1st Annual Conference COST ACTION FA 1204 - ROOTOPOWER Workshop

COST ACTION FA 1204
"Vegetable Grafting to Improve Yield and Fruit Quality under Biotic and Abiotic Stress Conditions"

PROGRAMME AND

BOOK OF ABSTRACTS

12-14 November 2013

Murcia, Spain

Table of contents

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Welcome note

Dear colleagues and friends,

On behalf of the MC of the COST ACTION FA1204, the local organizing committee of CEBAS-CSIC welcomes all interested stakeholders (horticulturalists, plant pathologists, plant breeders, physiologists, biotechnologists and policy makers) to attend the 1st COST ANNUAL CONFERENCE of the action, jointly organized with the 1st ROOTOPOWER WORKSHOP.

After more than fifty years of crop improvement principally selecting for above ground traits, scientists now perceive root system engineering as an opportunity to integrate new approaches to maintain sustainable crop production under changing environmental conditions while minimizing the demand for new resources. Root-specific traits such as root system architecture, sensing of edaphic stress and root-to-shoot communication can be exploited to improve not only resource capture and plant development under adverse conditions, but also fruit quality. The potential of grafting is as broad as the genetic variability available, and may allow horticulture to cross species barriers between rootstocks and scions, allowing a more direct and efficient exploitation of wild germplasm.

The COST action FA1204 aims at stimulating cutting-edge multidisciplinary transnational collaborations towards identifying and understanding how rootstock-mediated traits can improve vegetable crop yield and quality under adverse biotic and abiotic conditions. Central to both international initiatives is the use of grafting in vegetable species, allowing precise assessment of the effect of altering root traits on crop performance and fruit quality independently of shoot traits, by using wild germplasm, mapping populations and functional lines as rootstocks.

The strategic aim is to help crop producers and breeders to improve yield stability and fruit quality under a changing and challenging environment and to overcome the consequences of unsustainable agricultural practices that are causing soil degradation and depleting natural resources.

The workshop will present recent results in phenotyping, genetics and physiology of rootstock-mediated tomato crop improvement under individual and combined abiotic stresses.

This meeting will promote discussion on improving crop stress resistance and quality through more resource efficient rootstocks, allowing a more efficient use of soil, dwindling water and phosphorus resources, and a reduction of the excessive use of nitrogen and potassium fertilizers (which have a high carbon footprint), as well as how this research could be extended to other abiotic and biotic constraints and vegetable crops. Without this research there will be a trend for below-ground biotic and abiotic stresses to decrease plant growth and development throughout the world leading to serious crop yield losses, and hence endangering food security.

The Southeast region of Spain (Murcia and Almeria provinces) is the perfect location to hold this meeting since it is one of the major horticultural areas in the world and produces around 100 million grafted plants per year. Our programme includes around 75 oral and poster presentations, with 110 participants from public and private sectors coming from 25 countries. We wish you a successful conference and a very pleasant stay in Murcia, a city where you will find a wonderful weather, high quality gastronomy, historical and cultural sites and charming people.

With kind regards,

The Conference Chair,
Dr. Francisco Pérez Alfocea
CEBAS-CSIC
On behalf of the Organizing Committee

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD
CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

Committees

Local Organizing Committee

Francisco Pérez-Alfocea, CEBAS-CSIC, Murcia, Spain
Cristina Soriano-Carpena, CEBAS-CSIC, Murcia, Spain
Alfonso Albacete-Moreno, CEBAS-CSIC, Murcia, Spain
Cristina Martínez-Andújar, CEBAS-CSIC, Murcia, Spain
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Giuseppe Colla, *Chair*, University of Tuscia, Italy
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Andrew J. Thompson, University of Cranfield, UK
Halit Yetisir, University of Erciyes Melikgazi, Turkey
Jan Henk Venema, University of Groningen, The Netherlands
Ian C. Dodd, Lancaster University, UK
Dietmar Schwarz, Institute of Vegetable and Ornamental Crops, Germany
Roni Cohen, ARO, NeweYa'ar Research Center, Israel
Menahem Edelstein, ARO, NeweYa'ar Research Center, Israel
Cherubino Leonardi, University of Catania, Italy
Carmina Gisbert, Polytechnic University of Valencia-COMAV, Spain
Dimitrios Savvas, University of Athens, Greece
Zhilong Bie, Huazhong Agricultural University, China
Frank Louws, North Carolina State University, USA

Working Group Leaders and co-Leaders

WG1
Andrew J. Thompson, Cranfield University, UK
Halit Yetisir, University of Erciyes Melikgazi, Turkey

WG2
Jan Henk Venema, University of Groningen, The Netherlands
Ian C. Dodd, Lancaster University, UK

WG3
Dietmar Schwarz, Institute of Vegetable and Ornamental Crops, Germany
Roni Cohen, ARO, Newe Ya'ar Research Center, Israel

WG4
Cherubino Leonardi, University of Catania, Italy
Carmina Gisbert (COMAV), Valencia, Spain

Programme

1. MONDAY 11TH NOVEMBER

Venue: Hotel Silken 7 Coronas

20:00-21:00 Early registration

21:00-22:00 ***Welcome reception***

2. TUESDAY 12TH NOVEMBER

Conference room: ***Salón Lorca***

8:00-9:00 Registration. Mounting of Posters (*Salón Gaya*).

Loading presentations. *Contact Dr Alfonso Albacete at Conference room*

9:00-9:30 Official Opening

Local organizer/Vice-Chair: Dr Francisco Pérez-Alfocea
Chair: Dr Giuseppe Colla

SESSION I:

WG 1 - GENETIC RESOURCES AND ROOTSTOCK BREEDING

Chair*: Dr. Andrew Thompson. Cranfield University, UK.*

Rapporteur: *Dr. Halit Yetisir. University of Erciyes Melikgazi,Turkey.*

9:30-11:00 Oral presentations

9:30-9:45 'Understanding the genetic basis of root trait variation in tomato'
Andrew J. Thompson

9:45-10:00 'Horticultural and phytopathological evaluation of exotic watermelon germplasm as a source for rootstock breeding'
Edelstein, M. Cohen, R. Tyutyunik, J. Tadmor, K. Falik, E.

10:00-10:15 'Biotechnology for rootstocks micropropagation and breeding'
C. Gisbert, J.M. Mulet, J. Prohens, R. Serrano, B. Picó

10:15-10:30 'Potential new Cucurbita spp rootstocks with viral and fungal resistance'
G.H.S. Nunes, E.W.L.P. Nunes, M. Ferriol, A. Alfaro-Fernández, I. Font, C. Gisbert, B. Picó

10:30-10:45 'Comparison of the physiological parameters of drought between early stage in pot and mature stage in field for tomatoes I'
Yildiz Dasgan

10:45-11:00 'Current situation of gourd germplasm against virus diseases in Turkey'
Hakan Fidan, Nihal Denli, Pelin K. Ozturk, Çetin Nacar, Halit Yetisir

11:00-11:30 Coffee Break/Poster viewing/Loading presentations

SESSION II:

WG 2 - ROOTSTOCK-SCION INTERACTIONS AND GRAFT COMPATIBILITY

Chair: *Dr. Jan Henk Venema. University of Groningen,The Netherlands.*

Rapporteur: *Dr. Ian C. Dodd. University of Lancaster, UK.*

11:30-13:00 Oral presentations

11:30-11:45 'Abscisic acid and cytokinin interaction in root-to-shoot communication to improve salt-tolerance in tomato'
G.B. Öztekin, A. Martínez-Pérez, A. Albacete-Moreno, F. Pérez-Alfocea and C. Martinez-Andújar

11:45-12:00 'Rootstock xylem and scion leaf hormone concentrations are positively correlated'
Alfonso Albacete, Ian C. Dodd and Francisco Pérez-Alfocea

12:00-12:15 'Identifying salt-, drought- and ABA-responsive genes in tomato roots'
Ferrández-Ayela, A., Dodd, I.C., Martínez-Andújar, C., Pérez-Alfocea, F., Pérez-Pérez, J.M.

12:15-12:30 'Oxidative stress associated with rootstock-scion interactions'
P. Irisarri, H.J. Martens, P. Errea and A. Pina

12:30-12:45 'Assessment of grafting compatibility between globe artichoke and cardoon by SEM analyses'
Trinchera A., Pandozy G., Crinò P., Rea E.

12:45-13:00 'Detection of the graft union with electric impedance measurements'
László Gáspár, Eszter Vozáry, Viktor Teráz, Viktória Bőhm, Noémi Kappel, Noémi Lukács

13:00-14:30 Lunch (Hotel Silken 7 Coronas)

SESSION III:

WG 3 - ROOTSTOCK-MEDIATED RESISTANCE TO BIOTIC AND ABIOTIC STRESSES

Chair: *Dr. Dietmar Schwarz. Institute of Vegetable and Ornamental Crops, Germany.*

Rapporteur: *Dr. Roni Cohen. ARO, NeweYa'ar Research Center, Israel.*

14:15-14:30 Loading presentations

14:30-16:00 Oral presentations

14:30-14:45 'The need for tailor-made cucurbita rootstocks: what can we learn from growing grafted melons in desert agriculture?'
R. Cohen, I. Gal, A. Koren, Pivonia, S., Edelstein, M.

14:45-15:00 'Reducing susceptibility of trellised cucumber and melon plants to cucumber green mottle mosaic virus by agro-technique means and grafting'
Amnon Koren, Victoria Reingold, Aviv Dombrovsky

15:00-15:15 'Unraveling the molecular basis of the resistance to plum pox virus induced by grafting from almond to peach'
Manuel Rubio, Luis Rodríguez-Moreno, Manuel Castro de Moura, Albert Mascarell-Creus, Claudio Bonghi, Federico Dicenta, Pedro Martínez-Gómez

15:15-15:30 'Effects of grafting and rootstock genotype on nutrient uptake by tomato'
D. Savvas, G.B. Oztekin, M. Tepecik, A. Papanikolaou, V. Katsiki, A. Ropokis, G. Ntatsi

15:30-15:45 'Influence of grafting and nitrogen on yield and aerial pests population in hydroponics tomato crop'
Katja Zanic, Gvozden Dumicic, Branimir Urlic, Smiljana Goreta Ban

15:45-16:00 'Grafting reduces the cadmium translocation from roots to shoots and fruits in tomato'
Pradeep Kumar, Menahem Edelstein, Mariateresa Cardarelli, Elvira Rea, Giuseppe Colla

16:00- 16:30 Coffee Break

16:30 – 18:00 Poster viewing (*Salón Gaya*)

16:30 – 18:30 MC meeting (see agenda)

19:00: Social event: Tour around the city of Murcia

Meeting point: Hotel Hall

3. WEDNESDAY 13TH NOVEMBER

SESSION IV:

WG 4 - ROOTSTOCK-MEDIATED IMPROVEMENT OF FRUIT QUALITY

Chair: *Dr. Cherubino Leonardi. University of Catania. Italy.*

Rapporteur: *Dr. Carmina Gisbert. UPV-COMAV, Valencia. Spain.*

8:45-9:00 Loading presentations

9:00-10:30 Oral presentations

9:00-9:15 'Effect of pruning system on yield and quality of greenhouse grafted tomato'
Isabel Mourão, Joana Teixeira, Luis Miguel Brito, Maria Elvira Ferreira, Maria Luisa Moura

9:15-9:30 'The contents of certain primary and secondary metabolites of grafted tomato fruits regarding to salinity stress and growing period'
Nina Kacjan Maršić, Bernarda Brajović, Dominik Vodnik

9:30-9:45 'Sensory analysis of grafted watermelon grown in different Hungarian regions'
David Fekete, Evelin Várvölgyi, József Felföldi, Attila Gere, Zoltán Kókai Viktória Bőhm, Gábor Balázs, Noémi Kappel

9:45-10:00 'Differential evolution of physicochemical and phytochemical fruit composition during ripening in grafted and non-grafted watermelon'
Marios C. Kyriacou and Georgios A. Soteriou

10:00-10:15 'Effects of grafting and modified atmosphere packaging (MAP) on melon and aubergine quality parameters during storage'
E. M. Khah, S. Petropoulos, I. S. Arvanitoyannis, F. Bletsos

10:15-10:30 'Quantitative and qualitative response of Sicilian eggplant ecotypes to grafting onto *Solanum torvum'*
L. Sabatino, G. Iapichino, F. D'Anna

10:30-11:30 Working Groups parallel meetings

11:30-12:00 Coffee Break/Poster viewing/Loading presentations

SESSION V:

VEGETABLE GRAFTING: ON GOING PROJECTS AND STATE OF THE ART FROM A COMMERCIAL POINT OF VIEW

Chair: *Dr. Giuseppe Colla, University of Tuscia, Italy.*

Rapporteur: *Dr. Dimitrios Savvas, University of Athens, Greece.*

12:00-12:45 Ongoing Projects

12:00-12:15 'Grafting in organic horticulture'
Martin Koller (from BioGreenhouse COST Action)

12:15-12:30 'Overview of USDA-funded project to advance grafting technologies in the U.S. fruiting vegetable industry'
Frank J. Louws

12:30-12:45 'The History, Current Status and Future of the Cucurbit Grafting in China'
Zhilong Bie

12:45-14:30 **Round Table**. 'State of the art from a commercial point of view'
Moderators: *Dr. Jan Henk Venema and Dr. Andrew Thompson*
Syngenta, Monsanto, Centro SEIA, Ramiro Arnedo,Rijk Zwaan,Nunhems. (10 min each followed by discussion).

14:30-16:00 Lunch (Hotel Silken 7 Coronas).

SESSION VI:
WORKSHOP ON PHENOTYPING, PHYSIOLOGY AND GENETICS OF ROOTSTOCK-MEDIATED TOLERANCE TO SOIL ABIOTIC STRESSES IN TOMATO

Chair: *Dr. Francisco Pérez Alfocea. CEBAS-CSIC, Spain*.

Rapporteur: *Dr. Ian C. Dodd. University of Lancaster, UK.*

15:45-16:00 Loading presentations

16:00-16:15 'Introduction to the EU-ROOTOPOWER project'
F. Pérez-Alfocea, Project Coordinator

16:15-16:30 **'**Screening a tomato mapping population for root resistance to soil impedance plus polymorphism discovery in parental genomes'
Andrew Thompson, on behalf of the EU-ROOTOPOWER Consortium

16:30-16:45 'Rootstock-mediated variation in tomato vegetative growth under moderate salinity'
Alfonso Albacete, on behalf of the EU-ROOTOPOWER Consortium

16:45-17:00 'Phenotyping and physiology of rootstock-mediated tolerance to drought in tomato'
Sevilay Topcu, on behalf of the EU-ROOTOPOWER Consortium

17:00-17:15 'Effects of nitrogen stress on a population of *Solanum* rootstocks'
F. Pérez-Alfocea, on behalf of the EU-ROOTOPOWER Consortium

17:15-17:45 Coffee Break/Poster viewing (Salón Gaya)

17:45-18:00 'Phenotyping and physiology of rootstock-mediated tolerance to soil low phosphorus stresses in tomato'
Juan M. Ruiz-Lozano, on behalf of the EU-ROOTOPOWER Consortium

18:00-18:15 'Phenotyping of tomato rootstocks under low potassium supply'
Cristina Martínez-Andújar, on behalf of the EU-ROOTOPOWER Consortium

18:15-18:30 'Root-to-shoot signalling of soil abiotic stresses'
Ian C. Dodd, on behalf of the EU-ROOTOPOWER Consortium

18:30-18:45 'Improving tomato for tolerance to multiple abiotic stress factors'
María José Asins, on behalf of the EU-ROOTOPOWER Consortium

18:45-19:00 Discussion

19:00-19:30 Main conclusions. Closing of the Meeting

Chair: Dr Giuseppe Colla
Vice-Chair: Dr Francisco Pérez-Alfocea

21:00 Conference dinner (Restaurante HISPANO, Calle Radio Murcia, 4)

4. THURSDAY 14TH NOVEMBER

SESSION VII:

TECHNICAL VISIT

7:30 Journey to *Motril, Granada* *(about 4 hours)*

11:30-14:00 Visit to *Cooperativa La Palma*
La Palma is the largest producer in the world of cherry tomatoes (30 million Kg) and other tomato specialties using grafted plants. Its main markets are those in UK, France, Germany and Spain. The visit includes a tour around its greenhouses, where grafting experiments facing local constraints will be shown, as well as one of the most modern processing and packaging plants.

