluminium-induced toxicity in cucumber by grafting (Rouphael,Y., Cardarelli,M., Fiorillo,A., Bernabei,G., Ferri,E., Colla,G. Italy) **[P-1]**

The eggplants crop technology optimization by grafting (Bogoescu,M., Doltu,M., Dorin, S. Romania) **[P-2]**

Growth, Yield and Physiologic Responses of Salt-stressed Tomato to Grafting onto Rootstocks Differing in Salt Tolerance (Dasgan,Y.H., Çoban,A., Aktug,Ö., Bahadir,S., Akhoundnejad,Y. Turkey) **[P-3]**

Resistance Behavior of different tomato root stocks against root-knot Nematodes (Kell,K., Jaksch,T., Henning,V., Hermann,A., Schüchen,S. Germany) **[P-4]**

Physiological and morphological responses of pepino as affected by grafting with tomato and eggplant under salt stress conditions (Ulas,A., Yetisir,H., Yamac,M. Turkey) **[P-5]**

Surviving to salinity conditions through robust pepper rootstock (Penella,C., Landi,M., Guidi,L., Nebauer,S.G., Pellegrini,E., San Bautista,A., Remorini,D., Nali,C., López-Galarza,S., Calatayud,A. Spain) **[P-6]**

Response of *Cucumis metuliferus* accession BGV11135 against Mi virulent and avirulent populations of Meloidogyne spp. and effect on fruit melon quality. (Exposito,A., López-Gómez,M., Munera,M., Giné, A., Nogales,S., Ramos,J., Pujolà,M., Achaerandio,I., Picó,B., Gisbert,C., Sorribas,F.J. Spain) **[P-7]**

Abstracts of Oral Presentations and Posters

Abstracts of oral presentations

Session 1 Rhizosphere

O-1

Analysis of Primary and Secondary Plant Metabolites in Root Exudates of *Arabidopsis thaliana*

Katja Witzel[1], Nadine Strehmel[2], Susanne Baldermann[1], Franziska Hanschen[1], Dierk Scheel[2], Silke Ruppel[1], Monika Schreiner[1] and Rita Grosch[1]

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Plant roots secrete constantly chemicals into the rhizosphere not only as a part of the rhizodeposition process, but also to mediate microbial interactions. Nontargeted and targeted analyses of primary and secondary plant metabolites present in exudates of *Arabidopsis thaliana* roots were established. The aim was to characterise genotype-specific effects and application of endophyte on the metabolite composition. Six-week old plants, grown in sand and watered with nutrient solution, were used to collect root exudates. Nontargeted metabolite profiling was achieved using GC-MS and LC-MS. Targeted analysis was performed on glucosinolates and their respective breakdown products using HPLC and GC-MS, respectively. Hierarchical clustering revealed a genotypic pattern in root exudates when three accessions of A. thaliana were compared. When plants are colonized with the growth-promoting endophyte *Kosakonia radicincitans*, more than 50 primary and secondary metabolism compounds were differentially enriched. The results and possible implications of these analyses on plant-rhizosphere interactions are discussed.

O-2

Determination of Heritability of Soil Zinc Deficiency Symptoms in Pepper (*Capsicum annuum L.*) and Mapping for QTL/Genes Controlling Zinc Efficiency

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Zinc deficiency is a widespread problem reducing yield and quality of crop plants in Turkey like the world. This deficiency causes stunting, and leaf chlorosis reducing yield and quality of crops due in part to loss in photosynthetic capacity. It is important to improvement and use of molecular markers which linked to controlled to Zn efficiency for high Zn efficiency cultivars in Pepper (*Capsicum annuum L.*) For this aim; it was calculated to heredity of genes of controlled to Zn deficiency symptoms using , BC1, BC2 and F2 populations derived from *C. annuum L.* (Alata 21A) X *C. frutescens L.* (PI 281420) cross and also it was determined QTLs which linked to Zn efficiency using F2:F3 populations in pepper. As obtained results; genetic variance, additive variance, dominant variance and environment variance were calculated as 0,818, 0,226, 0,592 and 0,090, respectively. broad sense heritability, narrow sense heritability were calculated as (h2b) 0,906 and (h2n) 0,249, respectively. Also, it was calculated effect of additive gene as 28% and effect of dominant gene as 72% in total genetic variance. In addition, It was determined 12:3:1 genetic ratio as the best model for heredity of Zn deficiency symptoms as X2 analysis. Otherwise, controlled gene number to Zn deficiency symptoms was determined as 1,514 genes. It was obtained a genetic map with 929,6 cM length and 12 linkage groups using total 62 number polymorphic markers(31 SRAP, 19 SSR ve 11 RAPD primers) via JoinMap 4.1 program. Also, 41 linked QTLs with Zn efficiency for 9 characters were determined using F2:F3 populations at MapQTL.6 program. Obtained results show that it can be used to improvement of high Zn Effect pepper cultivars.

Keywords: Pepper, zinc efficiency, genetic mapping

O-3

Screening of rootstocks able to limit arsenic uptake in melon

Silvia Rita Stazi[1], Carla Cassaniti[2], Rosita Marabottini[1], Enrica Allevato[1], Francesco Giuffrida[2] and Cherubino Leonardi[2].

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Arsenic (As) is an element found in soil and water for both naturally and anthropogenic causes; it is toxic both for humans and plants. This element and its compounds are classified as cancerogenic even at low concentration (legislations limited at 10 µg/L As amount in drinking water).

European Food Safety Authority is keeping under watch some crops that can easily uptake this element from polluted soil (in its bioavailable form) and irrigation waters. However the variation in As sensitivity, and toxicity effect on plants are reported be species- and cultivar-dependent. Since no literature is currently present on As and melon grafted plants, our study wants to understand: i) the rootstock ability to uptake As from rhizosphere; ii) if the different rootstocks may affect As partitioning in plants.

Melon (*Cucumis melo* L.) cv. 'Proteo' was grafted onto 5 commercial rootstocks widely used: Strongtosa (*Cucurbita maxima* × C*. moschata*), Shintoza (*C. maxima* × C*. moschata*), RS841 (*C. maxima* × C*. moschata*), Dinero (*Citrullus lanatus*), Magnus (*Cucumis melo*); self-grafted plants were used as control. Plants were fertigated for one month period to a standard nutrient solution (NS) and a NS-enriched with 3 mg/L of sodium arsenate ($Na_2HAsO_4 \cdot 7H_2O$). Data concerning growth, As uptake and partitioning, will be presented and discussed.

O-4

Effect of reciprocal grafting on growth and development of two contrasting potato cultivars differing in nitrogen efficiency

