



International Symposium on Vegetable Grafting

PROGRAM & BOOK OF ABSTRACTS

www.grafting2011.com

Organized by



***University of Tuscia
Viterbo, Italy***



***Institute of Vegetable
& Ornamental Crops
Großbeeren, Germany***

International Symposium on Vegetable Grafting
3 – 5 Oct. 2011, Viterbo - Italy

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International Symposium on Vegetable Grafting

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Welcome

The Department of Agriculture, Forests, Nature, Energy of Tuscia University-Italy and the Institute of Vegetable and Ornamental Crops-Germany are pleased to welcome you to the International Symposium on Vegetable Grafting held in Viterbo, Italy, from October 3 to 5, 2011. The symposium takes place in the Grand Hotel Terme Salus Pianeta Benessere (Viterbo) located in the heart of Tuscia territory that was the ancient home of the Etruscans in the 8th century BC, and elected Papal seat in the Middle Ages. The symposium intends to reflect on the recent advances in vegetable grafting from different points of view in order to integrate this modernized technology as an effective tool for sustainable horticultural production. The symposium is comprised of scientific sections, with oral and poster presentations, addressing the advancement in grafting techniques, genetics, rootstock breeding, scion-rootstock interaction, phytopathological, physiological, and agronomical aspects of grafted plant response under open field and greenhouse conditions. In addition, the symposium includes a technical tour in the province of Latina, which is one of the most important vegetable production areas in Italy. This tour will provide an opportunity to see the benefits of using grafted plants in terms of increased productivity, and improved tolerance to biotic and abiotic stresses. We hope that the high scientific level of the symposium together with the beauty of Tuscia territory make it an unforgettable event.

The Conveners

Giuseppe Colla & Dietmar Schwarz

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Committees

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Angelica Krumbein, Institute of Vegetable and Ornamental Crops, Germany
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Jan Henk Venema, University of Groningen, The Netherlands
Halit Yetisir, University of Erciyes Melikgazi, Turkey

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Program

Monday 3 October, 2011		
Symposium Opening		
Chairmen: Giuseppe Colla & Dietmar Schwarz		
Time	Description	Speaker
14:00-15:00	Registration of participants and poster set-up	
15:00-15:30	Welcome to participants on behalf of Conveners and sponsor presentation	Dr. Giuseppe Colla
	Welcome to participants from the Rector of Tuscia University	Prof. Marco Mancini
	Welcome to participants from the President of Vegetable Crop Section belonging to the Italian Society of Horticultural Science	Prof. Antonio Elia
Section 1. Grafting techniques and transplant quality		
Chairmen: Jung-Myung Lee & Cherubino Leonardi		
Time	Title	Speaker
15:30-16:00	Factors affecting the quality of grafted vegetable transplants	[1] Jung-Myung Lee
16:00-16:30	Current topics and technical development in fully-automatic grafting robot in Japan	[2] Keita Yoshinaga
16:30-16:45	A new grafting technology applied to tomato plants for an effective seedborne disease management	[3] Giovanna Causarano
16:45-17:00	Acclimatization of grafted-cuttings with warming graft union at controlled low-air-temperature	[4] Toshio Shibuya
17:00-17:15	Use of chlorophyll fluorescence imaging as diagnostic technique to predict compatibility in grafted melon	[5] Angeles Calatayud
17:15-17:30	Use of unrooted grafted cuttings and low temperature storage – potential ways to advance vegetable grafting in the United States	[6] Chieri Kubota
17:30-17:45	Discussion	
17:45-18:10	Coffee Break	
Section 2. Genetics and rootstock breeding		
Chairmen: Athanasios S. Tsiftaris & Paola Crinò		
Time	Title	Speaker
18:10-18:40	Selection and breeding for robust rootstocks as tool to improve abiotic stress tolerance	[7] Jan Henk Venema
18:40-18:55	Molecular mechanisms underlining pepper fruit shape changes in relation to grafting	[8] Athanasios S. Tsiftaris
18:55-19:10	Tomato rootstock breeding	[9] Frank F. Millenaar
19:10-19:25	Discussion	
20:00	Welcome Cocktail	

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Tuesday 4 October, 2011		
Section 3. Biotic stresses		
Chairmen: Frank J. Louws & Roni Cohen		
Time	Title	Speaker
9:00-9:30	Integration of grafting technologies into tomato production systems in North Carolina	[10] Frank J. Louws
9:30-9:45	Critical aspect of grafting as strategy to control soil-borne pathogens	[11] Giovanna Gilardi
9:45-10:00	Grafting tomatoes for the management of bacterial wilt and root-knot nematodes	[12] Theodore McAvoy
10:00-10:15	Discussion	
10:15-10:40	Coffee Break	
Section 4. Abiotic stresses		
Chairmen: Zhilong Bie & Youssef Rouphael		
Time	Title	Speaker
10:40-11:10	Grafting to increase the tolerance to abiotic stresses	[13] Cherubino Leonardi
11:10-11:25	Preventing toxic element penetration into plants and fruits by using grafted plants	[14] Menahem Edelstein
11:25-11:40	Impact of grafting on cucumber tolerance to sodium chloride and sulfate salinity	[15] Youssef Rouphael
11:40-11:55	Does mycorrhiza improve salinity tolerance in grafted plants?	[16] Golgen B. Oztekin
11:55-12:10	Discussion	
12:10-15:00	Lunch and Poster viewing	
Section 5. Scion-Rootstock interaction: Physiology		
Chairmen: Francisco Pérez-Alfocea & Menahem Edelstein		
Time	Title	Speaker
15:00-15:30	Plant grafting as a mean for enhancing abiotic stress tolerance in vegetables: probing possible mechanism for grafting compatibility	[17] Benny Aloni
15:30-16:00	Use of recombinant inbred lines as rootstocks to improve resource use efficiency in vegetables: a case study of WUE in tomato	[18] Francisco Pérez-Alfocea
16:00-16:15	Evaluating the effects of root-supplied ABA and cytokinins on scion vigour and water use	[19] Ian C. Dodd
16:15-16:30	Rootstock cytokinin and abscisic acid overproduction improves tomato salinity tolerance	[20] Michel E. Ghanem
16:30-16:45	Discussion	
16:45-17:05	Coffee Break	

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Section 6. Scion-Rootstock interaction: Yield and fruit quality		
Chairmen: Angelika Krumbein & Chieri Kubota		
Time	Title	Speaker
17:05-17:35	Grafting - A chance to enhance flavour and health-promoting compounds in tomato fruits	[21] Angelika Krumbein
17:35-17:50	The quality of <i>Cucumis melo</i> L. var. <i>inodorus</i> and <i>reticulatus</i> fruits in relation to different rootstocks	[22] Concetta Condurso
17:50-18:05	Rootstock effects on grafted tomato plant survivorship, composition, yield and fruit quality in organic field production	[23] Matthew D. Kleinhenz
18:05-18:20	Discussion	
Round table		
Chairmen: Dietmar Schwarz & Giuseppe Colla		
Time	Title	Speakers
18:20-19:20	Prospects of vegetable grafting and future collaborations	Researchers from public and private companies
20:00	Gala Dinner	
Wednesday 5 October, 2011		
Time	Description	
8:30-19:30	Technical tour	

The Symposium is organized with the aegis of



Sponsor profiles

(alphabetic order)



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www.politicheagricole.it

The Ministry of Agricultural, Food and Forestry Policies (Italian - Ministero delle Politiche Agricole, Alimentari e Forestali, or MiPAAF) is an Italian government ministry. The ministry produces and coordinates government policy on agriculture, forests, food and fishing at a national, European and international level.

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Tea Project was established in 1997 for the production of automatic transplanting machines for greenhouse then the company has widened its range, offering automatic trimming machines, pot moving systems, robots. During the latest two years, Tea project has been involved in the development of an innovative project for the automation of vegetable grafting.

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Abstracts of oral presentations

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Section 1. Grafting techniques and transplant quality

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[1] Factors affecting the quality of grafted vegetable transplants

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Keywords: transplant quality, grafting method, acclimatization

Significant variations in quality of vegetable transplants are frequently observed among various growers and marked differences in quality of grafted transplants are commonly observed in the seedlings produced by commercial growers. The differences in seedling quality is most pronounced when the grafted transplants are produced in cell trays with varying number of cells per tray. In addition to the kind and health of scion and rootstock seeds, many factors are affecting seedling and transplant quality. Primed seeds are definitely preferred by the commercial growers to obtain high quality uniform seedlings for efficient grafting. Use of proper substrates is also the key factor for uniform germination and excellent seedling growth. Orientation of sowing angle often plays a major influence on the seedling vigor and uniformity in cucurbits. Many seeds are experiencing difficulties in taking off the seed coat after seedling emergence when the hilum end of the seed is orientated downward under most growing conditions, but the problems are much severe when the substrate are heavy and wet and the seed germination environments are not optimum in terms of temperature and relative humidity. Dry heat treated seeds and tetraploid watermelon seeds require higher germination temperatures and the optimum temperature range are much narrower unless the seeds are properly primed. Cell size varies depending upon the crops and grafting methods from 32 cells per tray (watermelons and melons) to more than 100 cells in peppers and other solanaceous crops. Commercial nurseries produce grafted seedlings preferably by splice grafting with or without the root of rootstocks to minimize several serious problems arising from the grafting plants out in the field conditions such as the root development from the scion, separation of grafted union during handling and growing, excessive development of shoots from the rootstocks. Less space is needed to raise the grafted seedlings as compared to some other grafting method such as tongue approach grafting method. Control of grafted seedlings after proper acclimatization also affects the quality of grafted transplants. Several cultural, physical, and chemical methods are being used to control the excessive outgrowth of grafted seedlings and maintain good seedling quality for much longer periods. The seedlings destined for long-distance shipping including export also receives special treatments. Twin-stemmed grafted tomato seedlings are favored by many growers to cut down the expense to purchase the seedlings without significant decreases in yield. Recent spread of noxious viruses and bacterial disease also causes problems in many growing areas over the world and use of certified or approved disease-free seeds is becoming more import these days to minimize the possible conflicts between seed companies, commercial nurseries, and individual farmers arising from unexpected crop losses due to the outbreak of these noxious diseases. Some of the details of the problems mentioned above will be discussed during the presentation with examples and photos relevant to the issues.

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[2] Current topics and technical development in fully-automatic grafting robot in Japan

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Keywords: grafting automation, robot, operation capacity

Grafting has been used in Japan for 80 years to stabilize production by eliminating injury by continuous cropping. Today, grafting accounts for about 97% of watermelons, cucumbers, and eggplants which are grown in greenhouses. Although grafting of nursery plants can be performed manually, it requires precise techniques and is becoming increasingly difficult due to the aging of skilled workers. In addition, since vegetables are cultivated two or three times per year, laborious harvest conflicts with grafting work, resulting in serious shortage of labor. Since it is becoming more difficult for individual farmers to produce grafted nursery plants due to the above-mentioned reasons, a large number of farmers have been recently buying seedlings from nursery growers. Under such a background, we developed a fully-automatic grafting robot based on the semi-automatic one in order to improve the efficient mass production of seedlings, especially for cucumbers. The fully-automatic grafting robot consists of two seedling feeding devices for scion and stock and a grafting device with a controller. The seedling devices are arranged in the left and right side of the grafting device which can be operated on the touch panel. After cell trays were manually placed on the seedling feeding devices, a series of grafting work is automatically done by pressing the operation switch. The robot can graft 800 plants/h, about three times more than manual grafting, with a success rate of 95 and 99% for watermelon and cucumber, respectively. The robot was marketed in 2010. Moreover, the fully-automatic grafting device without seedling feeding devices was also marketed. This device can produce 900 plants/ h by using three workers and be also used for grafting tomato seedlings.

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[3] A new grafting technology applied to tomato plants for an effective seedborne disease management

Giovanna Causarano^{1*}, Filippo Marcellino¹, Salvatore Longombardo¹, Mara Novero², Carlo Giovannucci³

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Keywords: laser, plant raisers, *Clavibacter michiganensis* subsp. *michiganensis*, fluorescence microscope, callose

The paper describes a recently developed methodology applied to tomato grafting. Tube grafting or Japanese top grafting is the common technique adopted in grafting industry. The procedure consists of 4 phases: production of rootstock and scion plants, plant grafting, grafted plant healing, plant hardening. Actually in Italy several specialized nurseries adopt tube grafting system having the capacity to produce up to 120-150 plants per hour per single operator. Phytosanitary risks can dramatically increase if no proper rules are adopted during the plant grafting phase. Risks are mostly due to the use of razor blades to prepare scions and rootstocks for grafting: seedborne diseases, such as *Clavibacter michiganensis* subsp. *michiganensis*, might rapidly spread from few infected plants to several healthy plants through infected blades. In order to limit phytosanitary risks a new grafting technique was set up eliminating the use of blades: the innovation is based on the use of a laser beam as a blade to prepare scion and rootstock. Because proper identification of size, age and type of plants to be grafted is the most important aspect of this innovative technique, since 2007 several trials have been carried out in order to verify the effects deriving from the adoption of laser based grafting in terms of graft welding and healing, vascular vessel connection at graft level, plant performances in semi field and field conditions. Microscopic evaluations were performed in order to verify the graft welding level. Longitudinal sections (50-100 um thick) of the graft zone were obtained by using a vibratome. Some sections were stained with phloroglucinol and observed under a light microscope to evaluate the xylem vessels continuity while some other were stained with aniline blue and observed under a fluorescence microscope to analyze the presence of callose deposition. Trials showed that no major problems arise after grafting with laser based technique. In conclusion the new grafting technique can be considered an effective tool to limit the risks of spread of seed borne disease such as *Clavibacter michiganensis* sub sp. *michiganensis*.

[4] Acclimatization of grafted-cuttings with warming graft union at controlled low-air-temperature

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Keywords: cutting graft, graft development, rooting, temperature control, water stress

The cutting graft is often used in the production of *Solanaceae* and *Cucurbitaceae* species. In this method, scions are grafted onto rootstock cuttings harvested from seedlings, and are then rooted in growing medium. The grafted cuttings are easily damaged by water stress in the acclimatization phase, because water absorption ability of cuttings is relatively low until their roots develop. In conventional acclimatization, relative humidity is raised using a plastic-film tunnel to prevent the water stress. However, the environment in the tunnel fluctuates greatly, both seasonally and daily, affecting the success of grafting. Here, we tested an advanced acclimatization technology which can improve the success of cutting graft by warming the graft union at controlled low-air-temperature. Scions of tomato (*Solanum lycopersicum*), eggplant (*Solanum melongena*) and cucumber (*Cucumis sativus*) were grafted onto tomato, *Solanum torvum* and squash (*Cucurbita moschata*) rootstock-cuttings, respectively, using a splice or hole-insertion graft in *Solanaceae* or *Cucurbitaceae* species, respectively. The graft union of cuttings was warmed under dim lighting in a cold room: they were soaked in warmed water held at 25 or 31°C from the basal end to the graft union at an air temperature of 9 or 12°C for 4 or 2 days in *Solanaceae* or *Cucurbitaceae* species, respectively. The warming treatment accelerated the development of graft-union and root primordia, and consequently reduced water stress of the cuttings immediately after grafting. The early growth of the warmed grafted-cuttings was improved significantly compared with that of non-treated cuttings, when the warmed and non-treated grafted-cuttings were grown under the same acclimatization condition. This warming technology would reduce labor requirements of transplant growers during acclimatization phase because the graft development and quality of rooting site of the rootstock can be improved stably with minimum loss of biomass and water at low air temperature.

[5] Use of chlorophyll fluorescence imaging as diagnostic technique to predict compatibility in melon graft

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Keywords: chlorophyll fluorescence imaging, compatibility, double graft, melon, simple graft

The capacity to generate the callus bridge between rootstock and scion is dependent of photosynthesis activity in graft area. We proposed the use of chlorophyll fluorescence imaging technique to predict graft compatibility or incompatibility that will eventually exhibit visible damage. Chlorophyll fluorescence, an indicator of the fate of excitation energy in the photosynthetic apparatus, has been used as early indication of many types of stress. Chlorophyll fluorescence image from photosynthetic tissues provides a non-invasive, sensitive, rapid and intuitive method that can be used to determine photosynthetic activity. Chlorophyll fluorescence imaging of melon plants was performed using an imaging-PAM fluorometer for measuring the fluorescence activity in callus zone formation and we identify fluorescence parameters that are most robust in predicting surface damage. We compared the scions “Piel de Sapo” (*Cucumis melo* L. var. *saccharinus*) cultivars “Ricura” and Sancho” grafted onto the rootstocks *Cucurbita maxima* x *Cucurbita moschata* “Shintoza” directly (single graft) or with Galia melon “Magnus” as intermediate rootstock (double graft). Cultivar “Ricura” has higher compatibility problems with Shintoza rootstock than “Sancho”. Among all fluorescence parameters measured (F_v/F_m , ϕ_{PSII} , q_L , ϕ_{NPQ} and ϕ_{NO}), the ratio F_v/F_m , proportional to the maximal quantum yield of PSII photochemistry, has showed as the most sensitive to identify tissue stress. The F_v/F_m ratio images values were higher in “Sancho” single grafted plants than in “Ricura” single grafted, while F_v/F_m values were similar in both cultivars in double grafted plants. On the other hand, “Ricura” double graft had higher F_v/F_m values than “Ricura” single graft. We concluded that this method is useful to evaluate graft compatibility.

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[6] Use of unrooted grafted cuttings and low temperature storage – potential ways to advance vegetable grafting in the United States

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Keywords: controlled environment, light compensation point, propagation method, unrooted cutting

In North America, vegetable grafting has been used only in hydroponic tomato greenhouses to increase yield. In order to advance the use of grafting in open fields, a key issue to address is the propagation capacity necessary to meet the large number of seedlings expected in a single shipment to supply the demands of typically large farms. We attempt to introduce use of unrooted grafted cuttings and storage of grafted seedlings as means to increase the overall grafting production capacity as well as to reduce the production/distribution costs. Use of unrooted grafted cuttings is currently practiced to a limited extent in East Asia and its advantage is to centralize the labor-intensive grafting operation and to reduce the shipping costs to distribute large amounts of grafted plants. In our preliminary experiment, we found that unrooted tomato grafted cuttings ('Durinta' scion and 'Aloha' rootstock) require a minimum of 3 days of post-grafting healing before harvest in order to maintain rooting capacity after 3-day simulated transportation. Transportation at a lower temperature of 10°C seems to contribute to maintaining better visual cutting quality than 20°C. For low temperature storage of grafted seedlings, we demonstrated that grafted cantaloupe seedlings were stored at 12-15°C under 12 $\mu\text{mol m}^{-2} \text{s}^{-1}$ PPF for 4 weeks without affecting post-storage growth or yields. Use of rootstocks tolerant to chilling improved the storability of scions grafted onto the rootstock. The capability of 4 week storage will increase the grafting capacity by up to 20 times of what propagators can achieve without storage. Although more research needs to be done to establish protocols suitable for various species and scion-rootstock combinations, both unrooted grafted cuttings and low temperature storage are possible breakthroughs to increase the production capacity and to advance the use of grafted plants in the U.S.

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Section 2. Genetics and rootstock breeding

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[7] Selection and breeding for robust rootstocks as tool to improve abiotic stress tolerance

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Keywords: abiotic stress, root physiological traits, tomato, rootstock selection, rootstock-scion interaction

Due to the combined challenges of limited arable land and climate change, the production of fruit vegetables is often done in areas where conditions are not optimal for yield and quality. Grafting is a promising tool to improve the tolerance of fruit vegetables against abiotic stresses like salinity, cold, heat, drought, flooding and nutrient deficiencies. However, the breeding for suitable rootstocks is still a matter of trial and error since practical selection tools like genetic markers are lacking. This is because knowledge about the physiology behind a successful rootstock-scion interaction is still very limited. In addition, most of the abiotic stress tolerances mentioned is complex multi-gene traits and the identified quantitative trait loci (QTLs) have hardly any value for practical breeding purposes. Instead of focusing on single allele-specific markers for desired root traits that are expressed in a particular hybrid combination, the identification of biomarkers (specific root-derived physiological traits) could deliver breeders generic tools to develop an effective screening method for rootstock selection. An overview will be given how grafting can alleviate the adverse effects of several abiotic stresses on the performance of vegetable crops at the agronomical, physiological, and biochemical level. Implications for the selection and breeding of robust rootstocks will be presented.