14:00-15:30 Lunch

15:30 Journey to *El Ejido (Almeria)*

17:00-18:30 Visit to the seed company *Ramiro Arnedo Research Station*

Back to Murcia

ABSTRACTS OF ORAL COMMUNICATIONS AND POSTERS

1st Annual Conference COST ACTION FA 1204 ROOTOPOWER Workshop

"Exploiting root-to-shoot communication for improving yield stability and fruit quality in vegetable crops"

SECTION I
WORKING GROUP 1

"Genetic Resources and Rootstock Breeding"

ORAL COMMUNICATIONS

I.1. UNDERSTANDING THE GENETIC BASIS OF ROOT TRAIT VARIATION IN TOMATO

Andrew J. Thompson[1]

My research aim is to understand the genetic control of root traits in *Solanum* and to identify molecular markers for breeding cultivars that are productive with lower water inputs. Using a soil-based rhizotron assay, a geotextile-based root penetration assay, and a hydroponic system, we have screened the publicly-available *Solanum lycopersicum* (M82) x *Solanum pennellii* (LA716) population of introgressions lines. QTLs for root:shoot ratio, vertical root distribution and ability to penetrate geotextiles were found and these are now subject to detailed study. I am mapping monogenic root mutants and progress with bushy root (*brt*) is the most advanced.

In transgenic experiments we have produced tomato plants in which the rate of abscisic acid (ABA) biosynthesis is increased in root tissues by the over-expression of single or multiple genes encoding rate limiting enzymes. By this approach we have developed root genotypes that are able to reduce transpiration in the scion, and that improve fruit production under root-zone stress. A major effect of engineering increased ABA biosynthesis in roots is to triple root hydraulic conductivity, and the importance of this trait for water capture will be discussed. We have also identified a tomato root-specific promoter for use in further manipulations of root-to-shoot signalling.

[1] Cranfield Soil and AgriFood Institute, School of Applied Sciences, Cranfield University, United Kingdom. E-mail: a.j.thompson@cranfield.ac.uk

I.2. HORTICULTURAL AND PHYTOPATHOLOGICAL EVALUATION OF EXOTIC WATERMELON GERMPLASM AS A SOURCE FOR ROOTSTOCK BREEDING

Edelstein, M.[1] Cohen, R. Tyutyunik, J. Tadmor, K. Falik, E.

Most of the watermelons grown in the Mediterranean basin are grafted, mainly on *Cucurbita* rootstocks which provide efficient protection against a wide range of soilborne pathogens. In certain cases, however, grafting may cause a reduction in fruit-quality, including hard fruit flesh with white fibers, changes in fruit size and fruit deformation. Grafting watermelon on watermelon rootstocks may eliminate the fruit-quality issues resulting from the use of *Cucurbita* rootstocks. Twenty-one exotic watermelon accessions were evaluated as potential sources for watermelon rootstocks. No difference was found in the total fruit yield and fruit quality index between non-grafted 'Extazy' fruit and 'Extazy' fruit from plants grafted on the different watermelon accessions. However when 'Extazy' was grafted onto *Cucurbita* rootstock, fruit rind was thicker, white fibrous flesh was observed, and the flesh of the grafted fruits was harder than non-grafted and self-grafted 'Extazy'. No bitter flavor and no cucurbitacin were present in 'Extazy' fruits of plants grafted on bitter fruit watermelon accessions. The response of the accessions to several diseases such as Fusarium wilt, Fusarium crown rot, nematodes, *Macrophomina* and *Monosporascus* was evaluated. Some accessions exhibited resistance indicating the possibility of breeding resistant watermelon rootstocks without negative effect on fruit quality.

[1] Department of Vegetable Crops, Agricultural Research Organization, Newe Ya'ar Research Center. Israel. E-mail: medelst@volcani.agri.gov.il

I.3. BIOTECHNOLOGY FOR ROOTSTOCKS MICRO-PROPAGATION AND BREEDING

C. Gisbert[1], J.M. Mulet[2], J. Prohens[1], R. Serrano[2], B. Picó[1]

Advances in our understanding of plant genomes increase the possibilities for biotechnological breeding. However, the high influence of genotype in the regeneration capacity and recalcitrance to regeneration and/or transformation make necessary the development of specific protocols for the genotypes of interest. In our laboratory we have developed protocols for *in vitro* culture and micropropagation of different rootstocks useful for grafting eggplant and plants of Cucurbitaceae family. In addition, we have developed protocols for genetic transformation, introducing the *BvSAT* gene into *Solanum torvum* and *Cucurbita moschata* genotypes. The former is commonly used as eggplant rootstock and the latter is very useful for its resistance to several viruses and fungi and for its vigorous root system. The *BvSAT* gene codifies a serine acetyl transferase, one of the enzymes responsible of the biosynthesis of the essential aminoacids cysteine and methionine and has been related to abiotic stress tolerance. Evaluation of these materials is underway.

This work has been funded by Universitat Politècnica de València (PAID 05-10)

[1] Instituto de Conservación y Mejora de la Agrodiversidad Valenciana (COMAV), Universitat Politècnica de València (UPV), Valencia, Spain. E-mail: cgisbert@btc.upv.es

[2] Instituto de Biología Molecular y Celular de Plantas (IBMCP), UPV, Valencia, Spain.

I.4. POTENTIAL NEW *Cucurbita* SPP ROOTSTOCKS WITH VIRAL AND FUNGAL RESISTANCE

G.H.S. Nunes[1], E.W.L.P. Nunes[1], M. Ferriol[2], A. Alfaro-Fernández [2] I. Font[2], C. Gisbert [3], B. Pico[3]

Grafting cultivars onto resistant rootstocks is an effective strategy to manage soilborne diseases in cucurbits. Improved resistance to some foliar diseases has also been reported in grafted plants. There is increasing evidence that systemic defense mechanisms play an important role in plant defense as a result of grafting. *Cucurbita* rootstocks are frequently used to graft watermelons (*Citrullus*), melons or cucumbers (*Cucumis*) as they develop vigorous roots and are usually non-host of soilborne pathogens such as *Fusarium* spp, *M. cannonballus* and nematodes. However, the genus *Cucurbita* includes many species that have not been tested as rootstocks. Some of them are promising sources of viruses and fugal resistance. We have tested some *Cucurbita* germplasm against a set of viruses and fungus. The most interesting are some *C. moschata* cultivars and some *C. ecuadorensis*, *C. okeechobeensis,* and *C. lundelliana* accessions that are multiresistant to the main potyviruses affecting cucurbits, ZYMV, WMV and PRSV, and also to the aerial fungal causal agent of powdery mildew *(Podosphaera xanthii). They have also* vigorous root systems and are resistant to soilborne pathogens. Despite grafting is used primarily for controlling soilborne diseases, the use of these multiresistant genotypes might contribute to improve crop resistance to foliar diseases.

This work has been supported by INIA project RTA2011-00044-C02-02 and cofunded with FEDER funds.

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[2] Instituto Agroforestal Mediterráneo (IAM-UPV) Universitat Politècnica de València, Valencia, Spain.

[3] Instituto de Conservación y Mejora de la Agrodiversidad (COMAV-UPV) Universitat Politècnica de València, Spain. E-mail: mpicosi@btc.upv.es

I.5. COMPARISON OF THE PHYSIOLOGICAL PARAMETERS OF DROUGHT BETWEEN EARLY STAGE IN POT AND MATURE STAGE IN FIELD FOR TOMATOES

H. Yildiz Dasgan[1]

Tomato research was carried out in order to investigate the relationships of drought physiological responses of the tomato plants between young and mature stages. Forty-five days old tomato plant grown in pot and 122 days old tomato plants grown in open field under the drought stress were compared for some physiological parameters. Twenty-four different tomato genotypes, mainly local materials were used. The physiological parameters investigated were stomatal conductance, membrane injury index, leaf water potential, leaf osmotic potential, leaf temperature, leaf Ca and K concentrations, shoot fresh weight and visual shoot appetence by the 1-5 scale evaluation subjectively. Two degrees of the drought stress; intermediate and severe, were applied to the tomato plants. In the intermediate stress, the irrigation was 50 % of control plants, and in the severe stress the irrigation was 25% of the control plants. For the parameters, the rates of change in the stressed plants compared to their controls without stress were calculated. The main results of the tomato research were 1) 50% irrigation was better than 25% irrigation in order to distinguish tomato genotypes according to their stress responses, 2) the calculated figures by the stressed plants compared to their controls were definitely better than absolute figures for the higher relationships between the early and mature stages, 3) the most important three physiological parameters determined in tomatos between early stage in pot and mature stage in field were ranked as "1st Leaf calcium (Ca) concentration (r = 0,573)", "2nd Membrane injury index (r = 0,528)" and "3rd Stomatal conductance (r = ,475)". The Leaf osmotic potential was the least important parameter or showed the insignificant relationship between the early plant stage in pot and mature stage in field. These relationships will be useful to shorten the drought breeding process and the tomato genotype that have high resistant to drought will be good rootstock breeding materials for future works.

[1] Department of Horticulture, Faculty of Agriculture, Cukurova University, Adana,Turkey. E-mail: dasgan@cu.edu.tr or ydasgan@gmail.com

I.6. CURRENT SITUATION OF GOURD GERMPLASM AGAINST TO VIRUS DISEASES IN TURKEY

Hakan Fidan[1], Nihal Denli[2], Pelin K. Ozturk[1], Çetin Nacar[2], Halit Yetisir[3]

Grafted watermelon production on different gourd rootstocks has become widespread in major watermelon production areas of Turkey. *Zuccini Yellow Mosaic Virus* (ZYMV) is one of the most damaging virus diseases in cucurbitaceous plants. Seed-transmission of ZYMV in gourd makes it more remarkable virus disease. Therefore ZYMV resistance sources should be added to rootstock breeding programs in gourd. In this paper we aimed to screen our gourd genotypes for ZYMV. We screened our gourd germplasm included 340 accessions for major virus diseases infections. The results showed that 188 genotypes (55%) were found to be infected by ZYMV, 71 genotypes (21%) by *Watermelon Mosaic Virus* (WMV) 40 genotype (12%) by *Cucumber Mosaic Virus* (CMV) single or mix infection and the rest was virus-free. Then seeds were collected from ZYMV infected plants. Seeds were sown and seedlings were tested serologically and RT-PCR techniques for ZYMV, WMV and CMV. We observed that ZYMV was transmitted by seeds in 3.19 % of the infected genotypes As a result of the observations; we have convinced that some of the gourd lines should be tolerant against to ZYMV

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[2] Alata Horticultural Research Station, Erdemli-Mersin, Turkey.

[3] Erciyes University, Faculty of Agriculture, Department of Horticulture, Kayseri, Turkey.

SECTION I
WORKING GROUP 1

"Genetic Resources and Rootstock Breeding"

POSTERS

PI.1. COLLECTION OF TURKISH BOTTLE GOURD (*Lagenaria siceraria* L.) GERMPLASM AND FORMATION OF CORE COLLECTION BASED ON MORPHOLOGICAL CHARACTERISTICS

Halit Yetişir[1]*, Nihal Denli[2], Adem Taş[1], Kahraman Gürcan[3]

In this study, bottle gourds [*Legenaria siceraria* (Malign) Stanley] genotypes were collected from different part of Turkey and core collection was established based on morphological characteristics. In collection studies, 380 bottle gourd genotypes were collected under frame work of two different projects from 2003 to 2011from different region of Turkey. Additional 38 bottle gourd genotypes were introduced from international genbanks. The collected bottle gourds were grown for morphological characterization and seed multiplication in Alata Horticultural Research Station of Ministry of Food, Agriculture and Livestock in Erdemli-Mersin in 2012. Seeds were produced in 324 genotypes by selfing and the genotypes were morphologically (25 quantitative and 30 qualitative traits) characterized from seedling stage to seed stage. Significant morphological variation was determined in Turkish bottle gourd germplasm with respect to morphological traits. Important variation was recorded in morphological traits such as fruit size, fruit length (5 - 175 cm), fruit shape (flat-elongate), seed size (3,8 g/100 seeds - 38 g/100 seeds) among accessions. Principle component analysis was done and grouping was recorded. However, among the studied accessions, no apparently distinct patterns such as geographical origin were detected. This may suggest that the accessions have been introduced to Turkey from multiple locations and/or their diversity had been distributed almost evenly across the Turkey. Based on our results from the morphological characterization, 100 genotypes were selected to develop a core collection in order to represent most of the genetic diversity of all accessions.

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[2] Alata Horticultural Research Station, Ministry of Food, Agriculture and Livestock Mersin, Turkey.

[3] Department of Biotechnology, Faculty of Agriculture, University of Erciyes, Kayseri, Turkey.

PI.2. USING OF TOMATO GENETIC RESOURCES OF LATVIAN ORIGIN AS ROOTSTOCKS

Līga Lepse[1]

Investigation on grafting of local tomatoes by using local genotypes as rootstocks was performed during the vegetation period of 2013 in unheated plastic tunnels. The objective of the investigation was to evaluate the grafting influence on the tomato yield and quality by using local genotypes (`Cēsu agrais`, `Jūrmala` and `Vidzemes karalis`) as rootstocks. `Rally`, `Pedro`, Cēsu agrais`, `Vidzemes Karalis` and `Jūrmala` were used as scions. Three types of grafting were used: Approach graft, Tongue and Cleft grafting. For Approach and Tongue grafting root systems of both plants used in grafting were left for each plant. All genotypes were grown also on their own root with and without grafting, as well. Investigation was set out as preliminary investigation without replications. Therefore results are indicative. Preliminary results show slight increasing of the yield for grafted tomatoes in comparison to ungrafted for some varieties. Some indications of increased yield are stated for varieties `Rally` (for 10%) and `Pedro` (for 9%) grafted on `Jūrmala` by Cleft grafting and for `Jūrmala` grafted on `Vidzemes karalis` (for 5%) by using Tongue grafting. Further investigations are necessary to clarify the usefulness of grafting for unheated plastic tunnels in Latvia. Other genotypes need to be tested as rootstocks as well.

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PI.3. COMPARISON OF THE PHYSIOLOGICAL PARAMETERS OF DROUGHT BETWEEN EARLY STAGE IN POT AND MATURE STAGE IN FIELD FOR MELONS

H. Yildiz Dasgan[1]

Melon research was carried out in order to investigate the relationships of drought physiological responses of the melon plants between young and mature stages. Twenty-nine days old melon plants grown in pot and 113 days old melon plants grown in field under the drought stress were compared for some physiological parameters. Twenty-nine different melon genotypes, mainly local materials were used. The physiological parameters investigated were stomatal conductance, membrane injury index, leaf water potential, leaf osmotic potential, leaf temperature, leaf Ca and K concentrations, shoot fresh weight and visual shoot appetence by the 1-5 scale evaluation subjectively. Two degrees of the drought stress; intermediate and severe, were applied. In the intermediate stress, the irrigation was 50 % of control plants, and in the severe stress the irrigation was zero of the control plants. For the parameters, the rates of change in the stressed plants compared to their controls without stress were calculated. The main results of the melon research were 1) zero irrigation was better than 50% irrigation in order to distinguish melon genotypes according to their stress responses, 2) the calculated figures by the stressed plants compared to their controls were definitely better than absolute figures for the higher relationships between the early and mature stages, 3) the most important three physiological parameters determined in melons between early stage in pot and mature stage in field were ranked as "1st Stomatal conductance (r = 0,504)", "2nd Leaf water potential (r = 0,491)" and "3rd Leaf temperature (r = 0,319)". The Leaf osmotic potential was the least important parameter or showed the insignificant relationship between the early plant stage in pot and mature stage in field. These relationships will be useful to shorten the drought breeding process and the melon genotype that have high resistant to drought will be good rootstock breeding materials for future works.

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PI.4. SELECTING TOMATO ROOTSTOCK FROM THREE DIFFERENT RIL POPULATIONS FOR HIGH VIGOUR UNDER LOW POTASSIUM CONDITIONS

Cristina Martínez-Andújar[1], Alfonso Albacete Moreno[1], Ascensión Martínez-Pérez[1], María J. Asins[2] and Francisco Pérez-Alfocea[1].