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In terms of nutrient requirement potato (*Solanum tuberosum* L.) is a crop which has a highest nitrogen (N) demand after potassium (K) for growth and development. However, due to shallow and weak root system, potato has a low nitrogen use efficiency as compared to other crops such as wheat, maize or sugar beet. In previous screening experiments two potato cultivars were characterized contrastingly as N-efficient (Van Gogh) and N-inefficient based on various growth and development parameters. However, N efficiency characters of these cultivars were not clearly known whether these characters are controlling and relating directly with shoot or root traits. The objective of the present study was to determine shoot and root characters which play essential role in N efficiency by reciprocal grafting of two contrasting potato cultivars. A nutrient solution experiment was carried out in a controlled growth chamber of plant physiology laboratory of Erciyes University, in Kayseri Turkey. To produce homogenous plantlets for hydroponic growth medium, tubers of two different potato cultivars were pre-cultured in a peat-perlit growth medium for 2 weeks. Thereafter, homogenously growed potato plantlets were carefully cut and freed from the tubers with no root damage and then transferred into 8 L plastic pots. In each pot 2 plants were grown in continuously aerated nutrient solution for 28 days in controlled growth chamber Nitrogen was supplied in two different concentrations (Low N: 0.5 mM N, High N: 3.0 mM N) by using $Ca(NO_3)_2$ as N source. The nutrient solution had the following composition (µM): K_2SO_4 (500); KH_2PO_4 (250); $CaSO_4$ (1000); $MgSO_4$ (325); NaCl (50); H_3BO_3 (8); $MnSO_4$ (0.4); $ZnSO_4$ (0.4); $CuSO_4$ (0.4); MoNa2O4 (0.4); Fe-EDDHA (80). Between complete renewals of the nutrient solution (7 days intervals) all nutrients were replaced when the N concentration of the nutrient solution in the 3.0 mM N rate pots fell below 0.5 mM, as measured daily with nitrate test strips (Merck, Darmstadt, Germany) by using a NitracheckTM reflectometer. Plants were separated into shoot and roots. The results indicated that significant differences were found between N rates in shoot growth (shoot fresh and dry matter, leaf area), however but not in root growth (fresh and dry matter) of reciprocal grafted plants. Cultivars differed significantly in shoot and root growth. However, no cultivar x nitrogen interaction was found. Interestingly previously characterized N-efficient potato cultivar Van Gogh showed lower growth performance compared to N-inefficient cultivar Agria without grafting. However, highest growth performance was shown when cv. Van Gogh was grafted onto Agria. On the other hand Agria showed much lower growth performance when it was grafted onto Van Gogh compared to non grafted Agria. All these showed that root morphological traits are contributing more than shoot traits to N-efficiency in potato cultivars.

Keywords: Potato, N-efficiency, cultivar, root morphology

O-5

Response of Cucurbit Breeding Material to *Fusarium spp.*, *Pythium spp.* and *Meloidogyne spp.*

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One of the main problems in cucumber greenhouse production is control of soil-borne pathogens and root-knot nematodes. Grafting cucumber plants represent an alternative method to control that is safety and does not pollute the environment. Immune forms to these pests are not established, but in some studies are found sources belong to Cucurbitaceae family that possesses resistant or tolerant response. The aim of this study was to evaluate response of cucurbit breeding material to *Fusarium spp., Pythium spp*. and root-knot nematodes (*Meloidogyne spp.*). During the period 2013-2015 twenty breeding materials belonging to Cucurbitaceae family were tested: Gergana, Kiara F1, TG, TD (*Cucumis sativus*); CM 720, SB-2, SB-3, CM-RH, CMK, Turban (*C. maxima*); Muskatna 51-17, Carotina, NY-1, PI 560946 (*C. moschata*), Grif 9448, PI 512680 (*Cucurbita ficifolioa*), AMB (*C. pepo*); Turban x Muskatna 51-17, CM 720 x Carotina (*C. maxima x C. moschata F1*); Local (*Lagenaria siceraria*). Two parallel trials were performed in greenhouse conditions. Local isolates of pests were used for the screening tests. Plants were grown in pots and inoculated with mixed infection of *Fusarium spp*. and *Pythium spp*. In trial with root-knot nematodes the plants were inoculated with 6000 second stage juveniles (J2). The response was recorded 60 days after inoculation. The most resistant response to soil-borne pathogens possess cucumber lines TG and TD (i=10-20%) and Lagenaria (i=10%). The lowest index of nematode infestation from 15 to 30% was established in CM 720 x Carotina F1, Turban x Muskatna 51-17 F1, PI 560946, Carotina and AMB. Tolerant response is found also in cucumber line TG (i = 25%). Tested cucurbit material can be used directly for grafting cucumber plants, and also be used as a basis for starting breeding program for rootstocks with tolerance to *Fusarium spp., Pythium spp*. and *Meloidogyne spp*.

O-6

Grafting in France: A national survey to evaluate the complete picture of the situation

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Grafting is used in France with different types of vegetables and for various reasons (to increase yield, reduce disease pressure...), but the exact situation has never been fully described.
A complete survey was conducted in France between 2014 and 2015 in order to evaluate the current status of vegetable grafting. This survey allowed to compile the results of 14 nurseries producing 66.35 million of cucurbits and solanaceae seedlings.
Comparison between French potential (regarding the growing areas) and collected data seems to indicate that in some cases only a small amount of the seedlings used in crops are produced in nurseries. This is mainly the case for melon, for which large scale melon growers produce seedlings themselves.
On the other side, for high value crops such as soilless tomato cultivation, 86% of the seedlings used in crops are produced by nurseries.

The diversity of rootstocks depends on the species: tomato has the highest diversity whereas cucumber and watermelon have the lowest diversity. For eggplant and pepper, the diversity is also limited.
De Ruiter remains the leader for tomato rootstocks and continues to select the most adapted rootstocks. For melon, the most commonly interspecific hybrid used as rootstock is Dinero, developed by Syngenta.

The amount of grafted plants for each crop has also been evaluated in this survey.
If the representativeness of the sample was high, the amount of grafted plants is calculated by the ratio “total number of grafted plants / total number of plants”. If the representativeness of the sample was low, different hypothesis were formulated and results were expertized by technicians and producers.
The results indicate that the amount of grafted plants varies from 5% for pepper and watermelon for example to 90% for soilless tomatoes.

The main grafting type used is the Japanese grafting (splice grafting or tube grafting), for solanaceous and cucurbits. Other grafting techniques remain anecdotic.
In this survey, price of grafted plants, reasons of grafting, choice of the rootstocks and impact on fruit quality have also been collected and analyzed.

Our study also shows that tomato and eggplant reached the highest ratio of grafted plants in crops possible. Prediction for melon is more difficult as melon grafting is currently used mainly to limit fusarium disease but new resistant varieties are developed by breeders preventing the expansion of the melon grafting.
Nurseries also dream of using robots to increase use of grafting and reduce costs, but these are not used for the moment.

O-7

Deciphering the plant microbiome for plant health and biocontrol

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The importance of microbial root inhabitants for plant growth and health has been recognized already 100 years ago. Since that time, much has been learned about microorganisms and their close symbiotic relationship with plants (Berg *et al.* 2014). Comparable to humans and other eukaryotic hosts, plants also may be realized as meta-organism that harbors a "second genome". These advances in knowledge were driven by both "omics"-technologies guided by next-generation sequencing and microscopic insights. Collectively known as the plant microbiome, plant-associated microbes can help plants fend off disease, stimulate growth, occupy space that would otherwise be taken up by pathogens, promote stress resistance, and influence crop yield and quality. Therefore, the plant microbiome is a key determinant of plant health and productivity. Plant microbiome discoveries could fuel progress in sustainable agriculture, such as the development of microbial inoculants as biofertilizers, biocontrol, or stress protection products (Berg 2009). Although we recognize a growing market for these bio-products, they still have their problems, e.g., short shelf-life, inconsistent effects under field conditions, and risk predictions. The application of "omics"-technologies has allowed for an enormous progression in the development of so-called next-generation bio-products (Köberl *et al*. 2012). New tools may have an impact on (i) the detection of new bio-resources for biocontrol and plant growth promoting agents (Köberl *et al*. 2011, Bragina *et al.* 2012), (ii) the optimization of fermentation and formulation processes for biologicals, (iii) stabilization of the biocontrol effect under field conditions and (iv) risk assessment studies for biotechnological applications (Alavi *et al.* 2013). Advances in these aspects could open new perspectives for sustainable agriculture by the development of high impact next-generation bio-products (Berg *et al.* 2013).