[8] Molecular mechanisms that underline pepper fruit shape in accordance to grafting

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Keywords: grafting, fruit shape, *Ovate*, *Sun*

The advantages of grafting, a popular and valuable technique used in the production of vegetables, are well known for years, particularly for facing the soil-borne diseases and nematodes and resistance as well as abiotic stresses. However, there are several disadvantages that prevent the optimization of this technique primarily being the extensive production cost. A major disadvantage is the detrimental effect of the rootstock on the fruit quality characters of the scion, such as taste, flavor, texture, shape etc, in vegetable plants like tomato (*S. lycopersicum*). In our laboratory a change in scion fruit shape was observed in pepper (*C. annuum*) plants generated when round fruited cultivar (cv. Round) scions were grafted on long fruited cultivar (cv. Long) rootstocks: scion fruits adopted the elongated shape of the rootstock fruits instead of the original round shape. Moreover this shape change was inherited in the progenies (T₂). In order to explore the molecular mechanisms behind this change in such an easy to observe, quantitatively inherited character as fruit shape we emphasized our study on three genes, *Ovate-like*, *Sun-like* and *GA20ox1-like* that in tomato have a major effect on the character's variance. Another gene, *Fw2.2-like* that influences fruit weight, was also studied. These genes were cloned, characterized and studied in two cultivars of different fruit shape, cv. Round and cv. Long as long as in the progenies (T₂) of the grafted plants with the change in the fruit shape. Detailed gene expression analyses by means of RT-Real Time PCR, were conducted in different developmental stages of flower and fruit development of the two cultivars and of the progenies. In order to clarify more the role of these genes in determining fruit shape in pepper, we employed Virus-Induced Gene-Silencing (VIGS) systems in order to try to mitigate, by silencing these genes, the shape changes occurred in the T₂ progenies.

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[9] Tomato rootstock breeding

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Keywords: *Solanum lycopersicum*, rootstock selection, grafting compatibility

Tomatoes are worldwide produced on grafted tomato plants. Tomato rootstocks are used on such a large scale mainly because of their resistance to soil born pests and diseases and the yield increase they provide to the scion hybrid. The main focus in tomato rootstock breeding is to select for rootstocks that further increase yield potential of scions grafted on these rootstocks under diverse growing conditions. This has already resulted in the development of a number of rootstock hybrids specifically adapted to different growing conditions. The rootstock - scion compatibility is under study as well as this greatly influences the potential a rootstock has to increase scion yield. Examples of how we study the rootstock-scion compatibility will be presented.

Section 3. Biotic stresses

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[10] Integration of grafting technologies into tomato production systems in North Carolina

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Keywords: *Fusarium*, *Ralstonia*, *Verticillium*, Root-Knot, IPM

Tomatoes in open fields and high tunnels represent an important component of farm gate income for many farms in North Carolina (NC), USA. Production is limited by soilborne pathogens including *Fusarium oxysporum* f.sp. *lycopersici* (FOL; races 0,1&2), *Verticillium dahliae* (VW; races 1&2), *Meloidogyne* sp. (RK), *Ralstonia solanacearum* (Rsol) and *Sclerotium rolfsii* (SSB). Multiple-year research station and participatory on-farm-research experiments were implemented in organic and conventional systems to determine the efficacy of selected rootstocks on disease incidence and crop yield. Selected rootstocks completely controlled Rsol bacterial wilt incidence compared to 50% to 100% plant death of non-grafted plants. Certain rootstocks performed well in Eastern NC and others performed better in Western NC, suggesting different populations of Rsol exist in these production regions. Complete management of FOL and RK was also achieved. In the case of RK, host resistance was incomplete in two rootstock selections whereas a third selection offered complete control and resulted in significantly low nematode populations at the end of the experiment. Selected rootstocks had SSB incidence ranging from 0% to 5% compared to 27% to 79% plant death using non-grafted plants. This was a first report of commercial SSB resistance. Whereas most interspecific rootstocks have the Ve gene conferring resistance to VW race 1, race 2 resistance is not known in any commercial tomato lines. Selected rootstocks did not reduce VW race 2 incidences but did reduce VW severity compared to non-grafted plants. Marketable yields from grafted plants in non-fumigated soils were comparable to yields generated from non-grafted plants growing in fumigated soils. Grafted heirloom tomato yields were also increased in high tunnel systems in the absence of documentable soilborne pathogens. Economic analysis of grafting partitioned the variable costs of plant production and demonstrated grafting is an economically viable technology for many NC production systems.

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[11] Critical aspect of grafting as strategy to control soil-borne pathogens

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Keywords: solanaceous crops, *Phytophthora nicotianae*, *Phytophthora capsici*, *Colletotrichum coccodes*

The management of soil-borne pathogens is nowadays complicated by the increasing restrictions in the usage of fumigants. The use of grafted plants in Piedmont is mainly spread in tomato cropping system but is becoming more popular also in the case of bell pepper and, in some areas, on melon crop. Several factors need to be considered for a sustainable use of this practice such as the susceptibility of the rootstocks against all the soil-borne pathogen which is age-dependent and the incomplete resistance of some of the rootstocks to one or more pathogens. Among the issues to be considered there is an evidence of a pathogenic variation among some isolates of *Phytophthora* spp. on solanaceous crops and on rootstocks and the development of new diseases or the re-emergence of already known pathogens after the phase out of methyl bromide. The potential critical aspects on grafting application for soil-borne pathogens management are discussed.

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[12] Grafting tomatoes for the management of bacterial wilt (*Ralstonia solanacearum*) and root-knot nematodes (*Meloidogyne spp.*)

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Keywords: grafting, tomato, root-knot nematode, bacterial wilt, disease

In the eastern USA the primary goal of grafting research has been to evaluate rootstocks for resistance to soil borne pests. Our research is focused on grafting tomatoes to manage bacterial wilt (*Ralstonia solanacearum*) and root-knot nematode (*Meloidogyne spp.*). Field experiments were conducted in Virginia and Florida to test the efficacy of grafting rootstocks on managing bacterial wilt. In addition, a container greenhouse experiment was performed in Florida to evaluate grafting rootstocks for the management of root-knot nematodes (*M. incognita* and *M. javanica*). The hybrid rootstock lines RST 106, Cheong Gang, Jjak Kkung, BHN 998, BHN 1053, and BHN 1054 were tested in both experiments. The Virginia bacterial wilt trial included a commercially grown ungrafted and a self grafted susceptible variety (BHN 602). In the Florida nematode and bacterial wilt experiments traditional variety Hawaii 7998 and BHN 602 were used as controls. Tomatoes grafted on rootstocks BHN 1054, Cheong Gang, BHN 998, and RST 106 had lower bacterial wilt incidence and higher yields than the ungrafted and self grafted controls. All hybrid rootstocks had significantly lower Root-Gall-Index (RGI), and nematode eggs in the roots than Hawaii 7998, and BHN 602. Hawaii 7998 had significantly lower RGI and nematode eggs in the roots than BHN 602. Grafting shows significant promise for soil borne pest management in the eastern USA.

Section 4. Abiotic stresses

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[13] Grafting to increase the tolerance to abiotic stresses

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Keywords: vegetables, grafting, abiotic stress

Vegetable grafting is nowadays extremely popular in some countries and is mainly used to improve plant tolerance to biotic stresses occurring particularly in intensive agro-systems. This technique has also been proposed as a way to enhance vegetable tolerance to abiotic stresses, since under such conditions plant show various disorders negatively affecting yield and quality of produce. Therefore many genotypes have been screened for their resistance in order to individuate rootstocks tolerant to specific or multiple stressing conditions. Among abiotic stresses occurring under intensive vegetable cultivation, grafting have been proposed to enhance plant response under stresses determined by extreme temperature, drought, salinity and flooding. In addition, grafting proved to improve nutrient uptake under not optimal conditions, reduce uptake of persistent organic pollutants from agricultural soils, improve alkalinity tolerance and limit the negative effect of boron, copper, cadmium, and manganese toxicity. This lecture, based on the review of available literature, concerns the response of grafted plants to diverse abiotic stressing conditions. Mechanism involved in stress tolerance of grafted plants will be also presented and discussed.

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[14] Preventing toxic element penetration into plants and fruits by using grafted plants

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Keywords: marginal irrigation water, fruit quality, melon

The use of marginal water for irrigation is increasing in arid and semiarid regions. Saline waters can contain high concentrations of salts and toxic microelements. Long-term use of these waters for irrigation could increase the accumulation and concentrations of microelements and saline elements (Na, and Cl) in the soil. Relatively high concentrations of Na⁺, Cl⁻, and microelements in the soil solution could be toxic to plants and to human beings. Absorption of these elements by the plants could affect their growth and yield, and increase the possibility of entry of contaminants into the human food supply chain. The effects of grafting on uptake and distribution of toxic microelements and Na within the plant were determined in two experiments, one in the field using non-grafted melon (*Cucumis melo* L. 'Arava') plants and melon plants grafted on pumpkin (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne 'TZ-148'), and one in the greenhouse using six combinations of melon and pumpkin plants: non-grafted, self-grafted, melons grafted on pumpkins and pumpkins grafted on melons. In the field experiment, non-grafted melon plants accumulated in their shoots and fruits more Na and Cl than those grafted on pumpkins. Moreover, the concentrations of the microelements B, Zn, Sr, Mn, Cu, Ti, Cr, Ni, and Cd in melon fruits from melon plants grafted onto pumpkin plants were lower than from non-grafted melon plants. In the greenhouse experiment, Na concentrations in the exudates from plants with melon root systems were higher than plants with pumpkin root systems. Quantitative analysis indicated that the pumpkin roots excluded ~74% of available Na, while there was nearly no Na exclusion by melon roots. Na retention by the pumpkin rootstocks decreased its amount in the shoot by an average 46.9% compared to uniform Na distribution throughout the plant. In contrast, no retention of Na could be found in plants grafted on melons. Grafting appears to be potentially useful for reducing the accumulation of toxic elements in fruits and thus in food-supply chains.

[15] Impact of grafting on cucumber tolerance to sodium chloride and sulfate salinity

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Keywords: *Cucumis sativus* L., gas exchange, mineral composition, sodium chloride, sodium sulphate

The aim of the current work was to determine whether grafting could improve salinity tolerance of cucumber using two different salt stressors such as NaCl and Na₂SO₄ with equimolar concentrations, and to study the changes induced by the rootstock in the shoot growth at agronomical and physiological levels. A greenhouse experiment was carried out to determine yield, growth, fruit quality, leaf gas exchange, electrolyte leakage, SPAD, and mineral composition and assimilate partitioning of cucumber plants (*Cucumis sativus* L. cv. 'Akito'), either ungrafted or grafted onto the commercial rootstock 'PS1313' (*Cucurbita maxima* Duch. × *Cucurbita moschata* Duch.) and cultured in quartziferous sand. Plants were supplied with three nutrient solutions: non-salt control, 27 mM Na₂SO₄, or 40 mM NaCl. Significant depression of yield, shoot and root biomass production in response to an increase of salinity concentration in the nutrient solution was observed with more detrimental effects with NaCl treatment. The two salt treatments, especially NaCl, inhibited photosynthesis, pigment synthesis, and membrane integrity. Salinity with NaCl and Na₂SO₄ improved fruit quality in both grafting combinations by increasing fruit dry matter and total soluble solids content. Moreover, at the two salt treatments the percentage of yield and biomass reduction in comparison to control was significantly lower in the plants grafted onto 'PS1313' than ungrafted plants, with the highest yield, shoot and root reduction recorded with NaCl in comparison to those recorded with Na₂SO₄ treatment. Grafted cucumber plants exposed to Na₂SO₄ were capable of maintaining higher net assimilation rates, higher chlorophyll content (SPAD index), a better nutritional status (higher K, Ca and Mg and lower Na) in the shoot tissues and higher membrane selectivity in comparison with ungrafted ones. The higher crop performance of grafted cucumber recorded with Na₂SO₄ than with NaCl, was attributed to the inability of the rootstock 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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[16] Does mycorrhiza improve salinity tolerance in grafted plants?

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Keywords: Grafting, endoroots, *Glomus* spp., NaCl

Grafting could be a strategy against salinity stress however rootstock genotype has a key role on the tolerance. Bio-control agents also enhance plant growth and increase salinity tolerance. The aim of this research was to combine the effects of rootstocks and mycorrhiza under salinity stress. The study was conducted in a PE covered greenhouse during the autumn and spring seasons of 2008 and 2009. 'Maxifort' and 'Beaufort' hybrid tomato rootstocks grafted with commercial cultivar 'Gökçe F₁'. Self grafted plants were used as control treatment. Half of the plants were put into solution with mycorrhiza (400 g da⁻¹ endoRoots[®] contained the spores of *Glomus* spp.) for one day before transplanting while the rest planted without any treatment. Plants were grown in plastic containers filled with perlite and substrate volume was 6 L per plant. The experimental design was randomized blocks with 3 replicates. Water and nutrient requirements of plants were supplied with complete nutrient solution via drip irrigation. The EC level of the solution was increased up to 6 dS m⁻¹ via NaCl. Irrigation timing was based on indoor integrated solar radiation level of 1.0 MJ m⁻². The amount of nutrient solution was adjusted according to the ratio of drain water/applied volume. Parameters related to plant growth, yield, fruit quality were determined. The use of rootstocks with mycorrhiza increased the total and marketable yield and plant growth. It was concluded that salinity tolerance could be improved if grafting is combined with mycorrhiza use.

Section 5. Scion-rootstock interaction: physiology

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[17] Plant grafting as a mean for enhancing abiotic stress tolerance in vegetables: probing possible mechanism for grafting compatibility

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Keywords: grafting, melon, *Cucurbita*, auxin, stress, ethylene, ROS

The use of grafting technology in vegetable crops represents a significant component of the vegetable industries. Most successful grafting combinations are selected on the basis of empirical testing. However, there is a need for better understanding of the endogenous factors which control rootstock-scion communication. Here we summarize experiments that lead us to suggest that auxin and ethylene may be involved in grafting incompatibility mechanism. We used compatible and incompatible *Cucurbita* rootstocks, grafted with melon (*Cucumis melo* L.) scion (var. 'Arava'). Naphthalene acetic acid (NAA), or ethaphon applied to roots, hydroponically, caused root decay in the incompatible grafted seedlings and were less harmful towards compatible and non-grafted melon seedlings. We suggest that auxin, produced in melon scion, is trans-located basipetally, to the root, and when reaching a threshold concentration, triggers ethylene evolution and root decay in incompatible seedlings. Incompatible pumpkin rootstocks, were more sensitive to high auxin and ethylene levels. One of the possible mechanisms that trigger degradation processes in the rootstock might be the enhancement of reactive oxygen species (ROS) activities. We have shown that application of high auxin concentration or high ethylene production by the roots of grafted melon seedlings lead to increased H₂O₂ concentration in the root, most notably in the incompatible grafted transplants. The compatible grafted seedlings accumulated significantly less H₂O₂ in their roots. On the other hand, the activities of peroxidase and SOD in the root system of compatible transplants were increased by NAA treatment and to higher levels than in the root of incompatible ones. We conclude that incompatibility may result from auxin-induced oxidative stress in the rootstock. In compatible grafting, anti-oxidative mechanism(s) may be activated, therefore reducing oxidative stress in the root and enabling its growth. Means for reduction of ethylene and ROS activities under salinity and high temperature stresses for enhancement grafting success will be presented.

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[18] Use of recombinant inbred lines as rootstocks to improve resource use efficiency in vegetables: a case study of WUE in tomato

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Keywords: ionome, plant hormones, reciprocal grafting, rootstock breeding, tomato

Increasing resource use efficiency is a major goal for modern agriculture. Although greenhouse tomato crops use 70% less water than open field crops, the water lost by transpiration is still enormous compared to the harvestable biomass produced: about 25 g of fruit per liter of water consumed. The delivery of commercial varieties with increased water use efficiency (WUE) has been hampered by the complexity of this trait. Few attempts have been made to improve WUE in tomato, and the high genetic variability for WUE existing in wild *Solanum* species has yet to be exploited. The major objective of this work is to identify and exploit rootstock-derived hormonal and ionic traits influencing shoot parameters related to WUE in commercial cultivars. A study performed with a subset of 40 lines selected from a F8 recombinant population (164 lines in total) derived from a cross between *Solanum lycopersicum* (cv. MoneyMaker) x *Solanum pimpinellifolium* (acc. TO-937), revealed that the variability for agronomic WUE was strongly associated with photosynthetic and growth parameters such as shoot dry weight, leaf area, stem diameter and intrinsic WUE (A_N/g_s). Interestingly, those parameters were positively correlated with the leaf sap concentration of the hormones abscisic acid (ABA) and cytokinins (CKs), while this correlation was negative with the ethylene precursor ACC and its ratios with ABA and CKs. Although plant breeding for those parameters is difficult, most of them can be manipulated in commercial varieties by using appropriate rootstock genotypes. However, reciprocal grafting between contrasting lines for water use and biomass production has revealed that WUE-related parameters depend essentially on the scion genotype. Nevertheless, our research demonstrates that some selected RILs can improve the water use efficiency of a given commercial scion variety by altering the root-to-shoot hormonal and ionic signaling, as reported for salinity and water-limited conditions in tomato.

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[19] Evaluating the effects of root-supplied ABA and cytokinins on scion vigour and water use

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Keywords: plant hormones, tomato, leaf area, stomatal conductance

The availability of tomato (*Solanum lycopersicum*) mutants and transgenics that are deficient in, or overproduce, various plant hormones provides an opportunity to determine the role of root-supplied hormones in regulating growth and water use of an economically important crop. Reciprocal grafting of isogenic wild-type (WT – Ailsa Craig) and the ABA-deficient *flacca* (*flc*) mutant revealed that the WT rootstock increased leaf area of *flc* / WT (scion / rootstock) plants by 1.6-fold (compared to *flc* self-grafts), by increasing xylem ABA concentration in *flc* scions (relative to *flc* self-grafts) up to 3-fold and normalising shoot ethylene relations. Partial restoration of leaf area of *flc* scions (relative to that of WT scions) suggests that the rootstock supplied insufficient ABA, or that leaf area was inhibited by an unknown, ethylene-independent mechanism. Reciprocal grafting of wild-type (WT – UC82B) and a constitutive isopentenyltransferase (*IPT*) expressing rootstock (WT/*35S::IPT*) demonstrated that WT/*35S::IPT* plants grown with 75 mM NaCl for 90 days had higher fruit *trans*-zeatin concentrations (1.5-2-fold) and yielded 30% more than WT/non-transformed plants, but the response of leaf area was not measured. To test whether additional cytokinin supply from the root system could enhance the phenotypic reversion of *flc*, it was grafted to UC82B, *35S::IPT*, Ailsa Craig and *flacca* rootstocks. All rootstocks increased leaf area of *flc* scions by 30-50% compared to *flc* self-grafts. Although there was no significant difference in *flc* leaf area when grafted on either UC82B or *35S::IPT* rootstocks, leaf area of *flc* / UC82B was 17% higher and stomatal conductance lower, than *flc* / Ailsa Craig. Further studies will determine whether these two rootstocks cause differences in ABA transport from root-to-shoot.

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[20] Rootstock cytokinin and abscisic acid overproduction improves tomato salinity tolerance

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Keywords: germplasm resources, root-to-shoot hormonal communication, rootstock breeding, root-targeted biotechnology

Soil salinity is an increasing problem for agriculture around the world. While most attention has focused on the role of ion accumulation in different plant organs, salinity also constitutes an osmotic stress that alters plant hormonal relations and growth. Hormonal profiling following stress imposition revealed temporal correlations between leaf growth and senescence and concentrations of the plant hormones cytokinins (CK) and abscisic acid (ABA) in roots, xylem sap and leaves. By increasing root CK and ABA production through two different approaches (inducible root CK production and grafting onto transgenic CK and ABA-overproducing rootstocks) we have improved tomato vegetative growth and increased fruit yield under moderate salinity. Tomato plants (cvs UC-82B and Ailsa Craig) transformed with the *IPT* (coding for isopentenyl transferase, a key enzyme for *de novo* CK biosynthesis) and *NCED* (*cis*-epoxycarotenoid dioxygenase, a key enzyme for ABA biosynthesis) genes respectively, under the control of constitutive CaMV 35S (*IPT*) and Gelvin-superpromoter (*NCED*), and heat shock inducible (*HSP70::IPT*) promoters, were used as rootstocks with a commercial F1 hybrid (cv TT-115, Unigenia Biosciences) scion. Grafted plants were cultivated in soil under greenhouse conditions in SE Spain with a drip fertigation system supplying a moderate salinity level obtained by increasing nutrient concentration (ECs: 4-7.5 dS m⁻¹). Enhancing CK and ABA biosynthesis specifically in the roots modifies hormonal root-to-signalling and improves not only physiological parameters influencing productivity (eg. leaf area, stomatal conductance and photosynthesis rate) but also the visual phenotype (ie. colour and vigour) of the scion variety. Targeting root-specific traits related to hormonal communication can be exploited to improve resource capture (water and nutrients) and thus plant development and crop yield under resource-limited conditions.

Section 6. Scion-rootstock interaction: yield and fruit quality

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[21] Grafting - A chance to enhance flavour and health-promoting compounds in tomato fruits?

