出國報告（出國類別：其他）

2011 溫室生態系統國際研討會
心得報告

服務機關:台糖公司台糖研究所
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出國期間:100 年 6 月 3 日至 6 月 12 日
報告日期:100 年　8 月 10 日

摘要

由國際園藝學會主辦之 GreenSys2011 國際會議於 2011 年 6 月在希臘舉行。本次舉辦之會議探討溫室生態環境永續利用相關議題，並對溫室設計、能源、水、溫室微氣侯、覆蓋材料、氣候控制、計算流體力學、環境友善技術、自動化及機器人傳感器、溫室作物生產之良好農業規範、栽培介質與水耕、植物保護、產品品質、作物栽培管理等問題進行報告及研討。

全世界現在均利用溫室來終年生產蔬菜及花卉。包括溫室結構、覆蓋物、溫室微氣侯控制系統、灌溉與施肥系統等議題，都受到產官學研之關切，寄望可以節能減碳、降低成本，以提高獲利。在特定區域，以合適的溫室型態及設備，配合當地氣侯及生產設備與作物。因此，近年來我們可以見到發展為較高與較大的溫室、創新的覆蓋物、封閉式或半封閉式的溫室、利用太陽能運作或是儲存太陽能作為加熱。在溫帶地區，網室擴展迅速，防蟲網之運用讓很多不同作物可以在網室內栽培。應用天敵防治溫室害蟲在歐洲已有民間公司持續進行研究開發及商品上市，此現象表示病蟲害綜合防治之觀念在歐洲已被普遍接受而有一定之應用市場。

目次

壹、目的

國際園藝學會（International Society for Horticultural Science）為世界性園藝科學組織，本次舉辦之會議探討溫室生態環境管理相關議題，並對溫室設計、能源、水、溫室微氣侯、覆蓋材料、溫室微氣候控制、計算流體力學、環境友善技術、自動化及機器人傳感器、溫室作物生產之良好農業規範、栽培介質與水耕、植物保護、產品品質、作物栽培管理等問題進行報告，為蒐集溫室生態管理相關資訊之最佳選擇。

貳、行程與工作概要

日期	起迄地點	工作內容
100/06/03-04	台南-希臘	出發
100/6/5	希臘	報到
100/6/6	希臘	研討會第 1 天
100/6/7	希臘	研討會第 2 天
100/6/8	希臘	研討會第 3 天
100/6/9	希臘	科學參訪
100/6/10	希臘	文化參訪
100/6/11-12	希臘-台南	返回

本次會議主要分為溫室設計、能源、水、溫室微氣侯、覆蓋材料、氣候控制、計算流體力學、環境友善技術、自動化及機器人傳感器、溫室作物生產之良好農業規範、栽培介質與水耕、植物保護、產品品質、作物栽培管理等主題進行探討，並對國際研究發展趨勢進行介紹，概述如下：

1.溫室設計

全世界現在均利用溫室來終年生產蔬菜及花卉。在特定區域，以合適的溫室型態及設備，配合當地氣侯及生產設備與作物。在各特定區域，包括溫室結構、覆蓋物、氣侯控制系統、灌溉與施肥系統，均是農民、設計者、學者關切之議題，目的是增加它們的效能及減少投入與最小化環境的負面影響。另外，驅動溫室設計研究的能量還包括：設計永續性之溫室，使用天然之非化石能源、最小量的必須用水與最少的環境限制及最大的獲利。因此，近年來我們可以見到發展為較高與較大的溫室、創新的覆蓋物、封閉式或半封閉式的溫室、利用太陽能運作或是儲存太陽能作為加熱，例如太陽能晶矽電池之運用為熱門議題。在溫帶地區，網室擴展迅速，防蟲網之運用讓很多不同作物可以在網室內栽培。科技發達也促使結構與設施之開發較以往更為快速與優良，例如 CFD (computational fluid dynamics, 計算流體力學)之運用，可以了解溫室結構、換氣風扇、防蟲網之運用等因素對溫室內微氣侯之影響。從相關研究可看出，目前方向在於研發改善現有溫室結構與組件。

2.能源

探討主題包含能源利用效能提升、節能設備應用，如發光二極體(light emitting diodes, LED)、節能燈、遮光網等，或利用太陽能、地熱等天然資源。

美國康乃爾大學選擇 Philips Elite Agro 315W 節能燈與 T5 及 T12 螢光燈管在生長箱進行比較，結果分別可以節省 30%及 58%的能源。

發光二極體與傳統燈具比較，其優點為具有堅硬之外殼，可以設定適合作物之波長，其廢熱可以由背面散發，發光面可距作物較近，可以應用在植床上，例如育苗、切花、扦插、觀賞花卉之生育期光照控制。目前的研究著重在測量使用 LED、傳統光照與日光之耗能差異，所蒐集之資料可供未來發展更經濟、長壽之 LED 元件應用在溫室照明。

希臘一篇報告指出，世界各國應用各種加熱方式在有熱能需求之溫室。最近十年，密閉式地熱熱泵之研究發展及運用急速增加。在溫室內或溫室外之地面覆蓋聚乙烯膠布，以提升溫度，並利用密閉式熱泵將熱量帶入溫室利用，且不用外加其它加熱系統。

另外，韓國首爾大學亦報告其利用地熱作為溫室加熱來源，溫室若終年生產，加熱所占

成本約 19~58%，其中 92%來自石油，所以天然資源，例如地熱之利用即為可行之方案，但需考量地形地貌、氣侯、作物、季節及加熱設備等之配套。

3.溫室微氣侯

根據文獻分析，近年來有關溫室微氣侯之研究方向，溫室微氣侯領域仍為增加趨勢，但是計算流體力學(CFD)領域則略有停滯或倒退。大多數已發表的研究報告（57%）已基於雙模型(dual modeling)之模擬試驗方法，而其餘的則關注於純粹的實驗。一般來說，這些研究大多在探討溫室加熱、冷卻、遮光網和作物蒸散作用等問題。有較多進展的是在田間試驗已可使用無線傳感器取得氣候和植物活動狀態相關資料，另外無線傳感器網路(Wireless Sensor Networks) 亦被應用在溫室計算流體力學之研究，特別是關於：（1）氣候分布狀態，特別是 1 公頃以上較大規模之溫室；（2）CFD 模擬複雜的幾何學，例如遮光網或冷卻墊；（3）複雜的耦合機制，如霧、通風、空氣中的真菌孢子轉移或藻類生物反應器於溫室利用。

最近的進展是研究關於改善溫室氣候條件，主要在生產系統的設計，以應付溫室可持續性：高緯度的封閉式節能溫室和低緯度簡易式遮蔽溫室。

4.環境友善技術

荷蘭一份報告指出，次世代植物工廠的設計超出現有植物生理及相關知識，並稱之為植物生產單位(Plant Production Units, PPU)。係利用多層次之設計並加入 LED、紅外線等技術，視需要加以控制溼度、空氣溫度、根部溫度、空氣流動、二氧化碳、水及養分；且無氣侯災害之問題，亦無病蟲害故不需使用農藥，水的使用較傳統減少約 90%；並指出此種人工環境可以全年 365 天，每日 24 小時生產作物，包括花卉及蔬菜；經估算，在人口約 14 萬人之城市，每人每日需 200 公克之蔬菜，需一個具 14 層占地 1 公頃之設備，包含在建築物內或地下層；因為在城市內，減少了輸送距離，亦可以節省能源之耗用。

義大利一篇報告指出，利用塑膠布覆蓋抑制雜草可以降低農藥使用，但因其不易分解，故需回收再利用，否則會對環境造成很大衝擊。若使用可自然分解之物質舖設畦面，可節省資源回收所耗用之能源或人力。該報告利用 2 種配方噴施在畦面以達抑草之目的，其一組成為蝦蟹殼粉加麥稈，另一組成為豆筴纖維加甘油；此 2 種配方設計目的，除了抑草之外，另有抑菌等功效。該報告利用太陽花作栽培試驗，結論為使用天然覆蓋物，距地表 20 公分處之溫度無變化，塑膠布則會升溫攝氏 1.5~2 度；唯太陽花切花產量以塑膠布覆蓋者優於天然覆蓋物者。

5.自動化及機器人傳感器

在西歐國家經營園藝產業，工資占生產成本很大的比重。除了必要的成本，擴大生產設施規模，尚有勞工技術養成、從業態度是否積極及勞工的健康問題，亦需注重專業化和特質化生產的作物栽培，因此，需求面是必須更加注重對勞工之保護與專業培養。提高勞動效率，將是西歐未來十年的關鍵成功因素。因應未來發展趨勢之解決方案如下：(1)市場或產品能更有效布局的公司；(2)彈性、最適且優化的勞動力調節；(3)以自動化設施減輕，甚至取代人類勞動的相關計畫。近年來溫室作物生產發展趨勢主要為提高勞動效率；其次，自動化的識別技術，以及填補現有缺口之研究，以達到降低生產成本之目標。

6.溫室作物生產之良好農業規範

一篇由約旦國際農業研究推廣中心發表之文章，近年來在靠近地中海區域之近東及北非之國家(Near East and North Africa countries, NENA)發展溫室工業，面積約 14.5 萬公頃(2008~2009 年資料)。且此類溫室係針對栽培複雜作物之小農所設計，以供應內外銷市

場。由於溫室栽培對經濟日益重要，在FAO的支持下，NENA國家在1993年成立一個合作團隊，以交換綜合生產與保護技術(Integrated Production and Protection, IPP)的相關知識，且產出一份良好農業規範(Good Agriculture Practices, GAP)，為充分利用該資源，已將該資料予以出版發行，以作為該區域溫室栽培之指導方針。且資料著重在解決地中海區域溫室作物生產之產量與品質之相關問題，另一個目的是促進該區域各會員國之間合作關係。該份資料之受益者包括農民、推廣員、科學家、政府官員等，提昇溫室生產管理並增進區域之合作。所建立的工作團隊繼續定期舉行2年1度的會議，以討論、交流，並制定共同的研究和推廣方案，領域包括溫室的設計和氣候控制、作物病蟲害綜合防治和管理、良好農業規範、生產經濟和市場營銷等。到目前為止，工作團隊已經進行多次會談，研究發展、主導與聯合援助的科學家來自比利時、西班牙、法國、德國和希臘等國。

7.植物保護

一篇以色列報告指出，不論在溫室或田間，葉蠕均可對作物造成嚴重損害。二點葉蠕(*Tetranychus urticae* Koch)在植物葉背進行取食，其發生危害嚴重與否，與植物生長勢、氣候條件息息相關。該報告的試驗係利用光譜儀(ASD FieldSpec Pro FR spectrometer)以光纖外接積分球(Li-cor, 1800-12s)分析植物葉片遭受危害程度，分為未受害、輕度受害、中度受害及重度受害。並將收集資料以ANOVA分析($p<0.001$)區分出未受害及輕度受害。報告結論，以此方法分析可以早期發現溫室二點葉蠕危害，可藉以及時擬定及施行防治措施。

比利時Viridaxis公司報告其天敵產品，該公司已開發出大量飼育蚜蟲寄生性天敵之方法。並藉其創新與獨特之方法，每年均有能力開發一種新的寄生性天敵。若採行病蟲害綜合防制(IPM)策略，通常在發現蚜蟲之後才進行防治措施就為時已晚；另外利用化學防治時，亦會將天敵與益蟲一併滅除，亦破壞IPM策略。該公司介紹其FresaProtect產品，係採雞尾酒療法，該產品內有多種針對蚜蟲之寄生性天敵，可藉以控制田間常見之蚜蟲種類。該產品已成功使用在草莓栽培上，目前也正在進行覆盆子、藍莓、花卉及蔬菜之試驗。