Selected references

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O-8

Root-to-shoot jasmonic acid signalling under water deficit

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Plant adaptation to low soil moisture conditions requires a coordinated response of both, shoots and roots, this coordination is carried out by both chemical and hydraulic signals. Although abscisic acid (ABA) is the systemic driver of the whole plant response to conditions affecting water status, other phytohormones can also play a significant role fine tuning plants responses to moderate or local water stress before plants water status is compromised. Jasmonic acid (JA) has been associated with variations in stomatal conductance (gs) in both ABA-dependent and independent pathways, enhancing root hydraulic conductivity (L) and extensive molecular crosstalk with ABA. Nevertheless, information about whole plant performance and physiological responses in JA deficient plants under water stress conditions is limited. Both local (organ level: root or shoot) and systemic (root-to-shoot) effects of JA deficiency were explored using JL5 (JA deficient) tomato seedlings reciprocally grafted with WT. Whole plant transpiration was mainly determined by the scion genotype, but WT scions grafted onto JL5 rootstocks had 28% lower gs than WT self-grafts. Unexpectedly, plants lacking JA had lower gs (38%) but WT rootstocks grafted to JL5 scions completely reverted the diminished transpiration of JL5 self-grafts, possibly due to the higher root hydraulic conductivity of WT rootstocks. Also root-to-shoot hormonal transport via xylem can significantly influence scion physiological responses. Whereas scion gs was affected by rootstock genotype, rootstock L was not affected by the scion in all graft combinations, and was significantly lower in JL5 rootstocks. Overall, JA deficiency affects physiological adaptation to water deficit in roots and shoots, thereby highlighting rootstock effects on root-to-shoot signaling (both hydraulic and chemical) and scion performance.

O-9

Rootstock genotype-mediated variation in xylem sap metabolite profiles of Grafted Tomato Plants

Alfonso Albacete, Cristina Martínez-Andújar and Francisco Pérez-Alfocea

Although recent studies on root-to-shoot communication have identified organic bioactive molecules, the direct effect of the root system on the chemical signature of xylem sap remains unknown. Therefore, a commercial tomato cultivar (*Solanum lycopersicum* cv Boludo F1, Monsanto) was either self-grafted (L/L) or grafted onto the interspecific commercial tomato rootstock Maxifort (Monsanto) obtained from a cross between *S. lycopersicum* and *S. habrochaites* (L/H), and onto a recombinant inbred line obtained from a cross between *S. lycopersicum* and *S. pimpinellifolium* from AVRDC (L/P). Grafted plants were cultivated under commercial greenhouse conditions during autumn season in Mazarrón (Spain). Xylem sap, collected by root pressure, was injected into a U-HPLC-MS system (EXACTIVE, ThermoFisher Scientific). The metabolite signature of the 'pimpinellifolium' L/P graft combination was strongly associated to the first principal component (PC1), which explained 47% of the total chemical variance, while the 'lycopersicum' L/L combination was linked to PC2, explaining 31% of the variance. The metabolite profile of the 'habrochaites' L/H plants clustered between the other two combinations. Additionally, we identified 81 putative compounds of both the primary and secondary metabolism. We have shown that the metabolite profile of the xylem sap can be qualitatively and quantitatively modified by changing the root system (rootstock), as a genotypic source of chemical variability.

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O-10

Rootstock-mediated ABA signalling in salinized tomato

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Saline irrigation water can limit plant growth and development of greenhouse tomato crops grown in Mediterranean environments with the plant hormone abscisic acid (ABA) playing a key role in adaptation to abiotic stress. In order to better understand the influence of this hormone in development and productivity of tomato (*Solanum lycopersicum* L.) plants, two independent transgenic lines, sp5 and sp12, overexpressing the *NCED1* (9-*cis*-epoxycarotenoid dioxygenase, the enzyme that catalyzes a key rate-limiting step in ABA biosynthesis) gene under the control of the constitutive "Gelvin Superpromoter", and the wild type (WT) cv Ailsa Craig, have been studied in different experiments either as whole plants or as rootstocks. Here, we present the results obtained (i) as whole plants cultivated hydroponically in half-strength Hoagland nutrient solution and two salt concentrations (0 and 100 mM NaCl) in controlled growth chambers for 3 weeks; and (ii) as rootstocks of a commercial tomato variety (cv Sugar drop) cultivated for 7 months under a low salinity level (EC = 35 dSm^{-1}) in soil-sand and greenhouse conditions. While *NCED1* overexpression penalizes growth under control conditions, it minimized the effect of salinity (whole plants) or significantly improved plant growth and yield in soil under low salt stress (as rootstocks). The analysis of the root xylem sap revealed 2-4 times ABA-overproduction in both whole and grafted plants under control and saline conditions in three-week experiments, compared to the WT. However, no increases in ABA concentration were observed in different tissues of grafted plants in the long-term experiments using *NCED1*-overexpressing plants as rootstocks. Therefore, the growth/yield phenotypes under different conditions were difficult to explain on the basis of ABA overproduction and/or transport to the shoot. However, the analysis of a more comprehensive hormone profiling (cytokinins, ethylene-precursor, ACC, gibberellins, jasmonic and salicylic acids) and the expression in the roots of a set of hormone and stress associated genes (analysed by real time PCR) that includes *TAS14* (salt, mannitol and ABA-responsive dehydrin), *ACS1a* (1-aminocyclopropane-1-carboxylate synthase), *LPTG2* (lipid transfer protein) *JA2* (protein associated with jasmonate metabolism), *GA2ox3* (protein related to gibberellin deactivation pathway) and *IAAsGH3* (auxin responsive protein) suggest that *NCED* overexpression and early ABA accumulation in tomato roots seems to alter several plant hormone metabolism and signalling pathways leading to local and systemic stress adaptive responses that could help to explain the observed phenotypes.

O-11

Unraveling graft compatibility of scion/rootstock interactions in pepper

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Grafting has been used for millennia to increase uniformity, vigour and resistance to biotic and abiotic stresses. Currently, although the use of grafted plants is rapidly increasing, this practice remains limited in some cases due to inconsistent grafting success. Considering the variation of graft compatibility between even closely related species, it seems necessary to evaluate the graft compatibility before considering the use of a rootstock for a specific scion genotype. The main goal of this work was to compare Chlorophyll Fluorescence Imaging (CFI) parameters with histological studies at the graft interface in several combinations scion/rootstock with different levels of compatibility in order to demonstrate whether CFI can be useful for a rapid determination of the compatibility in pepper combinations. For this purpose, we evaluated the compatibility between the commercial pepper cultivar 'Adige' (A) and different *Capsicum* spp. accessions selected as tolerant to salinity and water stresses (A5, B14, C12 and A25 codes) 30 day after grafting. In addition, we used different graft combinations with known graft compatibility as controls: eggplant grafted on *S. torvum* and pepper homografts (A/A, high compatibility), pepper grafted on *S. torvum* (incompatibility) and pepper grafted on tomato (high incompatibility). Callus formation, new cambium and vascular connections, and the chlorophyll fluorescence parameters Fv/Fm, Φ_{PSII}, NPQ and q_P were evaluated in those graft combinations. A stronger level of graft incompatibility was observed when 'Adige' was grafted onto *S. torvum* and 'Beaufort' (tomato), and in a lesser grade in A5. In these cases, histological examination provided clear evidences of discontinuous xylem elements in the graft union as well as large areas of unbroken necrotic lines along the wounded edges of the rootstock and the scion. These observations were correlated with lower Fv/Fm, Φ_{PSII}, NPQ and q_P. By contrast, anatomical observations provided clear evidences that the graft combinations A/A and A/A25 showed the highest vascular regeneration across the graft interface, and in a lesser extent were the accessions B14 and C12. In these cases, CFI values were lower than in the less compatible combinations, thus confirming that Chlorophyll Fluorescence Imaging can be an useful non-destructive technique for the diagnosis of graft compatibility in pepper grafted plants.