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Keywords: sugars, acids, aroma volatiles, carotenoids, rootstock/scion interaction

Tomato is one of the most important horticultural crops in the world and grafting has become an important cultural practice for this fruit vegetable. Generally, grafting is used to reduce infections by soil-borne pathogens and to enhance the tolerance against abiotic stresses. Among those are nutrient deficiency and temperature stress. The use of rootstocks to alleviate abiotic stress conditions can increase easily growth and yield. However, several conflicting reports have been published about the rootstock influence on quality characteristics of tomato fruits especially on health-promoting and taste-related compounds (sugars, acids). Beside external appearance and texture, flavour and health-promoting compounds have becoming more important for consumers. Along with sugars and acids, aroma volatiles contribute to the flavour. To the best of our knowledge, no data are available about the influence of grafting and the rootstock/scion interaction on aroma volatiles in tomato. Therefore, two scions, cv. Classy (round, truss) and cv. Piccolino (cocktail) were self grafted or grafted on two commercial rootstocks (cv. Brigeor, Maxifort) and cultivated in a greenhouse using nutrition film technique. Furthermore, the cultivation was combined with three different abiotic factors: potassium deficiency in the first experiment, influence of suboptimal temperature (cultivation at 17°C in comparison to 21°C) in the second experiment and influence of radiation in the third experiment. Tomato fruits were analysed in red-ripe tomatoes at three harvest dates for each experiment. Results were discussed in relation to health promoting compounds (lycopene, β -carotene, ascorbic acid) and flavour compounds (sugars, titratable acids, aroma volatiles). E.g. the rootstock 'Maxifort' was able to alleviate the decreased concentration of titratable acids and few lipid derived aroma volatiles at suboptimal temperature. Finally, the effectiveness of grafting with respect to upgrading fruit quality is increasing but dependent on rootstock/scion interaction and environmental conditions used.

[22] The quality of *Cucumis melo* L. var. *inodorus* and *reticulatus* fruits in relation to different rootstocks

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Keywords: *Cucumis melo* L. var. *inodorus*, *Cucumis melo* L. var. *reticulatus*, rootstock, sensory characteristics, volatile profile

A possible alternative to the use of agrochemicals for soil disinfestations in melon cultivation is the use of grafted plants. The choice of rootstock is mainly based on the resistance to soil pathogens but the effects on plant productivity and fruit quality have to be considered. In this regards the research aimed to evaluate the effects of different rootstocks, selected for their resistance to diseases, on the sensory characteristics, volatile aroma profile and nutritional quality of *Cucumis melo* L. var. *inodorus* and *reticulatus* fruits. To define the fruit quality, we evaluated the effect of the selected rootstocks on plant productivity, physico-chemical parameters, sensory characteristics, carotenoid content and volatile aroma profile which are fundamental parameters for the consumer acceptability. All the data statistically elaborated allowed to identify the best rootstock for resistance to pathogens, productivity, fruit characteristics and nutritional quality with the minor detrimental effects on flavour and aroma sensory attributes. The research evidenced that some rootstocks, easily available on the market, can be successfully used for controlling soil pathogens of the *inodorus* and *reticulatus* plants without determining important changes on the fruit sensory profile. Since the sensory quality of fruits meets the consumer needs, our results could be of great interest for attaining competitiveness in horticulture field.

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[23] Rootstock effects on grafted tomato plant survivorship, composition, yield and fruit quality in organic field production

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Keywords: compatibility, genetic distance, disease, yield, nutrient

We documented the survivorship, vigor, composition, yield and fruit quality of grafted and ungrafted, organically and field-grown 'Celebrity' tomato (*Solanum lycopersicon* L.) in 2008-2010. Scion seedlings 4-5 weeks old were grafted, using the cleft method, to seedlings of up to 36 experimental and commercial rootstocks developed at OARDC or by commercial suppliers. Grafted plant survivorship and vigor were recorded for 4 weeks thereafter. Grafted plants producing three-four new leaves while healing and acclimating and self- and ungrafted control plants were set into single-row, raised-bed, compost-amended, 9.3-m² plots replicated one-four times and arranged in either a randomized complete block or augmented design late May-early June annually. Plots contained ten plants (self- and ungrafted controls, experimental) and were covered at the soil line by black polyethylene film overlaying a standard drip irrigation line. Irrigation was applied throughout annual study periods at intervals based on soil conditions and expected evapotranspirative demand. All plants were pruned and trellised. Scion vigor and foliar disease were rated during vegetative growth using height, canopy cover and the Horsfall-Barratt scale. Total and marketable yield (number, weight) of 'blush-red' fruit was recorded six-seven times annually. At season's end, all green fruit of marketable size were removed to help estimate total plant productivity. Disease ratings were completed on non-marketable fruit while fruit of external marketable quality were forwarded to measures of Brix, pH, and titratable acidity two-three times annually. Grafting effects on plant nutrients, growth regulators and other biochemical constituents were explored with tissue and soil samples taken from a subset of plots. Rootstock affected grafted plant survivorship in a manner related to genetic distance. Grafting tended to lower yield in the earliest harvests but most grafted plots produced more total and marketable fruit annually than non- or self-grafted plots. Tissue and soil samples also suggest that grafting may alter scion tissue makeup.

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Abstracts of posters

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[P1] Influence of different rootstocks on growth and yield of cucumber (*Cucumis sativus* L.)

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Keywords: *Cucumis sativus*, grafting, nematode, rootstock, yield

Greenhouse experiments were conducted to evaluate the effect of different cucurbit rootstock on growth and yield of cucumber under the impact of root-knot nematode. Seven cucurbit rootstocks (Strongtosa, Shintosa supreme, Tetsukabuto, Local pumpkin, Bottle gourd, RT62800216 and RT62800113) were selected to test their graft compatibility with cucumber plant and their resistance against root-knot nematode. Cucumber cultivar "Zeza" was grafted onto these rootstocks either by tongue or by top grafting methods. The grafted plants were transplanted along with ungrafted plants in greenhouse and their performance was evaluated. Results indicated that grafting on Strongtosa and Shintosa supreme resulted in 100% survival rate as compared to RT62800216, RT62800113, Bottle gourd and local pumpkin. In addition, these two rootstocks resulted in more vigorous cucumber plant growth. For instance, the total dry weight of vegetative parts was 112-123% higher than ungrafted plants in the first season and 131-152% in the second season. Rootstock type affected the fruit yield where Strongtosa and Shintosa produced higher marketable yield ranging from 260% to 280% of that in ungrafted plants. In addition, both rootstocks showed a significant increase in fruit yield when compared with plants grafted to the Tetsukabuto and Gourd rootstocks. Results obtained with the Tetsukabuto and Gourd rootstocks showed an increase in marketable yield ranged from 203% to 214% of that in ungrafted plants. Rootstocks showed differences in galling index for root knot nematode. The RT62800216 and RT62800113 had the highest galling index and the plants were severely infested with nematodes. On the other hand, Strongtosa had the lowest galling index and the plants showed enhanced resistance against the root knot nematode. Therefore, it is recommended to use Strongtosa and Shintosa supreme as rootstocks for cucumber since they confer tolerance to root knot nematode and improves plant vigor that leads to higher yield.

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[P2] Screening of salt and stress hydric tolerant of pepper based in photosynthetic parameters

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Keywords: salinity, drought, pepper, net photosynthetic, stomatal conductance, transpiration rate, quantum efficiency

Scarcity water and salinity are the major constrain of crop production in Mediterranean area. One of the most effective ways to overcome abiotic stresses is the introduction of tolerant rootstocks that can be used to graft desirable varieties. The present study was designed to screen pepper genotypes for hydric and salt tolerance to be used as rootstocks, based on variability in photosynthetic and chlorophyll fluorescence parameters. Healthy 18 genotypes included into *Capsicum baccatum*, *C. pubescens*, *C. frutescens*, *C. annuum* and *C. chinenses* were studied under hydric stress (decrease 60% respect to control) and salinity (5.5 dS m⁻¹ respect 1.1 dS m⁻¹ in control). After 1 month of initially treatments, the physiological parameters were measured. All plants survived and no visual injury was observed. The genotypes C-40, Tressor, Pasilla (*C. annuum*), Baccatum 1 and 2 (*C. baccatum*) and Chinenses 2 (*C. chinensis*) showed higher tolerance to both stresses (salinity and hydric) based on similarity of the net photosynthetic, stomatal conductance, transpiration rate and quantum efficiency of PSII photochemistry values between plants grown in stress conditions and control plants.

[P3] Graft induced changes in pepper fruit shape

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Keywords: grafting, pepper, fruit shape

The advantages of grafting, a popular and valuable technique used in the production of vegetables, are well known for years mainly confronting the soil-borne diseases and nematodes and resistance against abiotic stresses. However, there are several disadvantages that prevent the optimization of this technique; primarily the elevated price of grafted plantlets, a problem mitigated by the development of automated grafting robots as well as the application of scion micropropagation prior to micrografting. A second major disadvantage is the detrimental effect of the rootstock on the fruit quality characters of the scion, such as taste, flavor, texture, shape etc. Whereas these quality characters of vegetable fruits are difficult to be studied, fruit shape, shown already to be affected in pepper (*Capsicum annuum*) grafted plants is an easy to observe, measured and studied character. In order to study the effect of the rootstock on the phenotypic characters of the scion, several graftings were carried out using diverse pepper cultivars (cv) with different fruit shape: cv. Platika (long fruited) and cv. Solario (blocky fruited) as long as other two native Greek cultivars, named Long and Round after the shape of their mature fruits. It was observed that only when cv. Round (scion) was grafted on cv. Long (rootstock), the shape of the fruits changed from the typical round to the more oblong, resembling the long fruit shape of the rootstock. Moreover, the study was carried on also in the T₂ generation where it was observed that this fruit shape change is heritable; the fruits of the plants of T₂ progenies were adopting the more oblong shape rather than the round one.

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[P4] Tomato rootstock performance under open field conditions

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Keywords: tomato, yield, nematodes

Using grafted tomato plants in open field vegetable production must overcome numerous challenges before it is accepted by the industry in the US. Studies were performed to address use of grafted tomatoes in a raised bed system under plasticulture with both drip and seepage irrigation. Experiments were conducted in Palm Beach Gardens, and Ft. Pierce, Florida. The rootstocks tested include 'Aloha', 'Camel', 'Multifort', 'BB', 'HI-7997' and 'FL-91', and 'FL-47' as the controls, which were self-grafted and used as the scion. All plants were grown for 30 days under greenhouse conditions. After reaching a stem diameter between 1.5 and 2.0 mm the plants were grafted. The experiments were a randomized complete block design with 4-6 replicates. Total yields were calculated in 11.4 Kg boxes per hectare. In the Palm Beach trial 'Aloha', 'Multifort' and 'Camel' had yields of 2845, 2821 and 2727 boxes respectively. Yields for 'BB', FL-91 (control) and 'HI-7997' were 2529, 2317 and 2087 boxes respectively. The increase in yield for 'Aloha' and 'Multifort' was 22% or greater than the 'FL-91' control. The rootstock 'HI-7997' had significantly less yield and smaller fruit size than the other rootstocks. In the Ft. Pierce trial, grafted plants were combined with alternative fumigants and an herbicide only control. End of season soil nematode counts were higher in the herbicide-only plots, and root-knot nematode numbers extracted from tomato roots were higher in the herbicide-only plots. Non-grafted rootstocks supported higher nematode numbers in soil and roots than all other rootstocks. Interactions occurred between soil treatments and rootstocks with regard to galling. The most galling occurred in herbicide-only soil with non-grafted plants. 'Multifort' and 'Aloha' provided the best resistance to galling in herbicide-only treated soil. No differences in galling occurred among rootstocks in soil treated with methyl bromide, methyl iodide, or DMDS.

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[P5] The history, current status and future of the vegetable grafting in China

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Keywords: vegetable grafting, current status, problem, countermeasures

In China, the earliest literature about vegetable grafting was recorded in an ancient book “Shi-Sheng-Zhi-Shu” in the first century, BC. However, research and rapid demonstration of the grafting of cucurbitaceous and solanaceous vegetables such as cucumber, watermelon, melon, bitter gourd, tomato, eggplant etc. in China began in the late 1970s. The main purpose of grafted seedlings in China is to overcome soil-borne diseases and increase resistance to abiotic stress such as low temperature, and soil secondary salinization. Several grafting methods have been employed including tongue approach grafting, tube grafting, cleft grafting, hole insertion grafting, and root pruning hole insertion grafting. Among them, the hole insertion is the most popular method for cucurbitaceous plants, and the cleft grafting is the most popular method for solanaceous plants in China. Grafted seedling production increased rapidly in recent years, there are more than 300 seedling nursery factories in China. Currently, there are some problems limiting the demonstration of grafted seedlings in China, including the lack of compatible multi-disease-resistant rootstocks, the treatment of seed borne diseases, 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, (2) to optimize the environment control technique for the healing and hardening of grafted seedlings, (3) to set up standard practice of grafting procedure especially for the large scale grafting company, (4) to develop facilities related to increasing the grafting efficiency and reducing labor cost, (5) to control seed borne diseases and produce healthy grafting seedlings.

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[P6] Current status of vegetable grafting in French production

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Keywords: grafting, Solanaceae, Cucurbitaceae, soil borne pathogens.

From few years, the use of grafting plants on vegetable crops enhance because of methyl bromide's removal in 2007. Without chemical protection, soil borne pathogens for instance *Verticillium dahliae*, *Phomopsis sclerotioides* or *Fusarium* sp. and also nematodes caused damage on crop and, in most of case the only one solution is the use of grafting intraspecific or interspecific. In 2011, only some Solanaceae and Cucurbitaceae are concerned such as tomato, cucumber, melon, pepper and eggplant. By using grafting, producer wants to protect their culture by using the high resistance level of rootstock. Indeed most of commercial varieties available with high quality level are sensitive. In addition, grafting is also used to gaining strength like temperature requirement; it is possible with rootstock used on melon, tomato, eggplant and cucumber culture. In that condition, graft plants could be plant earlier in cold ground. Depending on the crop, grafting methods are different; approach grafting is used for cucumber, inlay grafting for Solanaceae and melon, and grafting application for melon, zucchini, watermelon and cucumber. Success depends on the conditions following grafting; grafter needs to take care of grafting plants almost during one week by making them in a closed humid chamber. Recent years, surfaces of graft cropped increased especially on tunnel production; for example, in the South East of France, graft is commonly used for early melon production (tunnel) due to low temperature. Past five years, methods of grafting have become paramount for tomato production. However, recently, some symptoms of replant disease were highlight on rootstock melon; it is due to generalization of grafting in some regions so selection pressure is high. We should combine grafting method with others alternative method; resistance conferred by the rootstock may be more sustainable.

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[P7] Evaluation of biometric traits, yield and heads quality between grafted and ungrafted artichoke plants

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Keywords: artichoke, hybrids, cardoon, rootstock, scion

Seed propagated artichoke (*Cynara cardunculus* subsp. *scolymus*) cultivars, have been introduced in the last years. In order to improve earliness, yield and quality of heads, three years open field trials were carried out to compare grafted and ungrafted seed propagated plants. For the grafting, two cultivars of cultivated cardoon (*Cynara cardunculus* var. *altilis*), 'Belgio' and 'Madrid', were used as rootstock and two artichoke hybrids, 'Concerto' and 'Madrigal' as scion. The same two hybrids were tested as ungrafted plants. The planting was made on 9th July, 2007, while the second and the third cropping cycle started on 7th July 2008 and 10th July 2009 respectively. Plant density was about 8,300 plant ha⁻¹. A randomized block experimental design was arranged. Eleven harvests were made on mean, for each cropping cycle. The main biometric traits, yield characteristics and head quality parameters were collected at every harvest. The yield of grafted plants was higher than the ungrafted ones (191,000 vs 153,000 heads ha⁻¹) as well as the number of heads per plants (23 vs 18), whereas no differences were noted both for the heads mean weight and for head quality parameters. Plant height, number and height of leaves, were also higher in grafted plants. The rootstock did not affect the beginning of harvest and the harvest season.

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[P8] Grafting of vegetables improve the production of eggplant in Chhattisgarh

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Keywords: grafting, resistant rootstock, wilt, production, eggplant

Grafting of vegetables began in the 1920s using resistant rootstock to control soil borne diseases. This process is now common in Asia, parts of Europe, and the Middle East. In Japan and Korea, most of the cucurbits and tomatoes grown are grafted. In the central part of India, states like Chhattisgarh, wilt is a major problem for cultivation of Solanaceous crops like tomato, eggplant etc. We were working in this aspect from last five years and have tried various rootstocks and got good results with *Solanum torvum* and *Solanum macrocarpan* as it had showed very good resistance to Bacterial Wilt (*Ralstonia solanacearum*) which is the major problem in Chattishgarh .The soil of this region is acidic. Hence we started using it as the rootstock and grafted (using silicon tubes) the preferred varieties/hybrids in that area. In 2009 we supplied grafted plants of eggplant in wilt prone area of Chhattisgarh. The farmers over there have got very good production results with the mortality rate of only 1 %. The demand of grafted plants increased in 2010 and this year we have supplied more plants this year in comparison to 2009& 2010. The technology although is traditional but was not tried earlier in the central part of India. By use of this technique the farmers have regular supply of eggplant. The above mentioned rootstocks have very deep root system thus can survive in dry months. The above point clearly shows that grafting of different brinjal cultivars on resistant rootstocks *Solanum torvum* & *Solanum macrocarpan* is showing good results in Chhattisgarh. Future prospects are very bright and we are making sincere efforts to make the plants available to the tribal farmers of that area so that they can successfully cultivate eggplants unlike as in near past.

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[P9] Optimization of root substrate formulation and mineral nutrition during the production of vegetable seedling grafts

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Keywords: nutrition, root substrates, seedling grafts, vegetable crops

The use of seedling grafts has been increasingly popular in the production of fruit vegetables in Korea. Superior scion cultivars grafted on seedling rootstocks tolerant to soil-borne diseases often results in higher crop yield and quality. For the production of healthy grafted transplants, seedlings have to be grown under the most favorable cultural conditions. Root substrate composition and property as well as mineral nutrition play an important role. Various growing media containing peat, perlite, vermiculite and coir have been tested for aeration, water retention, and nutrient holding characteristics as well as their influence on seedling growth. Peat is the best ingredient for root substrates. When root substrate contains more than 50% coir, initial seedling growth was poor mainly due to high Na⁺ and K⁺ levels. As seedling size increases, the negative effect of high salinity became less evident. Plug-germinated seedlings of fruit vegetables appeared to be more tolerant to increased salinity (up to 3.0 dS m⁻¹) as compared to bedding plant seedlings which do not usually tolerate 2.0 dS m⁻¹ or higher salinity during plug culture. Elevated nutrient concentration (to 2X standard solution) enhanced pre- and post-graft seedling growth in green pepper and tomato. They contained higher tissue N, P, K, Ca, and Mg contents compared those grown with lower nutrient concentrations. Tissue P content was lowered when nutrient solution contained excess amount of Ca⁺² and Mg⁺² during plug culture. When elevated nutrient concentration is used, plants grown with greater leaching fractions (LF, amount leached/applied) had more biomass and plant vigor than when grown with lower or no LF. In general, elevated nutrient concentration used in combination with higher LF resulted in the production of healthier and more vigorous seedling grafts.

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[P10] Intra and interspecific grafting in cucurbits – Risks and advantages

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Keywords: *Cucurbita* rootstocks, melon, soil-borne pathogens, fruit quality

Suppression of soil-borne pathogens can be achieved by grafting susceptible scions onto resistant rootstocks of the same species (intraspecific grafting) or on a close member of the same botanical family (interspecific grafting). In tomatoes, for example, a large collection of tomato rootstocks contain different genes for resistance to various pathogens is available thus intraspecific grafting is very common. In melons, however, intraspecific grafting is mainly used to avoid damages caused by wilt pathogens such as *Fusarium*, while protecting the scion from root and stem rot diseases such as *Monosporascus* and *Macrophomina* is achieved by interspecific grafting using *Cucurbita* rootstocks. Intra and interspecific grafting have their own beneficial and detrimental characteristics as to phytopathological and horticultural behavior. *Cucurbita* rootstocks provide nonspecific but efficient protection against a wide range of soil-borne pathogens and against some abiotic stresses. However, such rootstocks may in certain cases affect fruit yield positively or negatively, and fruit quality. On the other hand, susceptible muskmelons grafted onto resistant muskmelons have less horticultural problems related to scion- rootstock compatibility, but their resistance is often limited to few pathogens, to a single pathogen, or even to a specific race of one pathogen. In certain cases melon and watermelon rootstocks can affect dramatically the scion vigor and yield quantities. Both inter and intraspecific approaches together with additional disease control means such as fungicides should be developed and adapted specifically to certain area and growing season.