日本近畿大學則報告利用具電場之防蟲網，以物理方式防止昆蟲入侵溫室。該種防蟲網為3層結構，中間層為絕緣導電網，外2層為接地導電網；該防蟲網目為2.0 mm x 2 .0 mm，其通風性較一般防蟲網為佳。對中間層施以0.1-8 kV之負電，可在中間層與外層之間形成電場，可以防止溫室外之小型昆蟲進入溫室內，包括粉蝨、薊馬、蚜蟲、潛葉蠅等小型昆蟲。另一篇來自同一研究團隊之報告指出，除了可防止小型昆蟲之外，該電網亦可防止白粉病及灰黴病之病原菌進入溫室危害番茄。會後被提問其售價，該研究團隊預估技術移轉廠商後之售價約每平方米5千歐元。

參、心得與建議

本次會議計有演講119場及海報105篇，與會人員分別來自33個國家，總人數約200人。本次會議系以溫室生態環境永續利用為主軸，與會之專家學者主要為溫室設計軟硬體人員。值得注意的是，雖然主辦國位於希臘，但在每個分項議題，荷蘭幾乎都沒有缺席，可與其分庭抗禮的是美國與德國。亞洲部分，中國大陸、日本、韓國之報告亦占相當之篇幅，且積極爭取主辦相關領域之研討會；相較之下，臺灣在本次會議僅中興大學1位教授及其學生參與2篇海報研討，由此可見臺灣在參與國際研討會之積極度尚有提昇之空間。

有關溫室設施之議題，在發光二極體、太陽能、地熱、熱泵等，其研究目標為節能減碳、提昇效能等，講者均聲稱其初步成果大致上符合目標，但均有許多議題值得繼續深入探討與克服。

有關生物防治之議題，應用天敵防治溫室害蟲在歐洲已有民間公司持續進行研究開發及商品上市，此現象表示病蟲害綜合防治(IPM)之觀念已被普遍接受而有一定之應用市場；然

而，生物防治之應用在臺灣難以普及化，與臺灣作物歧異度高、IPM觀念之推行與接受度不高、化學防治深植人心，應有高度之關聯性。建議官方持續推動生物防治之觀念。

GreenSys 2011

«Advanced technologies and management towards sustainable greenhouse ecosystems»

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Table of Contents

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Welcome

The University of Thessaly and the Center for Research and Technology-Thessaly are delighted to welcome you during the International Symposium on «Advanced technologies and management towards sustainable greenhouse ecosystems – GreenSys2011» organized in the Halkidiki peninsula, Greece, 5 to 10 June 2011.

The Symposium is organized in the PortoCarras Grand Resort located inside a paradise in Northern Greece on the western coast of Sithonia Halkidiki's central peninsula.

The Symposium comprises scientific sessions with oral and poster presentations that focuses on advanced technologies and management of greenhouse ecosystems towards sustainability and also deals with greenhouse design, crop substrates and hydroponics, greenhouse climate control, culture practises and plant protection as well as education and training. Innovative and efficient systems and technologies will be highlighted and explored. The symposium shows how high and innovative technologies and optimal management come together to create a sustainable greenhouse ecosystem for a better world.

We are sure that the above, in combination with the physical beauty of Greece and Halkidiki peninsula, will create an unforgettable event for all of us!

Prof. Constantinos Kittas,

Dr. Nikolaos Katsoulas, Dr. Thomas Bartzanas

Conveners

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D. Savvas, *Agricultural University of Athens, Greece*
D. Schwarz, *Institute Vegetable & Ornamental crops, Grossbeeren, Germany*
I. Seginer, *Agriculture Research Organization, The Volcani Center, Israel*
N. Sigrimis, *Agricultural University of Athens, Greece*
J. Son, *Dept. of Plant Science, Seoul National University, Korea*
P. Sonneveld, *Wageningen University, Wageningen, The Netherlands*
C. Stanghellini, *Wageningen University, Wageningen, The Netherlands*
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Y. Tuzel, *Ege University, Dept. of Horticulture Turkey*
C. Wien, *Cornell University, Dept. of Fruit & Vegetable Science, Ithaca, USA*
D. Willits, *North Carolina State University, Biological and Agricultural Engineering, USA*
H. Xu, *Agricultural Research Studio, Nagano, Japan*
Y. Zheng, *University of Guelph, Canada*

AREND-JAN (A.J.) BOTH

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EDUCATION AND TRAINING:

Wageningen Agricultural University, the Netherlands	BS	1986	Agricultural Engineering
Wageningen Agricultural University, the Netherlands	MS	1986-1988	Agricultural Engineering
Cornell University Ithaca, NY	PhD	1989-1994	Agricultural Engineering
Cornell University Ithaca, NY	Post-Doc	1995-1996	Agricultural Engineering

Professor Arend-Jan (A.J.) Both is Director of the Center for Controlled Environment Agriculture of the Rutgers, The State University of New Jersey. He completed his BS and MSc studies on agricultural engineering in Wageningen Agricultural University (1983-1988) and he continues with PhD and Post Doc research in Cornell University (1989-1996). His main research activities include Controlled environment agriculture, Greenhouse production, energy use in greenhouses, equipment and microclimate of greenhouses. He has received several honor and awards for his scientific excellence. He is member of several relative to agricultural engineering organizations and Associate Editor of the Transactions of the ASABE and Applied Engineering in Agriculture. He has several contributions in book chapters, peer-reviewed journals and conference proceedings. More info on http://www.aesop.rutgers.edu/~horteng and his e-mail: both@aesop.rutgers.edu

MUIEN M. QARYOUTI

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EDUCATION

Ph.D. in Plant physiology, University of Jordan, Jordan. (2001),

EXPERIENCE

Researcher at the National Center for Agricultural Research and Extension (1994 – present).
Director of Horticultural Research directorate (2005- present).
Coordinator of the FAO Regional Working Group on Greenhouse Crop Production in the Mediterranean Region (2006- present).
Local consultant in Global GAP & HACCP certificates 2005- present).

RESEARCH ACTIVITIES:

Testing and improving different soilless culture systems (Closed non-circulating and open systems), different substrates, different water salinity levels and their effects on plant productivity, fruit quality and water use efficiency.
Improvement of greenhouse conditions (ventilation, shading, heating) and introduction and testing of new greenhouse designs.

ELDERT J. VAN HENTEN

(1963) is heading the Farm Technology Group at Wageningen University since 2005 and has a position as Senior Scientist in the Technology group of Wageningen UR Greenhouse Horticulture Ltd. since 1994. He received his M.Sc. degree in Agricultural Sciences in 1987 with honours and his Ph.D. degree in Agricultural and Environmental Engineering in 1994, both at Wageningen University, The Netherlands. With protected cultivation and arable farming as main application fields, his research interest include sensing, modelling, design and (optimal) control of bio-systems, bio-robotics and high-tech automation and company logistics. He is (co-)author of more than 70 papers in peer reviewed journals and conference proceedings.

Program at a glance

June 5th, 2011

16:00 - 20:00	Registrations
20:00	Welcome Cocktail

June 6th, 2011

TIME	PLENARY ROOM	HALL I	HALL II	POSTER AREA
09:00 - 09:40	**Keynote Lecture I** Efficient use of natural resources in greenhouses *Dr. Arend-Jan Both*			**Poster Presentations P01-P30**
09:40 - 10:00	*Coffee Break - Visit to Poster & Exhibition Area*			
	Morning Sessions			
10:00 - 12:40	**Oral Presentations 1: Greenhouse Design** *Chairs: M. Teitel - G. Giacomelli* Session Keynote I Dr. M Teitel	**Oral Presentations 2: Energy I** *Chairs: G. Martzopoulos - F. Kempkes*	**Oral Presentations 3: Water** *Chairs: J.E. Son - Ch. Leonardi*	**Poster Presentations P01-P30**
12:40 - 14:30	Light Lunch			
	Afternoon Sessions			
14:30 - 16:10	**Oral Presentations 4: Greenhouse Microclimate** *Chairs: T. Boulard - C. Kittas* Session Keynote II Prof. T. Boulard	**Oral Presentations 5: Energy II** *Chairs: L. Albright - F. de Zwart*	**Oral Presentations 6: Covering Materials** *Chairs: S. Hemming - E.Schettini* Session Keynote III Dr. S Hemming	**Poster Presentations P01-P30**
16:10 - 16:30	*Coffee Break - Visit to Poster & Exhibition Area*			
16:30 - 17:50	**Oral Presentations 4: Greenhouse Microclimate** *(Continued)*	**Oral Presentations 5: Energy II** *(Continued)* Commission Protected Cultivation Meeting	**Oral Presentations 6: Covering Materials** *(Continued)*	

June 7th, 2011

TIME	PLENARY ROOM	HALL I	HALL II	POSTER AREA
09:00 - 09:40	**Keynote Lecture II** Automation and robotics in greenhouses *Prof. Dr. Ir. Eldert Van Henten*			**Poster Presentations P31-P71**
09:40 - 10:00	*Coffee Break - Visit to Poster & Exhibition Area*			
	Morning Sessions			
10:00 - 12:40	**Oral Presentations 7: Climate Control I** *Chairs: Ch. Martzopoulou - C. Stanghellini*	**Oral Presentations 8: CFD I** *Chairs: I.B. Lee - E. Baeza* Session Keynote IV *Prof. I.B. Lee*	**Oral Presentations 9: Environmental Friendly Technologies** *Chairs: M. Kacira - D. Mistriotis*	**Poster Presentations P31-P71**
12:40 - 14:30	Light Lunch			
	Afternoon Sessions			
14:30 - 15:50	**Oral Presentations 10: Climate Control II** *Chairs: Q. Yang - L. Marcelis*	**Oral Presentations 11: CFD II** *Chairs: S. Sase - J. Campen*	**Oral Presentations 12: Sensors, Automations and Robots** *Chairs: T. Gieling - J. Tanny*	**Poster Presentations P31-P71**
15:50 - 16:10	*Coffee Break - Visit to Poster & Exhibition Area*			
16:10 - 17:20		CFD MEETING	**Oral Presentations 12: Sensors, Automations and Robots** *(Continued)* Good Agricultural Practices in Greenhouses Commission Meeting	

Program at a glance

June 8th, 2011

TIME	PLENARY ROOM	HALL I	HALL II	POSTER AREA
09:00 - 09:40	**Keynote Lecture III** Good agricultural practices in greenhouse production *Dr. Muien Muhamad Qaryouti*			**Poster Presentations P72-P105**
09:40 - 10:00	*Coffee Break - Visit to Poster & Exhibition Area*			
	Morning Sessions			
10:00 - 12:40	**Oral Presentations 13: Growing Media and Hydroponics I** *Chairs: D. Savvas - D.Schwarz*	**Oral Presentations 14: Plant Protection** *Chairs: Ch. Lykas - Ch. Papaioannou*	**Oral Presentations 15: Crop Management and Cultural Practices I** *Chairs: S. de Pascale - T. Papadopoulos* Session Keynote V Dr. S de Pascale	**Poster Presentations P72-P105**
12:40 - 14:30	Light Lunch			
	Afternoon Sessions			
14:30 - 15:50	**Oral Presentations 16: Growing Media and Hydroponics II** *Chairs: N. Castilla - G. Mavrogiannopoulos*	**Oral Presentations 17: Product Quality** *Chairs: C. Kubota - E. Heuvelink* Session Keynote VI *Prof. C. Kubota*	**Oral Presentations 18: Crop Management and Cultural Practices II** *Chairs: Y. Tuzel - A. Dieleman*	**Poster Presentations P72-P105**
15:50 - 16:10	*Coffee Break - Visit to Poster & Exhibition Area*			
16:10 - 16:30			**Oral Presentations 18: Crop Management and Cultural Practices II (Continued**	
16:30 - 16:50	COMMISSION OF HORTICULTURAL ENGINEERING MEETING			
16:50	ISHS Presentation and Overview - Awards			

June 9th, 2011

TECHNICAL TOUR

Plenary Room

09.00-09.40 **Keynote lecture I**
Chairs: C Kittas, T. Bartzanas,N. Katsoulas
Efficient use of natural resources in greenhouses
Dr. Arend-Jan Both

09.40-10.00 **Coffee Break - Visit to Poster & Exhibition Area**

10.00-12.40 **Morning Sessions**

Plenary Room

10.00-12.20 **Oral Presentations 1: "GREENHOUSE DESIGN"**
Chairs: M. Teitel - G. Giacomelli

Session Keynote I

GREENHOUSE DESIGN: CONCEPTS AND TRENDS
M. Teitel[1], J.I. Montero[2], E.J. Baeza[3]
[1] Institute of Agricultural Engineering, Agricultural Research Organization, the Volcani Center, Bet Dagan, Israel.
[2]Institut de Recerca i Tecnología Agroalimentaries Centre de Cabrils, 08348 Cabrils, Barcelona, Spain.
[3]Fundación Cajamar, Estación Experimental, El Ejido, Spain.