On behalf of the ROOTOPOWER Consortium

Even though grafting provides a rapid and direct tool to transfer rootstock abiotic stress tolerance to commercial sensitive varieties, the potential existing in the wild species germplasm has been only little explored. Potassium (K^+) deficiency is a widespread problem in some soils, leading to a damage of physiological processes and thus a reduction in crop yield. With the aim to select rootstock conferring tolerance to K^+ deprivation, a commercial tomato cultivar (Boludo F1, Monsanto) was grafted onto 144 different introgressed lines populations as rootstocks derived from the following crosses: *Solanum lycopersicum* (cv cerasiforme E9) x *S. pimpinellifolium* (acc. L5), segregated for salinity resistance (P1, from IVIA), *S. lycopersicum* (CLN2498E) x *S. pimpinellifolium* (LA1579), selected for drought tolerance (P2, from AVRDC), and *S. lycopersicum* (cv M82) x *S. pennellii* (acc. LA716), selected for high root/shoot ratio (P3, from TGRC). Grafted plants were cultivated under commercial greenhouse conditions and irrigated with a half-strength Hoagland solution containing 6 (control) or 1 mM of K^+ (low K^+). Shoot fresh weight (FW) was determined for each graft combination and the 5 best high vigour lines for both control and low K^+ conditions of each population were selected for statistical study and compared with the commercial cultivar nongrafted (Boludo NG). The results have shown that the vigour of Boludo NG grown under low K^+ decreased (22%) in comparison with control conditions. In contrast, the vigour of selected RILS was either increased (P1) or maintained under K^+ deprivation (P2 and P3). After evaluating the performance of selected lines for control conditions from each population under low K^+, differences in FW among the 3 populations and Boludo NG were not observed and no FW correlation was found between the two different conditions, suggesting that this selection for high vigour under optimal conditions does not seem to be appropriate under K^+ deprivation. Hormonal and ionomic analyses are currently being performed in order to explain if the rootstook-mediated improvement observed under normal and low K^+ fertilization is conserved across different germplasm tomato sources.

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PI.5. NEW *CUCUMIS* SPP. RESOURCES FOR GRAFTING MELONS

Picó, B.[1]; Esteras, C.[1]; Martinez, E.[1]; Munera, M.[2]; Giné, A.[2]; Sorribas, F.J.[2]; Gisbert, C[1].

Cucumis melo is an economically important crop. Different types of soil stresses hamper melon cultivation. Grafting melons onto resistant rootstocks can overcome this limitation. Different cucurbits such as *Cucurbita, Lagenaria, Luffa*, etc. have been successfully used to avoid soil stress in melon crops. However, grafting melons onto different species affects melon quality. Fruit quality alterations could be diminished by using rootstocks more genetically closer to the melon scions. We are searching for new melon rootstocks within a collection of 200 *C. melo* and *Cucumis* spp genotypes. We are screening this collection against the main melon soil pathogens. Some genotypes show resistance to soilborne pathogens and are promising rootstocks. For example, some *C. melo* accessions belonging to the subspecies *agrestis* (Far Eastern *conomon* and African *agrestis* types) display some levels of tolerance to *Fusarium oxysporum* f sp. *melonis* race 1.2 and they are also resistant to *Monosporacus cannonballus*, the causal agent of melon vine decline. A similar multi resistant behaviour has been detected in *Cucumis metuliferus*, which is highly tolerant to *Fusarium* 1.2 and has been proved to be resistant to root-knot nematodes. The grafting compatibility of these selected genotypes with commercial melons is being tested.

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SECTION II
WORKING GROUP 2

"Rootstock-Scion Interactions and Graft Compatibility"

ORAL COMMUNICATIONS

II.1. ABSISIC ACID AND CYTOKININ INTERACTION IN ROOT-TO-SHOOT COMMUNICATION TO IMPROVE SALT-TOLERANCE IN TOMATO

G.B. Öztekin[1], A. Martínez-Pérez[2], A. Albacete-Moreno[2], F. Pérez-Alfocea[1] and C. Martínez-Andújar[1]

The aim of this study was to understand the rootstock-scion hormonal interactions in the response to salinity in tomato plants. The functional experimental approach was to modify both cytokinin (CKs) and abscisic acid (ABA) concentrations in the domestic tomato. Wild-type tomato seedlings (Ailsa Craig and UC82) and transgenic lines (overexpressing the *IPT* - for CKs- , and *NCED* - for ABA- genes) were self-grafted, and reciprocal grafting between these four lines was performed. Grafted plants were transferred into a growth chamber and hydroponic system used as a cultivation technique. Plants were grown 28 days in a growth chamber. After one week acclimation in control conditions, the seedlings were exposed to 0 (control) or 100 mM NaCl added to the nutrient solution. In this study leaf number, leaf area, stem height and rootstock and scion stem diameter, photosynthesis and stomatal conductance, plant biomass, total root length, chlorophyll fluorescence, xylem sap flow were measured. Meanwhile, leaf and root sugar contents, xylem sap and leaf ions and hormones and enzymatic activity associated with carbon metabolism were determined. Preliminary results have shown a positive effect of the ABA-overproducing rootstocks under salinity. However, the biomass of the reciprocal grafted plants between *NCED* and *IPT* lines decreased respect to the control ones, suggesting a negative effect of ABA-CK interaction on grafted tomato plant growing under salinity.

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II.2. ROOTSTOCK XYLEM AND SCION LEAF HORMONE CONCENTRATIONS ARE POSITIVELY CORRELATED

Alfonso Albacete[1], Ian C. Dodd[2] and Francisco Pérez-Alfocea[1]

Simultaneous multi-analyte techniques for phytohormone quantification allow comprehensive analysis of changes in plant hormone status induced by different rootstocks. This work assessed correlations between hormone concentrations in rootstock xylem sap (collected by root pressure), leaf (scion) xylem sap (collected by detaching a leaf, placing in Scholander pressure chamber, and applying an overpressure) and leaf (scion) extracts Tomato plants (*Solanum lycopersicum* L. cv. Ailsa Craig) self-grafted and grafted on two ABA-overproducing tomato genotypes (SP5 and SP12 rootstocks), were grown hydroponically in a controlled growth chamber under optimal conditions. Major class of phytohormones: cytokinins (*t*-Z, *t*-ZR), auxins (IAA), abscisic acid (ABA), gibberellins (GA1, GA3, GA4), jasmonic acid (JA), salicylic acid (SA) and the ethylene precursor (ACC) were measured according to Albacete et al., (2008, 2009), using a U-HPLC-MS system. Total hormone concentrations in root xylem sap were positively correlated with both leaf xylem sap (r = 0.5408, $P \leq 0.001$) and leaf extracts (r = 0.3103, $P \leq 0.001$). To highlight their relative importance in the correlation, hormones were grouped in chemically-related clusters. Root and leaf xylem sap concentrations were positively correlated for both basic hormones (*t*-Z and *t*-ZR, $r = 0.661$; $P \leq 0.05$) and weak acids (IAA, ABA, JA, SA and ACC, $r = 0.526$, $P \leq 0.01$). However, root xylem sap and leaf extract concentrations were positively correlated for the basic hormones (r = 0.818, $P \leq 0.001$) but not for weak acids and gibberellins. Since xylem sap requires less preparation (filtration) before injection into the U-HPLC-MS system than leaf samples (multi-stage solvent extraction and purification), collecting xylem sap represents a less time-consuming way to determine rootstock impacts on scion hormone status.

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II.3. IDENTIFYING SALT-, DROUGHT- AND ABA-RESPONSIVE GENES IN TOMATO ROOTS

Ferrández-Ayela, A.[1], Dodd, I.C.[2], Martínez-Andújar, C.[3], Pérez-Alfocea, F.[3], Pérez-Pérez, J.M.[1]

We aimed to identify specific and novel signal transduction components regulating stress responses in tomato roots by a combination of *in silico* approaches using available expression data and mutant analysis (1). On the one hand, 17 tomato genes were chosen on the basis of the salt-responsiveness of their ortholog genes identified in distinct plant species. On the other hand, 22 genes were identified from tomato microarray experiments and whose expression was reported to be specifically modified by drought and salt stresses. We next validated their expression by quantitative RT-PCR in roots from *in vitro* grown Ailsa craig wild-type and *flacca* ABA deficient mutant plants exposed to moderate salinity (75 or 125 mM NaCl) or ABA (1 μM). The expression of 13 of the studied genes was significantly affected by both treatments, while the expression of 9 and 9 genes was specifically affected by salt and ABA treatment, respectively, suggesting both common and divergent signaling transduction pathways.

Additionally, we tested whether the expression of 15 tomato genes putatively involved in root architecture and hormone signaling was affected by salt and ABA. Our gene expression platform is being used in the EU ROOTOPOWER project to characterize whether root gene expression in response to drought or salt stress is regulated by local or systemic signaling, using reciprocal grafts of wild-type and ABA-deficient mutants.

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II.4. OXIDATIVE STRESS ASSOCIATED WITH ROOTSTOCK-SCION INTERACTIONS

P. Irisarri[1], H.J. Martens[2], P. Errea[3] and A. Pina[4]

Reactive oxygen species (ROS) production may occur in plant response to abiotic and biotic stresses. A failure in the redox system leads to an increase of ROS levels, which are harmful to essential biological processes. To mitigate and *repair* damage initiated by ROS, some species have developed antioxidant protection mechanisms including antioxidant enzymes such as: superoxide dismutase (SOD), catalase (CAT) and ascorbate peroxidase (APX). Recently, it has been found that oxidative stress could trigger cell and tissue degradation processes in incompatible grafts. The main goal of this study was the identification of putative SOD, CAT and APX gene sequences *in fruit trees* using *publicly available plant genome databases*. The gene expression and activity of these enzymes along with *in vivo* ROS detection were also examined in different graft combinations (compatible and incompatible) from pear (*Pyrus communis L.*) and quince (*Cydonia oblonga* Mill. clon BA29) several days after grafting. Interestingly, we observed no correlation between enzyme activity and enzymatic gene expression for APX and CAT. Hence, it is expected that some posttranscriptional mechanisms are playing an important role in this biological process. ROS levels were slightly higher in the incompatible combinations compared to the compatible ones.

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II.5. ASSESSMENT OF GRAFTING COMPATIBILITY BETWEEN GLOBE ARTICHOKE AND CARDOON BY SEM ANALYSIS

Trinchera A.[1], Pandozy G.[2], Crinò P.[2], Rea E.[1]

In the present work, globe artichoke scions (GA) were grafted onto wild (WC) or cultivated cardoon (CC) rootstocks, and their grafting compatibility were assessed by studying tissue development on grafting point by electron scanning microscopy (SEM). The choice of the cardoon rootstocks was based on their potential for tolerating verticillium wilt and the used grafting technique was the cleft method. Two grafting experiments were performed: in autumn and in spring periods. After 3, 6, 9, 12, 17, 20 and 23 days from grafting, the structural development of globe artichoke/cardoon union formation was observed by SEM (EVO-MA LS, Zeiss) at variable pressure conditions.

High affinity between globe artichoke scion and cardoon rootstock was found: in particular, wild cardoon showed the highest compatibility with globe artichoke, being some genotype differences mainly associated with healing time between the two bionts. SEM images of scions/rootstocks longitudinal section showed, just after three days from grafting, an appearance of many plasmodesmal complexes between the two graft components, followed by a vascular rearrangement and a callus development during graft union formation. A seasonal effect was noticed within the two grafting experiments.

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II.6. DETECTION OF THE GRAFT UNION WITH ELECTRIC IMPEDANCE MEASUREMENTS

László Gáspár[1], Eszter Vozáry[2], Viktor Teráz[1], Viktória Bőhm[3], Noémi Kappel[3], Noémi Lukács[1]

The aim of the study was to follow the grafting of cucumber (cv. Szatmár, ZKI) with electrical impedance measurements to evaluate the method for the assessment of the graft union process.

Plants were grown in controlled environment (150/0 µmol s^{-1} m^{-2}, 25/20°C, 70/70% RH) on a mixture of peat and perlite. Ten-day-old plants were used as rootstock and scion for grafting by the one cotyledon method. Grafted plants were kept at 50/0 µmol s^{-1} m^{-2}, 30/30°C, 90/90% RH. Measurements were done on 40 mm long cut segments of the hypocotil of non-grafted plants (NG) and on segments containing the graft union area in self-grafted plants (SG) 3 to 7 days after grafting.

The magnitude (Z) and phase angle (φ) of electrical impedance of stem were measured at 1 V in a frequency range from 30 Hz to 1 MHz and from 75 kHz up to 20 MHz with HP 4284A and HP 4285A precision LCR meters, respectively. The stem was punctured with two pin electrodes.

Three days after grafting rootstock and scion seemingly developed hydraulic contact. Comparing electric impedance spectra of these plants to NG controls we observed clear differences: the phase angle band shifted to higher frequency and the impedance magnitude decreased for SG stems compared to the NG ones.

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SECTION II
WORKING GROUP 2

"Rootstock-Scion Interactions and Graft Compatibility"

POSTERS

PII.1. USE OF ROOTSTOCKS AND ASSOCIATED PROBLEMS IN TURKEY'S VITICULTURE

Semih Tangolar[1], Serpil Tangolar[1], Sevilay Topçu[2]

Viticulture in Turkey dates back to 4000 years B.C. due to the country's suitable geographic and climatic conditions. While grafting vines as a means of propagation was known as early as the 2nd century B.C., the use of rootstocks in Vitis genus, however, was not extensively used until 1880 in the world. Now much of the world's including the Turkish viticulture is based primarily on grafting, where the scion is a cultivar of *Vitis vinifera* and the rootstock is an interspecific Vitis hybrid or the like. The major reason to use rootstocks is in their resistance to some severe biotic problems such as phylloxera and nematodes.

Studies were conducted using phylloxera-resistant rootstocks such as Rupestris du Lot, 1103 P, 140 Ru, 110 R, 99 R, 8 B, 5 BB, SO4, 420 A, 161-49 C, Fercal, 41 B and nematode-resistant Salt Creek, Dogridge, Harmony, 1613 C and 1616 C in several research institutes and universities in Turkey. These experiments were focused on determining the affinity levels of different domestic and foreign table, raisin, juice and wine grape varieties. Suitability of rootstocks for the grafted or non-grafted vine sapling production was investigated also in vivo and in vitro conditions. This presentation gives detailed information on the above-mentioned grafting research in Turkey, emphasizing the associated constraints and limitations when using a wide range of rootstocks.

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PII.2. IDENTIFICATION OF BIOMARKERS FOR THE SELECTION OF ROBUST TOMATO ROOTSTOCKS

Jan Henk Venema[1], Robert Berkelmans[2], Leen A. Villerius, Tatsiana Charnikhova[3], Harro J. Bouwmeester[3], J. Theo M. Elzenga[1]

Breeding rootstocks for abiotic stress tolerance and nutrient-use efficiency is hampered by the lack of practical selection tools like genetic markers. This project, therefore, aims to identify the key-physiological characteristics that reflect the complex underlying genetic make-up of desired root-derived traits. The generated knowledge will be used to develop a screening method which supports the selection of vigorous robust rootstocks. During this project a set of inter-specific tomato hybrids with different vigour and cold tolerance was produced. These hybrids were used as rootstocks and grafted with tomato cv. 'Cappricia' as scion, and two commercial rootstocks, 'Maxifort' and 'Big Power', were used as control references. All rootstocks contained comparable resistances. These graft combinations were grown by an organic grower (BioVerbeek B.V., Velden, The Netherlands) in a glasshouse from February until November 2012. No significant differences in total yield, total fruit number or overall average fruit weight were observed between rootstocks. Instead, the more vigorous rootstocks produced a significantly higher number and total weight of side shoots. This trial indicates that in Dutch organic growing systems there may not be an advantage to use an expensive vigorous rootstock bred to maximise yield. Rather rootstocks can be selected that have strong (a)biotic stress resistances in combination with less excessive side shoot formation. In a subsequent trial in 2013, the same rootstock set was compared under more generative growth conditions in Southern France. In both trials hormonal profiling of young leaves was performed to identify the underlying physiological basis of differences in rootstock-scion performance.

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PII.3. CUCUMBER SCION RESPONSE TO DIFFERENT CUCURBIT ROOTSTOCKS – YIELD, FRUIT QUALITY AND BIOTIC STRESS

N. Velkov[1], R. Rodeva[2], G. Pevicharova[1], St. Masheva[1], V. Petkova[1], V. Yankova[1], D. Markova[1], E. Topalova[1]

The aim of present investigation was to evaluate the effect of cucumber grafting on yield, fruit quality and response to biotic stress. Three long parthenocarpic cucumber cultivars were grafted on five cucurbits rootstocks – *Cucurbita maxima, C. moschata, C. maxima x C. moschata F1, Lagenaria siceraria* and *Luffa cylindrica*. The yield and elements of the productivity were recorded for each grafting combination. The results showed that the used rootstock had stronger effect on yield than scion. The effect of rootstock on fruit quality was studied applying sensory analysis. Plants could be divided in three groups of similarity. The plants grafted on interspecies hybrid *C. maxima x C. moschata* F_1 possessing similar sensory properties of fruits with non grafted plants (control) formed the first group. The plants grafted on *C. maxima* and *C. moschata* made the second group. The plants grafted on *Lagenaria* and *Luffa* constituted the third group. Tested rootstocks reacted specifically depending on pests. Rootstocks of *L. siceraria*, *C. maxima* and *C. maxima x C. moschata* F_1 expressed the lowest level of infection to nematode (*Meloidogyne* spp.), *Fusarium* spp. and *Pythium* spp. Based on the comprehensive characterization the hybrid combination *C. maxima x C. moschata* F_1 could be pointed out as the most promising rootstock for further research on cucumber grafting.