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[P11] The risk of musculoskeletal disorders for workers due to repetitive movements of upper limbs during the vegetable graft in greenhouses

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Keywords: vegetable grafting, musculoskeletal disorders, repetitive movements

The herbaceous grafting in horticulture is a practice widely spread and it permits to unite the quality and productivity characteristics with those of resistance to pathology transmitted from the soil much more quickly as regards the time necessary for genetic improvement. There are different methods of grafting (crown, cleft, whip grafting, etc.), especially used by skilled workers with the help of manual tools such as the grafting knife. Grafting work requires an excessive effort of upper limbs, owing to the great number of repetitive movements and the precision required to cut the grafting sections. All this determines a risk for the workers who work more than six hours a day in these conditions, risk which may involve some pathologies, generally of different origin (such as wrist and shoulder tendinitis, lateral epicondylitis, syndrome of carpal tunnel etc.), defined "WMSDs" (work related musculo-skeletal disorders). The aim of this research is to assess the risk of musculo skeletal disorders due to repetitive work, for workers employed in manual grafting in greenhouses. To assess the real danger of this work, we used a method ("OCRA index" according to ISO 11228-3:2009 Ergonomics - Manual handling - Part 3: Handling of low loads at high frequency) which keeps into consideration several risk factors (repetitiveness, prehension force, posture). The results show a medium - high risk for the right limb which effects the cutting up on the small plant to be grafted and a medium risk for the left limb. The factors which have contributed to reach such results are to be attributed to the continuous pinch of the knife, to the great number of movements and to the lack of recovering time.

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[P12] Effect of nitrogen form and nutrient solution pH on growth, yield and mineral composition of selfgrafted and grafted tomatoes

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Keywords: *Solanum lycopersicum* L., ammonium, nitrate, N, P, K, Ca, Mg

Three greenhouse experiments were carried out to determine the effect of the nitrogen form and the nutrient solution pH on growth, yield, leaf gas exchange, mineral composition and partitioning of self-grafted and grafted tomatoes (*Solanum lycopersicum* L.) grown in hydroponics. Exp. 1 included five pH levels in the nutrient solution (3.5, 4.5, 5.5, 6.5, and 7.5) and cv. Moneymaker grafted either on itself or on cv. Maxifort; Exp 2 included four different ratios of NO_3^- to NH_4^+ (100:0, 70:30, 30:70, and 0:100) and cv. Moneymaker grafted either on itself or on cv. Maxifort. The separate effects of nutrient solution pH (Exp. 1) and the different ratios of NO_3^- to NH_4^+ (Exp. 2) were recorded on short term experiments (about 4 weeks until the first truss). The third experiment (Exp. 3) was carried out to investigate on long-term the effect of the N-form (same ratios as in Exp. 2) on crop performance, leaf gas exchange and mineral composition of self-grafted and grafted tomatoes. Neither the nutrient solution pH nor the grafting combinations significantly affected the plant growth characteristics, such as plant height, leaf number, leaf area and shoot dry weight. Contrary, the Ca concentration increased with increasing pH and was higher in grafted than ungrafted plants (Exp. 1). The largest impact on plant growth characteristics was recorded at both 70:30 and 30:70 treatments, and in grafted compared to selfgrafted plants (Exp. 2). In Exp. 3 the fruit yield and number decreased linearly as the NH_4 concentration in the nutrient solution increased above 70%. The increase in NH_4 concentration in the solution is the main cause of suppression of Ca concentration in the leaves fruits and the increase of blossom end rot.

[P13] A simplified and non-destructive method for tomato bacterial canker detection applied to tomato plants and handling tools

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Keywords: Plant raisers, *Clavibacter michiganensis* subsp. *michiganensis*, PCR, grafting

Tomato bacterial canker is a well known seed borne disease which can seriously damage high cash tomato crops. Protected tomatoes, and particularly grafted and/or soilless tomatoes, are more exposed to bacterial canker damages due to disease spread throughout grafting operations/tools (e.g razor blades, plant trays, etc.) and/or through the nutrient solution used in soilless cultivation systems. The paper describes the adoption of existing tools for a simply and quick detection of *Clavibacter michiganensis* sub. sp. *michiganensis* (CMM) on tomato plants and on the handling tools used for plant grafting (razor blades) and growing purposes (trays, benches, etc.). Several diagnostic tools are available for the detection and identification of CMM including semi-selective media, immuno-diagnostic, bio-molecular methods and EPPO guidelines give useful and practical information about diagnosis to be performed on seeds and on symptomatic and not symptomatic plants. End users and stakeholders need quick diagnostic responses in order to set up effective control measures, nevertheless, the diagnostic procedure might require long time and it could not perfectly fit growers' and plant raisers' needs. Moreover when analysis have to be performed on symptomatic plants, existing diagnostic tools need to displace potentially infected plants from field to laboratory. Finally the collection of a large number of samples is needed when analysis is performed on not symptomatic plants in order to reach an appropriate level of significance. In this regard an easy diagnostic system, which simplifies sampling and analytical methods avoiding the transportation of plants from the field to the laboratory, was set up. The method basically consists of a sampling procedure based on the use of a ready-to-use sampling solution. Plant tissues and/or liquid juices are collected and sampled from plants, and from tools potentially used with several plants such as razor-blades and growing trays. Afterward the sampling solution is centrifuged and the remaining pellet analyzed according to the PCR EPPO protocol. The paper gives some information about the sensitivity of the method and the validation tests carried out. Authors discuss the adaptability of the method particularly on grafted tomatoes for a quick quality control in nurseries during the different growing phases.

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[P14] Ideal morphophysiological stage for grafting cantaloupe 'Bônus no. 2'

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Keywords: *Cucumis melo* var. *reticulatus* Naud, cleft, rootstock, protected cultivation, seedlings

Due to cantaloupe being intensively cultivated under greenhouse conditions without crop rotation, problems of soil pathogens and salinity have recently become very serious. The use of grafted cantaloupe plants has been pointed as a good alternative to solve those problems. The objective of this research was to find out the ideal morphophysiological stage for grafting cantaloupe plants of the 'Bonus no. 2' variety by means of the cleft type of grafting. As rootstock plants of the hybrid pumpkin 'Shelper' were used. The results were evaluated in terms of grafting success, productivity, and fruit quality. The experiment was set according to a randomized complete block design with five treatments and five repetitions. Each repetition was formed by eight plants. The treatments were composed of four different development stages of the cantaloupe plants thusly described: developed cotyledonary leaves, developing first leaf, developing second leaf, and two developed leaves. The fifth treatment was formed by non grafted cantaloupe plants, that is, the check treatment. The following measurements evaluated the experiment results: surviving plants percentage, fruits mean weight, fruit length and diameter, fruit coat and pulp thickness, soluble solids content, and the coat reticulation index. The ideal stage for grafting cantaloupe plants is that one of the developing first leaf - the results were statistically similar to those of the check treatment.

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[P15] Rootstocks resistant to *Meloidogyne incognita* and compatible for grafting with cantaloupe

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Keywords : *Cucumis melo* var. *reticulatus*, plant diseases, cucurbitaceous, nematode

Due to the scarcity of studies concerning the grafting of cantaloupe viewing the control of soil pathogens, the objective of this research was to evaluate 16 cucurbitaceous species as to their resistance to *Meloidogyne incognita* as well as their compatibility for grafting with cantaloupe. The experiment was carried out at Jaboticabal, state of São Paulo, Brazil. Sixteen accessions of cucurbitaceous were used : *Benincasa hispida*, smooth luffa, pumpkin 'Jacarezinho', pumpkin 'Menina Brasileira', winter squash 'Exposição', winter squash 'Coroa', pumpkin 'Canhão seca', pumpkin 'Squash', field pumpkin 'Enrugado Verde', pumpkin 'Mini Paulista', pumpkin 'Goianinha', watermelon 'Charleston Gray', melon 'Redondo Gaucho', melon 'Redondo Amarelo', cucumber 'Caipira HS', and cucumber 'Caipira Rubi'. The resistance of these accessions was evaluated by means of the reproduction factor. Each rootstock was represented by 10 plants, each plant considered a statistical repetition. The grafted seedlings were transplanted to ceramic vases to which 10 ml of a solution containing 300 *M. incognita* eggs or second-stage juveniles were applied. Fifty days after transplantation, the plants were removed from the vases and the resistance to that pest evaluated. The degree of compatibility between cantaloupe and the rootstocks was verified by means of grafting the rootstocks on cantaloupe 'Bônus no. 2'. The genotypes smooth luffa, pumpkin 'Goianinha', pumpkin 'Mini Paulista', melon 'Redondo Amarelo', watermelon 'Charleston Gray' were found to be resistant to *M. incognita*. The best compatibilities took place with melon 'Amarelo' with 100% of success. The pumpkin 'Mini Paulista' was the second best with 94% of success. The rootstocks smooth luffa, watermelon 'Charleston Gray', and pumpkin 'Goianinha' showed low proportion of grafting success : 66, 62, and 50%, respectively.

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[P16] Reaction of pepper rootstocks to selected soil-borne pathogens under artificial inoculation conditions

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Keywords: *Phytophthora capsici*, *Verticillium dahliae*, *Rhizoctonia solani*, *Capsicum annuum*

Bell pepper (*Capsicum annuum*) is a popular vegetable crop, widely grown in Italy. Several cultivars grown in Piedmont (northern Italy) for fresh consumption are very much appreciated for their quality and taste. Bell pepper is commonly subject to the attacks of several soilborne pathogens; among those *Phytophthora capsici*, *Rhizoctonia solani* and *Verticillium dahliae* are economically important in most production areas. Grafting is a common practice in many countries and, after the phase out of methyl bromide as fumigant, is more widely used for a variety of diseases on solanaceous crops. Several trials were carried out under glasshouse under artificial inoculation of pepper rootstocks with selected strains of *Phytophthora capsici*, *Verticillium dahliae* and *Rhizoctonia solani*, obtained from infected plants and previously tested for pathogenicity on not grafted pepper plants cv. Cuneo. The susceptibility of several commercial pepper rootstocks against selected soil-borne pathogens is reported. Many of the commercial rootstocks were susceptible to one or more pathogens.

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[P17] Yield and fruit quality performance of new tomato rootstocks under salt stress conditions

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Keywords: sodium exclusion, Maxifort, Arnold, Armstrong, soilless system

As the use of tomato grafting is increasing worldwide, and multinational seed companies are introducing new rootstocks with promising yield and fruit quality performances and resistance to several diseases, it is of particular importance to test their tolerance to specific abiotic stress conditions. To this purpose, two annual greenhouse experiments were conducted in soilless system under NaCl stress conditions on tomato plants (*Solanum lycopersicum* L. cultivar 'Cuore di Bue'), either ungrafted or grafted onto commercial rootstocks such as 'Maxifort F1' (2009), 'Arnold F1' (2009 and 2010), and 'Armstrong F1' (2010). Plants were grown in 10 L pots containing a perlitepeat substrate mix (3:1, v/v) and irrigated with nutrient solution containing 0, 20, or 40 mM NaCl (2009) or 0 and 20 mM NaCl (2010). Sodium accumulation and compartmentalization in fruits, stem and young, fully expanded and senescent leaves were measured in order to assess the sodium exclusion ability of each rootstock. The results showed that salinity significantly reduced tomato fruit yield and the response to salt stress was significantly affected by rootstocks. In fact, a significantly lower Na⁺ content was found in fruits of grafted plants as compared to ungrafted plants, confirming that salt stress tolerance is modulated by rootstocks. In presence of 20 mM NaCl, the best yield performance was obtained by Arnold grafted plants, in both experiments, while no significant tolerance improvement was assessed at higher NaCl stress level, revealing that the rootstock Arnold may tolerate high NaCl stresses, but only below certain levels. As expected, salinity improved fruit quality by increasing fruit dry matter, soluble sugar, and titratable acidity contents of all plants, and had no significant effect on vitamin C content. While, an even fruit quality was observed, consistently in both experiments, between grafted and ungrafted plants.

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[P18] Does the scion influence the rootstock response to salinity in Solanaceous species?

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Keywords: grafting, salt stress, tomato, eggplant, biomass partitioning, mineral composition

An experiment was carried out to study if the scion could influence the response to salinity of solanaceous rootstocks. Tomato and eggplant were grafted onto two rootstocks ('Beaufort' and 'Heman'). Plants were grown in an open soilless cultivation system and supplied with two nutrient solutions: non-salt control or 15 mM Na₂SO₄. Plant biomass production and partitioning were significantly influenced by salinity in interaction with rootstock and scion. Tomato grafted onto Beaufort showed a reduction of shoot biomass due to salinity lower than the one observed for Heman. For eggplant the negative effect of salt stress was quite similar for both rootstocks. Significant interactions were also observed for root biomass. Root biomass of tomato grafted onto Heman was strongly reduced by salinity while no difference was detected for eggplant. The reduction of the leaf relative water content as consequence of salinity was evident for all treatments except for the combination eggplant-Beaufort. The leaf Na concentration was highest in tomato stressed plants grafted onto Heman while the difference between control and salinity was lowest in eggplant-Heman. The mineral composition of plant tissues demonstrated that the negative consequence of salinity on biomass production and partitioning was strictly related to the effect of toxic ions within plant organs and slightly to macronutrient content. The scion seems to influence the rootstock uptake of some ions under salt stress conditions.

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[P19] Effect of rootstocks on pepper grown under sodium chloride and sulphate salinity

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Keywords: grafting, salt stress, biomass partitioning, mineral composition

A preliminary study was conducted to evaluate some widespread rootstocks for pepper to improve salinity tolerance of the crop. Then we investigated if salt effect is ion specific or osmotic dependent. Dry biomass production and partitioning were measured on plants un-grafted and grafted onto 3 commercial rootstocks ('Atlante', 'Galaxy', 'Robusto'). Mineral composition of plant organs was also determined. Plants were supplied with four nutrient solutions: non-salt control, 15 mM Na₂SO₄, 30 mM NaCl, 21.5 mM Na₂SO₄. Sodium sulphate salinity treatments had the same concentration of Na or the same electrical conductivity of sodium chloride nutrient solution. The negative effect of salt stress on biomass production was different according to the rootstock adopted and the kind of salinity. Although shoot dry biomass of grafted plants was similar or lower than un-grafted plant under salt stress, the difference compared to the un-stressed control was lower for some rootstocks. Moreover, rootstocks differently affected the response of pepper to salinity treatments. Atlante was affected by salinity regardless the stress, Galaxy appeared more sensitive to sulphate salinity than chloride and Robusto was negatively affected only by the highest concentration of Na₂SO₄. The interaction between salt source and rootstocks was also observed for root growth. Root biomass of Galaxy and Robusto similarly decreased in all salinity treatments compared to the un-stressed control, whereas the roots of Atlante were significantly influenced only by NaCl. The relative water content was reduced by salinity in all rootstocks without interaction effects. Plant response to salt stress was more influenced by the different rootstock capability to restrict the Na⁺ and Cl⁻ shoot uptake than nutrient content.

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[P20] The effectiveness of grafting to improve watermelon tolerance to low potassium stress

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Keywords: watermelon, rootstock, grafting, potassium absorption, potassium utilization

To test the possibility that using appropriate rootstock could improve watermelon tolerance to low potassium stress, a greenhouse experiment was conducted to determine plant growth, leaf physiological responses and mineral contents of watermelon plants 'Zaochunhongyu' [*Citrullus lanatus* (thumb.) Matsum and Nikai], either ungrafted or grafted onto three commercial rootstocks: 'Hongdun' (*Citrullus lanatus* sp.), 'Jingxinzen No. 4' (*Cucurbita moschata* Duch.) and 'Nabizhen' [*Lagenaria siceraria* (Mol.) Standl.] grown under hydroponic conditions. Plants were supplied with nutrient solutions having two levels of potassium (6.0 or 0.6 mM K). Compared with plants treated with 6.0 mM K, the results showed that the 0.6 mM K treatment resulted in a significant decrease in shoot and root dry weight, net photosynthetic rate, leaf N and K contents in both grafted and ungrafted plants. However, a less decrease in shoot dry weight and net photosynthetic rate was observed in plants grafted onto 'Jingxinzen No. 4' and 'Hongdun' than those of ungrafted plants. The volume, Ca and Mg concentrations in xylem sap were significantly higher in plants grafted onto 'Jingxinzen No. 4' and 'Hongdun' than those of the ungrafted plants. In addition, no obvious advantage in plant growth, potassium absorption and transport was observed in the plants grafted onto 'Nabizhen' compared with the ungrafted plants. In conclusion, the above results support the hypothesis that watermelon plants grafted onto appropriate rootstocks (for example, 'Hongdun' and 'Jinxin No. 4') can enhance watermelon tolerance to low potassium stress.

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[P21] Growth and yield of grafted cucumbers in the soil infested with root-knot nematodes

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Keywords: *Cucumis sativus*, greenhouse, *Meloidogyne* spp, rootstocks

Cucumber is among the most grown crops in protected cultivation worldwide. Despite the expansion of soilless cultivation in greenhouses, there is still considerable acreage of soil grown cucumbers. The monoculture or narrow crop rotation are widely present in greenhouse production, and can result in problems with soil born diseases and pests. Grafting at tolerant rootstocks as alternative to usage of pesticides could be more sustainable approach, particularly for organic production. The aim of this research was to determine the effect of rootstocks on cucumbers growth and yield in soils infested with root-knot nematodes (*Meloidogyne* spp.). Cucumber (cv. Adrian) was grown on its own roots or grafted on three rootstocks of *Lagenaria siceraria* (Emphasis, S-1, and Gourd) and two interspecific hybrid rootstocks of *Cucurbita maxima* x *C. moschata* (Strong Tosa and RS 841 Improved). The experiments were carried out in commercial greenhouse, with cucumber grafted on three rootstocks in first, and five rootstocks in the second spring-summer season. The vegetative growth of plants (height and no. of leaves) was considerably affected by grafting on different rootstocks in both seasons. The yield (no. of fruits and weight per plant) was higher on plants grafted on Strong Tosa compared to other rootstocks or un-grafted plants in first season, and the same was found for Strong Tosa and RS 841 Improved in the second season. Although high variability was detected for number of nematodes per gram of root tissue the differences among rootstocks were not significant. Grafting of cucumbers on different rootstock was confirmed as an acceptable non-chemical method in overcoming limitations of soils infected with root knot nematodes, but the effect was highly dependable on choice of rootstock. The method could be suitable especially for small producers which could not adopt expensive soilless system of production.

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[P22] Effects of grafting and planting density on two watermelon F₁ hybrids grown in the north-western coast of Sicily

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Key words: *Citrullus lanatus*, grafted seedlings, spacing, mulching

As the demand for watermelon 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. The effects of *Cucurbita maxima* x *C. moschata* rootstock (RS 841) on two watermelon cultivars were studied by comparing grafted plants with non-grafted ones grown at four plant densities in the north-western coast of Sicily. Plug plants of Minirossa F1 and Minimonaco F1 hybrids were transplanted at plant densities of 0.50, 0.66, 1.0 or 2.0 plants m⁻² in the third week of April. A transparent polyethylene film was applied for mulching. Regardless of the cultivars tested, fruit yield and average fruit weight were positively affected by grafting. Increasing plant density resulted in higher yields in both cultivars. Total soluble solid content was not affected by the treatments tested. Rind thickness was higher in grafted plants whereas mesocarp thickness was higher in non-grafted plants as compared to grafted plants.

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[P23] Rootstocks resistant to root-knot nematodes and compatible for grafting with cantaloupe

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Keywords: *Cucumis melo* var. *reticulatus* Naud, *Meloidogyne incognita*, *Meloidogyne javanica*, plant disease

Nematodes attack severely cantaloupe plants under protected cultivation conditions. So, the objective of this research was to select plants to function as rootstocks resistant to *Meloidogyne incognita* and *Meloidogyne javanica* in grafted cantaloupes. The experiment was conducted under greenhouse conditions from October 2010 through February 2011 on the campus of Jaboticabal of the Paulista State University, Jaboticabal, state of São Paulo, Brazil. Thirty-three cucurbitaceous species, such as melons, pumpkins, cucumbers, winter squashes, watermelons, smooth luffas, gourds, and others, were investigated as rootstocks for grafting with cantaloupe. Ten plants per rootstock were used, each plant considered a statistical repetition. The grafted seedlings were transplanted to ceramic vases in which an inoculation with 3,000 eggs of *M. incognita* per root system was made. Fifty days after the inoculation, the plants were evaluated as to resistance to the nematode by means of the reproduction factor. Resistance to *M. javanica* was evaluated by the same procedures. The grafting compatibility between cantaloupe and the rootstocks previously characterized as resistant was evaluated by means of 60 graftings of the cleft type. The cantaloupe varieties 'Bônus no. 2' and 'Fantasy' were used for this purpose. The cucurbits CNPH 01-960, CNPH 01-962, CNPH 01-963, melon 'Gaúcho redondo', and *Benincasa hispida* were considered resistant to *M. incognita*. The cucurbits round yellow melon, melon 'Gulfcoast', melon 'Chilton', watermelon 'Charleston gray', progeny of the watermelon from Korea, water pumpkin, the meter long luffa, *Benincasa hispida*, and snake gourd (*Trichosanthes cucumerina*) were considered resistant to *M. javanica*. The other rootstocks were considered susceptible to both nematodes. The compatibility between cantaloupe and all the rootstocks was higher than 98%. Thus, the use of these species as rootstocks to cantaloupe is considered as a promising technique.