GD 1.
HORIZONTAL FLOW AND VERTICAL TRANSFER IN AND ABOVE AN INFINITE SCREENHOUSE
I. Seginer. (Presented by: J. Tanny)
Civil and Environmental Engineering, Technion, Israel Institute of Technology, Haifa, Israel

GD 2.
LESSONS LEARNED FROM EXPERIMENTS WITH SEMI-CLOSED GREENHOUSES
H.F. de Zwart
Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands.

GD 3.
SYSTEM DYNAMICS AND PERORMANCE FACTORS OF UA-CEAC LUNAR GREENHOUSE PROTOTYPE BIOREGENEATIVE LIFE SUPPORT SYSTEM
M. Kacira[1], G. Giacomelli[1], L. Patterson[1], R. Furfaro[2], P. Sadler[3], G. Boscheri[4], R. Wheeler[5], C. Lobascio[4], M. Lamantea[4], S. Rossignoli[6]
[1]Agriculture and Biosystems Engineering, University of Arizona, Tucson, AZ, USA.
[2]Systems and Industrial Engineering, University of Arizona, Tucson, AZ, USA
[3]Sadler Machine Company, Tempe, AZ, USA
[4]Thales Alenia Space Italia, Torino, Italy
[5] NASA Kennedy Space Center, FL, USA
[6] Aero Sekur, Aprilia, Italy

GD 4.
MODEL-BASED OPTIMAL GREENHOUSE DESIGN: A CASE STUDY FOR SOUTH SPANISH CONDITIONS
B.H.E. Vanthoor[1,2], C. Stanghellini[1], E.J. van Henten[1,2], P.H.B. de Visser[1]
[1]Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands
[2]Farm Technology Group, Wageningen University, Wageningen,The Netherlands

GD 5.
A 3D MODEL FOR CROP AND GREENHOUSE TO IMPROVE ILLUMINATION STRATEGIES IN GREENHOUSE CROPS
P.H.B. de Visser[1], G.H. Buck-Sorlin[2], **L.F.M. Marcelis[1]**
[1]Dept. of Greenhouse Horticulture, WUR, Wageningen, The Netherlands
[2]Biometris, WUR, Wageningen, The Netherlands

GD 6.
DESCRIPTION, OPERATION AND PRODUCTION OF THE SOUTH POLE FOOD GROWTH CHAMBER
R.L. Patterson[1], P.D. Sadler[2], R.M. Wheeler[3], M. Kacira[1], and G.A. Giacomelli[1]
[1]Dept Agricultural & Biosystems Engineering, University of Arizona, Tucson, Arizona, USA
[2]Sadler Machine Co, Tempe, Arizona, USA
[3]NASA-KSC, Florida, USA

Hall I

10.00-12.40 **Oral Presentations 2: "ENERGY I"**
Chairs: G. Martzopoulos - F. Kempkes

ENI 1.
NEXT GENERATION, ENERGY-EFFICIENT, UNIFORM SUPPLEMENTAL LIGHTING FOR CLOSED-SYSTEM PLANT PRODUCTION
D. de Villiers[1], **L. Albright[1]**, R. Tuck[2]
[1]Dpt of Biological and Environmental Engineering, Cornell University, Ithaca NY, USA
[2]Cycloptics Technologies, LLC, Gambier OH, USA

ENI 2.
DEVELOPING LED LIGHTING TECHNOLOGIES AND PRACTICES FOR GREENHOUSE CROP PRODUCTION
C.A. Mitchell[1], A.J. Both[2], C.M. Bourget[3], J.F. Burr[4], C. Kubota[5], R.G. Lopez[1], G.D. Massa[1], R.C. Morrow[3], E.S. Runkle[6]
[1]Dpt. of Horticulture and Landscape Architecture, Purdue University, West Lafayette, IN, USA
[2]Dpt. of Environmental Sciences, Rutgers University, New Brunswick, NJ, USA
[3]Orbital Technologies Corporation, Madison, WI, USA
[4]Krannert School of Management, Purdue University, West Lafayette, IN, USA
[5]School of Plant Sciences, The University of Arizona, Tucson, AZ, USA
[6]Dpt. of Horticulture, Michigan State University, East Lansing, MI, USA

ENI 3.
A CONCEPT FOR REDUCED ENERGY DEMAND OF GREENHOUSES: THE NEXT GENERATION GREENHOUSE CULTIVATION IN THE NETHERLANDS
A. de Gelder, E.H. Poot, J.A. Dieleman, H.F. de Zwart.
Wageningen UR Greenhouse Horticulture, Bleiswijk, The Netherlands

ENI 4.
PERFORMANCE AND TECHNO-ECONOMIC ANALYSIS OF A COVERED CLOSED LOOP GEOTHERMAL HEAT PUMP FOR GREENHOUSE HEATING
V. Firfiris[1], **P.G. Kougias[1]**, Ch. Nikita-Martzopoulou[2], G.G. Martzopoulos[1]
[1] Lab. of Alternative Energy Sources in Agriculture, Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece
[2] Lab. of Agricultural Structures and Equipment, Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

ENI 5.

PERFORMANCE OF COMBINED HEATING AND DEHUMIDIFICATION SYSTEM FOR GREENHOUSES

A. Arbel, M. Barak, G. Lidor, A. Shklyar
Dpt. of Growth, Production and Environmental Engineering, ARO The Volcani Center, Bet-Dagan, Israel

ENI 6.

DEVELOPMENT OF AN ASSESSMENT MODEL FOR GREENHOUSE USING GEOTHERMAL ENERGY SYSTEMS

S.-B. Lee, I.-B. Lee
Dpt. of Rural Systems Engineering, Seoul National University, Seoul, Korea

ENI 7.

GREENHOUSE ENERGY CONSUMPTION FOR TOMATO PRODUCTION IN THE IBERIAN PENINSULA

F.J. Baptista[1], A.T. Silva[1], L.M. Navas[2], A.C. Guimarães[2] and J.F. Meneses[3]
[1]Departamento de Engenharia Rural, Escola de Ciências e Tecnologia, Universidade de Évora/ICAAM, Núcleo da Mitra, Apartado 94, 7002-554 Évora, Portugal
[2]Departamento de Ingeniería Agrícola y Forestal, Universidad de Valladolid, Avda. Madrid, Palencia, España
[3]Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Centro de Estudos de Engenharia Rural, Tapada da Ajuda. Lisboa, Portugal

ENI 8.

INTRODUCTION AND POTENTIALS OF EXERGY ANALYSIS IN PRIMARY ENERGY SAVING RESEARCH FOR GREENHOUSES

F. Bronchart[1], P. Demeyer[1], J. Dewulf[2], M. Depaepe[3],E. Schrevens[4]
[1]Technology and Food Science Unit, The Institute for Agricultural and Fisheries Research, Merelbeke, Belgium
[2]Research Group EnVOC, Ghent University, Ghent, Belgium
[3]Department of Flow, Heat and Combustion Mechanics, Ghent University, Ghent, Belgium
[4]Department of Biosystems, Katholieke Universiteit Leuven, Leuven, Belgium

Hall II

10.00-12.00 **Oral Presentations 3: "WATER"**
Chairs: J.E. Son - Ch. Leonardi

WA 1.

PREDICTING THE IMPACTS OF SUBSTRATE WATER POTENTIAL ON EXTERNAL QUALITY TRAITS OF LILY GROWN IN GREENHOUSE

W. Luo, Y. Dong, G Li, D An, J Dai
College of Agriculture, Nanjing Agricultural University, Nanjing 210095, P R China

WA 2.

TOMATO PLANT WATER STATUS AND FRUIT GROWTH DYNAMICS IN RESPONSE TO WATER AVAILABILITY IN THE GROWING MEDIUM

T. De Swaef[1], K. Verbist[2], W. Cornelis[2], K. Steppe[1]
[1] Lab. of Plant Ecology, Dpt. of Applied Ecology and Environmental Biology, Ghent University, Ghent, Belgium
[2] Lab. of Soil Physics, Dpt. of Soil Management and Soil Care, Ghent University, Ghent, Belgium

WA 3.

GREENHOUSE CUCUMBER PRODUCTION UNDER DEFICIT IRRIGATION CONDITIONS

I.H. Tuzel[1], Y. Tuzel[2], G.B. Oztekin[2], K. Meric[3], U. Tunali[1], Z.A. Serbes[4]
[1] Dept. of Farm Structure and Irrigation, Agricultural Faculty, Bornova-Izmir/Turkey
[2] Dept. of Horticulture, Agricultural Faculty, Ege University, Bornova-Izmir/Turkey
[3] Bergama Vocational School, Ege University, Bergama-Izmir/Turkey
[4] Graduate School of Natural and Applied Sciences, Ege University, Bornova-Izmir/Turkey

WA 4.

MODEL-BASED ESTIMATION OF MOISTURE CONTENT OF ROOT MEDIUM AND IRRIGATION CONTROL FOR SOILLESS CULTURE OF PAPRIKA PLANTS

J. E. Son, J. H. Shin, T. H. Ta, T. I. Ahn,
Department of Horticultural Science, Seoul National University, Seoul, Korea

WA 5.

TRANSPIRATION MODELS FOR GREENHOUSE GERBERA (*GERBERA JAMESONII* H. BOLUS)

G. Carmassi[1], M. Bronzini[1], L. Incrocci[1] ,R. Maggini[1], L. Bacci[2], **D. Massa**[1], A. Pardossi[1]
[1] Dipartimento di Biologia delle Piante Agrarie, Università di Pisa, Pisa, Italy
[2] Istituto di Biometeorologia (CNR-IBIMET), Firenze, Italy

WA 6.

WIRELESS SENSORS NETWORKS FOR PRECISION IRRIGATION SCHEDULING TO BECOME THE FIRST IoT SERVING THE ENVIRONMENT

A. Anastasiou[1], P.I.Daskalov[2], D.Savvas[3], K.G.Arvanitis[1], **N.A.Sigrimis**[1]
[1]Dpt. of Natural Resources Manag. & Agric. Engineering, Agricultural University of Athens, Athens, Greece.
[2]Dpt. of Automatics and Informatics, University of Ruse, Ruse, Bulgaria
[3]Dpt. of Crop Science, Agricultural University of Athens, Athens, Greece

12:40-14:30 **Light Lunch**

14.30-17.50 **Afternoon Sessions**

Plenary Room

14.30-16.10 **Oral Presentations 4 "GREENHOUSE MICROCLIMATE"**
Chairs: T. Boulard - C. Kittas

Session Keynote II

RECENT TRENDS IN GREENHOUSE MICROCLIMATE STUDIES

T. Boulard
INRA-URIH, Sophia Antipolis, France

GM 1.