O-12

Inheritance and relationship of important characteristics for determination of graft compatibility in apricot

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Abstract

Given the relative importance of graft compatibility throughout the world, there is surprisingly little research dedicated to the study of this phenomenon. The large number of genotypes that can be combined by grafting produces a wide range of different physiological, biochemical and anatomical interactions when grafted, making selection progress slow in this research area. Important metabolic pathways have been identified as responsible for physiological failure in graft-incompatible rootstock-scion combinations, such as phenylpropanoid, cell wall biosynthesis or oxidative stress. However, little is known of the genetic control of graft compatibility in plants. In order to obtain further insight into the genetic factors that control this trait, the inheritance of the graft (in)-compatibility trait was studied in a population of 81 apricot seedlings obtained from a controlled intraspecific cross between the Spanish cultivar 'Moniqui' (female parent, incompatible) and the French cultivar 'Paviot' (male parent, compatible). Screening of graft compatibility on the progeny grafted onto the plum rootstock 'Marianna 2624' was based on anatomical symptoms. Bud take, growth, necrotic line and vascular discontinuity were observed during one year after grafting. The phenotypic parameters observed in the F1 individuals revealed that the necrotic line, discontinuities in the bark and wood, are highly correlated and play an important role in the development of the graft union and the establishment of vascular connections. Different histograms were also developed using average data for each F1 individuals grafted on 'Marianna 2624', showing a normal distribution for the three parameters measured related with graft incompatibility. Among the total number of F1 individuals evaluated, 16.04% of the descendants were found to be incompatible and 52.65% compatible. The remaining 11% descendants were admixed within the population at this time. The results obtained from this work highlight that graft compatibility is a complex agronomic trait. Knowledge of graft compatibility inheritance in other progenies will help cultivar and rootstock breeding and will contribute to understand the genetic mechanism of graft compatibility.

Keywords: correlations, inheritance, *Prunus armeniaca* L., rootstock breeding, rootstock-scion interaction

Session 2 Shoot / root interactions

O-13

Phloem transport of proteins and RNAs

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The plant vascular system is important for the long-distance transport of nutrients, assimilates, and water between different organs. Moreover, this pathway is used to transfer important information that is essential to coordinate nutrient availability with the resources required for defense responses, growth, and reproduction. In addition to small molecules like metabolites or phytohormones, hundreds of proteins and RNAs have been found in the transport fluids of phloem and xylem, and they have been implicated with signal transduction in response to various challenges.

Recently, we and others could comprehensively identify the protein and RNA complement of phloem and xylem saps, and could demonstrate by grafting experiments that specific endogenous macromolecules are indeed mobile over long distances through the phloem and can be involved in signal transduction following biotic or abiotic challenges.

We are now interested in understanding the detailed mechanisms of phloem loading and long-distance trafficking of macromolecules in protein- and ribonucleoprotein complexes on functional and structural levels.

O-14

Salinity stress in eggplant can be alleviated by grafting and inoculation with Serratia marcescens containing ACC-Deaminase

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Grafting on a salt-tolerant rootstock (*S. melongena* cv.Vista-306) and 1-aminocyclopropane-1-carboxylate (ACC)-deaminase (EC 4.1.99.4) containing bacteria (*Serratia marcescens*) inoculation were tested whether grafting and bacteria can alleviate salinity stress in eggplant. Two salt-tolerant eggplant genotypes ('Mardin Kızıltepe', 'Burdur Merkez') and two salt-sensitive eggplant genotypes ('Artvin Hopa', 'Kemer') were used as scions. Grafted and non-grafted seedlings with 4-5 true leaves were transferred to pots (165 cm × 160 cm; 2.5 L) filled with a mixture of peat and perlite (2:1) in a controlled greenhouse and were cultivated under temperatures of 23-25 °C with approximately 50-55% relative humidity. After 10 days from planting, 20 mL bacteria solution (cell density of $3x10^8$ cells/mL) per plant was applied to root region of the seedlings as inoculum. Salt solution (200 mM NaCl) was applied to plants for 20 days after 5 days from inoculation of the bacteria. Shoot fresh weight, shoot dry weight, stem length, leaf area and SPAD values were adversely affected by salt stress, but salt-tolerant genotypes were comparatively less affected. Potassium (K^+) and Ca^{++} contents of the leaves were also reduced, while Na^+ and Cl^- contents in the leaves were significantly enhanced. Moreover, malondialdehyde (MDA) content, the activities of catalase (CAT: EC 1.11.1.6), ascorbate peroxidase (APX: EC 1.11.1.11), glutathione reductase (GR: EC 1.6.4.2) and superoxide dismutase (SOD: EC 1.15.1.1) in the leaf tissues increased in salt stress conditions. Our results also showed that the grafted seedlings induced salt tolerance in especially 'Mardin Kızıltepe' and 'Artvin Hopa' genotypes, registering lower foliar concentrations of Na^+ and Cl^-, the lower lipid peroxidation and higher antioxidative enzyme activities. Inoculation of the bacteria significantly counteracted the salt-induced adverse effects on growth characteristics, leaf K^+, Ca^{++}, Cl^-, Na^+, MDA content and antioxidative enzyme activities. In conclusion, grafting and inoculation of the bacteria are effective in improving growth and some key physiological processes in eggplant under salt stress. Besides the bacteria can be used as an alternative source for protecting plants against the hazardous effects of salt stress as an ameliorative agent.

Keywords: Salt stress, *Solanum melongena*, grafted seedling, bacteria, enzymes, ions.

O-15

Improving Cadmium Stress Tolerance in Tomato by Grafting and Arbuscular Mycorrhiza

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Among the heavy metals, Cadmium (Cd) is the most hazardous metals and their excess level in irrigation water and soil have been reported to disturb physiological, biochemical, and metabolic processes leading to growth inhibition. To alleviate the negative effects of Cd-toxicity, various strategies have been suggested. One of these is a grafting strategy involving rootstocks that are known to enhance plants ability in mitigating the adverse environmental conditions and it can be a faster and sustainable tool. Another promising and environment friendly tool to overcome Cd toxicity in contaminated soils would be through inoculation with beneficial microorganisms such as arbuscular mycorrhizal (AM) fungi. The aim of the current experiment was to assess the effects of grafting and inoculation with the AM *Rhizophagus irregularis*, alone or in combination, physiological, biochemical, metabolite and gene expression changes of greenhouse tomato (*Solanum lycopersicum* L. cv. 'Ikram') plants under moderate external Cd concentration. The experiment was designed as a factorial combination of two Cd concentrations [0 (control), or 25 µM], two grafting combinations (self-grafted Ikram/Ikram, or Ikram/Maxifort), and two mycorrhizal treatments (with AM,+AM or without AM,–AM). Tomato plants responded to moderate Cadmium (Cd) concentration by decreasing yield and crop growth parameters due to the accumulation of Cd in leaf tissue, inhibition of the PS II activity, reduced nutrients translocation, and also to the oxidative stress as evidenced by enhanced hydrogen peroxide (H_2O_2) generation, ion leakage, and lipid peroxidation. AM inoculation was not able to alleviate the detrimental effect of Cd on growth and productivity because Cd could not be retained in intra-radical AM fungi, leading to translocation of Cd in the aerial parts. Grafting tomato, involving vigorous rootstock such as Maxifort, could effectively mitigate adverse effects of Cd stress by improving plant nutritional status (higher P, K, Ca, Fe, Mn, and Zn), photosynthetic pigments, photochemical activity of PSII, increase the capacity of antioxidant enzymes (CAT, APX), proline and metabolites linked to oxidative stress or clearly related to Cd tolerance (i.e., phytochelatin, fructans, and inulins). Hence, the contribution of Maxifort rootstock minimized the level of Cd-induced oxidative injury by decreasing the level of hydrogen peroxide, lipid peroxidation, and electrolyte leakage in tomato leaves, thus promoting the performance of tomato plants.