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[P24] Rustic cucurbitaceous resistant to *Didymella bryoniae* as rootstocks to cantaloupe

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Keywords : *Cucumis melo* var. *reticulatus* Naud, gummy stem blight, plant disease

Cantaloupe, growing under greenhouse conditions, is highly susceptible to gummy stem blight, caused by *Didymella bryoniae*. So, the objective of this work was to find rootstocks that, in addition to conferring resistance to that disease, were compatible with cantaloupe. Conducted at the Department of Plant Protection of the Paulista State University, campus of Jaboticabal, this experiment lasted from April through May of 2011. Eleven rustic cucurbitaceous species: Marenka (*Lagenaria siceraria*), Porongo snake (*Lagenaria siceraria*), African Warty, Porongo doll (*Lagenaria siceraria*), Bitter melon (*Momordica charantia*), Cucumber Dragon Egg (*Cucumis melo*), Cucumber Hmong Red (*Cucumis melo*), Yellow Cucumber Chinese (*Cucumis melo*), Mini pumpkin decorative wrinkled, Mini pumpkin decorative Moranga, Mini pumpkin decorative flat and two cantaloupe hybrid cultivars: 'Bônus n° 2' and 'Fantasy', were tested to *D. bryoniae*. The experiment was set according to a completely random design with 13 treatments and four repetitions. Each repetition was constituted by a vase with three seedlings. Each treatment had its own check treatment. The seedlings were inoculated with the pathogen in a culture medium, with the help of a toothpick. Fifteen days after the inoculation, grades were attributed to the seedlings as to their response to the pathogen. The rootstocks Bitter Melon, Cucumber Dragon Egg, Cucumber Hmong Red and Yellow Cucumber Chinese were considered resistant to *D. bryoniae*. The utilization of these materials to confer resistance to cantaloupe plants to *D. bryoniae* seems promising, studies about grafting compatibility should be performed.

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[P25] Water use efficiency of a commercial tomato variety grafted onto selected lines of a tomato RIL population used as rootstocks

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Keywords: tomato, grafting, rootstocks, leaf water potential, transpiration

This work is part of a larger project to study genetic variability in water use efficiency (WUE) in a tomato recombinant inbred line population (RIL). The results obtained under growth chamber conditions suggest the existence of differences among RILs in their root capacity to supply the demand of water from shoots. Under Mediterranean greenhouse conditions, root water supply is essential for productivity, considering that irrigation is not a limiting factor but climatic transpirational demand is high usually at midday. In these circumstances reduced plant water content determines a water backflow via xylem from fruits to leaves with the subsequent loss of yield. The objective of this research was to explore the performance under real greenhouse conditions of selected RIL lines used as rootstocks on which a commercial tomato variety was used as scion. We focused on stem diameter variation obtained by means of stem dendrometers as a plant water stress indicator. Dendrometers have been widely used to monitor plant water status in fruit trees, and the maximum daily stem shrinkage (MDS) has been shown to have the potential to serve as a plant water stress indicator. However, it is already known that other factors such as phenological stage and crop load can affect stem growth independently of plant water status. Previous work in our group suggested that stem could act as a water store in the tomato plant which could maintain water supply to leaves under high transpiration rates. Variation of MDS and stem growth rate in tomato grafted plants using selected RILs as rootstocks is discussed in relation with leaf water potential and plant fruit load.

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[P26] The Investigation on the inter specific hybridization possibilities and hybrid seed yield of winter squash (*Cucurbita maxima* Duch.) and pumpkin (*Cucurbita moschata* Pour) lines for rootstock breeding

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Keywords: inter specific hybridization, rootstock, breeding, watermelon

The hybrids of *Cucurbita maxima* x *C. moschat* have been used widely in grafted watermelon, melon and cucumber seedling producing. Inter specific hybrid seed production of *C. maxima* x *C. moschata* mainly depends on compatibility of genotypes. In this study, inter-specific hybridization at different combination was tried to obtain *C. maxima* x *C. moschata* rootstocks. The starting genetic materials (from Turkey, Japanese and Mexico) were inbred and purified up to S5 generation in this research. In addition, these genotypes were selected base on plant vigor, hypocotyls characteristics, and seed yields. 234 inter-specific hybridizations were made with using 12 *C. maxima* female genotypes and 11 *C. moschata* male genotypes. 79 inter-specific hybrid fruits were obtained from these hybridizations. The rates of normal (full seed) seeded fruits was found 12%. The normal (full) seeds were obtained from some hybrid combinations of 6 winter squash and 3 pumpkin genotypes. Hybrid compatibilities of MO8 pumpkin genotypes with winter squash genotypes were determined as fairly good according to the other genotypes. MA4, MA9 and MA12 winter squash genotypes were determined as promising lines for obtaining of hybrid seed production at the end of this study. In conclusion, RS3 (MA9 X MO8), RS4 (MA12 X MO2) and RS6 (MA4 X MO8) were valuable hybrids for seed yield (seed/fruit), seed number and seed fullness traits. The hybridization programs have been continued with these lines as determined promising cultivar the aspects of hybridization possibilities and hybrid seed yield. In addition, graft compatibility, resistance to *Fusarium oxysporum* FOC-FON-FOM, yield and quality have been made on these hybrid lines.

[P27] Rootstock effect on cold tolerance of grafted watermelon

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Keywords: grafting, cold tolerance, *Lagenaria siceraria*, *Cucurbita maxima*, *Cucurbita moschata*

In this study, effect of rootstocks on plant growth in grafted watermelon under low temperature was investigated. Watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nakai] cultivar Crimson Tide was grafted onto five *Lagenaria siceraria* landraces, one *Cucurbita maxima* landrace, two *L. siceraria* hybrids and four *C. maxima* x *C. moschata* hybrids by hole insertion grafting technique. Ungrafted watermelon plants were used as control. Study was conducted in an unheated greenhouse in 2010 winter. Grafted plants at 2-3 true leaf stage were transplanted to three l pots filled with peat: perlite (2:1) mixture and grown for 25 days. Mean temperature of greenhouse was 21 °C in day time and 13 °C night time. After 25 days, plants were harvested and number of branch, main stem length, number of leaves, leaf area weight of leaf, stem and root were determined. Calcium and Phosphorous concentrations of leaf were determined. Effects of rootstocks on the measured parameters were found statistically significant. Grafted plants had lateral branches while controls did not have lateral branch. Main stem length and weight two fold increased in grafted plants as compared to control. Leaf fresh weight was 3.53 g in control plants while mean leaf fresh weight of grafted plants was about 7.0 g per plant. Plants grafted onto Kublai (*C. maxima* x *C. moschata*) produced the highest leaf fresh weight. Grafted plants higher leaf area and leaf number than control plants. The highest leaf number per plants was recorded in the plants grafted onto *L. siceraria* landraces 33-35. Significant difference was not observed between plants grafted onto local *L. siceraria*, commercial *Lagenaria* and *Cucurbita* rootstocks as regarded to plant growth parameters.

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[P28] Influence of grafting rootstocks on quality and growth of tomato cultivars

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Keywords: tomato, resistance, quality, sugar content

Since 1997 glashouse trials (randomized blocks, 4 repeats) with tomato rootstocks are running in Weihenstephan. Using 'Encore' as standard cultivar for head grafting and as ungrafted comparison variant, each year established and new breded F1-hybrid-cultivars of *Lycopersicon esculentum* x *Lycopersicon hirsutum* from different seed companies were examined for their influence on growth, yield, fruit quality and resistance behavior of soil grown tomatoes. Grafted plants generally showed a stronger growth and in most years a significantly higher yield compared to an ungrafted crop. The yield difference was furthermore influenced by the duration of the cultivation period and the soil health. Even in healthy soil higher yields are possible. The longer the crop was cultivated the more distinctive the yield difference. Compared among themselves the examined rootstocks yield differences were rarely significant. The increase of yield is not caused by a higher amount but by larger size of the fruits, especially in the later state of cultivation. Since the sugar content in tomatoes correlates with fruit size, in tendency it was lower in fruits of grafted plants in comparison with grafted variants. Grafting had no effect on the firmness (Bareis-measured) of tomatoes. The rootstock cultivars differed in their resistance behavior, particularly with regard to nematodes (*Meloidogyne subsp.*) and corky root (*Pyrenochaeta lycopersici*). Root evaluations at the end of the cultivation period made clear that some cultivars allow an increasing of nematodes and therefore a damaging of following crops, although the grafted tomatoes themselves showed a normal growing behavior and high yield. Over the years especially 'Vigomax' (deRuitter) and 'Brigeor' (Enza) demonstrated a reliable resistance behavior towards *Meloidogyne ssp.*

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[P29] Grafting may improve water uptake and/or utilization efficiency in organic, soil-grown tomato

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Keywords: irrigation, yield, high tunnel, rootstock

We documented the performance of ungrafted and grafted 'Cherokee Purple' tomato (*Solanum lycopersicon* L.) plants grown on a standard or half-standard irrigation regime during organic high tunnel production. Four-five week old scion seedlings were grafted, using the cleft method, to seedlings of two experimental rootstocks (314, 338) developed at OARDC and known to be compatible with 'Cherokee Purple'. Grafted plants produced three-four new leaves before being set into single-row, raised-bed, 6.5-m² plots replicated four times and arranged in a randomized complete block design within a 9 m x 24 m single poly-layer high tunnel in late April of 2009 and 2010. Plots contained seven grafted or ungrafted control plants and were covered at the soil line by black, semi-permeable polyvinyl fabric and supplied by a standard drip irrigation line plumbed to operate independently from others within the different irrigation regimen. All plots were irrigated concurrently for the first 30-40 days after establishment, followed by the onset of flowering. Thereafter, irrigation events occurred every three ('standard') or six ('reduced') days depending on regimen with approximately 6.4 mm water delivered per event regardless of regimen. Irrigation in 'standard' plots totaled approximately 12 cm over the final 60 d and 17 cm over the final 90 d of the study in 2009 and 2010, respectively. Total and marketable fruit yield (number, weight) was recorded at weekly-biweekly intervals nine times in 2009 and eleven times in 2010 before fruit production and ripening stalled. Total and marketable yield were greater in grafted than ungrafted 'standard' plots in both years and in 'reduced' plots in 2009. Yield in 'reduced' plots was unaffected by grafting in 2010, possibly due to two instances of water infiltration from rainfall-fed surface flow. Overall, the data suggest that soil-grown grafted tomato plants have greater water uptake and/or utilization efficiency than their ungrafted counterparts.

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[P30] The influence of salinity on seedling growth of some pumpkin seeds used as rootstock

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Keywords: salinity, pumpkin, NaCl, rootstock

In this study, the effects of different NaCl levels (0, "control", 2, 4, 8, and 12 dS m⁻¹) on seedling growth of Obez, RS 841 and Ferro F₁ pumpkin varieties widely used around the world as rootstock were investigated. Seedlings grown under saline conditions were investigated for plant main stem length, plant length, root length, shoot length, root fresh weight, root dry weight, shoot fresh weight and shoot dry weights. In addition to the physical parameters relative water content, sugar, chlorophyll, carotenoid and total protein amounts were analyzed. The results revealed that root length, shoot length, root fresh weight, root dry weight, shoot fresh weight and shoot dry weights tend to decrease when the electrical conductivity of the solution is increased. Results indicated that these hybrids responded significantly different to some investigated parameters under saline conditions.

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[P31] Production and handling of virus-inactivated seeds for raising high quality grafted transplants in cucurbits

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Keywords: plant diseases, seed dry heat treatment, UV treatment, hot water soaking

Seed health issue is increasingly important in concomitant with recent increased international trade of seeds and grafted seedlings. As compared to most fungal diseases, seed-borne bacterial diseases and viruses are very difficult to control with agrochemicals, and in many case, are practically impossible. Recent explosive outbreaks and spread of some bacterial diseases such as bacterial fruit blotch (BFB) in cucurbits and bacterial canker of tomato are some of the examples. In addition, strains of tobamovirus such as *Cucumber green mottle mosaic virus* (CGMMV) and similar other strains (KGMMV and ZGMMV) are spreading all over the world in recent years, especially in Asian and European countries. Several seed companies were indeed bankrupted and sold to other multinational seed companies in order to compensate for the serious crop loss due to the use of virus-infected seeds and/or seedlings. Dry heat treatment (DHT) of the seeds at 70~80 °C for 3~5 days is so far the only effective means of inactivating these seed-borne viruses. DHT can also be effectively used to inactivate BFB in watermelons and some other cucurbits. DHT has been exclusively used to treat the seeds in many large seed companies around the world in recent years. Since there are no effective agrochemicals registered to use to treat the seed-borne virus, some other means of inactivating seed-borne viruses have been exploited. Use of UV lighting in combination with elevated temperature for several hours of exposure has been found to be effective in inactivating the virus and may be used to treat small amount of seed samples in a short period of time. Radiation of gamma rays and X-rays were so far ineffective and may also cause serious germination loss and seedling deformation. Hot water soaking of the seeds at 50~60 °C for 30~60 minutes may also be effective for some bacterial diseases as well as for several fungal diseases. Proper application of DHT, post DHT conditioning, and handling of dry heat treated seeds will be explained in detail along with possible other and/or alternative inactivation technologies closely associated with the healthiness of seeds and grafted seedlings.

[P32] The effect of different rootstocks on the sugar and vitamin C content in watermelon fruit

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Keywords: watermelon, grafting, rootstock, sugar content, vitamin C

The sugar and Vitamin C content of “L600”, ‘xiaohongyu’, “203Z”, and ‘Hongwei’ watermelon grafted on pumpkin, gourd, wild watermelon and xiaogan gourd watermelon were studied. The total sugar, fructose, glucose, sucrose, total Vitamin C (TAA), reduced vitamin C (AA) and oxidized vitamin C (DHAA) content of matured watermelon fruit were analyzed. The results showed that the effect of pumpkin rootstock on the growth potential of watermelon plants is the most significant and the second is xiaogan gourd. Additionally, the effect of different rootstocks on sugar and Vitamin C content of watermelon fruit was different. The total sugar and sucrose contents using pumpkin rootstock decreased observably, but the Vc content did not decrease. The sucrose and Vc content using gourd rootstock was obviously effected. Total sugar and fructose content of wild watermelon as rootstock declined, but the vitamin C content did not change. The sugar and vitamin C content of Xiaogan gourd as rootstock did not decline and the glucose contents of all watermelon varieties with different rootstocks had no significant change too.

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[P33] Effect of grafting on plant characteristics and yield in greenhouses-grown sweet pepper in SE Spain

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Keywords: *Capsicum annuum*, fruit quality, compatibility, rootstock, scion

Sweet pepper is an important crop in the Region of Murcia with more than 1,700 ha grown in greenhouses. The use of grafting could be an effective way to control soil-borne fungal diseases such as *Phytophthora* spp. and nematodes (*Meloidogyne incognita*) that are very common in this area. Apart from having resistance genes to the above diseases, rootstocks (normally belonging to *Capsicum* genera) should show good agronomic behaviour in the nursery and good rootstock/scion compatibility, and not have negative effects on grafted plant development and on potential commercial cultivar yield and quality. The objective of this research was to investigate the effect of three commercial rootstocks (Atlante F1, Creonte F1 and Terrano F1) grafted on the rectangular sweet pepper cv. Herminio on plant development, fruit yield and quality. Non-grafted plants of cv. Herminio were used as a control treatment. The experiment was carried out in two successive years in a disinfected soil. The grafted plants were taller and yielded more than the non-grafted plants, while they produced less fresh and dry vegetative matter, thus improving the harvest index. There were also significant differences among the scion/rootstock combinations with respect to fruit quality traits such as pH, titratable acidity and fruit dry matter. However, rootstock did not affect fruit firmness, pericarp thickness and °Brix. More studies on different scion/rootstock combinations are necessary in order to consider grafting as an alternative to chemical disinfection methods in pepper cultivation.

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[P34] Grafting issues and solutions for future farming systems

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Keywords: vegetable grafting, database

Grafting is a well-established technology in many parts of the world to enhance income stability and fruit quality in vegetable production systems. Public and private sector research and outreach efforts combined with practitioner experiences have rapidly advanced the utility of grafting in many regions of the world. A limitation in the global grafting community is the lack of a central site or comprehensive data source of information. For disease management, grafting provides a site-specific tool that relies on proper disease diagnosis and a firm understanding of the pathogen population combined with the selection of the best available rootstock. Due to the nature of this technology, efforts to educate growers and other practitioners of grafting requires a significant amount of training not only in grafting technique and the challenges associated with the propagation of grafted plants, but also in disease diagnosis. In a similar manner, further research is needed to help identify and screen rootstocks as they become available to commercial growers and convey the impact that pathogen population dynamics can have when a single rootstock is deployed over a large geographic area. The grafting practitioner community would be aided with the development of a searchable and publicly accessible database that provided comprehensive information on disease resistance, biotic stress resistance, compatibility issues, sources of rootstocks, vigor effects, grafting techniques and other important information. This would aid in technology transfer and better allow grafting technologies to be integrated into diverse production systems. The question arises: can a global community of scientists and practitioners develop and manage a database or other site that would serve future farming systems well?

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[P35] Development of grafting technology to improve sustainability and competitiveness of the USA fruiting vegetable industry

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Keywords: trans-disciplinary, graft, tomato, melon, IPM, economic analysis, multi-state

Fruiting vegetable growers in the USA face environmental, technical and market forces that demand innovative solutions. Constraints include loss of fumigants to manage soilborne diseases, persistent soilborne pathogens that force abandonment of prime land for specific crops, and limited host resistance mechanisms in 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. Properly deployed host resistance offers sustainable mechanisms to manage soilborne pests and optimize productivity. 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 soilborne pests and farming systems. We have assembled a multi-institutional domestic to international team that is stakeholder-driven, systems-oriented, collaborative, and trans-disciplinary to address the emergent critical need to advance the sustainable production of fruiting vegetables using grafting technologies. Private partners include every major sector of the industry to enhance rapid and informed progress. The work plan is coordinated through four stakeholder identified objectives: 1) optimize grafting technologies to reduce costs of producing and distributing grafted seedlings and make the technology readily available to US open-field producers; 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 and facilitate the application of grafted plants as a significant tool in vegetable crop production. This presentation will highlight our work plan and seek more international participation and feedback as the project develops.

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[P36] Evaluation of the response of a melon rootstock to mycorrhization with the AM *Glomus intraradices* in nursery

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Keywords: *Fusarium oxysporum* f.sp. *melonis*, melon, mycorrhization parameters, plant growth

Fusarium wilt of melon caused by *Fusarium oxysporum* f.sp. *melonis* is one of most destructive soil-borne diseases of melon in Italy. In several production areas in Central Italy grafting on resistant melon hybrid rootstocks represents the main prevention tool. Several soil fertility-related factors may contribute to the control of soil-borne diseases, including increased soil microbial activity, leading to increased competition and parasitism within the rhizosphere. Arbuscular mycorrhizal fungi (AMF) have considerable significance in the maintenance of soil health, fertility and prevention of plant diseases. The aim of the present work was to evaluate the response of the melon rootstock Dinero and the variety Proteo to mycorrhization in nursery with the AM *Glomus intraradices* (Aegis, Italtollina, Rivoli Veronese, Italy). Different parameters of mycorrhization were used to assess mycorrhizal status. The analysis of the parameters of mycorrhization recorded at 30, 45 and 60 days after inoculation (dai) revealed significant differences between two genotypes. In particular, 60 dai in Dinero the mycorrhizal intensity of mycorrhizal colonisation and arbuscule abundance in the root system were significantly higher compared to Proteo. To measure the efficiency of the AM symbiosis in promoting the plant growth, we determined biomass of two genotypes upon mycorrhization. AMF inoculation determined a strong enhancement of plant height of both genotypes significantly higher compared to not-mycorrhized control, whereas root system length was not affected. Response to the root biomass in terms of dry weight was also evaluated. The root biomass of Dinero was strongly increased as a result of mycorrhization with values significantly higher than that found in Proteo. Taking together, results indicate that Dinero effectively respond to the early inoculation with *G. intraradices*. More research is needed to standardise growth substrate and condition in nursery, as well as horticultural practices compatible with the mycorrhizal technology.

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[P37] The heat stress for workers employed in greenhouses for vegetable grafting

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Keywords: vegetable grafting, heat stress, Mediterranean greenhouse

The use of grafted plants on resistant genotypes is now widely widespread in the Mediterranean horticulture. Plants with greater resistance to infections by soil-borne pathogens and increased tolerance against abiotic stresses are obtained by the different grafting techniques. The vegetable grafting is carried out in controlled environments, the most used are greenhouses, in order to adjust the main climatic factors that affect the healing: temperature, relative humidity and solar radiation. The values of air temperature recommended in literature for the healing are at least 23-25 ° C although some authors indicate higher values, the relative humidity must be close to 95% and shade cloths must be used to reduce the radiation on plants. The total automation of grafting operations is difficult due to no perfect uniformity of the plant but some phases of the grafting can be automated to increase labor productivity. In this context, the presence of the operator cannot be eliminated and he is subject to heat stress beyond make over repetitive tasks. The aim of this study is to assess the heat stress of workers employed in Mediterranean greenhouses for vegetable grafting. For this aim in a farm, located in the north coast of the Lazio Region, climate data were recorded in a greenhouse used for vegetable grafting (tomato, watermelon, melon) for the period from September 2010 to June 2011 and the main indices used for heat stress (WBGT, PMV and PPD under the law, ESI as alternative to WBGT) were calculated. The results show a marked overcome of critical thresholds by all the indices in the months of May and June, but in April the thresholds are exceeded even if for short periods. In order to mitigate the conditions of heat stress we can take different measures: a more accurate control of higher temperatures in confined environment (ventilation, cooling), a better choice of clothing workers and a reduction in time of exposure to high temperatures.