THE EFFECT OF SHADING NETS ON GREENHOUSE MICROCLIMATE AND CROP PERFORMANCE

M. Teitel[1], Y. Gahali[1], M. Barak[1], H. Lemcoff[2], A. Antler[1], R. Amir[3], D. Harhel[4], S. Gantz[3], E. Wenger[1]
[1] Institute of Agricultural Engineering; [2]Institute of soil water and environment, A.R.O., the Volcani Center, P.O.Box 6, Bet Dagan, Israel 50250;
[3]Shaham, Ministry of Agriculture; [4]Mop Darom Experimental Station.

GM 2.

MODELING THE EFFECT OF THE POSITION OF COOLING ELEMENTS ON THE VERTICAL PROFILE OF TRANSPIRATION IN A GREENHOUSE TOMATO CROP

C. Stanghellini, A. Dieleman, Kang-Mo Lee, S.n Driever, L. Marcelis
Wageningen UR Greenhouse Horticulture, The Netherlands

GM 3.

CLIMATE CHANGE EFFECTS ON GREENHOUSE TOMATO PRODUCTION FOR A SPECIFIC REGION IN MEXICO

R. Salazar[1], **A. Rojano**[1], U. Schmidt[2], I.Lopez[1]
[1]Autonomous University of Chapingo. Km 38.5 Carr. Mécico-Texcoco Chapingo, Edo. México
[2]Division Biosystems Engineering, Humboldt University Berlin, Berlin, Germany

16.10-16.30 **Coffee Break - Visit to Poster & Exhibition Area**

Plenary Room

16:30-16.50 **Oral Presentations 4 "GREENHOUSE MICROCLIMATE"** (Continued)
Chairs: T. Boulard - C. Kittas

GM 4.

EFFECT OF THE HETEROGENEITY OF THE RADIATION DISTRIBUTION ON THE CROP ACTIVITY

B. Morille, C. Migeon, P.E. Bournet
Environmental Physics and Horticulture Research Unit, Agrocampus Ouest INHP, Angers, France

GM 5.

VERTICAL TEMPERATURE GRADIENTS IN A CROP: A PHYSIOLOGICAL EXPLORATION

A. Elings, A. de Gelder, E. Meinen, F. Kempkes
Wageningen UR Glasshouse Horticulture, P.O. Box 644, 6700 AP Wageningen, The Netherlands

GM 6.

MEASUREMENT AND ANALYSIS OF AIR FLOW AND AERIAL ENVIRONMENT OF RICE PLANT CANOPY IN A CLOSED PLANT PRODUCTION SYSTEM

K. Kashima[1,2], H. Nakajima[1], K. Isono[1], S. Honda[1], E. Goto[2], Y. Ishigami[2]
[1] Asahi Kogyosha Co., Ltd., Japan
[2] Graduate School of Horticulture, Chiba University, Japan

GM 7.

MICROCLIMATE INSIDE GREENHOUSE VERSUS SCREENHOUSE

Y.A. Al-Mulla, H. Al-Busaidi and M. Al-Balushi
Dpt. of Soils, Water and Agricultural Engineering, College of Agricultural and Marine Sciences, Sultan Qaboos University, Sultanate of Oman

Hall I

14.30-16.10 **Oral Presentations 5 "ENERGY II"**
Chairs: L. Albright - F. de Zwart

ENII 1.

CONTROL STRATEGY FOR THERMAL SCREENS OPENING IN GREENHOUSES: AN ALGORITHM FOR MINIMIZING HEAT LOSSES

D. Bastien, A.K. Athienitis
Dpt. of Building, Civil and Environmental Engineering, Concordia University, Montréal QC, Canada

ENII 2.
THE CLOSED SOLAR GREENHOUSE – TECHNOLOGY AND EVALUATION OF ENERGY HARVESTING UNDER SUMMER CONDITIONS
U. Schmidt[1], D. Dannehl[1], I. Schuch[1], T. Rocksch[1], R. Salazar[2], A. Rojano[2], I.Lopez[2]
[1] Biosystems Engineering Division, Humboldt University Berlin, Berlin, Germany,
[2]Autonomous University of Chapingo. Km 38.5 Carr. Mécico-Texcoco Chapingo, Edo. México

ENII 3.
UP SCALING AND TEST RESULTS OF AN ADVANCED FRESNEL GREENHOUSE
P. Sonneveld, G. J. Swinkels, B. van Tuil, H. Janssen
Wageningen UR, Greenhouse technology, Wageningen, The Netherlands

ENII 4.
THE EFFECT OF FRESNEL LENS-SOLAR ABSORBER SYSTEMS IN GREENHOUSES
D. Chemisana[1], **Chr. Lamnatou**[2], Y. Tripanagnostopoulos[3]
[1]University of Lleida, Lleida, Spain
[2]Solar and other Energy Systems Laboratory, NCSR "Demokritos", Athens, Greece
[3]University of Patras, Patras, Greece

ENII 5.
EXPERIMENT ANALYSIS OF HEAT RELEASE AND STORAGE WITH WATER FOR TEMPERATURE RISING IN SOLAR GREENHOUSE
H. Fang, **Q.C. Yang**
Institute of Environment and Sustainable in Agriculture, Chinese Academy of Agricultural Sciences, Beijing, China

16.10-16.30 Coffee Break - Visit to Poster & Exhibition Area

Hall I

16.30-17.10 Oral Presentations 5 "ENERGY II" (Continued)
Chairs: L. Albright - F. de Zwart

ENII 6.
PROTOTYPE DEVICE FOR FLUID FLOW MANAGEMENT IN COAXIAL PIPES OF ROOT ZONE HEATING SYSTEMS
G. Burchi[1], S. Cacini[1], M. Fedrizzi[2]
[1]CRA-VIV Unità di Ricerca per il Vivaismo e la Gestione del Verde Ambientale ed Ornamentale, Pescia (PT), Italy
[2]CRA-ING Unità di Ricerca per l'Ingegneria Agraria, Monterotondo (RM), Italy

ENII 7.
SENSIBLE AND LATENT HEAT RATIO IN CONTROLLED AGRICULTURE
A.Rojano[1], R. Salazar[1], J. Flores[2], U. Schmidt[3], I. Lopez[1]
[1]Universidad Autónoma Chapingo, Chapingo, México
[2]Colegio de Posgraduados, Montecillo, México
[3]Faculty for Agriculture and Horticulture, Institute for Horticultural Sciences, Department for Horticultural Engineering, Berlin, Germany

Hall I

17.10-17.50 Commission Protected Cultivation Meeting

14.30-16.10 **Oral Presentations 6 "COVERING MATERIALS"**
Chairs: S. Hemming - E.Schettini

Session Keynote III

COVERING MATERIALS FOR SUSTAINABLE GREENHOUSE ECOSYSTEMS
S. Hemming
Wageningen UR Greenhouse Horticulture, PB Wageningen, The Netherlands

CM 1.

GLOBAL, PAR AND DIFFUSIVE RADIATION TRANSMISSION OF AGRICULTURAL SCREENS: PRELIMINARY REPORT
M. Romero-Gamez, E.M. Suarez-Rey, T. Soriano, N. Castilla
IFAPA, Centro Camino de Purchil, Apartado 2027, Granada, 18012 Spain

CM 2.

VALIDATION COMPARISON OF TWO TYPES OF PLASTIC COVERING MATERIALS UNDER MEDITERRANEAN GROWING CONDITIONS: NIR ABSORBING POLYETHYLENE VS. STANDARD POLYETHYLENE
E. Baeza[1], R. García[1], J. Carlos López[1], C. Pérez[1], M. Vitali[3], C. Stanghellini[2], L. Pirondini[3], J. Carlos Gazquez[1], F. Kempkes[2], J. I. Montero[4]
[1]Experimental Station of the Cajamar Foundation El Ejido, Almería, Spain
[2]Wageningen UR Greenhouse Horticulture Wageningen, The Netherlands
[3]BASF Italia Srl Pontecchio Marconi BO, Italy
[4]I.R.T.A. Cabrils, Barcelona, Spain

CM 3.

EFFECTS OF ANTI-DRIP POLYETHYLENE COVERING FILMS ON MICROCLIMATE AND PRODUCTION OF A GREENHOUSE TOMATO CROP
N. Katsoulas[1], **E. Kitta[1],** T. Bartzanas[2]
[1]University of Thessaly, School of Agricultural Sciences, Dept. of Agriculture, Crop Production and Rural Environment, Volos, Magnesia, Greece,
[2]Centre for Res. & Technology-Thessaly, Inst. of Technology and Management of Agricultural Ecosystems, Volos, Greece

16.10-16.30 **Coffee Break - Visit to Poster & Exhibition Area**

16.30-17.50 **Oral Presentations 6 "COVERING MATERIALS"** (Continued)
Chairs: S. Hemming - E.Schettini

CM 4.

NEW GREENHOUSE CONCEPT WITH HIGH INSULATING DOUBLE GLASS WITH MODERN COATINGS AND NEW CLIMATE CONTROL STRATEGIES – MODELLING AND FIRST RESULTS FROM A CUCUMBER EXPERIMENT
S. Hemming, F. Kempkes
Wageningen UR Greenhouse Horticulture, Droevendaalsesteeg 1, 6708 PB Wageningen, The Netherlands, *silke.hemming@wur.nl*

CM 5.

COLOURED COVERING MATERIALS FOR PEACH PROTECTED CULTIVATION
E. Schettini[1], F.R. De Salvador[2], G. Scarascia Mugnozza[1], G. Vox[1]
[1]Department of Engineering and Management of the Agricultural, Livestock and Forest Systems (PROGESA), University of Bari, Bari, Italy
[2]CRA Tree Fruit Research Center, Roma, Italy

CM 6.

PHOTOSELECTIVE FILMS IN PEST AND DISEASE CONTROL

S. White[1], J. Clarkson[1], R. Napier[1], L. Pirondini[2] and D. Skirvin[1]
[1]School of Life Sciences, University of Warwick, UK
[2]Ciba-BASF Specialty Chemicals, Basel, Switzerland

CM 7.

GREENHOUSE CLIMATE AS AFFECTED BY A DIFFUSE GLASS COVER: FIRST RESULTS FROM A ROSE EXPERIMENT

F. Kempkes, C. Stanghellini, N. García Victoria, M. Bruins, P. Van Weel, T. Dueck
Wageningen UR Glasshouse Horticulture, Wageningen, The Netherlands

Poster Session 1

P 01.

GREENHOUSE SECTOR ASSESSMENT IN AZERBAIJAN AND PROSPECTS FOR SUSTAINABLE DEVELOPMENT

N. Katsoulas[1], E. Hadzilias[2]
[1]University of Thessaly, School of Agricultural Sciences, Dept. of Agriculture Crop Production and Rural Environment, Lab. of Agricultural Constructions and Environmental Control, Fytokou St., N. Ionia, GR-38446, Magnesia, Greece, nkatsoul@uth.gr
[2]Lille Catholic University, IESEG School of Management, Department of Management, Lille, France

P 02.

GREENHOUSES IN LANDSCAPE ARCHITECTURE AND URBAN HORTICULTURE - A DEVELOPING RELATIONSHIP

I.L. Tsirogiannis
Dpt. of Floriculture and Landscape Architecture, Technological Educational Institute of Epirus, Arta, Greece

P 03.

EVALUATION OF DROUGHT TOLERANCE OF PEPPER GENOTYPES UNDER HIGH CO_2 CONCENTRATION

F.M. del Amor, P. Cuadra-Crespo, M.C. Piñero
Dpt. of Citricultura y Calidad y Seguridad Alimentaria, Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario (IMIDA), La Alberca, Murcia, Spain

P 04.