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PII.4. STUDY OF POSSIBILITIES TO USE DIFFERENT *Solanum* SPECIES AS ROOTSTOCK FOR EGGPLANT IN VIEW OF ALTERNATIVE APPROACHES FOR CONTROL VERTICILLIUM WILT

François Villeneuve[1], Patricia Erard[2], François Latour[1], Théophile Théry[1], Christine Fournier[2], Marie-Christine Daunay[3]

In France, the eggplant cultures (*Solanummelongena*) are mainly grafted on tomato rootstocks (interspecific hybrids *S. lycopersicum* x *S. habrochaites* (*L. hirsutum*)) for the management of soilborne diseases, especially *Verticillium dahliae*(*Ve*-resistant tomato rootstocks). But a survey in fields (more than 50 samples for eggplants) shows the prevalence of vascular wilt fungi, *Verticillium* sp. on eggplant, whatever susceptible or resistant rootstocks or cultivars. Frequently these vascular fungi are associated to other bioagressors: the most frequent ones being *Colletotrichumcoccodes*, *Pythium* sp., *Macrophominaphaseolina*, *Rhizoctonia solani*, *Didymellabryoniae.* Nematodes were also often found, especially *Meloidogyne* sp. All these additional pathogens or pests are aggravating factors. On the other hand, in absence of chemical control, the low levels of resistance to *Verticillium* in eggplant germplasm and the difficulties to manage *Verticillium* with alternative techniques, one solution is to see the possibilities of utilization of *Solanum* spp. as rootstock. Two steps is necessary, first to know the grafting compatibility between eggplant and *Solamum*, and secondary to have an idea of the comportment of *Solamum* sp. regarding *Verticillium* sp.
In three years, we have examined the grafting compatibility of 64 accessions, mainly *Solanum* spp. from different section lake *Acanthophora, Androceras, Lasiocarp, Basarthrum… a*(see table below).In the first stage, the compatibility and the growth in compare with three controls: eggplant cvMonarca don't graft, Monarca graft himself and Monarca graft on Maxifort tomato rootstock. In a second stage, the best combinations where test for the agronomic performances.

	Solanum sp.	*Capsicum*	*Cypho-mandra*	*Lycianthes*	*Nicandra*	*Nicotiana*	*Physalis*	*Withania*
2011	15	2	1	1				
2012	17				1	2	2	
2013	22							1
	54	2	1	1	1	2	2	1

Globally, the accessions too distant of *S. melongena*don't present a good affinity. And some accessions seem to have a good comportment for example: *S. viarum*, *S. violaceum, S. torvum*. In a preliminary trial, some of these species present a good comportment regarding Verticillium wilt race 1 and race 2.

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PII.5. BOTH SCION AND ROOTSTOCK ALTER ROOT XYLEM SAP ABSCISIC ACID (ABA) CONCENTRATION

Francisco García-Sanchez[1] and Ian C. Dodd [2]

When xylem sap is collected from grafted plants by excising the shoot and allowing its spontaneous exudation under root pressure, it is uncertain whether rootstock-mediation variation in the concentrations of xylem sap constituents is real, or an artefact of differing sap flow rates (since faster sap flow rates dilute constituent concentrations). To determine the impact of sap flow rate on xylem ABA concentrations, self- and reciprocally-grafted wild-type (WT) and ABA deficient *flacca* (*flc*) tomato plants were grown in soil columns that could be placed in a pressure chamber, allowing sap flow rate to be varied to match *in vivo* transpirational flow rate. Although root exudation yielded sap flow rates only 5-7% of *in vivo* transpiration, the relative impacts of the different graft combinations on sap flow were similar. Also, the relative effects of the different graft combinations on root xylem sap ABA concentrations were similar, even though root xylem sap ABA concentrations were (on average) 4.5-fold higher in sap collected via spontaneous root exudation. Surprisingly, graft combinations with *flacca* as either scion or rootstock had the same root xylem ABA concentration as *flacca* self-grafts, about 60% lower than WT self-grafts. Thus both scion and rootstock contribute to root xylem composition.

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PII.6. CAN PHENOTYPIC SELECTION OF ROOTSTOCKS PROVIDES RESISTANCE TO MULTIPLE ABIOTIC STRESSES?

Sevilay Topcu[1], İmene Hichri[2], Francesco Giuffrida[3], Emma Worsfold[4], Stanley Lutts[2], Maria J. Asins [5], Ian C. Dodd[4]

On behalf of the ROOTOPOWER Consortium

Rootstocks may be selected for enhanced abiotic stress (e.g. drying soil, salinity) tolerance, but whether rootstock-mediated variation in tolerance to one stress confers resistance to another is not clear. Within the EU project ROOTOPOWER, a commercial tomato cultivar was grafted onto multiple rootstocks and grown in greenhouses at 3 sites under different environmental stresses:
- well-watered or drying soil in field soil for 2 months (unconstrained roots - Cukurova)
- well-watered or drying soil in pots for 2-3 weeks (constrained roots - Lancaster)
- salt (75 mM NaCl) applied hydroponically for 2 weeks (Louvain).

Shoot fresh weight (FW) was determined for each graft combination at each site and normalised to the mean FW of each experiment. Across all graft combinations, FW of salinised plants did not correlate with FW of plants grown in drying soil in the field, suggesting that short-term osmotic stress and long-term soil drying regulate growth differently. Otherwise, FW under optimal conditions was correlated with FW under different stresses (across multiple sites), suggesting that vigorous growth under optimal conditions is related to stress tolerance. Rootstocks that grew relatively better under stress conditions were identified, and will be exposed to combined drought and salt treatments in the next phase of the project.

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PII.7 DOMINANT EFFECT OF THE SCION IN WUE-RELATED PARAMETERS IN RECIPROCALLY GRAFTED CONTRASTING RILs UNDER OPTIMAL CONDITIONS

Elena Cantero-Navarro[1], Alfonso Albacete[1], Rafael Fernández-Muñoz[2] and Francisco Pérez-Alfocea[1]

Rootstocks-derived traits could be of potential use to enhance water use efficiency (WUE) in commercial tomato varieties, but rootstock-mediated variation in improvement WUE and related parameters is not clear. By reciprocal grafting, it is possible to determine whether plant developmental changes or physiological responses to environmental conditions are due to characteristics associated to the root or to the shoot system, or to their interaction.The aim of this study was to identify the relative importance of the scion and the rootstock genotypes for water, ionic and hormonal traits associated to WUE. Three F8 RILs derived from a cross between *Solanum lycopersicum* (cv Moneymaker) and *S. pimpinellifolium* (acc. TO-937) selected for their high, medium and low biomass and water use were reciprocally grafted. Nine rootstock/scion combinations (non-grafted, self-grafted and reciprocally grafted plants) were grown hydroponically in a greenhouse for a period of 7 weeks under optimal conditions (without any imposed stress). Across all graft combinations, the rootstock genotype did not significantly alter biomass, WUE and other physiological and hormonal parameters determined of their respective scions under the tested conditions. Such traits depended only on the scion genotype, suggesting that there was a dominant effect of the scion in the tomato graft combinations under short-term optimal growth conditions. These results support the idea that rootstock-mediated vigour on scion becomes more significant at the end (long-term) of the crop period and/or under suboptimal growing conditions.

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SECTION III
WORKING GROUP 3

"Rootstock-mediated Resistance to Biotic and Abiotic Stresses"

ORAL COMMUNICATIONS

III.1. THE NEED FOR TAILOR-MADE *Cucurbita* ROOTSTOCKS: WHAT CAN WE LEARN FROM GROWING GRAFTED MELONS IN DESERT AGRICULTURE?

Cohen, R.[1], Gal, I., Koren, A., Pivonia, S., Edelstein, M.

Selecting suitable rootstocks must take into consideration the special conditions prevailing in particular growing areas. The characteristics of a rootstock may be a two-edged sword that benefit the scion in one region and be inappropriate in the other. Cultivating grafted melons in the Arava desert of southern Israel is good example. *Cucurbita* rootstocks are less susceptible to salinity than melons enabling irrigating grafted melons with marginal water. However, the "biological filter effect" is not selective and may prevent proper Mg, Mn and Zn uptake from the soil to the scion. *Cucurbita* rootstocks are more tolerant to low soil temperatures than melons facilitating growing grafted plants in relatively cold soils but more susceptible to high temperatures thus may cause physiological collapse or growth reduction in hot soils. *Cucurbita* rootstocks used for grafting have been bred mostly in East Asian countries. More recently, they are being bred in the west by random crossing between *Cucurbita maxima* and *C. moschata* accessions. New problems encountered in the cultivation of grafted melons have led to a list of needed characteristics such as tolerance to high soil temperatures and appropriate mineral uptake. Searching for such traits in the *Cucurbita* germplasm may lead to precise rootstock breeding.

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III.2. REDUCING SUSCEPTIBILITY OF TRELLISED CUCUMBER AND MELON PLANTS TO *CUCUMBER GREEN MOTTLE MOSAIC VIRUS* BY AGRO-TECHNIQUE MEANS AND GRAFTING

Amnon Koren[1], Victoria Reingold[2], Aviv Dombrovsky[2]

Since 2007 an intensive outbreak of *Cucumber green mottle mosaic tobamovirus* (CGMMV) strains occurred in Israel at different locations. CGMMV infect greenhouse-grown plants (cucumber and melon) leading to serious economic losses.

CGMMV particles are capable to preserve infectively in plant materials and soil debris, thus to serve as a viral source in the following growing period. Moreover, the virus may adsorb to seed resulting in its transfer to distant locations. CGMMV has no known insect vector, though can be transmitted efficiently by mechanical means e.g. worker hands and tools. This mode of transmission serves as the main source of viral secondary spread from the primary infected plants to the entire plot.

In the last five years the virus has become a threat to trellised melon and cucumber crops in Israel. The primary inoculation of plants in the plots caused by the transplanting process in contaminated soil. Thus, applying better transplanting methods using virus free intermediate medium and grafted plants on CGMMV-resistant rootstocks, may result in reduction of the primary infection. Furthermore, appropriate sanitation of hands and tools combined with frequent monitoring within the plots while removing symptomatically infected plants, may reduce the viral spread under the economical threshold.

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III.3. UNRAVELING THE MOLECULAR BASIS OF THE RESISTANCE TO *PLUM POX VIRUS* INDUCED BY GRAFTING FROM ALMOND TO PEACH

Manuel Rubio[1], Luis Rodríguez-Moreno[2], Pedro Manuel Olivares[1], Manuel Castro de Moura[3], Albert Mascarell-Creus[3], Claudio Bonghi[4], Federico Dicenta[1], Pedro Martínez-Gómez[1]

Plum pox virus (PPV) is a limiting factor for peach production. Although no natural sources of resistance have been described for peach, recent studies have demonstrated that grafting almond cultivar Garrigues onto GF305 peach seedlings heavily infected with PPV progressively reduces disease symptoms in their leaves and virus accumulation. This response appears to be specific between almond and peach. Furthermore, grafting Garrigues onto GF305 before PPV inoculation completely prevented virus infection in the peach, showing that resistance is constitutive and not induced by the virus. To unravel the molecular basis of this mechanism, gene expression differences were studied after PPV infection in peach GF305 leaves using high-throughput Illumina RNA sequencing (RNA-Seq). First results showed that the early response to virus infection in peach is associated to an induction of genes involved in the jasmonate biosynthesis and signaling. In addition, processes occurring during the first phase of PPV infection are accompanied by the production of S-Adenosyl methionine (SAM), which is a general donor of methyl groups in the transmethylation reactions. New studies completing mRNA expression together with miRNA and Chip-Seq analysis will be carried out in order to understand in depth this interaction.

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III.4. EFFECTS OF GRAFTING AND ROOTSTOCK GENOTYPE ON NUTRIENT UPTAKE BY TOMATO

D. Savvas[1], G.B. Oztekin[2], M. Tepecik[3], A. Papanikolaou[4], V. Katsiki[5], A. Ropokis[6], G. Ntatsi[7]

Since the use of grafted plants is constantly increasing in greenhouse tomato cultivation, it is important to know the impact of grafting on nutrient uptake so as to establish special recommendations for nutrient solutions to be supplied to grafted tomato grown in closed-cycle hydroponic systems. In view of this background, an experiment with tomato grown in recirculating nutrient solution was established. The tomato plants (cv. Primadona) were either non-grafted, or self-grafted, or grafted onto the rootstocks He-man and Maxifort and supplied with a standard nutrient solution. The actual uptake concentrations of K, Ca, Mg, Fe, Mn, and Zn were estimated by applying two different methods. The first method was based on the removal of Mn, Zn, and water from the recycling nutrient solution. The second method was based on the total quantities of Mn and Zn that were recovered in plant biomass in combination with the total water uptake. The results indicated a slightly higher ability of Maxifort to take up some nutrients and especially Fe and Mn. To obtained estimations of mean uptake concentrations at four different plant developmental stages are useful for the establishment of standard nutrient recommendations for tomato grown in closed-cycle hydroponic systems under Mediterranean climatic conditions.

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III.5. INFLUENCE OF GRAFTING AND NITROGEN ON YIELD AND AERIAL PESTS POPULATION IN HIDROPONICS TOMATO CROP

Katja Zanic[1], Gvozden Dumicic[1], Branimir Urlic[1], Smiljana Goreta Ban[1]

Grafting and nitrogen (rates: 75, 140, and 205 mg/l N; and ratios: 92:8, 85:15 and 70:30 of NO_3^-:NH_4^+) effect on yield and pests populations was studied in hydroponics tomato during 2012 and 2013. Grafting did not affect marketable yield but affected populations of *Bemisia tabaci* and *Tuta absoluta*, in both experiments. The lower number of *B. tabaci* nymphs was recorded on grafted (rootstocks cv. Arnold or He-Man) than on self or non-grafted plants. The number of *T. absoluta* mines was the lowest on plants grafted on cv. Arnold. The lowest fruit mass was recorded on plants fertigated with 75 mg/l N in 2012. In 2013, number of fruits and total yield was higher on plants supplied with 8% NH_4^+ than on plants supplied with 30% NH_4^+ in nutrient solution. *B. tabaci* nymphs were the most numerous on plants grown at 205 mg/l N in 2012. The lowest nymphs population inhabited plants supplied with 30% NH_4^+ in 2013. *T. absoluta* infestation was higher on plants grown at 140 and 205 mg/l N in 2012 as on plants supplied with 15% NH_4^+ in 2013. Results could be applied in sustainable pests management.

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III.6. GRAFTING REDUCES THE CADMIUM TRANSLOCATION FROM ROOTS TO SHOOTS AND FRUITS IN TOMATO

Pradeep Kumar[1], Menahem Edelstein[2], Mariateresa Cardarelli[3], Elvira Rea[3], Giuseppe Colla[1]

A greenhouse experiment was carried out at the Experimental Farm of Tuscia University, Viterbo to determine whether grafting could reduce the Cd accumulation in above ground plant tissues including edible fruits of tomato under imposed Cd stress conditions. Five grafting treatments involving two commercial rootstocks of tomato ('Maxifort' and 'Unifort') and one of eggplant ('Black Beauty'), along with self-grafted and un-grafted tomato cv 'Ikram' were tested at two Cd levels (2.5 and 5.0 ppm) with control in quartziferous sand culture. Plants grafted onto 'Maxifort', 'Ikram' (self-grafted) or 'Unifort' performed better for most of the studied yield and related parameters than the ungrafted 'Ikram' plants and especially 'Black Beauty'. However, a significant reduction of Cd concentration in above ground plant tissues, including edible fruits, was recorded in plants grafted onto 'Maxifort' and especially 'Black Beauty', as compared to other grafting combinations. With respect to the root, plants grafted onto 'Unifort' and 'Black Beauty' exhibited significantly lower Cd accumulation as compared to others, while maximum was in 'Maxifort' grafted plants. The reduction in plant physiological performance like SPAD index and chlorophyll fluorescence, measured as the Fv/Fm ratio was lowest in plants grafted onto 'Maxifort' or self-grated 'Ikram', at both tested Cd levels.