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[P38] Tomato grafting: an open field experience

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Keywords: spacing, pruning, grafting, nematode, disease

In the eastern USA the primary goal of grafting research has been to evaluate rootstocks for resistance to soil borne pests such as bacterial wilt (*Ralstonia solanacearum*) and root knot nematode (*Meloidogyne spp.*). Several hybrid rootstock lines (RST 106, Cheong Gang, Jjak Kkung, BHN 998, BHN 1053, and BHN 1054) were identified that exhibited high levels of resistance to bacterial wilt. These rootstocks along with a susceptible variety (BHN 602) and Hawaii 7998 were evaluated in a greenhouse in pots inoculated with *M. incognita* and *M. javanica*. All hybrid rootstocks had significantly lower Root-Gall-Index (RGI), and nematode eggs than Hawaii 7998, and BHN 602. Hawaii 7998 had significantly lower RGI and nematode eggs than BHN 602. It was apparent that tomatoes grafted onto certain rootstocks exhibited more vegetative growth than other combinations. Experiments were conducted to determine the optimum plant spacing and axillary bud pruning practices for several grafting rootstocks in an attempt to increase fruit size and yield. The spacing experiment consisted of three graft combinations (un-grafted BHN 602, BHN 602/Cheong Gang, and BHN 602/Jjak Kkung) planted at three in row spacings (46, 61, and 91 cm). The pruning trial consisted of four graft combinations (un-grafted BHN 602, BHN 602/Cheong Gang, BHN 602/Jjak Kkung, and BHN 602/RST 106) pruned at three different levels (un-pruned, cotyledon suckers plus three removed, and cotyledon suckers plus six removed). In-row spacing and rootstock had a significant effect on fruit yield but pruning did not. In both cultural practice experiments, plants grafted onto Cheong Gang produced the greatest marketable yields. In the spacing trial, marketable fruit yields were higher at both 61 and 46 cm spacing compared to 91 cm spacing. In the pruning experiment, BHN 602 grafted onto Jjak Kkung produced greater marketable yields than the un-grafted control but less than Cheong Gang.

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[P39] Effects of rootstocks on sensitivity of grafted eggplants to airborne infections of *Sclerotinia sclerotiorum*: preliminary results

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Keywords: *Solanum* sp., tomato hybrids, *Solanum melongena*, airborne diseases

Sclerotinia sclerotiorum is a well know soilborne disease able to infect many protected and open field crops basically causing basal rot. Nevertheless the air dispersal, throughout the release of ascospores from apotecia, represents the major risk particularly inside the crop canopy. Grafting eggplant onto resistant rootstocks belonging to *Solanum* group (*S. torvum*) and to interspecific tomato hybrids (Beaufort, He Man, Maxifort) represents an effective tool that can improve non chemical control of soilborne pests and diseases such as root knot nematodes, vascular wilts and basal and root rots. Nevertheless growers prefer the adoption of *Solanum* sp. as rootstock particularly in South and Central Italy because better compatibility during hot and cold seasons. It has been demonstrated that interspecific tomato hybrids induce abnormal rootstock growth, often correlated to leaf yellowing, guttation and edema at scion level. Moreover stem necrosis caused by lytic bacteria (*Pectobacterium* spp.) was correlated to the use of interspecific tomato hybrids as eggplant rootstocks. Probably the major advantage of the interspecific tomato hybrids is a better tolerance to Verticillium wilt, although data recently collected did not fully confirm such characteristic. The paper reports preliminary results, collected in the framework of a research program, focused on the evaluation of potential advantages and disadvantages of eggplant rootstocks. Since basal rot caused by *Sclerotinia sclerotiorum* represents an emerging disease related to air dispersal of ascospores and subsequent infections, specific trials were designed to evaluate correlations between phenomena of guttation induced by interspecific tomato hybrids and airborne infections of *Sclerotinia* ascospores. Trials were carried out simulating grafted eggplant crops grown in a protected environment where the production of apotecia and the ascospore release were artificially obtained inoculating not cultivated areas with pathogen sclerotia. Trials confirmed that if ascospore release coincide with significant guttation phenomena, leaf and stem infections of *Sclerotinia sclerotiorum* are more likely to happen, due to the presence of film water on leaf surfaces. When tomato hybrids were used as rootstocks, *Sclerotinia sclerotiorum* incidence and severity appeared to be constantly higher compared with the infections occurred on eggplant grafted of *Solanum* sp. rootstocks. In conclusion data confirm that *Solanum* sp. rootstocks might represent a highly feasible and suitable choice for grafted eggplant.

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[P40] Effect of grafting, cultivar and cold storage on eggplant fruits

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Keywords: *Solanum melongena*, *Solanum torvum*, post-harvest, browning, oxidation potential

Eggplant is a perishable fruit that, once harvested, can be stored at 10 °C for several days. If long stored, fruits reduce their texture, skin brightness and become rubbery. Recently, grafting onto *Solanum torvum* has become more and more used to give resistance to biotic and abiotic stresses. The aim of this work was to study the effect of grafting, cultivar and cold storage on post-harvest changes of eggplant fruits. Grafted or ungrafted plants of four cultivars were grown in an unheated greenhouse during autumn-spring period. Three cultivars had skin with very dark purple colour (Black Bell, Black Moon and Longo) and one had skin with unhomogeneous light purple colour (Birgah). After harvesting, three berries per treatment were packed in perforated PE bags and stored at 10°C for 14 days. To evaluate post-harvest changes during cold storage, weight loss, skin colour (lower and upper section), pulp browning and oxidation potential were measured for each sample. In order to evaluate the oxidation potential, a cross section 1.0 cm wide was excised from the central section of fruits. Pulp colour was rapidly measured immediately after cutting and after 30 and 60 min. The oxidation potential was expressed as $\Delta L_{30} = L_0 - L_{30}$ and as $\Delta L_{60} = L_0 - L_{60}$. Grafting did not affect quality and colour of eggplant fruits during cold storage. Black Bell and Black Moon showed the highest values of pulp oxidation.

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[P41] Effect of grafting on yield and quality of eggplant (*Solanum melongena* L.)

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Key words: Solanaceae, *Solanum torvum*, eggplant cultivars, wilt disease, rootstock, skin colour, anthocyanins

Eggplants have fruits with different sizes, shapes and colours, according to the cultivar. Skin colour is due to anthocyanins, pigments located in the cell vacuole of fruit skin that belong to phenolic flavonoids, a powerful antioxidants group. Environmental conditions and growing techniques may influence fruits characteristics and their content of phenolic compounds. Grafting is a non chemical alternative for overcoming the effects of intensive and continuous cropping. The rootstocks preferred for eggplant are hybrids of tomato or tomato KVFN. Also species taxonomically close, as *Solanum torvum*, have been used and showed good vigour, compatibility and resistance to wilt disease. Information on yield and quality of grafted eggplants onto this rootstock is conflicting. Therefore, the aim of this study was to evaluate yield and quality of eggplant cultivars ('Birgah', 'Black Bell', 'Black Moon' and 'Longo') grafted or ungrafted onto *Solanum torvum*. Plants were grown in an unheated plastic greenhouse from October 2009 till May 2010. Grafted plants had lower mortality, while yield and quality of fruits were mostly influenced by cultivars. Differences among tested cultivars in growth characteristics, graft affinity and compatibility, could have caused the variations observed in growth and yield. 'Longo' and 'Black Moon' were not influenced by grafting, while grafted plants of 'Birgah' and 'Black Bell' had a higher portion of unmarketable production. Grafting onto *Solanum torvum* did not change the colour saturation of berries, with the exception of 'Birgah' that, when grafted, produced fruits with a less vivid colour. Also inner tissue browning was not influenced by grafting. Total phenolic content was greater in the ungrafted plants.

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[P42] Effect of different rootstocks and soil solarization in the control of *Phytophthora capsici* on pepper in greenhouse

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Keywords: methyl-bromide alternative, crown and root rot, yields, economic feasibility

Phase out of methyl bromide opened a perspective for new strategies to control *P. capsici* on pepper. In the present work results of the contemporary application of soil solarization and grafting of pepper on resistant rootstocks were reported. The first trial, of a two-year experiment, was carried out, starting on March 2009 in a plastic tunnel located at San Marzano sul Sarno (Salerno), with the aim to compare three rootstocks (Robusto, Rocal and PG 5738) on two pepper cultivars, Sanmarco and Peppone. Soil was solarized for 30 days one time in September 2009. In the first trial 95 days after transplant over 50 % of ungrafted plants were already killed by *P. capsici*. Plants from grafted combinations were infected and damaged starting from the end of July. Yield was influenced by disease and ranged from 2.1 t ha⁻¹ of cv. Sanmarco not grafted to 51.9 t ha⁻¹ of Peppone on Rocal. Nevertheless the incomes increase obtained with all grafted combinations did not justify the cost increase due to the use of grafted plants. On April 2010 started the second trial. On solarized soil cvs. Sanmarco and Filidor were grafted on Robusto, Rocal and Tresor were grown with the aim to evaluate the combined effects of grafting and solarization. The first effect of the combination was a delay in the outbreak of *P. capsici* infection. Ungrafted plants (45 %) were killed after 176 days from transplant. In 2010 yield of ungrafted plants of cv. Sanmarco (93 t ha⁻¹) increased of 432% while the best yield, 142 t ha⁻¹, was obtained with Sanmarco grafted on Rocal. The increase of gross incomes with combinations of Sanmarco onto Rocal, Robusto and Tresor justified, in this case, the adoption of grafted plants. Soil solarization appeared to be the crucial treatment to control *P. capsici* and renders useful the grafting.

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[P43] A two-year selection of rootstocks for watermelon cultivation under tunnel. Productive, qualitative and economic aspects

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Keywords: *Citrullus lanatus*, soil sickness, yield

A lot of rootstocks are available for watermelon grafting. In Italy, little information is available about criteria to choose the right rootstock for open field or tunnel cultivation. Our contribute deals with a comparison of different rootstocks tested under tunnel in two trials carried out on spring 2009 and 2011. Tested rootstocks were: PS 1313, Camelforce, Strongtosa, Rootpower, Polifemo, ES 03-100 belonging to the group of hybrids between *Cucurbita moschata* x *C. maxima*; FR Strong, Emphasis and Macis, belonging to the group of *Lagenaria* spp. The cultivar used as scion was Lady. Trials were located in two different farms in Piana del Sele (Salerno). Cultivated soil did not show high levels of parasites so our study pointed out the effect of rootstocks on earliness, productivity, quality of fruits and, in conclusion, on the economic feasibility of the grafting. The test started up on 2011 is in progress. First results, obtained on 2009, indicated that Lady not grafted showed the earliest yields; Lady maintained its earliness when grafted onto FR Strong and, at a lower level, onto Camelforce. But, these two grafting combinations and the ungrafted control gave the lowest total yields (60-80 t ha⁻¹). On the other hand, Lady onto PS 1313, Emphasis and Macis rootstocks produced the highest yields (around 100 t ha⁻¹) even if the early production was the lowest. Biometric characteristics of fruits did not change by grafting, but the total soluble solids content of flesh was higher in fruits of Lady not grafted (12 °Brix) and decreased until to 10 °Brix in grafting combinations. The gross income, subtracted the cost for buying grafted or not grafted plants, increased with the most productive grafting combinations.

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[P44] Combination of micrografting with micropropagation (M and M) in vegetable plants

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Keywords: micrografting, micropropagation, cucumber, tomato, melon

The demand of horticultural produce for internal market as well as for export is on rise. There is an urgent need to increase the production and productivity of vegetable crops, they play a significant role in human nutrition, in many regions around the world. Grafting is generally costly and labour intensive, as the farmers have to graft numerous seedlings within a limited period. Many attempts have been made to develop automated grafting robots that produce uniform seedlings at a lower cost. Since in grafted vegetables, scion is the most expensive part, an alternative way of reducing grafted vegetable production cost is scion micropropagation, prior to micrografting (M and M). The purpose of the current study is to present an efficient micropropagation and micrografting system for widely cultivated vegetables in Greece. An *in vitro* propagation system for four Greek melon varieties (Thraki, Peplo, Leuko Amyntaiou and Kokkini Banana), two cucumber (Brunex and Bambina), and three tomato (Garnet 622, Jumbo and Marvel) hybrids was established and experiments on micrografting were conducted. Micropropagated shoots were then micrografted on two or three week's old rootstocks respectively, with a rate reaching ~80%. Micropropagated plantlets after acclimatization were established *ex vivo*, flowered and matured normally. The different scion-rootstock genotypic combinations, the timing and the method of grafting, the afterwards treatments of grafted plants were studied and compared for finding the most effective M and M system for each vegetable crop. The combination of micropropagation with micrografting is an efficient alternative way of producing healthy seedlings with low costs for cucumbers, tomatoes and melons. And its future combination with automation in the grafting process could lower further the cost of grafted vegetable plants production.

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[P45] Effect of different rootstocks on quality traits of "Cuore di bue" tomato fruits

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Keywords: vegetables, antioxidant, phenolics, intrinsic quality

In the past years "Cuore di bue" tomato has been one of the most important types requested by the market because of its special flesh texture and flavor which is very pleased to the consumer. For fresh market products like "Cuore di bue" tomato, quality aspects play a key role so it is of great importance to consider how maturation affects these characteristics. Moreover, the increased market demand pushes producers to grow this vegetable very intensely (monoculture) arising serious problems of soil pathogens. In order to avoid this kind of problems grafting is becoming popular as the only sustainable way to control soil-born diseases since the ban of methyl bromide as provided by law. The aim of this study was to evaluate the effect of 2 different rootstocks, "Beaufort" and "Big Power", on the main quality traits of tomato fruits harvested at different maturity stage. In the experiment ungrafted tomato plants of "Profitto" variety were considered. As far as qualitative assessment is concerned, at the horticulture laboratory of the department of Environment Agronomy and Vegetable Crop of Padova University, tomato fruit's fresh and dry weight, dry matter, color, pH, electrical conductivity, °Brix, titratable acidity, total antioxidant capacity, total polyphenols, phenolic acids and reducing sugars were evaluated. The results showed how different maturation phases affected, sometimes strongly, tomato fruits quality. All phenolic acids increased significantly from first to sixth ripening stage (California Tomato Commission Ripening Stages) except for gallic acid and cinnamic acid which decreased. Antioxidant capacity and total phenols increased from first to complete ripening stage and this happened also for the sugars (glucose and fructose) and °Brix. EC and pH decreased from first to sixth maturation stage. The quality of tomato fruits was also influenced by grafting. As far as quality parameters (color, °Brix, electrical conductivity, pH, titratable acidity) and sugar content are concerned there were significant differences. Strong differences are attributable also to the contents of phenolic acids. In particular, ungrafted Profitto variety showed more coumaric and caffeic acid content than the other two grafted varieties. Profitto and Profitto x Beaufort showed more chlorogenic and cinnamic acid, than Profitto x Big Power variety. The last one variety contained, however, more gallic and ferulic acid than the other two.

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[P46] Impact of root-produced auxin on scion characteristics under sub-optimal temperature conditions using auxin-lacking mutants

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Keywords: grafting, photosynthesis, stress, transport, transpiration

Auxin is considered as a regulator of developmental processes and signaling networks involved in plant responses to a wide range of abiotic stresses, including low temperature. Its signaling and transport has been earlier shown to control root length and root growth direction. Moreover, IAA promotes cell enlargement. Growth responses to auxin are complex and require the coordination of three functions: production, transport, and perception. These functions are being controlled by numerous environmental factors such as light and temperature. In order to identify the key components and understand the role of auxin in plant responses at suboptimal temperature, reciprocal grafting of the VFN-8 cultivar expressing auxin and LA-1093 (dgt) a mutant lacking this phytohormone, was applied. After two weeks of regular growth in a greenhouse, the mean air temperature was lowered from 22 °C to 15°C for three weeks and then raised again to 22 °C to test plant adaptation. Growth characteristics, such as shoot length, leaf area, root and shoot mass as well as nutrient uptake were examined. Moreover physiological characteristics, such leaf chlorophyll content and gas exchange were measured. Suboptimal temperature reduced growth in the total absence of auxin. The photosynthetic apparatus was severely affected by the lack of auxin, especially under suboptimal temperature. However, stomatal conductance and transpiration rate were not affected at suboptimal temperature but they were severely affected when auxin was completely absent. In addition, the complete absence of auxin restricted nutrient uptake. Overall, the absence of auxin in the rootstock did not restrict plant growth and development. These results indicate that auxin coming from the rootstock does not contribute to tomato plant suboptimal temperature stress tolerance.

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[P47] Contribution of rootstock ABA to growth, nutrient uptake, gas exchange and antioxidative potential in tomato at suboptimal temperature

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Keywords: grafting, photosynthesis, transpiration, nitrogen, polyamines

The production of vegetables in areas of cold and even mild winter climate has to face to some extent suboptimal temperature conditions. Temperatures lower than the optimal range for growth forces plants to alter many metabolic processes and finally reduce growth and productivity. In order to alleviate cell damage and retain the ability to reproduce, plants have adaptive mechanisms to respond to suboptimal temperature. Abscisic acid (ABA) produced under low temperature plays an important role to enhance plant's tolerance against environmental stresses. The use of rootstocks tolerant to suboptimal temperature conditions is reported to improve whole plant's adaptation to temperature stress as well. In order to test the role of endogenous ABA on plant responses to suboptimal temperature stress, reciprocal grafting of a tomato cultivar (Ailsa Craig) and its mutant (Notabilis) expressing or lacking ABA was applied. After transplanting, two different root temperatures (15°C and 25°C) were applied. The results showed that suboptimal temperature and the absence of ABA in both leaves and roots decreased leaf area, length and plant dry matter but no significant interaction between root temperature and ABA was noticed. In contrast, the number of leaves was not influenced by any treatment. Additionally, the lack of ABA either in leaves or roots or in the whole plant reduced the chlorophyll concentration in the leaves. The exposure of the root to suboptimal temperature and the absence of ABA in both leaves and roots increased the levels of total amino acids in both plant parts of tomato. Although the leaf photosynthesis was not affected by suboptimal temperature, the absence of ABA in leaves and roots increased stomatal conductance and evapotranspiration, thereby reducing water use efficiency to the same extent at both temperature levels. The results indicate that ABA coming from the rootstock does not alter the behavior of the whole plant when the root temperature varies between 15°C and 25°C.

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[P48] Salinity response in melon scions as affected by grafting

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Keywords: rootstock, cantaloupe, salt stress, water relations

Grafted plants are often more tolerant to stresses such as drought and salinity than non-grafted controls. The wide literature available usually attributes the increased tolerance to different elements, such as ion exclusion or accumulation within the rootstock, impaired stress signaling, improved water uptake and exchanges, or even the increased vigor attributable to the grafting adaptation itself. Indeed, as far as salt tolerance goes, a rootstock effect, a scion effect and a rootstock x scion effect may be generally observed. In order to dissect the differential elements involved in the salt response in grafted melon, salt stress was imposed on several rootstock/scion combinations in three experiments under different environmental conditions and locations across Europe (Izmir, Turkey; Budapest, Hungary; Bologna, Italy). In all experiments the rootstock used was an interspecific squash hybrid (*Cucurbita maxima* x *Cucurbita moschata*), combined with different Cantaloupe (*Cucumis melo* var. *cantalupensis*) cultivars. Self-grafted and non-grafted controls were included in the trials in order to evidence grafting-related effects. Plants exposed to salinity (0, 40, and 80 mM NaCl), were monitored in terms of physiological (leaf gas exchanges, porometry and overall transpiration), biochemical (ion accumulation and osmolytes), and morphological (root and leaf features) adaptations.

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[P49] Response of grafted and self-rooted tomato plants to saline conditions in closed substrate system

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Keywords: rootstock, NaCl, plant growth, yield, quality

Salinity as the most important detrimental stress factor to the performance of agricultural products creates a high risk in greenhouses compared to open-field cultivation. It is also known that grafted seedlings can be used as an alternative solution against to salinity problem. In this research, the response of tomato rootstocks to salinity was studied in a PE covered greenhouse during the autumn and spring season of 2007-2008. 'Beaufort' (*L. esculentum* x *L. hirsutum*) and 'Resistar' (*L. esculentum*) were used as rootstocks and grafted with commercial cultivar 'Gokce F₁'. Both rootstocks were compared with self-grafted plants as control. Tomato seedlings were transferred into the greenhouse at 14.09.2007 in autumn; 28.03.2008 in spring season and were grown in perlite (6 L plant⁻¹) in closed system with 3.5 plants m⁻². The experimental design was randomized parcels with 2 factors with 3 replicates. There were 12 plants in each replicate. Plants were fed with a complete nutrient solution at the EC levels of 2.0 (control), 5.0 and 10.0 dS m⁻¹ in order to determine rootstock-salt reaction. Salinity level of the nutrient solution was increased three weeks after planting by NaCl. The results showed that rootstocks increased plant height, stem diameter, root and shoot fresh and dry weight, total and marketable yield. These parameters decreased dramatically with the increase of salinity. Salinity stress especially decreased mean fruit weight and increased amount of unmarketable fruits. Although higher yield were obtained at 2 dS m⁻¹ in both growing seasons, the plants grafted with Beaufort had the highest yields under saline conditions. It was concluded that grafting could be used as an alternative against salinity stress due to the increase in plant vigor and yield. Beaufort, *L. esculentum* x *L. hirsutum* hybrid rootstock, have found more appropriate against salinity compared to *L. esculentum* rootstocks.