AGRONOMICAL AND PHYSIOLOGICAL RESPONSE OF GERANIUM TO SALINITY AND BORON TOXICITY

S. Bañón[1,2], J. Miralles[1], R. Valdés[1], E. Conesa[1], J.A. Franco[1,2], M.J. Sànchez-Blanco[2,3]
[1]Dpt. de Producción Vegetal. Universidad Politécnica de Cartagena. Cartagena, Spain
[2]Unidad Asociada de Horticultura Sostenible en Zonas Áridas, Cartagena, Spain
[3]Centro de Edafología y Biología Aplicada del Segura-CSIC, Murcia, Spain

P 05.

EFFECTIVENESS OF PASSIVE BIOREACTORS FOR TREATING GREENHOUSE EFFLUENT CONTAMINATED BY PATHOGENS AND NUTRIENT POLLUTANTS

N. Gruyer[1], M. Dorais[1], B. Alsanius[2] ,G. J. Zagury[3]
[1]Agriculture and Agri-Food Canada, Horticultural Research Centre, Laval University, Quebec, QC, Canada
[2]Department of Horticulture, SLU. Alnarp, Sweden
[3]Civil, Geological, and Mining Engineering Dept., École Polytechnique de Montréal, Montréal QC, Canada

P 06.

AIR DEHUMIDIFICATION INSIDE A DOUBLE INFLATABLE FILM GREENHOUSE (POTTED PLANTS)

C.Migeon, A. Pierart, D.Lemesle, A.Travers, G. Chassériaux
UP EPHOR, Agrocampus-Ouest, Institut National d'Horticulture et de Paysage, Angers, France

P 07.

THERMAL PERFORMANCE OF AN UNHEATED GREENHOUSE UNDER SEMI-ARID CONDITIONS DURING THE NIGHT

K. Mesmoudi [1], P.E. Bournet [2], S. Bougoul [3]
[1] Department of Agronomy, Faculty of Science, University of Batna, Batna, Algeria
[2] Environmental Physics and Horticulture Research Unit, INHP, Angers, France
[3] Laboratory of Applied Physics, University of Batna, Batna, Algeria

P 08.

DESIGN AND TEST RESULTS FOR CPV SYSTEMS IN A NIR CONCENTRATOR INTEGRATED IN A GREENHOUSE

P. Sonneveld, G. J. Swinkels, B. van Tuil, H. Janssen
Wageningen UR, Greenhouse technology, Wageningen, The Netherlands

P 09.

A MODEL FOR PREDICTING ENERGY CONSUMPTION AND CO_2 RATE IN GLASSHOUSES

E. Brajeul[1], T. Beaussé[2]
[1] Fruit and vegetable scientific department, Ctifl, Carquefou, France
[2] Expert Gaz EnergY Services, GDF Suez, St Denis La Plaine, France

P 10.

PHOTOVOLTAIC ARRAY SHADING EFFECTS ON WELSH ONION GROWTH

M. Kadowaki[1], **A. Yano**[1], F. Ishizu[2], T. Tanaka[3], S. Noda[4]
[1]Faculty of Life and Environmental Science, Shimane University, Matsue, Shimane, Japan
[2]Shimane Agricultural Technology Center, Izumo, Shimane, Japan
[3]Graduate School of Science and Engineering, Yamaguchi University, Ube, Yamaguchi, Japan
[4]Shimane Institute for Industrial Technology, Matsue, Shimane, Japan

P 11.

WATER BALANCE AND ENERGY PARTITIONING IN A SEMI CLOSED GREENHOUSE

M. Teitel[1], **H.F. de Zwart**[2], F.L.K. Kempkes[2],
[1] Institute of Agricultural Engineering, A.R.O., the Volcani Center, P.O.Box 6, Bet Dagan, Israel
[2]Wageningen UR Greenhouse Horticulture, P.O.Box 16, Bornsesteeg 65, 6700 AA Wageningen, The Netherlands.

P 12.

DESIGN AND APPLICATION OF A CONCENTRATED PHOTOVOLTAIC SYSTEM WITH SEASONAL THERMAL STORAGE FOR APPLICATION IN HIGH TUNNELS

E. Wenger[1,2] and M. Teitel[1]
[1]Institute of Agricultural Engineering, Agricultural Research Organization, the Volcani Center, P.O.B. 6, Bet Dagan, 50250, Israel
[2]AFEKA Tel-Aviv Academic College of Engineering, Tel Aviv, Israel

P 13.

ATTITUDE-BASED MODEL FOR THE IMPLEMENTATION OF ENERGY EFFICIENT TECHNOLOGIES IN THE BAVARIAN HORTICULTURAL SECTOR

M. Hertel, K. Menrad
University of Applied Sciences Weihenstephan-Triesdorf, Freising, Germany

P 14.
EXPERIMENTAL STUDY OF IMPROVING THE COEFFICIENT PERFORMANCE VALUE OF A GROUND SOURCE HEAT PUMP USED FOR GREENHOUSE HEATING AND COOLING
P.G. Kougias, V. Firfiris, G.G. Martzopoulos
Lab. of Alternative Energy Sources in Agriculture, Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

P 15.
ENERGY SAVING IN TOMATO GREENHOUSES EQUIPPED WITH A VENTILATION SYSTEM WITH AND WITHOUT HEAT RECUPERATION
L. Wittemans[1], K. Goen[2], F. De Nayer[2], T. De Swaef[3], J. Hanssens[3], K. Steppe[3], H. Marien[4], J. Desmedt[5]
[1]Research Station for Vegetable Production, Sint-Katelijne-Waver, Belgium
[2]Research Center Hoogstraten, Hoogstraten, Belgium
[3]Lab. of Plant Ecology, Dpt. of Applied Ecology and Environmental Biology, Ghent University, Ghent, Belgium
[4]Katholieke Hogeschool van de Kempen, Geel, Belgium
[5]Flemish Institute for Technological Research (VITO), Mol, Belgium

P 16.
« ENERGY SUSTAINABLE GREENHOUSE » Project: REDUCTION OF ENERGY CONSUMPTION AND ENERGY STORAGE IN AQUIFER
A. Grisey, R. Tisiot, L.Rosso, F. D'Amaral, M. Narcy, E. Powaga
CTIFL, 751 Chemin de Balandran, France

P 17.
EFFECTS OF A CLOSED GREENHOUSE ON PLANT GROWTH AND SECONDARY PLANT COMPOUNDS OF TOMATOES (*SOLANUM LYCOPERSICON* L.)
D. Dannehl[1], I. Schuch[1], T. Rocksch[1], S. Huyskens-Keil[2], U. Schmidt[1]
Dep. for Crop and Animal Sciences, [1]Biosystems Engineering Division and [2]Division Urban Plant Ecophysiology, Humboldt-Universität zu Berlin, Berlin, Germany

P 18.
EXPERIMENTAL VALIDATION OF A MATHEMATICAL MODEL FOR THE ESTIMATION OF ENERGY REQUIREMENTS IN INFRARED HEATED GREENHOUSES
A. Kavga[1], G. Alexopoulos[1], V. Bontozoglou[2], Th. Panidis[1]
[1] Dpt. of Greenhouse Cultivations and Floriculture, Highest Technological Educational Institution of Messologi, Messologi, Greece
[2] Dpt. of Mechanical Engineering, University of Thessaly, Volos, Greece
[3] Dpt. of Mechanical Engineering and Aeronautics, University of Patras, Patras, Greece

P 19.
ASSESSMENT OF ENERGY USE AND GROWTH EFFECT OF LIGHTING SYSTEMS (HPS AND LED) IN CUT ROSE CULTIVATION
L. Blindeman[1], **B. Schamp**[1], P. Lootens[2], H. Vansteenkiste[1], B. Gobin[1]
[1]PCS - Research Centre for Ornamental Plants, Destelbergen, Belgium
[2]ILVO - Institute for Agricultural and Fisheries Research, Merelbeke, Belgium

P 20.
NEW METHOD FOR COOLING GREENHOUSES IN ARID AREAS
A.I. Binsulaiman
Ministry of Agriculture, Riyadh, Saudi Arabia.(a_binsulaiman@hotmail.com)

P 21.

THE INFLUENCE OF A HYBRID SOLAR ENERGY SAVING SYSTEM ON THE GROWTH AND THE YIELD OF TOMATO CROP IN GREENHOUSES

G.K. Ntinas, Z. Morichovitis, Ch. Nikita-Martzopoulou
Lab. of Agricultural Structures and Equipment, Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

P 22.

INFLUENCE OF CO_2 ENRICHMENT IN GREENHOUSES ON THE YIELD OF THE PEPPER PLANT (CAPSICUM ANNUUM L.), UNDER HIGH TEMPERATURE CONDITIONS

D. Vafiadis[1], Ch. Papamanthos[1], G.K. Ntinas[2], Ch. Nikita- Martzopoulou[2]
[1]Ministry of rural development and food, Regional centre of plant protection and quality control, Thessaloniki, Greece
[2]Lab. of Agricultural Structures and Equipment, Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

P 23.

EVAPOTRANSPIRATION MEASUREMENTS AND MODELLING IN A VINEYARD COVERED WITH A SHADING SCREEN

M. Pirkner, U. Dicken, M. Bahar, **J. Tanny**
Institute of Soil, Water and Environmental Sciences, Agricultural Research Organization, Volcani Center, Israel

P 24.

MISTING COOLING TECHNIQUE OF PROTECTED CULTURE FOR ONCIDIUMS ORCHIDS IN SUBTROPICAL REGIONS

C. Chen
Department of Bio-industrial Mechatronics Engineering, National ChungHsing University, 250 Kuokuang Road, Taichung Taiwan

P 25.

TEMPERATURE AND HUMIDITY RELATIONSHIP UNDER COPULA THEORY A.Rojano[1],

R. Salazar[1], W. Ojeda[2], U. Schmidt[3], I. Lopez[1]
[1]Universidad Autónoma Chapingo, Chapingo, México.
[2]Instituto Mexicano de Tecnología del Agua, Jiutepec Morelos.
[3]Faculty for Agriculture and Horticulture, Institute for Horticultural Sciences, Department for Horticultural Engineering, Lentzeallee 55 - 14195 Berlin, Germany.

P 26.

APPLYING COOLING BELOW OR ABOVE THE CROP: AN EXPERIMENTAL STUDY IN SEMI-CLOSED GREENHOUSES

A. A. Sapounas, J.A. Dieleman and J.B. Campen
Wageningen UR Greenhouse Horticulture, PO Box 644, 6700 AP Wageningen, The Netherlands

P 27.

EFFECT ON ROSE PRODUCTION AND QUALITY OF A DIFFUSE GLASS GREENHOUSE COVER

N. García Victoria, T.Dueck, M. Bruins, P. Van Weel, F. Kempkes, C. Stanghellini
Wageningen UR Glasshouse Horticulture, Violierenweg 1, 2665 MV Bleiswijk, The Netherlands;

P 28.

THE EFFECT OF COLORED PLASTIC FILMS ON THE GROWTH AND YIELD FORMATION OF TOMATOES

G. Gmizo, I. Alsiņa, L. Dubova
Institute of Soil and Plant Science, Latvia University of Agriculture, Jelgava, Latvia

P 29.

INFLUENCE OF TWO NEW GREENHOUSE COVERING MATERIALS ON GREENHOUSE MICROCLIMATE AND COOLING LOAD

E. Kitta[1], T. Bartzanas[1], N. Katsoulas[2]

[1]Centre for Res. & Technology-Thessaly, Inst. of Technology and Management of Agricultural Ecosystems, Volos, Greece

[2]University of Thessaly, School of Agricultural Sciences, Dept. of Agriculture, Crop Production and Rural Environment, Volos, Magnesia, Greece

P 30.