O-16

Phenotypic Variations in Root Morphology in *Cucurbita spp.* (*C. moschata, C. maxima, and C. maxima x C. moschata*) Rootstock Genotypes for Cucumber under Low Temperature Conditions

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The low temperature is one of the most important abiotic stress factors inflicting heavy economic relevant yield losses by reducing plant growth and development. Cucumber is one of the vegetable species that are the most sensitive to low temperature. Because of this reason, cucumber growing periods are limited at the low temperature conditions in Turkey. Grafting is a promising tool to enhance plant performance of Cucurbitaceae family under growth conditions in which plants (roots) have to deal with suboptimal and/or supraoptimal temperatures, water stress. Pumpkin is recommended as rootstocks in low temperature conditions for grafted cucumber growing. The objective of this study was to quantify the phenotypic variation in root production thirty *C. moschata*, twenty *C. maxima*, and two *C. maxima x C. moschata* lines and to classify the root architecture observed. Breeding lines of Cucurbita spp., grown at air temperatures of 12°C / 8°C day /night under 16 / 8 h photoperiod. Root growth parameters were assessed at 30 d after seeding. Root systems were scanned and digitized by the WinRHIZO program. Data collected included taproot length, shoot length, and root and shoot dry weight. Data generated by WinRHIZO included total root length, surface area, average root diameter, and root volume. Based on the relative scores assigned in this study, rootstock breeders could select parents of F1 hybrid cultivars to maximize root production in an early planting production system.

KeyWords: Root, Cucurbita, Rootstock, Breeding, Low temperature

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O-17

Tolerance of Grafted Tomato Plants to Virus Infections

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Yields and quality of tomato production in Bulgaria are mainly depending on sustainable agronomic practices, improved varieties and resistance to diseases caused by bacteria, viruses and fungi. Many viruses infect the tomato crops in Bulgaria, but with economic importance are *Tomato mosaic virus* (ToMV), *Potato virus Y* (PVY), *Cucumber mosaic virus* (CMV) and *Tomato spotted wilt virus* (TSWV). Tomato grafting is a techniques applied to control mainly soilborne and also some foliar pathogens, including viruses. The purpose of present investigation was to test the effect of rootstocks on the reaction of grafted tomato plants to some important viruses. Nine tomato rootstocks (Yedi, King Kong, Big Power, Emperador, Stallone, Bruce, Montezuma, Colosus and Kaiser) were involved in the study. The seeds were kindly provided by Rijk Zwaan Breeding B.V., De Lier, The Netherlands. Bulgarian tomato cultivar Rosalina Rossa was used as scion. Non-grafted, self-grafted and grafted on nine rootstocks tomato plants were inoculated with standard virus suspensions according to Noordam. Inoculated plants were daily observed for virus symptoms. The presence or absence of the viral infection in tomato plants was proved by DAS-ELISA serologic assays with specific polyclonal immunoglobulin G for the relevant plant virus according to Clark and Adams. DAS-ELISA kits (LOEWE, Germany) were used for identification of virus infection. Seven days after inoculation with ToMV small local necrotic spots developed on the leaves only. The plants inoculated with PVY and CMV showed no visible symptoms. Despite of absence of visible virus symptoms all inoculated with PVY tomato rootstocks and scions had systemic virus infection, according to DAS-ELISA results 14 days after inoculation. Most of grafted tomato plants inoculated with PVY and CMV remained symptomless showing tolerance to virus infection and could be used for qualitative production.

Session 3 Plant metabolomics and fruit quality

O-18

Root engineering for crop improvement using CKX technology

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In recent times the plant root system has gained importance as an important but underutilized tool for designing strategies to improve plant growth and yield. Roots are relevant to plants for sensing and transporting of nutrients and water from the ground. Therefore, root system architecture (RSA) has become a major target for attempts to increase tolerance to abiotic stresses acting on the root, such as nutrient deficiency, drought and salinity. Cytokinin is known to be a negative regulator of primary root growth and lateral root formation. Consistently, lowering the cytokinin content by ectopic expression of cytokinin-degrading *CKX* genes in roots of model plants such as *Arabidopsis* and tobacco leads to plants with an increased root system size and altered RSA. These plants were shown to be more tolerant to drought and nutrient deficiency (Werner *et al.,* Plant Cell 22: 3905-3920, 2010). Presently we are investigating whether applying the CKX technology to different crop plants, in particular barley and maize, would have similar consequences for RSA in these monocot plants. Transgenic barley and maize lines containing different root specific promoter::*CKX* combinations were obtained by *Agrobacterium*-mediated gene transfer. Transgenic plants were shown to form a 25-30% larger root system on dry weight basis in a hydroponic test system without showing any reduction of shoot growth or yield penalty. Moreover, transgenic plants were shown to accumulate higher content of some essential elements in their seeds. These and other traits such as performance under various abiotic stress conditions will be discussed.

O-19

Effect of partial root-zone drying on grafted tomato

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In a short term experiment, tomato plants (*Solanum lycopersicum cv. Belle*) ungrafted, self-grafted and grafted onto He-man rootstock were grown in a greenhouse under two irrigation regimes, partial-root zone drying (PRD) and fully irrigated (FI), to investigate whether grafting can alleviate drought stress and promote water-use efficiency (WUE).

Grafted plants under PRD accumulated less biomass than those under the FI treatment, but significantly more than the FI ungrafted and self-grafted plants. A comparison of dry matter (DM) partitioning between organs showed that PRD suppressed vegetative growth in grafted plants and allocated more DM to fruits. There were no significant differences in early yield between irrigation treatments in grafted plants, but there were differences between grafting types under FI. No differences were found in plant mineral concentrations between treatments, although it seems that grafting under PRD promotes the uptake of N and K. Generally, average WUE was higher under PRD. However there were no differences between the grafted plants, only between the ungrafted and self-grafted plants. PRD seems to suppress vegetative growth without influencing early yield in grafted tomato. The PRD and rootstock effects should be investigated in longer-term experiments.

O-20

From Ein Tamar to Berlin: On the complicity of Cucurbita rootstocks

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Cucurbits can be grafted onto rootstocks from the same species or on rootstocks from another cucurbit species. Most of the commercial cucurbits, however, are being grafted on inter-specific *Cucurbita* rootstocks produced mainly by crossings between *C. maxima* and *C. moschata*. The reason for using the inter-specific rootstocks is not clear. The non-proved paradigm is that such rootstocks will be more vigorous, resulting in better yields and high-level resistances. Nevertheless, seed yields of such inter-specific crosses and are low and germination is often poor, thus making seed production not efficient.

In the current study, we evaluated the response of melon grafted onto 15 *Cucurbita* rootstocks, under field and greenhouse conditions, to various root temperatures and to soil-borne pathogens. The rootstock collection used consisted of five hybrids and their respective *C. maxima* and *C. moschata* parents, enabling comparing the contribution of the parents to the performance of their respective inter-specific hybrids.

The results showed that, in most cases, there was no advantage of the inter-specific rootstocks over one or both of their respective parents. Using parental accessions or intraspecific *Cucurbita* hybrids, selected to answer defined obstacles in a particular growing environment, may lead to more precise and economical rootstock breeding.