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[P50] Yield and quality of mini watermelon as influenced by plant density

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Keywords: *Citrullus lanatus*, grafting, rootstocks, *Fusarium oxysporum*

The decrease of fruit yield and quality caused by soil diseases is one of the major problems of watermelon production. Soil disinfection with methyl bromide has been used to prevent fungus attacks; however, its use is being restricted because this substance damages the ozone layer. Studies show the effectiveness of grafting watermelon on rootstocks resistant to diseases caused by soil fungi. The graft is being used in Mexico mainly in medium-sized triploid watermelon, but in mini watermelon is still limited because it requires higher density of plant which is more expensive. On the other hand, demand for mini triploid watermelon has been increasing in the United States which is the main market of Mexico. For this reason, it is essential to optimize the density of grafted plants and make their use more feasible. This study was carried out in open field in soil infested with *Fusarium oxysporum* f. sp. *Niveum* and Melon Necrotic Spot Virus (MNSV) in Colima, México. We used triploid watermelon Mielhart, and diploid watermelon Minipol; both grafted on RS841 rootstock (*C. maxima* x *C. moschata*). The experimental design was randomized complete block with four treatments and four replications. Each plot consisted of 3 rows of 12 m long. The separation between rows was 1.8 m and the spacing between plants were 0.35 m, 0.50 m, 0.60 m and 70 m to obtain the following treatments: 15873, 11111, 9259 and 7936 plants/ha respectively. The amount of diploid plant was 1/3 of total of each treatment plant. Triploid plants were placed in the center of row. Diploid plants were placed aside of triploid plant. The soil was mulched with polyethylene gray/black. We determined the number of fruits/m², number of fruits/plant, kg ha⁻¹, total soluble solids (Brix) and firmness (kg cm⁻²) of triploid plants. There was no significant difference between treatments for yield (kg m²), number of fruits per m² and average weight of fruit. The number of fruits per plant showed a significant difference between treatments, it increased with decreasing plant density. The content of soluble solids and firmness were not significantly different between treatments. The average production was 7.4 kg m² and soluble solids content was 11.4 ° Brix, so that the plant density of mini watermelon can be reduced by 50%.

[P51] Behavior of resistance to *Meloidogyne incognita* and *Phytophthora* spp. pepper rootstock

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Keywords: *Phytophthora* root rot, *Capsicum annuum*, soil borne plant pathogens, nematodes

The control of soil-borne pathogens of pepper (*Phytophthora* spp y *Meloidogyne incognita*) in the greenhouses of southeastern Spain was carried out, more than 20 years, by chemical disinfection. The withdrawal of methyl bromide and limitations in the provision of other disinfectants has prompted the search for alternative non-chemical. The vigorous rootstock grafting and carriers of resistance to *M. Incognita* (genes *Me1*, *Me3* y *Me7*) and to *Phytophthora* is seen as an effective way to control pathogens. In greenhouses contaminated to *Phytophthora parasitica* and *M. Incognita*, has evaluated the behavior of 35 rootstocks, most of them were carriers of resistance to *Phytophthora* and gene *Me7*, 1 rootstock carries the gene *Me1*, and 3 of the genes *Me1* and *Me7*, plus resistance to *Phytophthora*. In consecutive years, the growing of grafted plants on some rootstocks was repeated, in same soil, to verify the stability of resistance as reference plant cultivars were susceptible to both pathogens. Over 80% of rootstocks were resistant to *P. parasitica*, while the resistant *M. incognita* were no more than 60%. The behavior of most of the rootstocks didn't change against *P. parasitica* when repeated the growing of some rootstocks in the same soil. However, there was an increase in aggression and changes in virulence of populations of *M. Incognita* which resulted in highest galls indexes and highest percentage of plants colonized of rootstocks carriers gene *Me7* while the infestation didn't change rootstocks carriers gene *Me1*.

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[P52] Interaction *Meloidogyne incognita* & *Phytophthora* spp. Resistances in peppers rootstocks

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Keywords: nematodes, fungi, *Capsicum annum*, soil-borne plant pathogens, *Phytophthora* root rot

Phytophthora spp (*capsici* and *parasitica*) and *Meloidogyne incognita* are major pathogens of pepper in greenhouses of southeastern Spain. The grafting over rootstocks carries resistance genes to the pathogens was evaluated as an alternative to chemical disinfection of soil. In the some greenhouse, virulent populations were selected by repeating the cultivation of plants grafted on resistance rootstocks carrying the gene *Me7* of resistance to *M. incognita*, infesting the rootstocks with *Me7*, but not the rootstocks carrying *Me1*, *Phytophthora* resistance, incorporated into most of the rootstocks, has behaved efficient and stable, hasn't broken the resistance to repeat the crop in the same soil. With the aim to establish strategies for resistance management in the use of grafting, has investigated the possible interaction that may exist between the infestation of roots by *M. Incognita* and stability of resistance to *Phytophthora*. Under controlled conditions, the interaction was evaluated in 6 rootstocks with resistance to *Phytophthora*: 2 without resistance to *M. Incognita*, 2 carrying gen *Me7* of resistance to *M. Incognita*, 1 carrying gene *Me1* and other carrier of genes *Me1* and *Me7*. As references we used a commercial cultivar susceptible to both pathogens. We used two populations of *M. incognita* race 2 collected peppers, one virulent towards the gen *Me 7* and other avirulent, and a highly aggressive isolate of *P. capsici* and other less aggressive *P. parasitica*. We did not observe interaction between both pathogens which could involve breaking the resistance to *Phytophthora*. The isolate of *P. capsici* caused the death of 100% of the plants of susceptible cultivar and some rootstocks carrying resistance to *Phytophthora*, whether they had been previously inoculated with *M. incognita* or not and whether or not carrying the nematode resistance genes. The isolate of *P. parasitica* alone caused root-rot in growing plants commercially sensitive.

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[P53] Pepper rootstocks: influence of genetic background on the expression of resistance to *Meloidogyne incognita*

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Keywords: greenhouses, grafting in pepper, resistance genes, *Capsicum annuum*

In the region of Murcia, the pepper crop in greenhouse covers about 1.700 ha. *Meloidogyne incognita* is major soil pathogens. The limitations on the use of chemical disinfectants (methyl bromide, 1,3-dichloropropene) has motivated the search for alternative non-chemical disinfection (biodesinfection) and new methods (biocontrol agents, resistance) control soil pathogens. Grafting on rootstocks carrying resistance to *M. incognita* and *Phytophthora* spp, and which do not alter the productive potential of varieties, has been evaluated as a method of control of pathogens. In some greenhouses, the repetition of growing plants grafted onto rootstocks that carry the gene *Me7*, for resistance against *M. incognita*, virulent nematode populations were selected, able to overcome the resistance conferred by the gene *Me7*, but not by gene *Me1*. In order to establish management strategies of resistance to nematode, the behavior of the resistance conferred by *Me7* and *Me1*, when these genes are introduced into different genotypes used in the production of rootstocks has been studied. In greenhouses with virulent and avirulent populations for the gene *Me7* behavior was evaluated against *M. incognita* race 2 "pepper" of various rootstocks with different genetic backgrounds. These rootstocks were compared with the varieties not grafted that do not carry known resistance genes. We found differences in rootstocks carrying gene *Me7* to grow them in soil with virulent populations *Me7*, both in the rate of galls on the roots and the percentage of infested plants. No differences were found between rootstocks carrying gene *Me1*, for which no populations are known virulent. These results lead to study in future works genetic characteristics of the lines in which the gene *Me7* has been introduced.

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[P54] Water-conservation in non-transgenic scions of tomato (*Solanum lycopersicum* L.) grafted onto abscisic acid overproducing rootstocks

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Keywords: water-conserving, tomato rootstocks

Predicted climate changes indicate that water will become a scarce commodity. Breeding plants that can produce equivalent yields with reduced water input (improved water use efficiency (WUE)) is widely thought to be an important feature of sustainable crop production in the future. The phytohormone abscisic acid (ABA) is a central component of plant responses to dehydration. Water deficit induces redistribution and synthesis of ABA in both shoots and roots, resulting in more restricted stomatal opening. We have previously shown that it is possible to manipulate stomatal behaviour in tomato in order to save water by increasing ABA production under well-watered conditions. ABA is synthesised via oxidative cleavage of oxygenated carotenoids (xanthophylls). Three key enzymes involved in the ABA biosynthetic pathway are: 9-*cis*-epoxycarotenoid dioxygenase (NCED) which catalyses the oxidative cleavage step; β -carotene hydroxylase (BCH) which catalyses the conversion of β -carotene to zeaxanthin, the first xanthophyll in the pathway; and phytoene synthase (PSY) which results in the formation of phytoene, a colourless precursor from which β -carotene is eventually synthesised. Transgenic tomato plants constitutively over-expressing a tomato NCED-encoding gene have increased ABA concentration and improved WUE. However, the degree of ABA production by these *NCED* over-expressers may be limited, particularly in the root system, by the supply of ABA precursors. To increase xanthophyll precursor pools and therefore ABA production in root tissue, the over-expression of *NCED* has been combined with the over-expression of both *BCH* and *PSY*. This triple transgenic line is being evaluated for its effectiveness as a water conserving rootstock, following grafting to non-GM tomato scions. We are seeking to find out whether or not an equivalent yield of non-GM tomato fruit can be obtained using less water. To do this we are employing the technique of grafting normal plants onto water-conserving rootstocks (WCR technology).

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[P55] Study of the grafting technique on artichoke

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Keywords: artichoke, grafting, rootstocks, cultivated cardoon, wild cardoon

In order to verify the possibility of employment for grafted plants of artichoke (*Cynara cardunculus* subsp. *scolymus*) in horticulture, experimental tests were performed with the objective of enhancing knowledge about herbaceous grafting in this species, with particular concern to some aspects of grafting technique and the effect of different rootstocks on scion. Field tests started in spring – summer 2010, tests were conducted according to an experimental factorial design, consisting in a comparison between two different grafting techniques (tube grafting and cleft grafting), two scions (Istar and Romolo) and two rootstocks (cultivated cardoon and wild cardoon). Results showed that tube grafting technique is more suitable than cleft grafting technique, although a lower engraftment percentage, because it prevents root emission by rootstock from grafting site. Results have also shown that engraftment percentage was influenced by scion and rootstock. Scion was observed to produce adventitious roots since the early stages of engraftment, particularly in plants grafted with tube grafting technique and using "Romolo" as scion.

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[P56] Earliness and yield in artichoke grafted onto cardoon rootstock

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Keywords: *Cynara cardunculus* L. subsp. *scolymus*, *Cynara cardunculus* L. subsp. *cardunculus*, propagation, grafting, rootstock

Herbaceous grafting is an established practice in the nursery production of many species of vegetables which is especially appreciated as a mean to face phytosanitary problems due to soil exhaustion both in the greenhouse and in the open air. In artichoke (*Cynara cardunculus* L. subsp. *scolymus*) grafting could be useful to face *Verticillium* spp. infections, which are common in many Italian areas where artichoke is cultivated. Furthermore, grafting may increase plant vigour and yield due to great vigour, longevity and deep roots of cardoon (*Cynara cardunculus* L. subsp. *cardunculus*) used as rootstock. The possibility to graft artichoke onto cardoon rootstock has been studied since 2008. A rather uniform and stable artichoke line, derived from cv. 'Terom' by massal selection (T3 line) was used as scion, and a very vigorous and thornless cardoon (cv. 'Bianco gigante inerme a foglia intera') was used as rootstock. Cotyledonary-stage seedlings were grafted by cleft and struck plantlets were transplanted into the field at the end of July 2008. The earliness and the number of heads per plant of grafted artichoke plants were detected in spring of 2009, 2010 and 2011 in comparison with non-grafted T3 plants (control). Results show an evident increase in earliness and yield in grafted plants respect to control.

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[P57] Rootstocks resistant to *Didymella bryoniae* and compatible for the grafting with cantaloupe

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Keywords : *Cucumis melo* var. *reticulatus* Naud, gummy stem blight, plant disease

Cantaloupe, grown under greenhouse conditions, is highly susceptible to gummy stem blight, caused by *Didymella bryoniae*. The objective of this work was to find rootstocks that, in addition to conferring resistance to that disease, were compatible with cantaloupe. Conducted at the Department of Plant Protection of the Paulista State University, campus of Jaboticabal, this experiment lasted from August through October of 2010. Thirty-three cucurbitaceous species (melons, pumpkins, cucumbers, winter squashes, watermelons, smooth luffas, gourds, and others) were tested as rootstocks. The experiment was set according to a completely random design with 33 treatments and four repetitions. Each repetition was constituted by a vase with 3 seedlings. Each treatment had its own check treatment. The seedlings were inoculated with the pathogen in a culture medium, with the help of a toothpick. Fifteen days after the inoculation, grades were attributed to the seedlings as to their response to the pathogen. The degree of compatibility between the rootstocks classified as resistant and the cantaloupe plant was evaluated by grafting the rootstocks on cantaloupe of the 'Bônus no. 2' and 'Fantasy' varieties, each variety grafted 60 times. The rootstocks hybrid 'Keij', the pumpkin 'Maranhão', the pumpkin 'Brasileirinha', and the watermelon and pumpkin 'Goianinha' progeny were considered resistant to *D. bryoniae*. All rootstocks showed compatibility with cantaloupe higher than 98%. The utilization of these materials to confer resistance to cantaloupe plants to *D. bryoniae* seems promising.

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[P58] Cloning and characterization of a *DCL4* gene in pepper

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Keywords: grafting, siRNAs, *DCL4*, VIGS

In grafted vegetables, the effect of rootstocks on scion fruit quality is well documented in vegetable plants like melon (*C. melo*) and tomato (*S. lycopersicum*). In pepper (*C. annuum*) a change in scion fruit shape was observed in pepper plants produced when cv. Round plants (scion) were grafted on cv. Long rootstocks: scion fruits adopted the elongated shape of the rootstock fruits rather than the original round shape. Moreover this rootstock effect was stable in scion seed progenies, for two generations tested. This effect could be attributed to the translocation of small RNAs, generated by the RNA silencing machinery, from the rootstock to the scion. Small interfering RNAs (siRNAs) are a class of small regulatory RNAs that play fundamental roles in developmental regulation, epigenetic modifications, and viral defense and recently proven to take part in a systemic information highway within the plant, during its development. They are processed by distinct Dicer-like (DCL) proteins: in *Arabidopsis* there are four such proteins but DCL4 (producing 21-nt siRNAs) is required for the silencing and the siRNAs spread and movement. In order to identify the possible role of *DCL4* in pepper and especially in the possible trafficking of siRNAs generated by the rootstock affecting fruit quality of the scion, we report the cloning and characterization of the pepper *DCL4* gene, by reverse transcriptase polymerase chain reaction (RT-PCR). Real time PCR was used for semi-quantitative comparative expression analysis in various stages of flower and fruit development as long as in diverse plant organs. We present also the down regulation of *DCL4* expression in pepper plants using the Tobacco Rattle Virus (TRV) -based Virus-Induced Gene-Silencing (VIGS) system, a system used in our lab to down regulate the expression of the *Ovate-like* gene in pepper with concomitant changes in pepper fruit shape. Further experiments are underway to massively sequence the sRNAs populations in intact and hetero-grafted pepper plants.

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[P59] Watermelon rootstocks: evaluating resistance to soil-borne pests

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Keywords: *Cucurbita* rootstock, Fusarium wilt, *Macrophomina phaseolina*, root-knot nematodes

The use of grafted vegetables, including watermelons, on resistant rootstocks for managing soil-borne diseases is increasing worldwide. Most of the watermelons grown in Israel are grafted onto *Cucurbita* rootstocks. The resistance provided by such grafting is broad and non-specific. However, in certain cases, fruit quality can be negatively affected following inter-specific grafting. For example, grafting mini watermelon cv. Extazy onto the *Cucurbita* rootstock cv. TZ-148 leads to development of larger and distorted watermelons with white fibers and off-grade flesh texture and taste. Grafting commercial watermelon scions onto watermelon rootstock (intra-specific grafting) that contains resistances to soil-borne diseases and pests may overcome the obstacles related to fruit quality. Twenty wild watermelon accessions were screened for resistance to Fusarium wilt and Fusarium crown rot caused by *Fusarium oxysporum* f. sp. *niveum*, and *F. oxysporum* f. sp. *radicis cucumerinum*, respectively. Their responses to root and stem rot caused by *Macrophomina phaseolina* and to the root-knot nematodes *Meloidogyne javanica* and *M. incognita* were evaluated as well. The results indicate that wild watermelon accessions possess a diverse range of resistances to pathogens. This enables breeding rootstock resistance to a wide range of soil-borne diseases that may replace the *Cucurbita* rootstocks.

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[P60] Control of *Fusarium* race 1.2 in melon: interest and limit of grafting in the French conditions

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Key words: grafting, melon , *Fusarium oxysporum* f.sp. *melonis*, Fusarium wilt

Melon (*Cucumis melo*) production is a significant component of the vegetable industry in France. French melon growers have found themselves confronted with melon root decay. Accordingly, Ctifl, in close collaboration with the regional research stations, INRA and seed companies, set up a study designed to gain greater knowledge of the various phytosanitary problems and identify the probable cause(s) in grafted and non-grafted situation. For the early production, melon is generally grafted on interspecific hybrid squash, *Cucurbita maxima* x *C. Moschata*, mainly RS 841 (Monsanto), TZ 148 (Clause), Azman (Rijk Zwaan). Later in the production season, melon rootstocks (*Cucumis melo*) are used: Dinero and Marengo (Syngenta), Magnus (Clause), PG 22 (Gautier). The principle aim of the study was to monitor pathogen distribution changes in melon. A number of samples from the different production areas were studied (from 2003 to 2011). The symptoms that developed during the years of the study were identified based all these data. The results show the prevalence of problems related to *Verticillium dahliae* in the spring situation and to yellowing race 1-2 of *Fusarium oxysporum* f. sp. *melons* often found together with or along with other pathogenic soil fungi like *Macrophomina phaseolina*, *Didymella bryoniae*, *Pyrenochaeta terrestris* or *Phomopsis sclerotioides*. These pathogens seem to be enhance the disease aggravating factors. The isolates of *F. oxysporum* f. sp. *melonis* collected from samples appear more virulent than the reference strains used in the breeding tests for resistance.

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[P61] The effect of grafting on plant growth and yield of tomato plants cultivated outdoors and indoors under water stress

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Keywords: tomato, *Lycopersicon esculentum* L., grafting, water stress

The effect of grafting technique on plant growth (height and number of internodes, fresh and dry weight of plant tissues) and yield (number of flowers and green fruit, number and fresh and dry weight of mature fruit) of tomato plants (*Lycopersicon esculentum* L. cv. Despina) cultivated under water stress, either self-rooted (P7) or grafted on to themselves (P6) and five different rootstocks [P1, P2, P3, P4, P5]. Plants were grown both indoors (heated glasshouse) and outdoors, whereas water stress was simulated by applying three levels of salinity [Control (0.69), 3 and 6 mS/cm) on growth medium. The results of the study showed that grafted plants grown outdoors formed more internodes than self-rooted plants, regardless water stress level, whereas for plants grown indoors there were differences only at the level of 3 mS/cm where scion x P2 plants formed less internodes than the others. Self-rooted plants formed more flowers than grafted ones when grown indoors, regardless of water stress level, whereas growing outdoors resulted in more flowers for grafted plants. Plants grafted on to rootstocks P2, P4, P5 and P7 had the best ratio of mature: green fruit than the other combinations, for indoor cultivation and the level of 6 mS/cm, without however significant differences among them, whereas for outdoor cultivation scion x P1 combination showed the best results. Regarding yield, grafted plants formed more fruit in total and had a higher total yield than self-rooted plants at the level of 6 mS/cm when grown indoors, without mean fruit weight being different between scion x P1, P3, P4 and P7 combinations. For outdoor cultivation scion x P1 and P2 combinations were superior to others at the level of 6mS/cm, regarding total number of fruit and total yield. In conclusion, implementing grafting technique on tomato plants results in the formation of more internodes and therefore flowers, especially for outdoor cultivation, whereas significant effects are observed on both total number and total weight of fruit for indoor cultivation. In addition, rootstock x scion combination has a significant effect on plant growth and yield and could be used as a useful means in order to alleviate problems that arise from water stress due to either lack of water or high salinity of irrigation water.