EFFECT OF CONDENSATION ON LIGHT TRANSMISSION AND ENERGY BUDGET OF EIGHT GREENHOUSE COVER MATERIALS

C. Stanghellini, M. Bruins, V. Mohammadkhani, G.-J. Swinkels, P. Sonneveld

Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands

Tuesday June 7th, 2011

09.00-09.40 **Keynote Lecture II**
Chairs:C Kittas, T. Bartzanas,N. Katsoulas
Automation and robotics in greenhouses
Prof. Dr. Ir. Eldert Van Henten

09.40-10.00 **Coffee Break - Visit to Poster & Exhibition Area**

10.00-12.40 **Morning Sessions**

Plenary Room

10.00-12.20 **Oral Presentations 7: "CLIMATE CONTROL I"**
Chairs: Ch. Martzopoulou - C. Stanghellini

CCI 1.
TOWARDS A MORE SUSTAINABLE, WATER EFFICIENT PROTECTED CULTIVATION IN THE GULF REGION
J.B. Campen
Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands

CCI 2.
ZINEG - THE LOW-ENERGY GREENHOUSE: THE EFFECT OF HIGH HUMIDITY ON TOMATO PRODUCTION IN SEMI-CLOSED GREENHOUSES
H.P. Klaering
Leibniz-Institute of Vegetable and Ornamental Crops, Grossbeeren, Germany

CCI 3.
EVALUATION OF EVOLUTIONARY ALGORITHMS IN PARAMETER ESTIMATION OF A GREENHOUSE CLIMATIC MODEL
R. Guzman-Cruz[1], R. Castaneda-Miranda[1], I.L. Lopez-Cruz[2]
[1]Universidad Politécnica del Sur de Zacatecas, Zacatecas, México
[2]Posgrado en Ingeniería Agrícola y Uso Integral del Agua, Universidad Autónoma de Chapingo, Estado de México, México

CCI 4.
EFFECTS OF HIGH LIGHT INTENSITY, HIGH HUMIDITY AND WIDE TEMPERATURE REGIMES ON CROP GROWTH AND ENERGY CONSUMPTION ON POTTED PLANTS
F.R. van Noort
Wageningen UR Glasshouse Horticulture, Bleiswijk, The Netherlands

CCI 5.
GLOBAL SENSITIVITY ANALYSIS OF GREENHOUSE CROP MODELS
I.L. López-Cruz, A. Rojano-Aguilar, R. Salazar-Moreno, A. Ruiz-García
Dpt. of Agricultural Engineering, University of Chapingo, Chapingo, México

CCI 6.
DYNAMIC TEMPERATURE INTEGREATION WITH TEMPERATURE DROP TO IMPROVE EARLY FRUIT YIELD AND CONSERVE ENERGY IN GREENHOUSE TOMATO PRODUCTION
X. Hao[1], Md.S. Borhan[1], L. Zhang, S. Khosla[2] and J.M. Zheng[1]
[1]Greenhouse and Processing Crops Research Centre, Agriculture and Agri-Food Canada, Harrow, Ontario, Canada
[2]Ontario Ministry of Agriculture, Food and Rural Affairs, Harrow, Ontario, Canada

CCI 7.
SIMULATION OF FIXED AND VARIABLE PRESSURE FOGGING IN A NATURALLY VENTILATED GREENHOUSE, WATER AND ENERGY SAVINGS AND STABILITY OF CLIMATE
F. Villarreal Guerrero, M. Kacira, E. Fitz-Rodriguez
Agricultural and Biosystems Engineering, University of Arizona, Tucson, AZ, USA

10.00-12.40 **Oral Presentations 8: "CFD I"**
Chairs: I.B. Lee - E. Baeza

Session Keynote IV
STATUS AND FUTURE OF CFD FOR AGRO-ENVIRONMENTAL APPLICATIONS
I.B. Lee
Department of Rural Systems Engineering and Research Institute for Agriculture and Life Sciences, College of Agricultural and Life Sciences, Seoul National University, Seoul, Korea

CFI 1.
INFLUENCE OF DIFFERENT AIR TREATMENT SYSTEMS TO THE ENVIRONMENT OF SEMICLOSED GREENHOUSES: SIMULATION STUDY OF COMMERCIAL GREENHOUSES WITH POT PLANTS
A.A. Sapounas, J.B. Campen, F.L.K. Kempkes, Th.H. Gieling
Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands

CFI 2.
COMPUTATIONAL FLUID DYNAMICS SIMULATION OF HERBIVORE-INDUCED PLANT VOLATILES AROUND GREENHOUSES
T. Kuroyanagi[1], J. Abe[2], M. Uefune[3], J. Takabayashi[3]
[1]National Agriculture Research Center for Western Region, NARO, Zentsuji, Kagawa, Japan
[2]National Agriculture Research Center for Western Region, NARO, Ayabe, Kyoto, Japan
[3]Center for Ecological Research, Kyoto University, Otsu, Shiga, Japan

CFI 3.
A CFD MODEL TO STUDY EXTERNAL SHADING AND ON-COVER SHADING OF GREENHOUSES
J.I. Montero[1], M. Melé[1], **D. Piscia[1]**, J. Flores[1], E.J. Baeza[2] and J. Perez-Parra[2]
[1] Department of Environmental Horticulture. IRTA. Carretera de Cabrils Cabrils (Barcelona), Spain
[2] Estación Experimental de Cajamar "Las Palmerillas". Autovía del Mediterráneo, El Ejido, Almería, Spain.

CFI 4.
NUMERICAL ESTIMATION OF PRESSURE COEFFICIENTS OVER SINGLE AND MULTISPAN PITCHED ROOF GREENHOUSES
D.L. Kateris[1], T.A. Kotsopoulos[1], V.P. Fragos[1], Ch. Nikita-Martzopoulou[1]
[1] Department of Agricultural Engineering, Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

CFI 5.
OPTIMIZATION OF VENT CONFIGURATION DURING VENTILATION FOR DEHUMIDIFICATION PURPOSE USING COMPUTATIONAL FLUID DYNAMICS TECHNIQUE
K. He[1], J. Chen[1], Z. Liu[2], M. Liu[2]
[1]School of Electronic, Information and Electrical Engineering, Shanghai Jiao Tong University, Shanghai, China
[2] Sunqiao Lab, Shanghai Key Lab of Protected Horticultural Technology, Shanghai Sunqiao Modern Agriculture Development Zone, Shanghai, China

CFI 6.

ANALYZING VENTILATION EFFICIENCY USING AGE OF AIR THEORY AND CFD TECHNOLOGY

K.-S. Kwon[1], I.-B. Lee[1], H.-T. Han[2], C.-Y. Shin[2] H.-S. Hwang[1], S.-W. Hong[1], J. P. Bitog[1], I.-H. Seo[1]

[1] Department of Rural Systems Engineering, Research Institute for Agriculture and Life Sciences, College of Agriculture and Life Sciences, Seoul National University, Seoul, Korea.

[2] Department of Mechanical Engineering, Kookmin University, Seoul, Korea.

Hall II

10.00-12.40 **Oral Presentations 9: "ENVIRONMENTAL FRIENDLY TECHNOLOGIES"**

Chairs: M. Kacira - D. Mistriotis

ET 1.

PLANTLAB, THE NEXT GENERATION OF GROWING

M. Kers

PlantLab

ET 2.

ENVIRONMENTAL ACCEPTABILITY OF GREENHOUSE TOMATO PRODUCTION IN FRANCE: PRELIMINARY RESULTS

T. Boulard[1], F. Hayer[2], R. Brun[1], F. Lecompte[3], G. Gaillard[2]

[1] INRA-URIH , 400, route des Chappes, BP 167, 06903 Sophia Antipolis, France.

[2] Agroscope Reckenholz-Tänikon ART , Reckenholzstr. 191, CH-8046 Zürich

[3] INRA-PSH,Domaine Saint Paul,Site Agroparc, 84914 Avignon cedex 9, France

ET 3.

INFLUENCE OF THE USE OF DRIP IRRIGATION SYSTEMS AND DIFFERENT MULCHING MATERIALS ON ORNAMENTAL SUNFLOWERS IN GREENHOUSE CULTIVATION

A. Anifantis[1], G. Canzio[2], G. Cristiano[2], B. De Lucia[2], B. Immirzi[3], M. Malinconico, G. Russo[1], G. Santagata[3], L. Vecchietti[2]

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[2]Dpt. DSPV Department of Crop Science, Aldo Moro University of Bari, Bari, Italy

[3]Institute of polymers chemistry and technology, Pozzuoli, Napoli, Italy

ET 4.

A WEB-SERVER-EMBEDDED ENVIRONMENTAL CONTROL SYSTEM FOR CLOSED GREENHOUSE

D. He[1], P. Yang[2]

[1] Laboratory of Agricultural Engineering of Structure and Environment, China Agricultural University, Beijing, China

[2] Beijing Lighting Valley Technology Company, Beijing, China

ET 5.

IMPLICATIONS OF SUSTAINABLE GREENHOUSE SYSTEMS FOR PEST AND DISEASE CONTROL

S. White[1], J. Clarkson[1], R. Napier[1], Á. Bálint[2], N. Garcia[3], L. Incrocci[4], E.J.B. Romero[5], D. Skirvin[1]

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[2] Mórakert Zöldség-gyümölcs Termelői Értékesítő Szövetkezet, Hungary

[3]Applied Plant Research, Wageningen UR, The Netherlands

[4] Dipartimento di "Biologia delle Piante Agrarie", Università Degli Studi di Pisa, Italy

[5] Department of Horticulture, Estación Experimental de la Fundacion Cajamar, Spain

ET 6.
DEVELOPMENT OF THERMAL ENVIRONMENT MODELING & ENERGY SAVING TECHNIQUE IN CHINESE SOLAR GREENHOUSE
Qichang Yang
Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences, Beijing, China

ET 7.
HYDROLYZED PROTEIN BASED MATERIALS FOR BIODEGRADABLE SPRAY MULCHING COATINGS
E. Schettini[1], L. Sartore[2], M. Barbaglio[2], G. Vox[1]
[1]Department of Engineering and Management of the Agricultural, Livestock and Forest Systems (PROGESA), University of Bari, Bari, Italy
[2]Depatment of Mechanical and Industrial Engineering, University of Brescia, Brescia, Italy

ET 8.
HIGH-TEC GREENHOUSES FOR ORGANIC FARMING?
J. Meyer, M. Schlüpen
Department of Plant Science, Technical University of Munich, Bavaria, Germany

12.40-14.30 Light Lunch

14.30-17.20 Afternoon Sessions

Plenary Room

14.30-15.50 Oral Presentations 10 "CLIMATE CONTROL II"
Chairs: Q. Yang - L. Marcelis

CCII 1.
REVIEW OF ENERGY EFFICIENT LIGHTING TECHNOLOGIES IN THE GROWING OF PLANTS AND VEGETABLES
A. Lojans, J. Fridrihsons
Latvia University of Agriculture, Institute of Agricultural Energetic

CCII 2.
APPLICATIONS OF FAR-RED LIGHT EMITTING DIODES IN PLANT PRODUCTION UNDER CONTROLLED ENVIRONMENTS
C. Kubota, P. Chia, Z. Yang, Q. Li
School of Plant Sciences, The University of Arizona, Tucson, AZ, USA

CCII 3.
NEURAL NETWORK PREDICTIVE CONTROL IN A NATURALLY VENTILATED AND FOG COOLED GREENHOUSE
E. Fitz-Rodríguez, M. Kacira, F. Villarreal Guerrero
Department of Agricultural and Biosystems Engineering, University of Arizona, Tucson, AZ, USA

CCII 4.
MODELLING GREENHOUSE TEMPERATURE AND HUMIDITY DYNAMICS IN ORDER TO DEVELOP AN ENERGY SAVING MODEL-BASED CONTROL STRATEGY
D. Volkaerts, A. Youssef, S.E. Özcan, V. Exadaktylos, D. Berckmans
Department of Biosystems: M3-Biores, Catholic University of Leuven, Leuven, Belgium

CCII 5.