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SECTION III
WORKING GROUP 3

"Rootstock-mediated Resistance to Biotic and Abiotic Stresses"

POSTERS

PIII.1. PRESENT STATE OF RESEARCH ON GRAFTING IN PEPPER IN THE REGION OF MURCIA

C Ros[1], F. Sánchez, CM Lacasa, MM Guerrero, V Martínez, A Hernández, MC Martínez A Lacasa

The reduction in the availability of soil fumigants and guidelines on integrated pest management, allow consider to use of friendly alternative over environmentally, as the use of genetic resistance to control pathogens. The grafting of pepper grown in greenhouses in the Region of Murcia has been evaluated as an alternative to disinfection of the soil for a decade. *Phytophthora* spp. (*capsici* and *parasitica*) and *Meloidogyne incognita* are the two limiting pathogens pepper cultivation in the South-eastern Spanish. Repeated use rootstocks growing in the same soil without disinfection occurs, in addition to the accumulation of specific fatigue pepper, the selection of nematode populations capable of infesting grafted plants carry the gene *Me3* or *Me7* resistance at same level non-grafted susceptible plants with consequent reduction in commercial yield. Nowadays, the integrated management strategies of resistance genes to *M. incognita* are evaluated; these are based on the alternation of genes, in the coculture (intercropping) of plants with different genes, and in the cultivation of plants rootstock grafted carrying two genes and graft combination with soil biosolarización. The strategies have been evaluated in greenhouses with commercial crops and experimental greenhouses, for three or more consecutive years. In all cases we have obtained a progressive decrease in the incidence of the nematode. In greenhouses with virulent populations for the gene *Me3* or *Me7*, alternation of crop plants grafted on rootstocks gene carriers with soil chemical disinfection following year is not a reduction in the incidence of the nematode or the reversibility of the process of selection of virulence. The evolution of the incidence of nematode has been found that is different between rootstocks carrying the same gene *Me3* or *Me7*, depending on the background in which the gene has been introgressed. When the alternation is carried out with rootstocks *Me1* gene carriers there is a decrease in the incidence of nematodes in plants not grafted, in the year in which it is grown in disinfected soil.

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PIII.2. THE EFFECTS OF GRAFTING METHOD AND ENDOGENOUS MYCORRHIZA APPLICATION ON CHEMICAL COMPOSITION AND STAND ESTABLISHMENT RATE OF GRAFTED CUCUMBER (*Cucumis sativum* L) SEEDLINGS

I. Babaj[1], G. Sallaku[1], P. Krasniqi[2], S. Kaciu[2], H. Göransson[3], B. Rewald[3], and A. Balliu[1]

Graded seeds of cucumber (cv. Ekron F_1), and graded seeds of a rootstock (cv. Nimbus F_1; *C. maxima* Duchesne x *C.moschata* Duchesne), were sown in polysterol trays, one seed for each plugs (60 cm^3), filled with a mixture (vol:vol; 9:1) of vermiculite and expanded clay grains contains spores of endogenous mycorrhiza. Prior to sowing, the substrate was brought to full water content capacity by addition of nutrition solution contains respectively, NPK; 170, 80, 250 mg L^{-1}. One fourth of cucumber seedlings were left intact (NG). The rest were either self grafted (SEG) or grafted onto the rootstock by two different grafting methods; splice grafting (SG) and root pruned splice grafting (RPSG). 15 day after grafting, the plants were transplanted in larger pots (300 cm^3) filled with vermiculite, only, where two different salinity levels were applied. Plant relative growth rate (RGR), and root relative growth rate (RRGR), were computed, and C/N analyses and nutrient analyses were conducted on leaf dry matter. Significantly higher amounts of Ca, Fe, K, Na, P and S were found in leaf dry matter due to mycorrhiza application. Grafting cucumber onto rootstock seems to be an efficient way of reducing Na content in scion's leaves, but grafting method itself do not have any significant effect on the chemical composition of grafted plants. Anyway, the effect of grafting method was highly significant regarding the stand establishment rate of transplanted plants.

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PIII.3. LIMIT OF RESISTANCE AND GRAFTING FOR THE PROTECTION OF MELON AND EGGPLANT AGAINST VASCULAR WILT DISEASES (*Fusarium oxysporum* F. SP. *Melonis* OR *Verticillium* SP.)

François Villeneuve[1], François Latour[1], Théophile Théry[1], Christian Steinberg[2], Cécile Hérault[2], Véronique Edel-Hermann[2], Marie-Christine Daunay [3]

For melon and eggplant cultures, wilt diseases have severe economic impacts given the absence of curative methods. Breeding for resistance as well as grafting susceptible scions on resistant rootstocks have started over 60 years ago in France. Direct breeding of resistant varieties was variously successful given pathogens frequent adaptation via emergence of virulent races. The utilization of intra- and interspecific grafting was also developed. In France this approach started in seventies, but growers use the grafting technique for about twenty years only. However, after several years of grafting utilizationgrowers observed new pathologies on grafted plants, with wilt like symptoms.

Ctifl, in association with INRA, technical regional stations, seed companies and growers carried out an important diagnostic work (more than 200 samples for melons, and 50 samples for eggplants) and identification of the fungus isolated. The genetic diversity of *Fusarium oxysporum* f.sp. *melonis* strains was also looked at.

The results show the prevalence of vascular wilt fungi, respectively *F. oxysporum* f.sp. *melonis* on melon, and *Verticillium* sp. on eggplant. Frequently these vascular fungi are associated to other bioagressors: the most frequent ones being *Colletotrichum coccodes*, *Pythium* sp., *Macrophomina phaseolina*, *Rhizoctonia solani*, *Didymella bryoniae.* Nematodes were also often found, especially *Meloidogyne* sp.

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PIII.4. IMPLEMENTATION OF GRAFTING TO MANAGE MAJOR SOILBORNE PATHOGENS IN NORTH CAROLINA TOMATO PRODUCTION SYSTEMS

Frank J. Louws[1]

North Carolina has a high level of biodiversity, including subtropical to temperate soilborne pathogens such as *Ralstonia solanacearum* (race 1; bacterial wilt; BW), *Sclerotium rolfsii* (southern stem blight; SSB), *Meloidogyne incognita* (southern root knot), *Verticillium dahliae* (Vd; particularly race 2) and *Fusarium oxyporum* f.sp. *lycopersici* (all races). Rootstocks have been deployed throughout the State using grafting technologies to manage each of these serious diseases in organic, high tunnel or conventional systems. In the case of BW, land is often abandoned once the bacteria become resident. Multiple small plot and large (10 ha) on-farm field experiments demonstrated selected rootstocks confer high levels of resistance. Consistent with the diversity of the pathogen, some rootstocks performed well in one part of the State but not in another (eastern vs. mountain regions). The research also discovered SSB can be effectively managed with selected rootstocks, a distinct advantage for many organic fields with an indigenous population. No resistance is known to Vd race 2 but some rootstocks appeared to offer tolerance generating high yields in the presence of disease compared to non-grafted controls that wilted. Integration of grafting as an IPM tool has been facilitated by grower-driven research and where economic benefits occurred.

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PIII.5. PHYSIOLOGICAL AND GROWTH RESPONSES OF GRAFTED CUCUMBER GROWN UNDER DIFFERENT SALT SOURCES

Youssef Rouphael[1], Rama Jawad[1], Pradeep Kumar[3], Mariateresa Cardarelli[2], Elvira Rea[2], Antonio Fiorillo, Giuseppe Colla[3]

Salinity in soil or water is one of the major abiotic stresses that reduce vegetable growth and productivity worldwide. The aim of the current work was to determine whether grafting could improve salinity tolerance of cucumber (*Cucumis sativus* L. cv. 'Ekron') using different salt stressors such as with equimolar concentrations. A greenhouse experiment was carried out at the Experimental Farm of Tuscia University, Viterbo, Italy to determine yield, growth, SPAD values, electrolyte leakage, and mineral composition and assimilate partitioning of cucumber plants, either ungrafted or grafted onto two commercial rootstocks: 'Affyne' (*Cucumis sativus* L.) and 'P360' (*Cucurbita maxima* Duch. × *Cucurbita moschata* Duch.) and cultured in soilless culture. Plants were supplied with four nutrient solutions: non-salt control, 20 mM $CaCl_2$, 30 mM NaCl or 10 mM $CaCl_2$ + 15 mM NaCl. our results demonstrate that in both grafted and ungrafted plants, the reduced yield and biomass production was due to both osmotic and ion specific effects, with $CaCl_2$ being more phytotoxic than NaCl and $CaCl_2$ + NaCl. The percentage of yield and biomass reduction in comparison to control was significantly lower in the plants grafted onto 'P360' and especially 'Affyne' than ungrafted plants. Grafted cucumber plants exposed to NaCl and $CaCl_2$ +NaCl were capable of maintaining higher chlorophyll content (SPAD index), and a better nutritional status (higher N, K, and Ca, and lower Na) in the shoot tissues and higher a membrane selectivity in comparison with ungrafted ones. The concentration of Na^+ in the aerial parts was less in grafted than in ungrafted plants in particular with Ekron/Affyne combination. Finally, the higher crop performance of grafted cucumber plants recorded with NaCl than with $CaCl_2$, was attributed to the limited capability of the rootstocks (Affyne and P360) to restrict Cl^- shoot uptake, thus Cl^-, which continues passing to the leaves, becomes the more significant toxic component of the saline solution.

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PIII.6. RETROSPECTIVE INQUIRY IN THE BULGARIAN SCIENTIFIC LITERATURE ON VEGETABLE GRAFTING

R. Rodeva[1], N. Velkov[2]

A complete bibliography of Bulgarian scientific literature on the application of grafting in vegetable crops was made. The retrospective inquiry showed that the first studies were conducted in the period 1944-1947. The main results were obtained in Cucurbitaceae. Grafting of melon on pumpkins and watermelon on *Lagenaria* spp. resulted in increased yield and precocity. The positive effect was characterized by intensive growth of over- and underground mass, opportunity for normal development at relatively low soil temperatures, more intensive accumulation of dry matter in the leaves and fruits. The movement and distribution of radioactive phosphorus P^{32} and carbon C^{14} was studies in grafted plants of melon, watermelon and pumpkin. Several PhD theses were successfully defended. Some results were obtained in grafting of Solanaceae representatives as tomato, eggplant and pepper. The most of publications were written in Bulgarian. The data obtained in Bulgaria in the past are summarized in a review in order to make the most important results accessible to the broader scientific community.

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PIII.7. THE GRAFTING IN PEPPER IN THE REGION OF MURCIA: RETROSPECTIVE VIEW

A. Lacasa[1], MM Guerrero, C.M. Lacasa, V. Martínez, M.C. Martínez, F. Sánchez, C. Ros

In the 1997-1998 season were started the earliest evaluation work grafted plants on resistant rootstock to soil pathogens, as part of a program to search for alternatives to methyl bromide (MB). The annual soil fumigation with MB was how to control *Phytophthora* spp (*capsici* and *parasitica*) and *Meloidogyne incognita* in pepper monoculture conducted in greenhouses. At the end of the 2001-02 had evaluated the agronomic and to pathogens behavior of 67 rootstocks of different backgrounds. 61% of the rootstock showed a good level of resistance to *Phytophthora* and more than 45% lower levels of damage to the roots *Meloidogyne*, and several rootstocks showed a commercial production similar or higher than non-grafted plants grown in soil disinfected with BM. Reiterating the monoculture of plants grafted onto rootstocks carrying resistance to *M. incognita* conferred by specific resistance genes was overcame from the third year of repetition, while *Phytphthora* resistance remained stable. A large number of rootstocks were compatible with most of the varieties and some influence on the behavior of the varieties compared to abiotic streses. Many led to an increase commercial production in relation to non-grafted plants grown in soil disinfected with chemicals. Was revealed that the expression of resistance to M. incognita conferred by determined genes is influenced by the background in which they are introgressed. The combination of biosolarización and grafting has been evaluated for the integrated management of resistance to *M. incognita*, which allows increase the time it for the resistance is conferred by some genes was overcame. The combination allows for to mitigate the effects of fatigue soils which is showed for growing plants grafted the same way as for the plants without grafting. No adverse effects were found in the infestation of plants by virulent populations to specific resistance genes *M. incognita* on the behavior of resistance to *Phytophthora*. For three consecutive years was conducted a pilot program to promote the graft as an alternative to BM, distributing among farmers more than a million grafted plants each year.

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PIII.8. ROOTSTOCK AFFECTS ANTIOXIDANT LEVELS IN PEPPER CULTIVATED UNDER CONVENTIONAL AND DROUGHT CONDITIONS

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Antioxidants, as an important part of the nutraceutical value of pepper, are affected by genotype, maturity and growing conditions. Grafting is an important technique which influences plant growth, yield, and quality of scion fruits. In this experiment, antioxidants levels of Lamuyo type pepper have been studied using different rootstocks under two cultivation conditions, i) control with usual irrigation conditions and ii) drought stress (35% reduction respect to control). Variety Adige (Sakata) was used as scion grafted onto nine different rootstocks: two commercial rootstocks, Antinema and Tresor; two *C. chinense*; one *C. baccatum*; and four *C. annuum*, Chimayo, Numex, Jalapeño and Adige itself (grafted and also nongrafted, as controls). Ascorbic acid content (AAC) and total phenolics (TP) were measured in green ripe fruits. On average, antioxidants increased under drought conditions, AAC from 99.44 mg AA/100 g FW in control conditions to 104 mg AA/100 g FW and TP from 112 mg CA/100 g FW to 137 mg CA/100 g FW. However there was a great effect of the grafting combination and a remarkable interaction grafting combination - cultivation conditions was also found. Under drought, Adige onto *C. baccatum* and Adige onto *C. chinense* produced the highest levels of AA and TP respectively. This study emphasizes the importance of optimizing the rootstock-scion combination depending on the growing conditions.

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PIII.9. INCREASING WATER STRESS TOLERANCE OF PEPPER BY GRAFTING

Consuelo Penella[1], Sergio G. Nebauer[2], Alberto San Bautista[2], Salvador López-Galarza[2], Ángeles Calatayud[1]

Capsicum spp accessions previously selected were tested as rootstocks of a pepper cultivar under severe water stress conditions in soil, some of them showing higher marketable yields when compared with ungrafted plants.

In a concomitant experiment, the behaviour of the same cultivar grafted onto both tolerant and sensitive rootstocks from the previous screening, was evaluated in PEG-induced water stress conditions (3.5 and 7% PEG) during 14 days in hydroponic conditions, to identify physiological traits that could distinguish the pepper accessions for its tolerance or sensitiveness to water stress. Water relations, proline accumulation and gas exchange were measured. In general terms, PEG-induced water stress provoked a strong decrease in the gas exchange parameters of the scion grafted onto the sensitive accessions as well as in the ungrafted plants, related with a lower RWC as a consequence of lower proline accumulation. However, plants grafted onto the tolerant rootstocks have the ability to maintain the protective capacity of the photosynthetic machinery as a consequence of higher proline content.

Both experiments suggest that tolerant accessions used as pepper rootstocks are suitable for drought conditions. Furthermore, other physiological parameters could be useful to new screening processes.

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PIII.10. THE RESPONSE OF S*olanum torvum* TO SOUTHERN SPAIN EGGPLANT ISOLATED OF *Verticillium dahliae*

CM. Lacasa, MC. Martínez, V. Martínez, A. Lacasa[1]

Eggplant (*Solanum melongea*) grafting on *Solanum torvum* rootstock is used in Southeast Spain in outdoor and greenhouse crops, where *Verticillium dahliae* and *Meloidogyne incognita* are the main soil pathogens. *Solanum torvum* is considered as resistant to *Verticillium dahliae* and *Meloidogyne incognita*. The partial resistance to Verticillium wilt is affected by the environmental conditions. High incidence of Verticillium wilt in eggplant crops grafted in *Solanum torvum* in several mediterranean Spanish provinces is the reason of this study. Under controlled conditions, the response of three commercial lines of *Solanum torvum* (rootstock P1, P2 and P3) to five isolates of *Verticillium dahliae* obtained in 2012 of grafted plants (A1 and A2) and between 1984 and 1992 of ungrafted plants (Vd8, Vd17 and Vd66) was evaluated.

Isolates A1 and A2 infected all roostocks and the cultivar. There are differences between rootstocks in the number of diseased plant infected by these isolates. All Vd isolates infected the cultivar and the rootstock P2. The Vd17 isolate also infected P3 but without symptoms. The rootstock P2 was as much as or more sensitive than the reference cultivar when it was inoculated with all isolates.