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[P62] Management of root knot nematode with grafted tomatoes

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Key words: *Meloidogyne*, resistant rootstocks, sandy soils

Lack of registration and availability of soil fumigants and particularly of effected pre-plant nematicides might represent a technical limitation to be faced particularly for protected tomatoes grown in sandy soils in south Italy. In this framework the adoption of alternative strategies and solutions have been tested throughout several demonstrative trials carried out in Ragusa province (Sicily) among witch tomato rootstocks have been tested for their ability to limit negative effects of root knot nematode on plant development and on marketable yield. The effectiveness of grafting was evaluated under different circumstances in 2009 and 2010, always representing standard growing condition for south Italy tomatoes. Rootstocks were selected among the rootstocks available on the market and several trials were organized and carried out in the municipalities of Scicli, Vittoria and Acate on protected tomatoes. Trials were carried out under cold and hot seasons and in sandy and sandy loam soils. Grafted tomatoes were grown according with local procedures and generally with two stems per each rootstock. Experimental design included the combination of adoption of grafted tomatoes with not fumigated or with the pre-plant soil fumigation in soil infested by *Meloidogyne hapla*, *M. javanica*, *M. arenaria* and *M. incognita*. On the basis of the evaluation of galling index, experimental trials did not shown significant effects of rootstock choice in term of nematode control even if grafted tomatoes showed better ability to improve yield compared with not grafted ones. The data confirm the difficulties to control root knot nematodes only on the basis of available rootstocks. Nevertheless grafting technique represents an essential tool in a more complex strategy able to made possible the cultivation of tomato in sandy soils affected by high nematode pressure.

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[P63] Effects of pumpkin rootstocks on growth, yield and quality of grafted Hami-melon in Hainan

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Keywords: rootstock, Hami-melon, grafting, growth, yield, fruit quality

The effects of nine different pumpkin rootstocks on growth, development, yield and quality of grafted Jinmi No.6, Jindiwang Hami-melon were studied. The results showed that Jiuzhen No.1, Jingxin No.3 pumpkins could be used as the ideal rootstock for grafting Jinmi No.6 Hami-melon and BG0901, Jiuzhen No.1 could be used as the ideal rootstock for grafting Jindiwang Hami-melon in Hainan province.

[P64] Current status and history of vegetable grafting in Turkey

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Keywords: grafting, vegetables, watermelon, tomato, Turkey

Fruit bearing vegetables grafting is a common horticultural practices for many years in East Asia to overcome problems associated with intensive agricultural use of limited areas. Grafting in vegetables was introduced to Turkey in the late 1990s. The first experiment on grafting was conducted on eggplant by grafting on tomato in Turkey in 1989 and following years in watermelon. Watermelon was grafted onto different rootstocks against soil-borne diseases in Cukurova University in 1998. Commercial grafted vegetable seedling production was started after 2000 by grafting watermelon and tomato. The purposes of grafting are resistance to soil-borne diseases and nematodes and increasing yield. Currently, watermelon, tomato and eggplant are mainly grafted species in Turkey. Some experimental studies have been also carried out on cucumber and melon and in both public and private research institutes. At present, over 90 million grafted vegetable seedlings are estimated to be used annually in Turkey. There are 14 seedling companies with improved grafting methods suitable for commercial production of grafted vegetable seedlings. Several experiments have been conducted for promoting use of grafted vegetable seedlings in both protected cultivation and open fields by research institute and the seedling companies. Commercial scale grafted seedling production units were established and desirable number of grafted seedling can be produced in tomato, eggplant and watermelon. However, further detailed studies on some areas such as suitable plant density for certain rootstock/scion combination, fertilization, irrigation, and harvest time and fruit quality are needed. In this review, history and current status of vegetables grafting in Turkey was summarized.

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[P65] Rooting properties of some gourd rootstocks used for watermelon

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Keywords: *Lagenaria siceraria*, *Cucurbita maxima*, *Cucurbita moschata*, rooting, survival rate, grafting

In this study, rooting properties of some commercial rootstocks and bottle gourds (*Lagenaria siceraria*) collected from different places of Turkey was investigated when they were used as rootstocks for watermelon in slant cut grafting technique. In slant cutting grafting technique, since scion is grafted on rootstock one of whose cotyledons and roots are cut (rootstock cutting), rooting properties of rootstock cutting is important. The study was conducted at two stages. At the first stage, cuttings were prepared by removing roots of gourd seedling and one cotyledon then they were planted in mixture of peat:perlite (2:1) under high humidity and low light conditions in a plastic tunnel. Rooting level (1-4 scale), root length, root thickness, root fresh weight, root dry weight were determined after 20 days. In addition to this, effect of Indole Butyric Acid on rooting was investigated but rooting was not affected by IBA application. At the second stage, Crimson Tide watermelon cultivar was grafted on the gourd cuttings without root by slant cut grafting technique and they planted in mixture of peat:perlite (2:1). Survival rate of grafted plants placed in post graft care unit for 10 days were determined. Rooting level (1-4 scale), root length, root thickness, root fresh weight, root dry weight were determined 30 days after grafting. While significant differences were determined between gourd genotypes regarding rooting properties and survival rate, it was determined that local bottle gourd genotypes showed rooting capacities as much as commercial rootstocks did. Survival rate of grafted plants varied from 84 % to 100 %.

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[P66] Effect of rootstocks on macro and micro element content of watermelon leaf

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Keywords: grafted, watermelon, plant nutrition, nitrogen use efficiency

In this study, the watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nakai] cultivar Crimson Tide was grafted onto one *Lagenaria siceraria* landrace (Birecik) and three hybrids (Skopje, Emphasis, 216 and FRGold) to investigate rootstock effect of plant nutrition uptake. Ungrafted Crimson Tide watermelon cultivar was used as the control. The plants were grown under low tunnel conditions until the outdoor temperature was suitable (22-25 °C) for watermelon growth. Plants were fertilized with 180 kg N/ha, 200 kg P₂O₅/ha and 180 kg K₂O/ha. Micro nutrient fertilization was not applied. Total P was applied before transplanting to the field. Nitrogen and K₂O were divided into three equal portions. The first portion was applied before transplanting to the field, the second 20 days after transplanting and the third 40 days after transplanting in the field. The experimental design was a completely randomized block design. Each treatment was replicated four times with 15 plants in each replicate. Plants were grown with 2.0 x 0.5 m spacing. Plants were irrigated with drip irrigation. Fully developed sixth or seventh leaves from shoot tip were sampled for plant nutrient analysis. There was no significant difference between grafted and ungrafted control plants in N and Ca concentration but K, P and Mg concentration showed significant difference based on rootstocks. All grafted plants had higher Fe concentration in leaf than control plants. Cu and Zn concentration significantly altered based on rootstock. Grafted plants had higher nitrogen use efficiency (ton yield/kg N) than control plants. Rootstocks used in this study promoted plant nutrition uptake and total yield.

[P67] Rootstocks effect on plant nutrition concentration in different organs of watermelon grafted onto various rootstocks

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Keywords: watermelon, grafting, rootstocks, plant nutrition partitioning

In this study carried out in 2009 and 2010 growing seasons, the effect of rootstocks on plant nutrition partitioning in grafted watermelon onto four gourd rootstocks was investigated. Ferro, RS841 (*Cucurbita maxima* x *C. moschata*) and Argentaio and Macis (*Lagenaria* hybrid) were used as rootstocks. Crimson Tide and Crisby watermelon cultivars were used as scion. Grafted and ungrafted seedlings were produced by a commercial seedling company. Plants were grafted by one cotyledon grafting techniques. Experiment was conducted in Alata Horticultural Research Institute in Mersin. The grafted plants were planted under low tunnel in early spring and regular cultural practices for watermelon were applied. Plant nutrition concentrations were determined in leaf, fruit rind, fruit flesh and seeds. Leaf sample was taken at flowering stage, rind, flesh and seed sample were taken from fully mature fruit. Nitrogen concentration was determined by modified Kjeldahl methods. Phosphorous concentration was determined by vanadomolybdophosphoric acid method. K, Ca, Mg, Fe, Mn, Zn and Cu concentration of samples were determined by atomic absorption spectrophotometry. Plant nutrient concentration in leaf, rind, flesh and seed were significantly affected by rootstocks. Increase in concentration of N, P, K, Ca and Mg in leaf was not observed in grafted plant while ungrafted plant had higher concentration of Fe, Mn, Zn and Cu in their leaf. Ca concentration in rind of fruits from grafted watermelon was higher than ungrafted control plant except Macis/Crimson Tide and Argentario/Crimson Tide graft combinations. Plant nutrition content of fruit flesh was significantly affected by rootstocks and scion. Magnesium, Fe, Zn and Mn concentration of seed was not significantly influenced by rootstocks and scion while other plant nutrient content was significantly affected rootstocks and scion.

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[P68] Hawthorn grafted survival rate and POD activity of scion-rootstock from different combinations

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Keywords: heterograft, homeograft, *Crataegus* L., graft survival ratio, POD

The aim of the paper is to find the early evaluation methods for hawthorn graft-compatibility. The *Crataegus laevigata* 'Paul's Scarlet' (CL) was grafted on three rootstocks: *C. sanguine* (CS), *C. pinatifida* (CP), and itself. The first two combinations were heterografts and the late one homeograft. The grafted survival rate and growth from heterografts and homeograft were significantly different. The graft survival rate from heterografts CL/CS and CL/CP were 96% and 92.5% respectively, and 79.3% from homeograft CL/CL. On the 54th day after grafting, the length and diameter of new branches from the CL/CS were biggest, the CL/CP second, and the CL/CL smallest. On the 18th and 54th day after grafting, the peroxidase (POD) activity of scion and rootstock bark, up and down from junction part at the 1cm, was analyzed with spectrophotometry. From heterografts, the POD activity between scion and rootstock were different obviously, but no obviously differences in homeograft. The differences of POD activity from CL/CS were the largest, and the CL/CL was the smallest. In general, the POD activity between scion and rootstock can show graft compatibility. The bigger different it is, the less compatibility. But our result was differed from others. That maybe because the different testing part or hawthorn species so the role of the POD activity to indicate the compatibility of scion and rootstock in graft need further researched.

[P69] 3D imaging of *Vitis vinifera* graft union by X-Ray tomography

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Keywords: X-ray tomography, 3D imaging, Grafting union, grapevine, *Vitis vinifera*

Successful grafting requires a functional vascular system established between scion and rootstock. Understanding spatial tissue organisation between the two partners is of a paramount importance to better manage grafting in grapevine. Until now this issue has only been addressed through classical histology that generates only 2D information. X-ray tomography, derived from medical X-Ray Imaging, makes a sectional image through the plant body by moving the X-ray source and the camera in opposite directions during the exposure. Tomography involves gathering projection data from multiple directions and feeding the data into a tomographic 3D reconstruction software algorithm processed by a computer. In this paper we investigate 3D tomography X-Ray as a new imaging method to study stock and rootstock interface. We used 18 month old omega bench grafted plants. Data were collected using Skyscan 1076. A setting has been done to adapt the usual process for minerals or animals to vine samples. Parameters such as X-Ray energy, filter, pixel size and rotated degrees were adjusted. The high resolution (9 µm) and optimized parameters allowed mapping tissue density differences (eg: phloem, xylem vessels). 3D reconstructions of the grafting zone in *vitis* clearly imaged the graft union interface and showed spatial tissue reorganization at the interface of two grafting partners. These results suggest that this new tool can be used to realize a graft union follow-up during plant growth and development. It could be convenient to detect a putative bad union that may occur at the graft interface. It should be helpful to obtain an accurate monitoring of the vascular bundles junction between rootstock and stock. Potentialities offered by this new tool for graft union monitoring is discussed.

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[P70] The grafting of the yew (*Taxus baccata* L.)

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Keywords: *Taxus baccata*, sex reversal, vegetative multiplication, grafting techniques

English yew (*Taxus baccata* L.) is also known as the “tree of death”, because of its leaves that are highly poisonous. Yew is the wood of choice for artifacts and bow making since the prehistory, taking advantage of its natural properties. Nowadays, this species grows in many forest nurseries worldwide, and it is used in landscaping and ornamental horticulture. The pharmaceutical industry considers the taxol derived from the leaves and the bark as an efficient inhibitor to be used in cancer chemotherapy. Seed propagation of yew is very hard, the seed dispersal is endozoochorous, and the germination is favoured by birds and mammals eating the arils. Seed germination in the forest nursery can be obtained in one and a half years after several treatments of vernalization and/or chemical scarification. For these reasons, the vegetative multiplication is widely used. Different protocols about cutting techniques have been tested with success rate up to 80%, but corresponding methods for the species’ grafting, potentially useful for ornamental and pharmaceutical productions, are still unknown. *Taxus baccata* is considered dioecious, rarely monoecious, but in recent investigations we observed as the species’ biology is more complex because of sex reversal phenomena that could occur, even yearly, under specific environmental conditions. We are investigating the factors affecting sex reversal by trials, using grafted plants. After several attempts, we selected the grafting approximation as the most performing technique. In this presentation the adopted method will be showed and discussed.

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[P71] Graft compatibility in peach: growth analysis and phenylalanine ammonia-lyase expression

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Keywords: FCC, graft incompatibility, PAL activity, *Prunus*, vegetative growth

The phenylalanine ammonia-lyase (PAL) is considered a key enzyme of the phenylpropanoid pathway. This pathway is responsible for biosynthesis of many secondary compounds, such as anthocyanins, flavanols and lignins. The higher level of PAL is associated with accumulation of phenolic compounds in the union of the incompatible grafts. The aim of this work was to identify incompatible combinations according to tree vegetative growth and to determine the PAL expression and activity in the bark as a biochemical indicator of graft incompatibility in *Prunus*. The study was performed two years after grafting with three rootstocks: 'Capdeboscq' (*Prunus persica* L. Batsch), 'Tsukuba 1' (*P. persica* L. Batsch) and 'Umezeiro' (*P. mume* Sieb. et Zucc.) grafted into the scion 'Chimarrita' (*P. persica* L. Batsch). The vegetative characteristics were measured and the results indicated that 'Umezeiro' rootstock induces a feeble growth of the scion resulting in the death of some trees. However, the others rootstocks tested showed a vigorous growth without dead trees through all years of evaluation. The PAL expression and activity was higher in 'Umezeiro' than in the other combinations. In conclusion, our data show that 'Umezeiro' presents high level of incompatibility with 'Chimarrita' and that the PAL gene expression and activity can be used as biochemical indicators of graft incompatibility.

[P72] Graft union formation and cell to cell communication via plasmodesmata in stem unions of *Prunus* spp

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Keywords: callus, cell-to-cell communication, graft responses, *in vitro* unions and histology

Graft compatibility with at least most commercial cultivars is an essential trait in rootstock breeding programs for orchard performance and longevity. However, its range of application is restricted by physiological and biochemical factors that produce incompatible grafts. As a biological process, it is difficult to study the incompatibility reaction due to the wide range of different scion-rootstocks interactions produced when grafted. The aim of this study was to characterize the early cellular signs of graft incompatibility based mainly on histochemical tests and the study of cell-to-cell communication via plasmodesmata using a novel method termed *in vitro* 'stem unions'. Histological and histochemical aspects are described in this work by means of light and confocal microscopy at early developmental stages in different *Prunus* graft combinations. Through FRAP experiments; we determined the plasmodesmal coupling between different kinds of cells involved in grafting processes. Plasmodesmal coupling between callus cells was quantified by determining the mobile fraction and half-life of fluorescence redistribution and compared with that of other cell types. Results demonstrated that adhesion and callus proliferation occurred in both compatible and incompatible combinations one week after grafting. Nevertheless, the new cambium formation derived from the callus tissue appeared to be delayed in incompatible heterografts. A different cell wall composition as well as an enhanced metabolism was detected in the incompatible unions. Dye-coupling analysis revealed that the plasmodesmal coupling was highest between callus cells. In addition, a stronger cell-to-cell communication was also observed at the graft interface from compatible graft combinations two weeks after grafting. These new findings strengthen the idea that callus cells are playing a central role in scion/rootstock interaction and that late rejection is predetermined already at the initial steps of union formation.

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[P73] Functioning scenario of successful omega bench grafting of grapevine

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Keywords: *Vitis vinifera*, bench-omega grafting, cambial connections, quality test, incompatibility

Grafting is widely used for grapevine production as it appears necessary to control phylloxera worldwide. This technique is essentially based on practical experience and what a good grafted vine is, remains poorly understood. The aim of this study was to investigate the graft union development in nine scion/rootstocks combinations known to present different behaviors towards grafting. 100 omega bench-grafted vines per combination were installed in a nursery field. 25 to 30 samples of them were selected randomly two months after the grafting to characterize the morphological and the functional developments at the graft interface. Each graft union was cut into successive sections and fixed before being embedded in a glycomethacrylat resin. Precise observations were done on each plant of these combinations to measure different variables such as the number of cambial connections between scion and rootstock, the new xylem/phloem production and the starch quantity. The other plants of the same batches followed the normal scheme of the vine grafting for commercial purposes that involves a screening of the grafted vine quality at the end of the growing season. The rate of plants removed because of the poor quality of the graft union or because the abnormal root development was calculated for each combination. Statistical analyses and correlations were done between the early cellular events observed by histological technique and the latter screening in the same batches. A good correlation was obtained, on five combinations, between new xylem formation in the junction and the percentage of plants that passed the quality test successfully. Nevertheless this sole criterion was inefficient to explain by itself the good quality of the graft interface. Specific abnormalities were characterized in the three incompatible combinations. We propose a functioning scenario in the early events that lead to a grafted vine of good quality.

[P74] The proteome of the graft union of grapevine

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Keywords: grapevine, graft union, proteomics

Grafting is widely used in the agriculture of fruit crops such as grapevine. The graft interface is presumably central to scion/rootstock interactions and the movement of solutes and metabolites around the plant. At early stages, grafting involves numerous developments at the interface between the two genotypes, which must involve wound responses, cell recognition and communication, plasmodesmata formation, the initiation of cell cycle and vascular differentiation. Little is known about the molecular interactions that occur between the two genotypes of a hetero-graft; however we know that these interactions support the harmonious development of the functioning graft union. This work aims to investigate graft union development in different scion/rootstock combinations of grapevine (along with auto-grafted control plants) during the first few months of graft union formation. The genotypes studied were the commercially grown scion cultivar *Vitis vinifera* cv 'Cabernet Sauvignon' auto-grafted and grafted onto the rootstock genotypes *V. riparia* cv 'Gloire de Montpellier' and the *V. berlandieri* x *V. rupestris* hybrid cv '1103 Paulsen'. Lignified canes were grafted using table-top omega grafting and then left to stratify for one month in sawdust-filled boxes at 28°C and 90% humidity. The plants were then transferred to soil-filled pots and placed in a greenhouse. One and two months after grafting, the graft union interface as well as the tissue just above (scion) and below (rootstock) the graft interface were sampled. 2D gel electrophoresis of proteins and LC-MS/MS identification were then used to characterize the succession of protein accumulation changes induced by graft union formation and how these changes differ in different scion/rootstock combinations. The expression of genes potentially involved in graft union formation was also examined by qPCR. We believe that understanding the first steps of the development of a grafted plant, the graft union formation, is key to understanding scion/rootstock interactions.

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[P75] Effect of two different environmental conditions on yield and quality of grafted sweet pepper in greenhouses-grown in SE Spain

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Key words: *Capsicum annuum*, fruit quality, fruit yield, radiation stress, rootstock.

The use of grafting in sweet pepper is progressively more common in the province of Murcia, since it could be an effective way to control soil-borne diseases such as *Phytophthora* spp. and *Meloidogyne* spp. In this province the sweet pepper production is normally distributed between spring and late summer. To avoid the problem of too high temperature and high radiation during late spring and summer period, growers reduce the incident radiation with several methods. The aim of this work was to study the two different environmental conditions (blanking and no blanking greenhouse) on yield and quality of grafted sweet pepper in greenhouse-grown. The research was conducted on Atlante rootstock grafted on rectangular sweet pepper cv. Herminio and non-grafted plants of cv. Herminio (control). Grafted plants were more productive than the non-grafted and the highest yield was obtained in grafted plants grown under blanking greenhouse. There were no significant differences between the cultivar and the grafted plant respect to fruit characteristics (fresh and dry weight, length and width, firmness and pericarp thickness). On the contrary, significant differences were found on fruit characteristics when the two environmental conditions were compared, particularly respect to fruit width, which was higher in blanking greenhouse. There were hardly significant differences between the cultivar and the grafted plant respect to fruit chemical characteristics (soluble solids, pH, EC and titratable acidity). Fruits of plant grown under no blanking greenhouse reached higher values of soluble solids and pH than fruit grown under blanking conditions. The environmental conditions also affected significantly the vitamin C and phenols content, reaching the highest values in plants grown under no blanking greenhouse. Finally the fruits of cultivar presented higher vitamin C and phenols values than the fruits of grafted plant.

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