O-21

Rootstock influences tomato quality at different ripening stages

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Traditionally grafting was used to restrict negative effects of soil-borne pathogens, but nowadays, it has also become a strategic tool to improve plant vigor. However, the influence of rootstock has to be considered also on fruit quality and health-promoting compounds, since the increased interest of consumers in the sensory and nutritional quality of vegetable products. In addition ripening stage at harvest can affect fruit characteristics. The current research has the aim to evaluate the influence of three tomato rootstocks characterized by different vigor (Armstrong - high; Interpro - medium; He-Man - low) on fruit quality at two ripening stages (4 and 5 of OECD Scheme of Tomato Color Gauge). Sir Elyan F_1 hybrid was used as scion. Lycopene content changed with rootstock and increased with ripening stage. Fruits of plants grafted onto Armstrong have the lower β-carotene at second ripening stage compared the first one, but increased with Interpro; any variation was observed with He-Man. Vitamin C remained constant in fruits of plants grafted onto Armstrong and Interpro at both ripening stage, whereas decreased with He-Man rootstock at 5 OECD Scheme. Antioxidant activity varied with rootstock (lowest value showed by Armstrong) and ripening stage (it decreased at second stage). Results of sensory analysis showed the major differences for consistency, pulp color, tomato smell, crunchy. For aroma volatiles, were totally identified 36 compounds, grouped in aldehydes, ketons, alcohols, acids, esters, terpenes, aromatic hydrocarbons, which varied with rootstock combination and ripening stage. The titratable acidity significantly decreased in Armstrong and Interpro with ripening.

O-22

The green colour of the rootstock fruits affect the quality of the scion fruits

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Photosynthesizing chloroplasts develop in response to light and are mediated by photomorphogenic signalling pathways. The sustained capacity of particular cells and tissues to form chloroplasts is strongly influenced by *Golden 2*-transcription factor. Sugars, pigments and secondary metabolites needed for ripe fruit flavour and health related attributes depend on photosynthesis and chloroplasts in green fruit. We postulate that dark green tomato fruits containing more chloroplasts also have an enhanced flavour or health related attributes. Based on this hypothesis, we screened >50 cultivars with different developments of the green colour of their fruits and analysed their quality characteristics. Now, we selected one light green tomato (less chloroplasts) and two dark green tomato (many chloroplasts) as rootstocks and grafted two light green cultivar (*S. lycopersicum* cvs. LA-4442 and Piccolino) onto them. The results show the effectiveness of a dark green tomato rootstock to enhance fruit weight, chlorophylls, sugars, and titratable acids, firmness and the total plant growth rate. Some of the fruit quality characteristics were not significantly affected when the scion was grafted on a dark green tomato rootstock, such as fruit juice pH.

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O-23

Plant Root Exudates - How to measure? – What is measured?

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Apart from the function of plant roots as organs for water and nutrient uptake and ancorage in soils, roots are able also to release a wide range of organic and inorganic compounds into the rhizosphere. Soil-chemical changes related to the presence of these compounds and products of their microbial turnover are important factors affecting microbial populations, availability of nutrients, solubility of toxic elements in the rhizosphere, and thereby, the ability of plants to cope with adverse soil-chemical conditions. Organic rhizodeposition includes lysates, liberated by autolysis of sloughed-off cells and tissues, intact root border cells, as well as root exudates, released passively (diffusates) or actively (secretions) from intact root cells.In annual plant species, 30-60% of the photosynthetically fixed carbon is translocated to the roots, and a considerable proportion of this carbon (up to 70%) can be released into the rhizosphere. This rhizodeposition is affected by multiple factors such as light intensity, temperature, nutritional status of the plants, activity of retrieval mechanisms, various stress factors, mechanical impedance and sorption characteristics of the growth medium, and microbial activity in the rhizosphere.

Since the methods employed for collection and analysis of root exudates play an important role for the qualitative and quantitative interpretation of measured exudate this contribution summarizes current methodolocical approaches for exudate collection in different culture systems including a discussion of advantages, disadvantages, limitations, „do´s and don´ts“.

O-24

Emerging organic contaminants in fruits of *Cucumis melo spp*. grafted on different rootstocks. Preliminary data.

A. Verzera, Condurso, F. Cincotta, G. Tripodi, G. Dima, P. Crinó, A. Paratore

Organic micropollutants are comprised of a broad spectrum of compounds belonging to different chemical classes and used for a large number of applications. Among these, emerging contaminants include pharmaceuticals, personal care products, plasticizers, surfactants, herbicides and their degradation products. The concentration of micropollutants in agricultural irrigation waters ranged from 10 to 5130 ng L-1 and the human exposure through fruit and vegetable consumption was estimated to be 9.8 µg per person per week. The health implications of some of these are well known, as example phthalate esters, the most common industrial chemicals, were estrogenic compounds.

In this regards, the research aimed at evaluating the presence of emerging volatile contaminants, such as solvents (chloroform, carbitol), antioxidants (BHT, BHA), aromatic compounds from petrochemical industry (BTX), plasticisers (phthalates) etc., in the fruits of *C. melon* spp. grafted on different resistant rootstocks.

The data showed a different amount of contaminants in melon fruits depending on the different rootstock-scion combinations. Grafted fruits of *C. melo* cv. Incas showed a lower amount of contaminants than ungrafted fruits, the opposite happened for the cv. Proteo. In particular, the Incas-Elsi and Incas-Sting grafting combinations showed the lowest amount of contaminants whereas the Proteo-Sting and Proteo-AS10 the highest.

The different behavior can be attributed to a different interaction rootstock-scion that may exhibit dissimilar abilities to take up nutrients and non-nutrient elements. Further studies are necessary to confirm the data here reported also in crops under different biotic and abiotic conditions.

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O-25

Rootstock effect on grafted runner bean yield and fruit quality

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Runner bean is a major protected crop in Portugal which has recently begun to benefit from grafting to control soilborne diseases, mainly caused by *Fusarium* spp. in soil systems, or to increase nutrient uptake in hydroponic systems.
This study evaluated the effects of grafting cultivars Rajado and Oriente (*Phaseolus vulgaris*) onto *P. coccineus* rootstocks, on the incidence of *Fusarium* spp. and *Meloidogyne* spp. and on crop yield and quality. The rootstocks used were cv. Aintree (P1) and cv. White Emergo (P2) from Tozer Seeds and the Portuguese landrace cv. feijão 7 anos (P3). The experiment was conducted in the spring/summer season 2015 under greenhouse conditions at NW Portugal, with a randomized block design with 3 blocks. Self-grafts and ungrafted plants were used as controls and the number, length, fresh and dry weights of the pods were recorded.
Preliminary results showed that rootstock P3 increased the total number of pods and yield compared to P1, P2 and ungrafted plants for the higher yielding cv. Oriente. For the cv. Rajado, P2 and P3 increased crop yield compared to P1, self-grafts and ungrafted plants. Therefore, the Portuguese landrace cv. feijão 7 anos may have the potential to enhance runner bean yields compared to more commonly use commercial rootstocks such as those from Tozer Seeds.

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O-26

Agronomic and physiological responses of tomato when ABA-deficient plant are used as rootstock

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The present trial aimed at analyzing the effect of ABA-deficient tomato used as rootstock and/or scion on plant phenology, yield and fruit quality. Wild type (WT), flacca (flc) and notabillis (not) mutants of Ailsa Craig tomato variety were used as rootstock and/or scion.

Tomato were planted the 21st April 2015 in a greenhouse (Venlo-type) of 350 m^2 area. A monitoring of plant phonology was performed by measuring the stem diameter, elongation, flowering stage and leaf area and leaves area. Fruits were harvested each 5 days and total yield was calculated. Fruit quality has been evaluated by measuring the soluble solids content, the total acidity and the firmness. Physiological analyses such photosynthesis, water potential were carried out. Finally, real-time measurements of changes in turgor pressure of leaves were attempted by using non-invasive magnetic turgor pressure probes.