CLIMATE MODELLING IN A GREENHOUSE WITH PROPORTIONAL ENVIRONMENTAL CONTROL SYSTEM

M. Louro[1], **F.J. Baptista**[2] and I. Mourão[3]
[1]Altri Florestal S.A. Quinta do Furadouro, Portugal
[2]Departamento de Engenharia Rural, Escola de Ciências e Tecnologia, Universidade de Évora/ICAAM, Núcleo da Mitra, a, Portugal
[3]Escola superior Agrária de Ponte de Lima, Instituto Politécnico de Viana do Castelo, Refóios, Portugal

15.50-16.10 Coffee Break - Visit to Poster & Exhibition Area

Hall II

14.30-16.10 Oral Presentations 11 "CFD II"
Chairs: S. Sase - J. Campen

CFII 1.

NUMERICAL ANALYSIS OF WIND LOADS ON AN INTEGRATED SYSTEM CONSISTED OF A GREENHOUSE AND A NET-COVERED WINDBREAK

A. Mistriotis, A. Giannoulis, D. Briassoulis
Dpt. of Agricultural Engineering, Agricultural University of Athens, Athens, Greece

CFII 2.

UNSTEADY COMPUTATIONAL STUDY OF AIR FLOW CHARACTERISTICS AROUND AN AGRICULTURAL STRUCTURE MODEL

G.K. Ntinas[1], D.L. Kateris[1], V.P. Fragos[1], N.A. Malamataris[2], C.N. Nikita-Martzopoulou[1]
[1]Lab. of Agricultural Structures and Equipment, Faculty of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece
[2]Dpt. of Computational and data Sciences, George Mason University, Fairfax VA, USA

CFII 3.

OPTIMUM DESIGN OF BUBBLE-COLUMN PHOTO-BIOREACTOR FOR MICROALGAE CULTIVATION USING COMPUTATIONAL FLUID DYNAMICS

I.-H. Seo[1], I.-B. Lee[1], H.-W. Lee[2], J.P. Bitog[1], S.-W. Hong[1], K.-S. Kwon[1]
[1]Department of Rural Systems Engineering and Research Institute for Agriculture and Life Sciences, College of Agricultural and Life Sciences, Seoul National University, Seoul, Korea.
[2]Department of Agriculture Civil Engineering, Kyungpook National University, Daegu, Republic of Korea

CFII 4.

RADIATION-CONVECTION COUPLING USING CFD IN A TUNNEL GREENHOUSE WITH A LETTUCE CROP : PRELIMINARY RESULTS

P. Vidal[1], T. Boulard[2], H. Fatnassi[2]
[1] Department of Engineering Environmental Agronomy and Forestry, University of Extremadura, Spain.
[2] UR880, Institut National de la Recherche Agronomique, Sophia-Antipolis, France

CFII 5.

ASSESSMENT OF SIDEWALL AND ROOF VENTS OPENING CONFIGURATIONS TO IMPROVE AIRFLOW INSIDE GREENHOUSES

R. Gil[1], C.Bojacá[1], H. Casilimas[1], E. Schrevens[2], **R. Suay**[3]
[1] Centro de Biosistemas, Universidad de Bogotá Jorge Tadeo Lozano, Chia, Colombia
[2] Department of Biosystems, Faculty of Applied Bioscience Engineering, Katholieke Universiteit Leuven, Leuven, Belgium
[3] Centro de Agroingenieria, Instituto Valenciano de Investigaciones Agrarias, Valencia, Spain

15.50-16.10 Coffee Break - Visit to Poster & Exhibition Area

16.50-17.20 CFD MEETING

14.30-15.50 Oral Presentations 12 "SENSORS AUTOMATIONS AND ROBOTS"
Chairs: T. Gieling - J. Tanny

AR 1.
A REAL TIME MONITORING AND CONTROL SYSTEM TARGETED TO SUPPORT GREENHOUSE AUTOMATION & INTERNET CONNECTIVITY
I. Gravalos[1], S. Loutridis[2], D. Moshou[3], Z. Tsiropoulos[1], D. Kateris[3], P. Xyradakis[1]
[1]Dpt. of Biosystems Engineering, School of Agricultural Technology, Technological Educational Institute of Larissa, Larissa, Greece
[2]Dpt. of Electrical Engineering, School of Technological Applications, Technological Educational Institute of Larissa, Larissa, Greece
[3]Aristotle University, School of Agriculture, Department of Hydraulics, Soil Science and Agricultural Engineering, Thessaloniki, Greece

AR 2.
EFFECT OF STEM AGE ON THE RESPONSE OF STEM DIAMETER VARIATIONS TO PLANT WATER STATUS IN TOMATO
J. Hanssens[1], T. De Swaef[1], K. Goen[2], F. De Nayer[2], L. Wittemans[3], H. Marien[4], J. Desmedt[5], K. Steppe[1]
[1]Lab. of Plant Ecology, Dpt. of Applied Ecology and Environmental Biology, Ghent University, Ghent, Belgium
[2] Proefcentrum Hoogstraten, Meerle, Belgium
[3] Proefstation voor de groenteteelt, Sint Katelijne Waver, Belgium
[4] Katholieke Hogeschool van de Kempen, Geel, Belgium
[5] Flemish institute for technological research (VITO), Mol, Belgium

AR 3.
EXAMINATION OF THE SURFACE RENEWAL TECHNIQUE FOR SENSIBLE HEAT FLUX ESTIMATES IN SCREENHOUSES
Y. Mekhmandarov, M. Pirkner, U. Dicken, **J. Tanny**
Institute of Soil, Water and Environmental Sciences, Agricultural Research Organization, Volcani Center, Israel

AR 4.
TOWARDS PHENOTYPING AND HIGH THROUGHPUT SCREENING USING LED INDUCED CHLOROPHYLL FLUORESCENCE TRANSIENT IMAGER
H. Jalink, R. van der Schoor, J.F.H. Snel
Wageningen UR Greenhouse Horticulture, P.O. Box 16, 6700 AA Wageningen, The Netherlands

15.50-16.10 Coffee Break - Visit to Poster & Exhibition Area

16.10-16.50 **Oral Presentations 12 "SENSORS AUTOMATIONS AND ROBOTS"** (Continued)
Chairs: T. Gieling - J. Tanny

AR 5.
MEASURING LEAF MOTION OF TOMATO BY MACHINE VISION
E.J. van Henten[1,2], G.E.H. Marx[1], J. Hemming[2], V. Sarlikioti[2], J.W. Hofstee[1] ,
[1]Farm Technology Group, Wageningen University, Wageningen, The Netherlands
[2]Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands

AR 6.
USING A WIRELESS SENSOR NETWORK TO DETERMINE CLIMATE HETEROGENEITY IN A GREENHOUSE ENVIRONMENT
J. Balendonck[1], **A.A. Sapounas**[1], E.A. van Os[1], R. van der Schoor[1], B.A.J. van Tuijl[1], L.C.P. Keizer[2]
[1]Wageningen University and Research Center - Greenhouse Horticulture, Wageningen, the Netherlands
[2]Wageningen University and Research Center - Plant Research International (Biometris), Wageningen, the Netherlands

16.50-17.20 **Good Agricultural Practices in Greenhouses Commission Meeting**

Poster Session 2

P 31.
MONOCHROMATIC LED-LIGHT AND ITS INFLUENCE ON DEVELOPMENT AND FLOWERING OF PETUNIA HYBR. AND LYCOPERSICON ESCULENTUM
K.-J. Bergstrand, H.K. Schüssler
Dept. of Horticulture, Swedish Univ. Agr. Sci., Alnarp, Sweden

P 32.
LOCAL AND GLOBAL SENSITIVITY ANALYSIS OF A GREENHOUSE CROP TRANSPIRATION MODEL
I.L. López-Cruz[1], J. A. Sánchez-Molina[2], A. Ramírez-Arias[1], F. Rodríguez-Díaz[2], J.L. Guzmán-Sánchez[2]
[1]Dpt. of Agricultural Engineering, University of Chapingo, Chapingo, México
[2]Dpt. of Languages and Computation, University of Almería, Spain

P 33.
GREENHOUSE CLIMATE CONTROL BASED ON `SPEAKING PLANT APPROACH - SYSTEM DEVELOPMENT TO DETECT NEGATIVE CONDITIONS
G. Akyazi and H.J. Tantau
Biosystems- and Horticultural Engineering Section, Leibniz University Hannover, Germany

P 34.
A KALANCHOË PHOTOSYNTHESIS MODEL FOR CLIMATE CONTROL
O. Körner[1], K.L. Nielsen[2]
[1]AgroTech, Institute for Agri Technology and Food Innovation, Taastrup, Denmark
[2]Knud Jepsen A/S, Hinnerup, Denmark

P 35.
DEVELOPMENT OF A CONTROLLED PLANT GROWTH MODULE WITH CHANGEABLE RATIO OF R-G-B AND W LED SPECTRA AND ANALYSIS OF ENERGY AND PPFD EFFICIENCY
J. E. Son , W. H. Kang, T. I. Ahn, J. H. Shin, T. T. Hung
Dept. of Horticultural Science, Seoul National University, Seoul, Korea

P 36.
PAD-AND-FAN COOLING SYSTEM CAPABLE OF EASILY INSTALLING AND COMBINING WITH NATURAL VENTILATION IN GREENHOUSES
T. Shimazu[1], S. Inoue[1], I. Tanaka[1] and Y. Sakaida[2]
[1]Faculty of Applied Biological Science, Gifu University, Gifu, Japan
[2]IBIKO Corporation, Gifu, Japan

P 37.
EFFECT OF THE SHADING AND GRAFTING TECHNIQUE ON GROWTH AND FRUIT PRODUCTION OF SWEET PEPPER PLANTS
J. López-Marín, M.F. Vidal, A. Gálvez, A. González
Departamento de Hortofruticultura, IMIDA, 30150, La Alberca. Murcia. Spain.

P 38.
IMPROVING INPUT RESOURCE UTILIZATION EFFICINCIES FOR PLANT FACTORIES OF PLANT FACTORY AND GREENHOUSES
Kozai, T.[1], T. Maruo[2], H. Ikeda[1], M. Takagaki[1,2]
[1]Center for Environment, Health and Field Sciences, Chiba University, Kashiwa city, Japan,
[2]Graduate School of Horticulture, Chiba University, Matsudo, Chiba

P 39.
EMISSIONS OF PLANT PROTECTION PRODUCTS FROM GREENHOUSES TO THE AIR
A.A. Sapounas[1], H.J. Holterman[2], E.A. Van Os[1], M.A. Bruins[1], S. Beulke[3]
[1] Wageningen UR, Greenhouse Horticulture, Wageningen, The Netherlands
[2] Wageningen UR, Agrosystems Research, Wageningen, The Netherlands
[3]The Food and Environment Research Agency, Sand Hutton York, UK

P 40.
GREENHOUSE INSIDE CLIMATE: A DATA-BASED MODELLING APPROACH REFERRING TO THE PREDICTION OF INSIDE TEMPERATURE AND RELATIVE HUMIDITY
E. Ntoula[1], A. Youssef[2], V. Exadaktylos[2], N. Katsoulas[1], C. Kittas[1], D. Berckmans[2]
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[2] Division Measure, Model & Manage Bioresponses (M3-BIORES), Dept. of Biosystems, Katholieke Universiteit Leuven, Leuven, Belgium.