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PIII.11. INCREASING PEPPER YIELDS IN SALINE SOILS USING TOLERANT ROOTSTOCKS

Consuelo Penella[1], Vicente Penella[2], Sergio G. Nebauer[2], Alberto San Bautista[2], Salvador López-Galarza[2], Ángeles Calatayud[1]

Salinity stress is the most significant environmental stress in agriculture and improving yield under saline soils is a major goal of plant breeding. Eight *Capsicum* accessions previously selected for their good adaptation to saline stress in containers have been tested as pepper rootstocks of the 'Lamuyo' type cultivar 'Adige' in saline soil conditions (3 – 4 dS m^{-1}) in the south coastal area of Valencia, Spain, and were compared to the un-grafted and self-grafted plants.

Three accessions performed well, but only one gave both higher marketable yields and plant biomass than the rest of plants combination. Further, the percentage of fruits with blossom-end-rot (BER) was the lowest in this accession. An important increase of yield was observed in self-grafted plants respect plants grafted onto different accessions.

Consequently, the use of selected wild accessions of *Capsicum* as rootstocks is an appropriate technique to avoid restrictive saline soil conditions for pepper crops due to both the increase of yields and the reduction of the BER disorder.

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PIII.12. EFFECT OF GRAFTED CUCUMBER DASHER II ON RS841 ROOTSTOCK (*Cucumis maxima* x *C. moschata*) ON *Meloidogyne incognita* POPULATION GROWTH AND YIELD LOSS

Giné, A. [1], González, C. [1], Serrano, L. [1], Ornat, C. [1], Sorribas, FJ. [1]

A field experiment was conducted from April to July 2013 in a plastichouse in Barcelona (northeastern Spain) to identify resistant and /or tolerant response of rootstock RS841against *M. incognita.* Cucumber plants cv Dasher II grafted or not were grown in 9.6 m^2 individual plots. Composite soil samples were taken at the beginning (*Pi*) and at the end (*Pf*) of the cropping season to determine nematode population densities, and the multiplication rate (*MR=Pf/Pi*) was calculated. Yield of cucumber was determined from the eight central plants of each plot. In addition, ecophysiological parameters of grafted and ungrafted cucumbers were assessed, and the relationship between those parameters and *Pi* or relative cucumber yield was determined. Nematode densities at planting grated plants ranged from 0 to 6,180 juveniles 250 cm^{-3} soil, and from 0 to 894 in ungrated ones. The relationship between *Pi* and *MR* did not differ between grafted and ungrafted cucumbers. Then, a general model was constructed. The maximum multiplication rate was 1,030 juveniles 250 cm^{-3} soil, and the equilibrium density 290 juveniles 250 cm^{-3} soil. The relationship between *Pi* and grafted or ungrafetd cucumber yield fitted the Seinhorst damage function model. The maximum relative yield was 0.27 and the tolerance threshold 53 juveniles 250 cm^{-3} soil. On both grafted and ungrafted plants, increasing *Pi* led to the development of leaf chlorosis as indicated by the correlation between *Pi* and a spectral based chlorophyll index, which led to a decrease in net photosynthetic rate. Moreover, variation in relative yield was related to changes in relative PN suggesting that reflectance based chlorophyll estimates might provide a tool to evaluate the effects *Pi* on photosynthetic capacity and yield. Under our conditions grafting cucumber on rootstock RS841 is not an alternative method to manage RKN or to reduce yield losses caused by RKN.

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PIII.13. EFFECT OF IRRIGATION DEFICIT ON PLANT GROWTH, LEAF GAS EXCHANGE AND WATER USE EFFICIENCY OF SWEET PEPPER GRAFTED PLANTS GROWN IN A GREENHOUSE

J. López-Marín[1], A. Gálvez[1], C. Lacasa[2], C. Egea-Gilabert[3], J. A. Fernandez[4]

The objective of this study was to evaluate the effect of two irrigation treatments on plant growth, leaf gas exchange, and water use efficiency of the 'Herminio' plants ungrafted and grafted onto the commercial rootstock Creonte, grown under greenhouse conditions. Irrigation treatments were 1.0 (no stress) and 0.5 (water stress) evapotranspiration (ET) rates. In general, the grafted plants performed better than the ungrafted ones under stress and no stress conditions. Water stress reduced plant height, leaf number, area, FW and DW, leaf FW/DW ratio, stem FW and DW and root FW and DW. Generally, this growth reduction was lesser in grafted plants. Water stress also affected to net CO_2 assimilation rate, stomatal conductance, intercellular CO_2 concentration, transpiration rate, vapour pressure deficit leaf and water use efficiency, but not to Fv'/fm', Fv/fm or SPAD values. In water stress conditions plants grafted onto Creonte had higher values of net CO_2 assimilation rate, stomatal conductance, intercellular CO_2 concentration, transpiration rate and water use efficiency than ungrafted plants. These results suggest that the use of rootstock Creonte is a proficient choice to alleviate water stress in greenhouse-grown sweet pepper.

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PIII.14. EFFECT OF DIFFERENT IRRIGATION LEVELS ONTO PLANT DEVELOPMENT, YIELD AND QUALITY OF GRAFTED AND NO GRAFTED WATERMELONS UNDER ÇUKUROVA CONDITIONS

Selçuk Ozmen[1]

This study was conducted at the experimental field of the Department of Agricultural Structures and Irrigation, Faculty of Agriculture, University of Çukurova between 2006 and 2008.

In this study, the effect of grafting on the yield, plant growing and fruit quality of watermelon which is grown using deficit irrigation approach was investigated under Çukurova conditions. In the experiment, different irrigation (I100, full irrigation; I70, deficit irrigation; I50, full deficit irrigation) and grafting (grafted, *Crimson Tide*+*Jumbo*-CTJ; control, no grafted, *Crimson Tide*-CT) treatments were used. The experiment was designed as Strip Block design with three replications. Irrigation was started during the branching development stage of watermelon plants using drip irrigation once or twice (3 and 4 days intervals) per week and, then terminated between four and eleven days before the harvest.

In the experiment, irrigation water (IW) amount and seasonal evapotranspiration (ET) among treatments varied between 135.9-413.5 mm (12-16 events) and 311.3-520.6 mm, respectively. The highest IW with 413.5 mm and seasonal ET with 520.6 mm were obtained from CTJI100 in 2006. The highest monthly average ET was 214 mm for I100 in May; average reference ET was 163.1 mm in this month for watermelon. Crop coefficient (Kc) values for initial, midseason and late-season stages ranged 0.24-0.67, 0.87-1.66 and 0.83-0.93, respectively. There was no significant effect ($p>0.05$) of irrigation level on yield, fruit quality and plant development. Grafting effected ($p\leq0.05$) significantly yield and development, but had little effect on fruit quality. The highest yields were obtained from I100 with 16.90 kg per plant and CTJ with 19.32 kg per plant in 2008.

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PIII.15. PHENOTYPING AND PHYSIOLOGY OF ROOTSTOCK-MEDIATED TOLERANCE TO DROUGHT IN TOMATO

Sevilay Topcu[1*], Ian C. Dodd[2], Nebahat Sarı[3], Eser Çeliktopuz[1], İlknur Solmaz[3], Selim Eker[4]

On behalf of the ROOTOPOWER Consortium

Although insufficient supplies of irrigation water may limit crop production even in greenhouse horticulture, rootstock selection can enhance crop yield and improve drought tolerance. Within the framework of the EU project ROOTOPOWER, a commercial tomato cultivar (Boludo F1) was grafted onto rootstocks comprising 147 recombinant inbred lines (RILs) from crosses between the cultivated tomato *Solanum lycopersicum* and the wild relatives *S. pimpinnellifolium* and *S. pennellii*, and grown under well-watered or drying soils in pots (Lancaster) or in field soil (Cukurova). Soil water content, stomatal conductance, leaf water potential, leaf chlorophyll concentrations (SPAD), shoot fresh and dry weights and leaf area were measured to evaluate the impact of drying soil on growth, leaf gas exchange and water relations of different graft combinations. Since there was no significant rootstock-mediation in leaf water potential of plants grown in drying soil, xylem sap was collected from the de-topped root system under root pressure to analyse the role of root-supplied hormones and ions in regulating growth and water use. Soil drying increased xylem GA4 (by 31%) and JA (by 23%) concentrations but decreased xylem concentrations of ACC, GA1, iP, tZ and ZR by 28%, 15%, 25%, 15% and 15% respectively.

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PIII.16. ABA-OVERPRODUCING ROOTSTOCKS IMPROVE TOMATO PLANT PERFORMANCE UNDER SALINITY

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Salinity limits plant growth and productivity by modifying plant hormonal and nutrient balances. Increased ABA concentration in response to root water deficits is considered a primary effect on shoot changes. Since our previous results show that the overproduction of ABA in the whole plant enhances the response of tomato plants under salinity, we wanted to assess if the increase levels of ABA only in the root could also enhance the tolerance to salt stress. For this purpose, wild type plants (*Solanum lycopersicum* L. cv Ailsa Craig, AC) were grafted onto ABA-overproducing (transgenic line sp12, overexpressing the *NCED1* gene under the control of a constitutive promoter) and compared with AC sel-fgrafted (AC SG). The plants were cultivated hydroponically in half-strength Hoagland's nutrient solution under two salt concentrations (0 and 100 mM NaCl) for three weeks. Preliminary results have indicated that, under salinity conditions, sp12 used as a rootstock increased plant fresh weight and leaf area in comparison with AC SG. This increase in plant growth was correlated with a rise in photosynthetic rates, but not in stomatal conductance or transpiration rates. The hormonal analyses showed that *NCED1* overexpression only in the roots results in higher levels of ABA in both xylem sap and leaves which could mediate the better performance of these plants by improving photosynthetic and water status.

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PIII.17. DIFFERENTIAL APPROACH AND VALIDATION OF TWO CANDIDATE GENES TO WATERLOGGING RESPONSE UNDER HYPOXIA CONDITIONS IN TWO PRUNUS GENOTYPES

Beatriz Bielsa[1], Esther Canchel, Maria José Rubio-Cabetas[2]

The main consequence of waterlogging associated with poor drainage in soils is anoxia and hypoxia in the root environment affecting plant growth. Stone fruits (Prunus spp.) are affected by this type of stress, peach and almond that they are among the most sensitive and the plum the most tolerant. Some plants are able to survive long time in these conditions, due to the synthesis of 20 proteins namely anaerobic polipeptides (ANPs). In order to understand waterlogging response a differential approach was investigated in two Prunus rootstocks. Plant material included the almond x peach hybrid (P. amygdalus x P. persica) 'Garnem' and 'P.2175' (P. cerasifera). "In vitro" plants were submitted to hipoxia and normoxia conditions. The hypoxic treatment was carried out in airtight chambers with 3% O2, 0.03% CO2 and 97 % N2 gas composition for 2 h and 24 h. For each experimental point (0, 2h and 24 h) a sample representing three sets of roots were taken for each genotype.
A ChillPeach cDNA microarray containing 4,261 ChillPeach unigenes full-length cDNA was use to identify genes that are differentially expressed under hypoxia treatment in root tissues of two Prunus genotypes. Gene expression analysis of two genes coding for enzymes alanine aminotransferase and vacuolar pyrophosphatase showed higher expression in hipoxia than in normoxia. The transcript level was differently expressed under hypoxia and normoxia treatment, showing a regulatory response to waterloging stress in Prunus genotypes.

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SECTION IV
WORKING GROUP 4

"Rootstock-mediated Improvement of Fruit Quality"

ORAL COMMUNICATIONS

IV.1. EFFECT OF PRUNING SYSTEM ON YIELD AND QUALITY OF GREENHOUSE GRAFTED TOMATO

Isabel Mourão[1], Joana Teixeira[2], Luis Miguel Brito[1], Maria Elvira Ferreira[3], Maria Luisa Moura[1]

This study aimed to evaluate the effects on tomato yield and quality of three pruning systems (2, 3 and 4 stems) of grafted plants (cv. Vinicio and Multifort). It was also investigated if the two stems from nodes of the cotyledon leaves (P2c) improved crop performance compared to the two stems from the first true leaves nodes (P2). The experiment was conducted in the spring/summer season, under greenhouse conditions at NW Portugal, with a randomized block design with 3 blocks and the four pruning crop treatments. Total yield was significantly increased for the double-stem tomato crop, without significant differences between P2 and P2c (26.5 kg m^{-2}), compared to plants with 3 and 4 stems (19.5 kg m^{-2}). The fruit grade between 57-102 mm represented 96.3% of total yield and this was similar for all plant treatments. Fruit quality was not influenced by the pruning systems and mean characteristics were: fruit firmness (1.0 kg), content of soluble solids (5.1°Brix), acidity (1.0 g 100 g^{-1}), pH (4.4), DM (4.9%), and unblemished fruits (90.9%). Higher yield and fruit quality from double-stem tomato plants offset the increased planting labour and higher plant cost, compared to the 3 and 4 stems grafted plants. The similar results obtained with P2 and P2c suggest that the P2c plants should not be recommended due to the higher nursery pruning care they need.

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IV.2. THE CONTENTS OF CERTAIN PRIMARY AND SECONDARY METABOLITES OF GRAFTED TOMATO (*Lycopersicon esculentum* Mill.) FRUITS REGARDING TO SALINITY STRESS AND GROWING PERIOD

Nina Kacjan Maršić[1], Bernarda Brajović[2], Dominik Vodnik[1]

The aim of our study was to evaluate the effect of salinity stress on the content and composition of some primary and secondary metabolites at different salinity levels (2, 4 and 6 dS m^{-1}) in two growing periods (March – August and May – September). Two tomato cultivars 'Belle F1' and 'Gardel F1' and rootstocks 'Beaufort F1' and 'Maxifort F1' were used. The physiological response of plants to salinity stress was also examined. In both period clear effects of salinity were expressed. Water potential decreased to 50 %, transpiration to 60 % and photosynthesis to 40 %.Water deficit increased glucose and fructose content (to 20 %); citric, malic and ascorbic acid (20-50 %) and content of certain phenols (to 30 %). Fruits of 'Beaufort F1' grafts contained to 40 % more ascorbic acid, lycopene and β-carotene. Fruits of 'Maxifort F1' grafts contained to 60 % more certain phenolic acids. We found that a proper combination of rootstock and a scion had an advantage for sustaining salt stress under harsh summer conditions, when salinity was combined with high temperatures and high evaporative demand, but was non-benificial under less-extreme late-season conditions.

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IV.3. SENSORY ANALYSIS OF GRAFTED WATERMELON GROWN IN DIFFERENT HUNGARIAN REGIONS

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In 2013 an experiment was carried out to determine fruit quality of watermelon (*Citrullus lanatus* (Thunb.) Matsum and Nakai), either ungrafted or grafted onto two commercial rootstocks `FR STRONG' [*Lagenaria siceraria* (Mol.) Standl.] and `RS 841' (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne), grown in three region in Hungary. The fruit characteristics of grafted plants of 'RX 467' seedless watermelon cultivar have a big importance for the hungarian gardeners, producing for export markets. There are many conflicting reports on changes in fruit quality due to grafting and the differences may be attributed to different environments/production methods and to the type of rootstock/scion combination. The quality of fresh cut watermelon fruit is a combination of firmness, full red color and sweetness, therefore emphasis has been put on consumer reviews taking into account the results of laboratory tests. Fruit pH, total soluble solids, glucose, fructose, sucrose, lycopin content was measured and sensory evaluation was confirmed with electronic tongue measurement. Both grafting combinations reduced the soluble solids and according to the results (regardless of rootstock and growing location) the fruits from ungrafted plants were most preferred by panelist.

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IV.4. DIFFERENTIAL EVOLUTION OF PHYSICOCHEMICAL AND PHYTOCHEMICAL FRUIT COMPOSITION DURING RIPENING IN GRAFTED AND NON-GRAFTED WATERMELON

Marios C. Kyriacou[1] and Georgios A. Soteriou[2]

Synchronized maturation has been a common assumption in the assessment of fruit quality in grafted and non-grafted watermelon. The current study examined the evolution of physicochemical and phytochemical components of quality during watermelon ripening in response to grafting on *Cucurbita* hybrid rootstock. Flesh reflectance colorimetry, mechanical texture analysis, pH, titratable acidity (TA), and soluble solid (SS), soluble carbohydrate, lycopene and citrulline content of watermelon fruit were assessed throughout ripening (30-50 days post-anthesis; dpa) in grafted and self-rooted plants. Grafting increased firmness, TA, and lycopene content though it delayed its peak. Lycopene content was mostly ripening-dependant, highly correlated and synchronous with changes in pulp chroma (C*) and color a*. The sweetness was affected only by ripening. However, total sugars and SS peaked later in fruit of grafted plants than in non-grafted ones, and significant interaction of ripening with grafting was observed. Citrulline content increased with ripening in fruit of grafted plants, reaching a peak at 45 dpa; whereas in non-grafted ones it was unchanged between 30-45 dpa and declined at 50 dpa. As ripening overall was retarded by grafting, fruit quality of grafted watermelon may benefit from belated harvest.