The results showed significant effect of ABA-deficient tomato used as rootstocks on plant phenology (flowering stage, weekly elongation and leaves area), physiology (water potential, water turgor pressure). Effect on fruit quality (SSC, Acidity) occurred when ABA-deficient tomato are used as scion.

O-27

Yield and quality of two melon [*Cucumis melo*] cultivars grafted on four *C. maxima x C. moschata* rootstocks

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Over the last 10 years in Cyprus, melon varieties are grafted mostly on the hybrid *C. maxima* x *C. moschata* rootstock 'TZ148'. Introduction of new hybrid rootstocks by the local nurseries raises questions regarding their effects on field performance and fruit quality and on their overall suitability for grafting melon cultivars. The objectives of this study have been to evaluate the performance of two commercial odorous melon cultivars ('Elario' and 'Raymont') as per their response to grafting onto four interspecific hybrid squash rootstocks ('TZ148', 'N101', 'Carnivore' and '30900'). Non-grafted plants of each cultivar were used as controls. The study was performed in a greenhouse between February-May at the Zygi Experimental Station in Cyprus. Plants were grown in a sterilized peat-perlite (2:1) medium in 30 l black plastic pots. During the harvest period, 16-36% of cv. Raymont plants, depending on rootstock, were lost to wilting, whereas no losses were incurred on non-grafted plants. Plant wilting was determined as non-pathogenic. Rootstocks 'TZ148', 'N101' and 'Carnivore' reduced cv. Raymont scion's dry weight in relation to the non-grafted plants. No plant wilting was observed with cv. Elario scions, irrespective of rootstock. Grafting on hybrid rootstocks did not affect yield per plant, number of fruit per plant, fruit weight and shape of either cv. Raymond or cv. Elario; moreover, no differentiation was observed between rootstocks. Rootstock effects on the quality characteristics of the two melon cultivars differed. Fruit soluble solids content (SSC) of cv. Elario benefited from grafting on all rootstocks whereas cv. Raymont SSC was affected negatively by rootstock '30900'. Flesh firmness of cv. Elario was decreased on all rootstocks whereas cv. Raymont firmness decreased only on rootstocks 'N101'and 'Carnivore'. Further differentiation among rootstocks, was observed for scion fruit rind thickness, skin netting, flesh lightness (L*) and chroma (C*), soluble carbohydrate and dry matter content.

Poster Abstracts

P-1

Alleviation of Aluminium-Induced Toxicity in Cucumber by Grafting

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Vegetable crops are sensitive to even micromolar concentrations of aluminium (Al) in soils, indicating that Al toxicity can reduce horticultural productivity to a significant degree, especially in acidic soils (pH < 5), which accounts for approximately 30% of arable land worldwide. Our hypothesis was that grafting onto selected rootstocks may raise Al tolerance of cucumber (*Cucumis sativus* L. cv. Ekron) by limiting the transport of Al to the shoot. To verify this hypothesis, a greenhouse experiment was carried out to compare the growth, yield, SPAD index, electrolyte leakage, mineral composition and assimilate partitioning in ungrafted or grafted plants onto the following rootstocks: *Cucurbita ficifolia*, P360 *Cucurbita maxima* Duch. × *Cucurbita moschata* Duch.). Plants were cultured in pots filled with quartziferous sand and supplied with nutrient solutions having different pH and aluminium concentration (pH 6.0, pH 3.5 or pH 3.5 + Al). The low pH treatment had the same nutrient composition plus HCl, whereas the aluminium treatment (pH 3.5 + Al) was induced by adding 0.75 mM of $AlCl_3 \cdot 6H_2O$. Significant depression of yield, biomass, SPAD index, leaf area, and macronutrient concentration in leaf tissue was observed in response to low pH with more detrimental effects with pH 3.5 + Al. The grafted plants onto the *Cucurbita* hybrid rootstock under Al toxicity treatment had higher productivity and dry biomass than those observed in grafted plants onto *Cucurbita ficifolia*, and ungrafted plants. Grafted cucumber plants grown under acidity and Al conditions had higher macronutrient concentration in leaf tissue compared to ungrafted plants. The higher agronomical performance in cucumber plants grafted onto P 360 could be attributed to the capacity of maintaining higher SPAD index, and better nutritional status in response to Al toxicity with respect to ungrafted plants.

P-2

The Eggplants Crop Technology Optimization by Grafting

Marian BOGOESCU, Madalina DOLTU, Sora DORIN

Soil fumigation has been an essential component of greenhouses crops since the 1960's. Growing vegetables without soil fumigants has remained a challenge, in part because commercially acceptable eggplant cultivars produced through conventional breeding lack resistance to many soil borne plant pathogens. In field production, crop rotation is important to prevent infestation of diseases and pests. However, crop rotation is rarely practiced in greenhouse production, which allows soil borne pathogens and pests to accumulate, progressively reducing crop yields. Grafting cultivars with high quality and productivity on rootstocks that are resistant to the soil pests and diseases is a method known from years ago, which was improved and quickly spread in the last years. Therefore, the aim of this research was to evaluate the performance of the eggplant grafting on the some rootstocks, in greenhouse conditions. There have been determined and calculated the marketable yield, fruits quality, frequency and root galling index of soil-born disease and nematodes, in the experimental variants. Grafting was found to resulted in a increased marketable yield and significantly reduce the incidence of *Verticillium dahliae* and *Fusarium oxysporum f. sp. melongenae*.

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P-3

Growth, Yield and Physiologic Responses of Salt-stressed Tomato to Grafting onto Rootstocks Differing in Salt Tolerance

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Tomato (*Solanum lycopersicum*) genotype Tom-121 that is salt sensitive is either self-grafted or grafted onto the salt-tolerant accession of *Solanum lycopersicum var.cerasiforme* (Tom-174). Tom-174 is also self-grafted. Plants were grown at two different treatments control or salt with 50 mM NaCl in glasshouse during 110 days from February to June 2015. Yields of grafted tomato plants in salt stress comparison to control were; self-grafting Tom-121 decreased fruit yield by 44%, grafting Tom-121 onto Tom-174 only decreased yield by 2.5 %, self-grafting of Tom-174 increased fruit yield by 17%. Stomatal conductance values of grafted tomato plants in salt stress comparison to control were; self-grafting Tom-121 increased by 44%, grafting Tom-121 onto Tom-174 decreased by 31 %, self-grafting of Tom-174 decreased by 61%. Leaf water potential values of grafted tomato plants in salt stress comparison to control were; self-grafting Tom-121 decreased by 45%, grafting Tom-121 onto Tom-174 decreased by 24 %, self-grafting of Tom-174 decreased by 4 %. Leaf osmotic potential values of grafted tomato plants in salt stress comparison to control were; self-grafting Tom-121 increased by 14%, grafting Tom-121 onto Tom-174 increased by 31 %, self-grafting of Tom-174 decreased by 59%. Some fruit quality analysis (dry matter production, vitamin C, titrable acidity, total soluble solid contents) and Na and Cl ions analysis in shoot and root are currently being at the moment, also plant growth data like shoot dry weight, leaf area will be presented and discussed during the meeting.