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IV.5. EFFECT OF GRAFTING AND MODIFIED ATMOSPHERE PACKAGING (MAP) ON MELON AND AUBERGINE QUALITY PARAMETERS DURING STORAGE

E. M. Khah[1], S. Petropoulos, I. S. Arvanitoyannis, F. Bletsos

In Greece, melons are grafted mainly to control Fusarium wilt caused by *Fusarium oxysporum* f. sp. *melonis* and aubergines to control of *Verticillium dahliae, which* both are devastating diseases. Our experimental works were focused on the effect of rootstocks on both melon and aubergine scion fruit quality and postharvest performance in relation to the above infested soil diseases. Therefore, the physicochemical (pH, mechanical firmness and vitamin C) and sensory parameters of grafted and ungrafted of melon and aubergine plants were studied in relation to storage time (at 10^{o} C up to 21 and 17 days respectively) and in air (control). Melon seedlings of cultivar 'Galia' were grafted on commercial hybrids 'Mamouth' and '9075' rootstocks to avoid the soilborne disease caused by *Fusarium oxysporum* f. sp. *melonis*. Eggplant plants of cultivar 'Tsakoniki' were grafted on *Solanum torvum* and *S. sisymbriifolium* rootstocks in order to avoid the soil borne disease caused by *Verticillium dahliae.* The fruits of both crops were stored in two polyethylene bags, one under MAP (modified atmosphere packing) i.e. 30% CO_2 και 70% N_2 and the other in air. The results showed that in melon, vitamin C was not affected by grafting and MAP but decreased during storage whereas, in eggplant vitamin C was negatively affected by grafting and storage, while MAP prolonged its shelf life. Although in both crops pH was not affected by grafting, they were positively affected by MAP. Flesh firmness was negatively affected by grafting and reduced over storage negatively. Sensory analysis in melon, did not reveal almost any statistical differences between fruits from grafted and ungrafted plants whereas, this in eggplant showed higher ratings of fruits from ungrafted plants for sweetness and hardness. In both crops MAP helped in better maintaining of the fruits in comparison with air. It was concluded from Sensory analysis no difference was detected for overall acceptance and grafting plants did not have a serious impact on fruit quality.

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IV.6. QUANTITATIVE AND QUALITATIVE RESPONSE OF SICILIAN EGGPLANT ECOTYPES TO GRAFTING ONTO *Solanum torvum*

L. Sabatino[1], G. Iapichino[1], F. D'Anna[1]

Eggplant fruits present a high content of antioxidant molecules which are nowadays considered health-related compounds. In addition, eggplant represents an important source of minerals for the human diet as it provides significant quantities of various minerals (e.g. P, K, Ca and Mg. The quantity and quality of these compounds generally depend on the genotype, the growing environment and the cultural methods. As the demand for vegetable grafted seedlings is growing rapidly, more research is being focused both on the management of grafted plants and on the effects of the stock/scion combination on the agronomic and qualitative characteristics of the cultivar. In the present study, the effects of *Solanum torvum* rootstock on four Sicilian ecotypes of eggplant were studied by comparing grafted plants with non-grafted ones grown in the open field in Sicily (Italy). The agronomic results were correlated with the HPLC-MS analysis. Our results showed that grafting has a positive effect on fruit dry matter content, marketable fruit production, number of fruits per plant. This increment might be related to the increase on phenylamide content, which is known as a growth and development promoter. Our results also showed that grafted plants had a higher content of caffeoyl conjugates which represented the majority of the oxidable metabolites.

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SECTION IV
WORKING GROUP 4

"Rootstock-mediated Improvement of Fruit Quality"

POSTERS

PIV.1. GRAFTING IN *CUCURBITACEAE*: A GLOBAL APPROACH FOR THE FRUIT QUALITY DETERMINATION

A. Verzera[1], P. Crinò[2], A. Mazzaglia[3], C.M. Lanza[3], G. Dima[1], C. Restuccia[4], C. Condurso[1], G. Tripodi[1], D. Romano[3], A. Paratore[3]

A possible alternative to the use of agrochemicals for soil disinfestations in *Cucurbitaceae* cultivation is the use of grafted plants. The increasing consumer attention for high quality vegetable crops makes necessary to carefully select rootstocks/scion combinations capable of ensuring also a high quality fruits. In this regards the research aimed to the evaluation of the effects of different rootstocks, selected for their resistance to diseases, on the quality of different varieties of melon and watermelon fruits.

The plants were cultivated under greenhouse conditions in Pachino (Syracuse, Italy) which is situated in the south-east corner of the Sicily island. To define the fruit quality, we evaluated the effect of the selected rootstocks on plant productivity, physico-chemical and microbiological parameters, sensory characteristics, carotenoid content and volatile aroma profile. All the data were elaborated statistically in order to identify the most appropriate rootstock. Chemical, instrumental and sensory data were correlated each other. The data evidenced that some rootstocks, easily available on the market, can be successfully used for controlling soil pathogens without determining relevant changes on *Cucurbitaceae* fruity quality. The research also emphasized the importance of a global approach in fruit quality determination and the usefulness of sensory analysis which plays an important role in consumer's satisfaction.

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PIV.2. UPTAKE AND PARTITIONING OF ARSENIC IN TOMATO CROPS GROWN IN POLLUTED SOILS

Silvia Rita Stazi[1] and Roberto Mancinelli[2]

Arsenic (*As*) is a ubiquitous metalloid that is introduced into the environment from both anthropogenic and geochemical sources. *As* can be introduced to food through plant uptake from soil wet by contaminated ground or irrigation water.
Fields nearby mining, volcanic and thermal zones can reach such an high level of *As* concentration that impairs plant growth or contaminate the human food chain. Soil *As* concentrations above 40 mg kg^{-1} soil may pose health risks, especially for children.
Most plants tolerate soil *As* concentrations between 1 and 50 mg kg^{-1}. At higher levels some plants are negatively affected, while others have developed strategies to adapt to these conditions. Carbonell-Barrachina *et al*. (1997) stated that *As* absorption, translocation and accumulation, which finally determine *As* toxicity, depended on plant species.
The *As* tends to concentrate mainly in plant roots and older leaves, with a smaller concentration in stems and young leaves, and the lowest concentrations in seeds.
As toxic species may be accumulated in tomato tissues and, consequently, could enter in human food chain through the ingestion of its berries.
We conducted experiments in field, on tomato plants, to compare how two different managements, conventional and organic, can affect the mobility of total *As* in the soil/plant system. Moreover, we are planning an experiment to study the influence of rootstock on the *As* accumulation into the fruits.

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PIV.3. DEVELOPING PEPPER ROOTSTOCKS: FROM THE GERMPLASM SELECTION TO THE FRUIT QUALITY ANALYSIS

María Dolores Raigón[1], Alicia Sifres[2], Paloma Sánchez-Torres[3], Antonio Olmos[3], Carmina Gisbert[2]

Grafting of vegetable crops is one of the major research lines at the COMAV Institute (UPV, Spain). In order to use this technique to improve yield and fruit quality under biotic stress conditions, different works have been carried out to develop rootstocks able to cope with several pathogens that limit pepper production. Thus, we have studied the aggressiveness and genetic diversity of *Phytophthora capsici* isolates infecting pepper and have evaluated germplasm for *P. capsici* and nematode resistance. This allowed the development of two hybrids which showed good levels of both resistance and agronomic performance when used as rootstocks. In the evaluations of these materials, we observed the importance of scion-rootstock interactions and the value of making comparisons with self-grafted plants. The absence of negative modifications for quality parameters, such as pericarp thickness, lobes per fruit, vitamin C and mineral content, indicate that these hybrids could be suitable pepper rootstocks. We have also identified new sources of *Meloidogyne incognita* resistance which are very interesting to develop new rootstocks.

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PIV.4. FRUIT QUALITY IN EGGPLANTS FROM PLANTS GRAFTED ONTO INTERSPECIFIC HYBRIDS WITH EGGPLANT RELATIVES

Carmina Gisbert[1], María D. Raigón[2], Jaime Prohens[1]

We analyzed apparent fruit quality and proximate and mineral composition of eggplant (*Solanum melongena* L.) 'Black Beauty' fruits from plants grafted onto interspecific hybrid rootstocks developed from crosses between *S. melongena* and *Solanum incanum* L. or *Solanum aethiopicum* L. These results are compared with non-grafted and self-grafted controls and, with *S. melongena* 'Black Beauty' scions grafted onto *Solanum torvum* Sw. and *Solanum macrocarpon* L. Little difference was observed among treatments for apparent fruit quality traits (length, width, curvature, cross section, calyx length, prickles in the calyx and seed index), except for a greater prickliness and fruit calyx length of fruits from plants grafted onto *S. macrocarpon*. These fruits were also more irregular and presented higher phenolics content with respect to the rest of treatments. Dry matter, protein content, soluble solids and mineral contents did not differ significantly among plants grafted onto the interspecific hybrids and the controls. Thus, from a quality point of view, these rootstocks are adequate for grafting eggplant.

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PIV.5. GRAFTING WATERMELONS CROP TECHNOLOGICAL POSSIBILITY FOR IMPROVEMENT OF FRUIT QUALITY

M. Bogoescu[1], Madalina Doltu[1], D. Sora[1]

In Romania, the watermelons represent one of the most popular crop. The watermelons crop is particularly sensitive to the attack by soil diseases and nematodes. Since crop rotation is rarely adopted, the reduction of yield, both in quantity and quality, progressively affects the crops, thus making necessary the adoption of soil disinfestations practices or, other methods. The treatment of soil with methyl bromide was used only by large commercial farmers (107.72 tons methyl bromide in 2003). Since the adhesion to the Montreal Protocol, Romania government decided to phase out methyl bromide use starting 2005. Results of the experimental plots obtained in 2011 - 2012 indicated for the Romanian conditions, the following methyl bromide alternatives were suitable for soil disinfestation: metham sodium (chemicals methods), and grafting watermelons (non-chemical method). Grafting watermelons cultivars with high quality and productivity on rootstocks that are resistant to the soil pests and diseases is a method known for years ago, but which was improved and quickly spread in the last years.

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PIV.6. TRADE-OFFS BETWEEN RESISTANCE AND YIELD IN BELL PEPPER DURING ORGANIC GREENHOUSE TRIALS UNDER LOW DISEASE PRESSURE

Justine Dewitte[1], Tom Beyers[1]

Only a small number of crops proves to be profitable when grown in heated organic greenhouses. As such, the options for crop rotation are limited and populations of soil pathogens often increase over consecutive years. Then the only sustainable solution is the use of resistant rootstocks.

In order to characterize the potential of four novel bell pepper rootstock that were selected for disease resistance, quantitative and qualitative parameters for fruits, vegetative plant parts and roots were recorded during the cropping season and compared to a widely used, commercially available rootstock.

The overall good condition of the roots of the commercially available reference rootstock and the low incidence of corky roots and root knots indicated a low disease pressure in the greenhouse soil. Similarly, disease incidences were low on roots of the rootstocks that were selected for resistance. However, total yield, average fruit size, number of fruits produced and the number of premium quality fruits were significantly decreased in plots that were grafted on the resistant rootstocks as compared to the commercial reference.

The choice for disease resistant rootstocks might thus adversely affect bell pepper yields under low disease pressures.

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PIV.7. EFFECTS OF GRAFTING WATERMELONS ON *Citrullus lanatus* VAR. *citroides* GENOTYPES FOR PLANT GROWTH, YIELD AND FRUIT QUALITY

Ilknur Solmaz[1], Güzin Tarim[1], Haşim Kelebek[2], Nebahat Sari[1]

The aim of this study is to investigate the rootstock potentials of wild watermelon species *Citrullus lanatus* var. *citroides* genotypes which belong to the watermelon genetic resources collection of Çukurova University, Faculty of Agriculture, Department of Horticulture for watermelon and their effect on fruit quality (sugar content, carotenoid content). Argentario, a bottle gourd rootstock widely used for watermelon and Maximus, a *Cucurbita maxima* x *Cucurbita moschata* hybrid rootstock is used for comparison. Crimson Tide F1 is used as scion and non- grafted Crimson Tide plants are used as control.

Time of first male and female flower initiation as well as time of 50% male and female flower initiation, diameter of main stem, length of main stem, number of nodes on main stem, total branch number, yield, fruit weight, fruit, length, fruit, diameter, fruit rind thickness, total soluble solids, flesh firmness, are analysed in 5 plants in each plot. Sugars (saccarose, glucose, fructose, maltose) and caratenoids (lutein, fitoen, fitofluen, α-carotene, β-carotene and ζ-carotene) are extracted and analysed as fruit quality parameters. Results will be presented in details and discussed during the COST meeting in Murcia.

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SECTION V

"Vegetable grafting: ongoing projects and state of the art from a commercial point of view"

ORAL COMMUNICATIONS

V.1. GRAFTING IN ORGANIC HORTICULTURE

Martin Koller[1]

Grafting is one of the most important preventive measurements in organic greenhouse horticulture (OGH). At least for Mid – Europe the percentage of grafted tomatoes, cucumbers, eggplants and sweet pepper is most likely higher than in conventional crop. It is important to notice that in most European countries cropping in substrate is not permitted and plants are nourished primarily through the soil ecosystem (EC 834/2007, Art 5a). For a sufficient nutrient uptake plant roots have therefore to explore more ground compared to plants in fertigation systems. Important factors are stronger growth, enhanced nutrient uptake and a higher resistance to soil borne pathogens and nematodes.

Specific requirements according to organic standards (EC 889/2008) which concerned grafted plants are; plantlets has to be grown in organic certified nursery, seeds organically propagated has to be used if available and GVO plants are prohibited. Private standards however have in some cases stricter regulations, e.g. varieties out of protoplast fusion were prohibited.

In future rootstock with stronger root growth and enhanced nutrient acquisition, without overstimulation of the vegetative growth of the scion will be important for OGH. Moreover resistance to new strains and new species of nematodes will be important.

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V.2. OVERVIEW OF USDA-FUNDED PROJECT TO ADVANCE GRAFTING TECHNOLOGIES IN THE U.S. FRUITING VEGETABLE INDUSTRY

Frank J. Louws[1]

In the USA, fruiting vegetable growers face environmental, technical and market forces that demand innovative solutions. Constraints include loss of soil fumigants, persistent soilborne pathogens that are difficult to manage, and limited host resistance in specialty cultivars that garner premier market opportunities. In contrast, emerging markets include extended season production using high tunnels, organic and specialty markets, sustainable intensification on large farms, and a general heightened awareness of health benefits with increased fresh vegetable consumption. By uncoupling root genetics from scion genetics through grafting, growers can grow superior cultivars to meet changing market conditions, yet choose site-specific rootstock solutions to manage soilborne diseases and abiotic stress. We have assembled a multi-institutional domestic to international team that is stakeholder-driven to advance the productivity and profitability of US fruiting vegetable enterprises by integrating grafting technologies into these systems. The work plan is coordinated around four core objectives: 1) optimize grafting technologies to reduce costs of producing and distributing grafted seedlings; 2) integrate discovery-based, applied and on-farm research to optimize field production outcomes; 3) evaluate economic and social metrics to guide the direction of emerging grafting technology advancements; and 4) translate outcomes to stakeholders. This talk highlights the USDA coordinated project.

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V.3. THE HISTORY, CURRENT STATUS AND FUTURE OF THE CUCURBIT GRAFTING IN CHINA

Zhilong Bie[1] and Yuan Huang

In China, the earliest literature about vegetable grafting was recorded in "Book of Fan Shengzhi" in the first century, BC. However, research and rapid demonstration of the grafted Cucurbitaceous vegetables such as cucumber, watermelon, melon, and bitter gourd etc. in China began from the late of 1970s. The main purpose of grafted seedlings in China is to overcome soil-borne diseases. Currently, China produces more than half the world's watermelons and cucumbers, and approximately 40% of these are grafted. Several grafting methods have been employed including hole insertion grafting, root pruning hole insertion grafting, tongue approach grafting, and cleft grafting. Among them, the hole insertion is the most popular method for cucurbit grafting in China. Many seedling nursery companies, institutes and universities carry out studies on the rootstock breeding, the application and plant physiology in relation to cucurbit grafting. At least 50 varieties of rootstock for the cucurbit grafting have been bred and released. Currently, there are some problems identified that limiting the demonstration of grafted seedlings in China, including the lack of compatible multi-disease-resistant rootstocks, the greater risk of seed-born diseases (BFB, CGMMV), the increasing price of grafted seedlings owing to the rapid increase of labor cost, the small scale of grafted seedling production, and along with some negative effects of grafting on fruit quality. To solve these problems, some countermeasures are put forward: (1) to strengthen the breeding of rootstock with high quality, (2) to produce virus free seeds and healthy grafted seedlings, (3) to optimize the environment control technique for the healing and acclimation of grafted seedlings, (4) to develop facilities related to increasing the grafting efficiency and reducing labor cost, (5) and to strengthen the fundamental research on the mechanism of physiology, fruit quality, and molecular biology in relation to grafting.