P-4

Resistance Behavior of different tomato root stocks against root-knot Nematodes

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Since 1997 different interspecific hybrid rootstocks were investigated concerning their abilities to improve yield and quality performance of tomato cultivars in greenhouse production in Weihenstephan. Root health was examined as well in terms of a scoring in root discoloration and the level of root galling caused by nematodes at the end of cultivation. The rootstock cultivars differed in their resistance behavior, particularly regarding the root-knot nematode *Meloidogyne incognita* and corky root (*Pyrenochaeta lycopersici*). Furthermore these root evaluations at the end of the cultivation period pointed out that some rootstock cultivars with galling allow a multiplication of nematodes and therefore a damaging of the following crops, although the grafted tomatoes themselves showed a normal growing behavior and fetched high yield.

To get a better specification 9 respectively 13 tomato rootstocks were examined in 2010 and in 2013 with tomato cultivar 'Encore' as scion - not only by root scoring at the end of cultivation but additionally by extracting, counting and identifying nematode larvaes of each grafted variant from soil samples at the beginning and additional root samples in the end of cultivation.

There was hardly any root-knot growth in both years, but variations in terms of multiplication of nematodes among the rootstocks were obvious. The highest root-knot growth was found in the ungrafted variant. Although some rootstocks did not show any knots, a reproduction of nematode larvae in the soil and roots was observed. The results show that the root-knot development itself doesn't allow a conclusion to be drawn about the multiplication of root-knot nematodes. Hybrid rootstocks can produce more healthy roots and gain higher yields than ungrafted tomatoes but they cannot suppress nematode multiplication successfully. This has to be taken into account planning the following crop.

P-5

Physiological and morphological responses of pepino as affected by grafting with tomato and eggplant under salt stress conditions

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Abstract

Salinity is one of the major abiotic factors affecting crop growth and productivity negatively. Particularly in the arid and semi-arid regions of the world the decline in vegetable production is considerably high due to this problem. However, between plant species and among cultivars responses to salinity are very diverse. Since some plants species or cultivars are resistant or can tolerate high levels of salinity while others can tolerate little or no salinity. The objective of the present study was to determine grafting compatibility between pepino-tomato and pepino-eggplant combinations and to identify physiological and morphological responses that affected by grafting under salt stress condition. A nutrient solution experiment was carried out in a growth chamber of plant physiology laboratory of Erciyes University, in Kayseri Turkey. For the grafting compatibility three different vegetable crop species (pepino, tomato and eggplant) from the same family (*Solanaceae*) were compared. Homogenously grown pepino seedlings were used as scion while tomato and eggplant seedlings were used as rootstocks. After grafting process the grafted and non-grafted control plants were transferred into acclimation chamber for a while. After that healthy and homogenously grown plants were selected and transferred into 8 L plastic pots. In each pot 2 plants were grown in continuously aerated nutrient solution for 35 days in controlled growth chamber. Salt was supplied gradually in three levels (Low: 0.5 dS m^{-1}, Medium: 4.0 dS m^{-1}, and High: 8.0 dS m^{-1}) of electrical conductivity (EC) by using NaCI with four replications. The nutrient solution had the following composition (µM): $Ca(NO_3)_2$ (1000), K_2SO_4 (500); KH_2PO_4 (250); $CaSO_4$ (1000); $MgSO_4$ (325); NaCl (50); H_3BO_3 (8.0); $MnSO_4$ (0.4); $ZnSO_4$ (0.4); $CuSO_4$ (0.4); $MoNa_2O_4$ (0.4); Fe-EDDHA (80). Between complete renewals of the nutrient solution (7 days intervals) all nutrients were replaced when the N concentration of the nutrient solution in the 2.0 mM N rate pots fell below 0.5 mM, as measured daily with nitrate test strips. Two plants per pot were harvested 35 days after treatment (DAT). Plants were separated into shoot and roots. The results indicated that shoot (fresh and dry matter, leaf area, SPAD value, photosynthesis) and root (root fresh and dry matter, root length) growth significantly ($P<0.001$) negative affected by different levels of salt supply. Highly significant ($P<0.001$) differences in shoot and root growth parameters were found between graft combinations. The interaction between salt and graft combinations was also significant ($P<0.01$) in some shoot and root parameters. In terms of graft compatibility pepino-eggplant showed better performance compared to pepino-tomato graft combinations, however only at low level of salt supply. On the other hand pepino-tomato combination showed better performance than pepino-eggplant

combination at both medium and high levels of salt supply. Interestingly the ungrafted pepino plants exhibited best performance in growth and development as compared to pepino-tomato and pepino-eggplant graft combinations at both medium and high levels of salt supply. This indicating particularly root morphological traits of pepino have a contribution to salt tolerance. Therefore, this hypothesis will be checked in the next grafting study by using pepino as a rootstock and tomato and eggplant as scion under salt stress conditions.

Keywords: Pepino, grafting, root morphology, salt tolerance

P-6

Surviving to salinity conditions through robust pepper rootstock

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The performance of the commercial pepper cultivar 'Adige' grafted onto wild-type salt-tolerant pepper (*Capsicum annuum* L.) accession A25 plants (A/A25) and un-grafted plants (A) under salinity conditions (80 mM NaCl) for 14 days was assessed in a greenhouse experiment conducted to determine growth, chlorophyll *a* fluorescence parameters, MDA and proline content. Salt stress induced significantly stunted growth of A plants (-40.6% of leaf DW) compared to the control conditions, while no alterations were observed in A/A25 at the end of experiment. The maintenance of shoot vigor is dependent mainly on photosynthetic capacity. In A plants a progressive decrease in ETR under salinity conditions was compensated *via* increased thermal dissipation (NPQ), even though these plants experienced a greater excitation pressure on PSII and more reaction centers were closed as evidenced by an over-reduction of Q_A (qP decreased). In addition, a strong buildup of MDA by-products suggested their inability to counteract the salt-triggered damages. Conversely, no alterations in chlorophyll *a* fluorescence parameters, and MDA levels increased only slightly in A/A25 salt-treated plants confirming that biochemical and photochemical chloroplast processes remain intact. The accumulation of osmolytes, such as proline, is a well-known adaptive mechanism in plants against salt stress conditions, our results underline that, A/A25 showed higher salt tolerance, likely due in part of increase in proline accumulation. The higher amount of marketable fruits (+75%) and the reduction of BER incidence (-31%) in A/A25 plants grown in the field under 80 mM salt is the best demonstration of the validity of A25 rootstock under high salinity.

P-7

Response of *Cucumis metuliferus* accession BGV11135 against Mi virulent and avirulent populations of *Meloidogyne spp*. and effect on fruit melon quality.

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Several experiments were carried out in pot conditions to determine if the resistant response previously showed by the *Cucumis metuliferus* accession BGV11135 to one population of *M. incognita* and one of *M. javanica* was dependent of the interaction with several *Meloidogyne* populations, or with *Mi*-virulent populations. In addition, a first year experiment was carried out in plastic-house to determine the effect of grafting melon Cantaloupe cv. Paloma onto *C. metuliferus* BGV11135 on *M. incognita* population densities and disease severity compared to the ungrafted one, as well as fruit melon yield and quality of both ungrafted and grafted cv. Paloma compared to those on noninfested soil.

In pot experiments, *C. metuliferus* BGV11135 was resistant to three *M. javanica*, two *M. incognita,* and one *M. arenaria Mi*-avirulent populations, as well as to one of each *Mi*-virulent populations of *M. javanica* or *M. incognita*. Results from the plastic-house experiment, until now, has revealed that accumulated melon yield from ungrafted cv. Paloma are 50 and 10% those registered on the grafted one in noninfested and infested soil, respectively. Nematode population densities in soil and roots of ungrafted plants are higher than in grafted ones, as well as the number of dead plants. Fruit yield quality assessment is underway, but it seems that no great differences will be found comparing commercial melon fruits irrespective of if plants were or not grafted or cultivated in nematode infested or noninfested soil.

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