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ROUND TABLE

"State of the art from a commercial point of view"

SECTION VI

ROOTOPOWER WORKSHOP

"Phenotyping, physiology and genetics of rootstock-mediated tolerance to soil abiotic stresses in tomato"

VI.1. ROOTOPOWER: *EMPOWERING ROOT-TARGETED STRATEGIES TO MINIMIZE ABIOTIC STRESS IMPACTS ON HORTICULTURAL CROPS*

Francisco Pérez-Alfocea[1], Maris Jose Asins[2], Andrew J. Thompson[3], Stephan Declerk[4], Francisco Rubio[1], Sevilay Topcu[5], Ian C Dodd[6]

On behalf of the ROOTOPOWER Consortium

The EU ROOTOPOWER project (2012-2015- grant number 289365) aims to develop new tools, targeted to the root system, to enhance agronomical stability and sustainability of dicotyledonous crops under multiple and combined stress conditions. Central to our approach is the use of tomato as a model species since it can be very easily grafted, (and indeed is usually grafted in commercial protected cropping). This surgical technique attaches genetically different shoot and root systems, allowing precise assessment of the effect of altering root traits on crop performance independently of shoot traits, since the scion (shoot) is constant. This project will analyze and exploit the natural genetic variability existing in wild-relative tomato species (used as *rootstocks*) and their beneficial interactions with natural soil microorganisms (*arbuscular mycorrhizal fungi, AMF and plant growth promoting rhizobacteria, PGPR*). This project will obtain genetic information and physiological understanding of mechanisms vital for high-performing root systems. The key research challenges are to (i) identify stress-resistant root systems and rhizosphere microorganisms (and their synergisms) for enhanced resistance to individual and combined abiotic stresses (ii) understand the underlying genetic and physiological mechanisms, which are potentially fundamental to all crops, and readily exploited in dicotyledonous crops. Primarily, ROOTOPOWER will evaluate rootstocks of a recombinant inbred line population from a cross between *Solanum lycopersicum* var. cerasiforme and *S. pimpinellifolium* for their performance under multiple abiotic stresses (drought, salinity and low nutrient supply) and for their interaction with AMF and PGPR. These genotypes represent a unique resource that have already been used to identify the first rootstock-specific QTL conferring salinity resistance. This project will conduct detailed analysis of the underlying rootstock-derived physiological and morphological mechanisms that influence fruit yield and quality, with special emphasis of rootstock effects on root-to-shoot signalling.

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VI.2. SCREENING A TOMATO MAPPING POPULATION FOR ROOT RESISTANCE TO SOIL IMPEDANCE PLUS POLYMORPHISM DISCOVERY IN PARENTAL GENOMES

Andrew J. Thompson[1], John Andrews[2], Fady Mohareb, Robert King and Zoltan Kevei

On behalf of the ROOTOPOWER Consortium

Roots encounter compacted soil below the plough pan and their ability to penetrate and exploit this part of the soil profile is in part genetically determined. Deeper penetrating roots allow increased water capture and improved yields in water limited environments and reduce nitrogen leaching. The traits relevant to penetration of soil by roots include root anatomy, root architecture, root response to impedance and root vigour.

We developed an assay for root penetration consisting of a geotextile material clamped below a column of soil. The grade of geotextile was selected based on its ability to allow some but not all roots of genotype M82 to penetrate, and genotypes were successfully scored by counting the number of roots emerging from the lower surface of the geotextile. This assay was used to score a recombinant in-bred line population derived from a cross between *Solanum pimpinellifolium* L5 and *S. lycopersicum* var. cerasiforme E9 in order to detect QTL.

To assist in the future fine-mapping of QTL the parental genomes of this RIL population were re-sequenced to approximately 50x coverage using Illumina HiSeq next generation sequencing. Reads were mapped to the Heinz 1706 reference genome and we detected 5.4 x 10^6 and 6.9 x 10^5 high quality polymorphisms (SNPs and InDels) between the reference and L5 and E9, respectively. A survey of mutations which are highly likely to cause null mutations revealed 3813 and 738 frame-shift mutations in L5 and E9, respectively, relative to the reference. The InDels which are ≥ 10 basepairs and are polymorphic between L5 and E9 are being used as simple PCR product size markers for fine mapping of a known QTL for rootstock inferred salinity tolerance.

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VI.3. ROOTSTOCK-MEDIATED VARIATION IN TOMATO VEGETATIVE GROWTH UNDER MODERATE SALINITY

Imène Hichri[1], Emna Gharbi[1], Alfonso Albacete[2], Stanley Lutts[1]

On behalf of the ROOTOPOWER Consortium

Salt tolerance can be transferred to a more sensitive cultivar by using tolerant rootstocks that maintain Na^+ homeostasis over time and alter root-derived hormonal signals that increase leaf area and delay salt-induced senescence thus improving tomato productivity under salinity (Albacete et al., 2009; Albacete et al., 2010). This work tested the hypothesis that rootstock-mediated traits are important in explaining the scion phenotype under salinity. Grafted tomato plants, with rootstocks comprising 147 recombinant inbred lines from crosses between the cultivated tomato *Solanum lycopersicum* and the wild relatives *S. pimpinnellifolium* and *S. pennellii*, were grown hydroponically in a glasshouse under moderate salinity (75 mM NaCl) for 14 days. Three consecutive assays (each containing 2 replicates of each graft combination) were conducted using a Latinised alpha row-column design. Plant growth and foliar ion accumulation (Na^+, K^+) were measured and xylem sap collected by excising the shoot and applying a pneumatic pressure to the roots. Ions (ICP-OES) and hormones (U-HPLC-MS) were analyzed in the xylem sap samples.There was significant rootstock-mediated variation in shoot fresh weight (2.7-fold), foliar Na^+ concentration (2.6-fold) and foliar K^+ concentration (3-fold) under moderate salinity, but not in xylem Na^+ or K^+ concentrations. Although foliar Na^+ and K^+ concentrations were inversely correlated, neither correlated with shoot fresh weight. In Assay 1, both xylem sap K^+ and Na^+ concentrations were significantly ($P < 0.05$) correlated with leaf K^+ and Na concentrations, indicating that xylem sap concentrations adequately predicted leaf ionic status. Considering the entire data set (all 3 assays), xylem Na concentration was almost significantly ($P = 0.051$) correlated with leaf Na concentration, while xylem K concentrations was not correlated ($P = 0.41$) with leaf K^+ concentration. Additionally, principal component analysis (PCA) revealed that ionic (PC1) and hormonal (PC2) traits clustered separately and both were important to explain the variability observed. However, xylem Na^+ and especially K^+ concentrations did not associate to any PC and they were not good indicators of rootstock-mediated variability in growth under moderate salinity.

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VI.4. PHENOTYPING AND PHYSIOLOGY OF ROOTSTOCK-MEDIATED TOLERANCE TO DROUGHT IN TOMATO

Sevilay Topcu[1], Ian C. Dodd[2], Nebahat Sarı[3], Eser Çeliktopuz[1], İlknur Solmaz[3], Selim Eker[4]

On behalf of the ROOTOPOWER Consortim

Although insufficient supplies of irrigation water may limit crop production even in greenhouse horticulture, rootstock selection can enhance crop yield and improve drought tolerance. Within the framework of the EU project ROOTOPOWER, a commercial tomato cultivar (Boludo F1) was grafted onto rootstocks comprising 147 recombinant inbred lines (RILs) from crosses between the cultivated tomato *Solanum lycopersicum* and the wild relatives *S. pimpinnellifolium* and *S. pennellii*, and grown under well-watered or drying soils in pots (Lancaster) or in field soil (Cukurova). Soil water content, stomatal conductance, leaf water potential, leaf chlorophyll concentrations (SPAD), shoot fresh and dry weights and leaf area were measured to evaluate the impact of drying soil on growth, leaf gas exchange and water relations of different graft combinations. Since there was no significant rootstock-mediation in leaf water potential of plants grown in drying soil, xylem sap was collected from the de-topped root system under root pressure to analyse the role of root-supplied hormones and ions in regulating growth and water use. Soil drying increased xylem GA4 (by 31%) and JA (by 23%) concentrations but decreased xylem concentrations of ACC, GA1, iP, tZ and ZR by 28%, 15%, 25%, 15% and 15% respectively.

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VI.5. EFFECTS OF NITROGEN STRESS ON A POPULATION OF *Solanum* ROOTSTOCKS

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On behalf of the ROOTOPOWER Consortium

In the Netherlands, over 90% of the tomato and egg-plants cultures consist of grafted plants. In important crops as pepper and cucumber, rootstocks are still hardly/not used, however, the search for rootstocks that can improve the cultivation of these crops continue. The economic importance of grafting vegetable crops in The Netherlands and Europe is large, for its opportunities to improve crop production levels, as well as for the possibilities rootstock can offer in dealing with soil diseases, nutrient shortage, salinity and drought (especially in South/East Europe.

The EU project ROOTOPOWER aims at improving crop stress resistance and developing more resource-efficient crops. In order to do so, the objective is to understand crop responses to multiple below-ground stresses, by analysing the relationships between root genotype and shoot performance. One of the aims of ROOTOPOWER is to determine the genetic variation of a population of *Solanum* rootstocks to abiotic stresses. At Wageningen UR Greenhouse Horticulture, the effect of nitrogen stress was determined in three consecutive experiments in 2012.

The effects of nitrogen stress (2 mM vs. 12 mM) on a population of F7 lines of *S. lycopersicum var. cerasiforme* x *S. pimpinellifolium* rootstocks was tested with Boludo as a scion. Plant characteristics were measured manually and non-destructively in an imaging system, determining plant height, plant width, leaf area and leaf colour. Furthermore, at the end of the experiments, xylem sap was obtained to determine plant hormones and nutrients.

Total above-ground plant weight varied considerably with the genotype of the rootstock. The sequence differed at high and low N. The amount of xylem sap collected correlated well with the plant dry weight. Plantalyser data showed that non-destructive measurements of leaf area of young tomato plants correlated well with destructive measurements of leaf area.

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VI.6. PHENOTYPING AND PHYSIOLOGY OF ROOTSTOCK-MEDIATED TOLERANCE TO SOIL LOW PHOSPHORUS STRESSES IN TOMATO

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On behalf of the ROOTOPOWER Consortium

We conducted experiments with 144 tomato grafted plants lines cultivated either under normal nutrient availability (Hoagland nutrient solution containing complete formulation and 2 mM P) or under P deficiency (Hoagland nutrient solution containing complete formulation except for P that contained 0.2 mM P). The plants were cultivated on sand (1 kg per pot and per plant) for a period of four weeks. Each plant received 60 ml of the corresponding Hoagland nutrient solution on alternate days during the four weeks growing period. After this growing period, plants were harvested and sap collected. The sap exudation rate was calculated and sap samples were used for hormonal and ionomic analyses. The shoot and root fresh and dry weights were recorded and biomass production was used as an integrative measurement of plant performance under the growing conditions assayed. Shoot tissues were used for subsequent ionomic analysis and quantification of P concentration. Results showed that an important number of RILs grew similarly or even better under P deficiency than under normal P availability. We could select 10 RILs as the best performing lines under P deficiency. These lines are: RIL TL01743, RIL TL01749, RIL TL02230, RIL TL02231, RIL TL02254, RIL A207, RIL A173, RIL A79, RIL K and RIL 234.

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VI.7. PHENOTYPING OF TOMATO ROOTSTOCKS UNDER LOW POTASSIUM SUPPLY

Cristina Martínez-Andújar[1], Alfonso Albacete Moreno, Ascensión Martínez-Pérez and Francisco Pérez-Alfocea

On behalf of the ROOTOPOWER Consortium

Grafting provides a rapid and direct tool to transfer rootstock abiotic stress tolerance to commercial sensitive varieties. Potassium (K^+) deficiency is a widespread problem in some soils, leading to a damage of physiological processes and thus a reduction in crop yield. The conventional approach to solve this problem is to apply K^+ fertilizer. The aim of this study was test the hypothesis that tomato root traits could alleviate stress symptoms under low K^+ supply. For this purpose, a commercial tomato cultivar (Boludo F1, Seminis Vegetable Seeds) was grafted onto rootstocks from a population of 133 recombinant inbred lines derived from a *Solanum lycopersicum* x *S. pimpinellifolium* cross. Grafted plants were cultivated in sand under commercial greenhouse conditions. Plants were irrigated with a half-strength Hoagland solution containing 6 (control) or 1 mM of K^+ (low K^+) for a period of 40 days. Shoot fresh weight (FW) were recorded as well as K^+ concentrations were assessed in a mature leaf feeding an actively growing fruit truss. Hormone concentrations were analyzed in the xylem sap by UHPLC-MS. A clear negative effect of low K^+ supply was not observed among RILS population for plant growth related parameters, suggesting that rootstock-mediated vigour was independent of K^+ fertilization. SFW correlation between control and low K^+ deprivation treatments showed a great variability within RILS population. We observed that the performance of some lines was either good (e.g. 47, 162 and 132) or bad (eg.162) under both optimal and suboptimal conditions. In contrast, another group of lines showed high SFW only under K^+ deprivation (e.g. TL02254 and 40) or under normal conditions (e.g. 162).

Principal components analysis (PCA) of the whole population under low K^+ supply showed that K^+ use efficiency (KUE) was explained by PC1, in which most hormones were strongly associates, suggesting that hormone factors are directly related with KUE.

Our study suggests that the use of RILs as rootstocks of a tomato commercial cultivar would have a positive effect under low K^+ supply by maintaining growth and increasing nutrient use efficiency.

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VI.8. ROOT-TO-SHOOT SIGNALLING OF SOIL ABIOTIC STRESSES

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On behalf of the ROOTOPOWER Consortium

There is increasing interest in using novel rootstocks to confer resistance to abiotic stresses in horticultural species, and to understand the physiological mechanism(s) conferring these responses. Grafted tomato plants, with rootstocks comprising 147 recombinant inbred lines from crosses between the cultivated tomato *Solanum lycopersicum* and the wild relatives *S. pimpinnellifolium* and *S. pennellii*, were grown in (semi-)hydroponics or soil under various stresses (drought, salinity, high soil mechanical impedance, low nitrogen, low phosphorous or low potassium). Plant growth was measured and xylem sap collected by excising the shoot and allowing its spontaneous exudation under root pressure (typically) or applying a pneumatic pressure to the roots (salinity or low phosphorous). Xylem sap flow rate was determined and samples analysed for multiple ions and phytohormones. All abiotic stresses had significant impacts on multiple analytes. Although the flow rate at which xylem sap was collected often had significant effects on xylem ion and hormone concentrations, there were instances when rootstock-mediated variation could not be attributed to variation in xylem sap flow rate. For some abiotic stresses, rootstock-mediated effects on xylem sap composition were correlated with rootstock vigour suggesting the regulation of scion growth by root-to-shoot signalling.

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VI.9. IMPROVING TOMATO FOR TOLERANCE TO MULTIPLE ABIOTIC STRESS FACTORS

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On behalf of the ROOTOPOWER Consortium

Abiotic stress combinations concurrently or temporally separated are common in the field. Breeding tomato rootstocks to integrate the tolerance responses of the root system facing several abiotic stresses, including nutrient deficiencies, could be a successful strategy to extend tomato cultivation to marginal areas and to gain culture sustainability. To accomplish these purposes, a population of 130 F_8 lines derived from a salt sensitive genotype of *Solanum lycopersicum* var. Cerasiforme and a salt-tolerant genotype from *S. pimpinnellifolium* L. previously genotyped and evaluated as rootstock for tolerance to high salinity (Estañ et al 2009), was used to genetically analyze the effect of the rootstock under control and three stress factors in separate experiments: medium salinity, water stress and phosphorous deficiency. Searching for genomic regions explaining significant correlations between the tolerance response to all of them, no single genomic region was found where tolerance QTLs for the three factors were detected; nevertheless, three regions included tolerance QTLs for two stress factors. Interestingly, one of them on chromosome 9 includes salt and water stress tolerance QTLs and is already under a fine mapping experiment.

Estañ MT, Villalta I, Bolarín MC, Carbonell EA, Asins MJ (2009) "Identification of fruit yield loci controlling the salt tolerance conferred by *Solanum* rootstocks" Theor. Appl. Genet. 118:305-312.

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