P 41.
EVALUATION OF COST-EFFICIENT LIGHT CONTROL BASED ON WEATHER FORECASTS AND ELECTRICITY PRICES ON GROWTH AND FLOWERING IN CAMPANULA
K.H. Kjaer[1], C-O. Ottosen[1], B.N. Jørgensen[2]
[1]Dpt. of Horticulture, Aarhus University, Aarslev, Denmark
[2]The Maersk Mc-Kinney Møller Institute, University of Southern Denmark, Odense, Denmark

P 42.
HIGHER PLANTS IN CLOSED LIFE SUPPORT SYSTEMS - REQUIREMENTS FOR FUTURE RESEARCH
S.A. Wolff, A-I. Kittang
Centre for Interdisciplinary Research in Space (CIRiS), NTNU Samfunnsforskning AS, Trondheim, Norway

P 43.

GROWING PLANTS IN THE EUROPEAN MODULAR CULTIVATION SYSTEM (EMCS) ON THE INTERNATIONAL SPACE STATION

H. Svare, A-I. Kittang.
Centre for Interdisciplinary Research in Space (CIRiS), NTNU Samfunnsforskning AS, Trondheim, Norway

P 44.

GREENHOUSE CLIMATE IDENTIFICATION BASED ON DYNAMIC NEURAL NETWORK

A. Ruiz-García, **I. López-Cruz**, A. Ramírez-Arias
University of Chapingo, Texcoco, Mexico

P 45.

INFLUENCE OF TWO DIFFERENT THERMAL SCREEN MANAGEMENTS ON YIELD, QUALITY AND ENERGY CONSUMPTION OF A SOILLESS TOMATO CULTURE

C. Gilli, C. Camps
Research group greenhouse crops, Research Station Agroscope Changins-Wädenswil ACW, Conthey, Suisse

P 46.

IMPLEMENTATION OF AN ALGORITHM FOR OPTIMAL FERTILIZATION WITH PURE CARBON DIOXIDE IN MEDITERRANEAN GREENHOUSES

C. Stanghellini[1], J. Bontsema[1], A. de Koning[2]
[1] Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands
[2] HortiMaX, KC Pijnacker, The Netherlands

P 47.

ADDITIONAL ROOF VENTILATORS TO IMPROVE LEEWARD VENTILATION SYSTEMS

V. Raya[1], M. Parra[1], M.C. Cid[1], R. Suay[2], J.I. Montero[3]
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[2]Centro de Agroingeniería, IVIA, Moncada, Valencia, Spain
[3]Centre de Cabrils, IRTA, Cabrils, Barcelona, Spain

P 48.

ECOPHYSIOLOGIC AND ENERGY-EFFICIENT CULTIVATION OF TOMATOES IN AN INTELLIGENT AND SMART CONTROLLED GREENHOUSE

J. Desmedt[1], L. Van Meulebroek[2], J. Hanssens[2], T. De Swaef[2], K. Steppe[2], K. Goen[3], F. De Nayer[3], L. Wittemans[4], H. Marien[5]
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[2] Lab. of Plant Ecology, Dpt. of Applied Ecology and Environmental Biology, Ghent University, Ghent, Belgium
[3] Research Centre Hoogstraten, Meerle, Belgium
[4] Research Station for Vegetable Production, Sint Katelijne Waver, Belgium
[5] Katholieke Hogeschool van de Kempen, Geel, Belgium

P 49.

AIRFLOW AND MICROCLIMATE PATTERNS IN ENERGY SAVING GREENHOUSES: AN EXPERIMENTAL AND CFD ASSISTED STUDY

JB. Pouillard[1], H. Fatnassi[1], **T.Boulard**[1], A. Grisey[2], JC. Roy[3]
[1]URIH -INRA, Sophia Antipolis, France
[2] Ctifl - Centre de Balandran, Bellegarde - France.
[3] UMR 6174, Université de Franche-Comté, Département Crest, Institut Femto-st Parc Technologique - Belfort - France.

P 50.

CFD SIMULATION TO PREDICT THE IMPACT OF THE SUN PATH ON THE LOCAL CLIMATE AND CROP ACTIVITY INSIDE A GREENHOUSE

B. Morille, P.E. Bournet, C. Migeon.
Environmental Physics and Horticulture Research Unit, Agrocampus Ouest INHP, Angers, France

P 51.

PARAMETRIC STUDY OF NATURAL VENTILATION OF GREENHOUSES CLUSTERS

R. Suay[1], V. Raya[2], J.I. Montero[3]
[1] Centro de Agroingenieria, Instituto Valenciano de Investigaciones Agrarias, Valencia, Spain
[2] Instituto Canario de Investigaciones Agrarias, ICIA, Tenerife, Spain
[3] Ingenieria y Agronomia de Biosistemas, IRTA, Cabrils, Spain

P 52.

NATURAL AND FORCED VENTILATION: NUMERICAL SIMULATION OF AN EXPERIMENTAL GREENHOUSE LOCATED IN A COMPLEX ENVIRONMENT

A.A. Sapounas[1], Ch. Nikita-Martzopoulou[2], G. Martzopoulos[2]
[1] Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands
[2]Department of Hydraulics, Soil Science and Agriculture Engineering, School of Agriculture, Aristotle University of Thessaloniki, Thessaloniki, Greece

P 53.

COMPARATIVE ANALYSIS OF A BIG SCALE SCREENHOUSE WITH PLANE AND MULTISPAN ROOF BY USING COMPUTATIONAL FLUID DYNAMICS (CFD)

J. Flores-Velazquez[1], E. Mejía[1] J.I. Montero[2], D. Piscia[2]
[1]Postgrado en Hidrociencias, Colegio de postgraduados Ctra.Montecillo, Edo de México.
[2]Institut de Recerca i Technologies Agroalimentaries (IRTA), Cabrils, Ba, Spain A. Rojano Universidad Autónoma Chapingo, Chapingo, México.

P 54.

EXPERIMENTAL RESULTS AND NUMERICAL MODELING OF SOLAR RADIATION DISTRIBUTION IN A NATURALLY VENTILATED GREENHOUSE

C. Kittas[1], Ch. Papaioannou[2], D. Fidaros[3], N. Katsoulas[1], C. Baxevanou[3], T. Bartzanas[3]
[1]University of Thessaly, Department of Agriculture, Crop Production and Rural Environment, Magnesia, Greece
[2]Technological Institute of Larisa, School of Agricultrural Technology, Department of Biosystems Engineering, Larisa, Greece
[3]Center for Research and Technology-Thessaly, Institute of Technology and Management of Agricultural Ecosystems, Volos, Greece

P 55.

3D NUMERICAL INVESTIGATION OF A FAN VENTILATED GREENHOUSE TAKING INTO ACCOUNT EVAPO-TRANSPIRATION AND RADIATION

D. Fidaros[1], C. Baxevanou[1], **T. Bartzanas[1]**, C. Kittas[1,2]
[1]Centre for Research and Technology-Thessaly, Institute of Technology and Management of Agricultural ecosystems, Technology Park of Thessaly, 1st Industrial Area of Volos, 38500 Volos, Greece
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P 56.

INCREASING ENERGY EFFICIENCY OF GREENHOUSES BY THE USE OF ROTARY SPEED REGULATED CIRCULATING PUMPS

V. Sauer, K. Menrad, L. Köhler, D. Prucker
University of Applied Sciences Weihenstephan Triesdorf, Freising, Germany

P 57.
ESTIMATING THE SURFACE OF CANOPY IN GREENHOUSES USING IMAGE ANALYSIS
F. Carvajal, J. Sánchez-Hermosilla, F. Agüera, R. López
Dpt. Ingeniería Rural, Escuela Politécnica Superior, University of Almería, Spain

P 58.
PERFORMANCE OF ORGANIC TOMATO (Lycopersicon esculentum Mill.) UNDER INCREASING COMPOST AND WATER LEVELS IN GREENHOUSE
S. Abubaker, J. Al-Zubi
Dept of Plant Production and Protection, faculty of Agricultural Technology, Al Balqa Applied University Al Salt, Jordan

P 59.
DIGESTED LIVESTOCK MANURE AS ORGANIC N-FERTILIZER FOR GREENHOUSE LETTUCE
A. Trinchera, C.M. Rivera, A. Marcucci, E. Rea
Agricultural Research Council - Research Centre for Soil-Plant System, Rome, Italy

P 60.
STUDY OF DEGRADABLE MATERIALS FOR SOIL MULCHING IN GREENHOUSE-GROWN LETTUCE
J. López-Marin[1], C. Abrusci[2], A. González[1], J.A. Fernández[3]
[1] Departamento de Hortofruticultura. IMIDA. La Alberca. Murcia. Spain
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[3]Departamento de Producción Vegetal. Universidad Politécnica de Cartagena. Cartagena, Murcia. Spain

P 61.
EFFECT OF DIFFERENT METHODS OF VERMIWASH PREPARATION
H.A. Alikhani, S. Rahmatpour, S.H. MirSeyedHoseini, L. Mohammadi
Dpt. of Soil Science, University College of Agriculture & Natural Resources, University of Tehran, Karaj, Iran

P 62.
COMPARISON OF PHYSICO-CHEMICAL PROPERTIES OF COMMON COMPOST AND VERMICOMPOST AND THE EFFECT OF THEIR APPLICATION ON TOMATO PLANT GROWTH INDICES
H.A. Alikhani, L. Mohammadi
Dpt. of Soil Science, University of Tehran, Karaj, Iran

P 63.
HUMIC ACID AND SEAWEED EXTRACTS IMPROVED YIELD AND QUALITY OF ORGANIC GREENHOUSE CHERRY TOMATO PRODUCTION
J. Javanmardi, H. Azadi
Department of Horticulture, Faculty of Agriculture, Shiraz University, Shiraz, Iran

P 64.
REMOVAL OF SULFATE AND NITRATE IN RECYCLED GREENHOUSE EFFLEUNT SOLUTION USING ARTIFICIAL WETLANDS
N. Gruyer[1], M. Dorais[1], B. Alsanius[2] ,G. J. Zagury[3]
[1]Agriculture and Agri-Food Canada, Horticultural Research Centre, Laval University, Quebec, QC, Canada
[2] Department of Horticulture, SLU. Alnarp, Sweden
[3] Civil, Geological, and Mining Engineering Dept., École Polytechnique de Montréal, Montréal QC, Canada

P 65.

DEVELOPMENT OF AN AUTOMATIC FRUIT SET REAGENT SPRAYING ROBOT FOR TOMATO PLANTS TO UNIFORM THE FRUIT RIPENESS

H. Kurosaki, H. Ohmori, M. Takaichi
Advanced greenhouse production research team, National Institute of Vegetable and Tea Science, Aichi, Japan

P 66.

ASSESSMENT OF TRACEABILITY FUNCTIONS IN GREENHOUSE ORIGINATED AGRI-FOOD SUPPLY CHAIN

D.D. Bochtis[1], R. Berruto[2], P. Busato[2], T. Bartzanas[3], C. Kittas[4]
[1]Aarhus University, Faculty of Agricultural Sciences, Department of Biosystems Engineering,
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[4]University of Thessaly, School of Agricultural Sciences, Department of Agriculture Crop Production and Rural Environment, N. Ionia Magnesias, Greece

P 67.

TRACEABLE DOCUMENTATION AND EVALUTION OF THE PRODUCTION PROCESSES IN PROTECTED CULTIVATION

A. Kreuzpaintner, J. Meyer
Department of Plant Science, Technical University of Munich, Bavaria, Germany

P 68.

DEVELOPMENT OF A NEW DEVICE ('HORTISPEC') FOR MEASURING UV, PAR, IR, LIGHT SPECTRUM, RADIATION AND LEAF TEMPERATURE

J. Beemster[1], **M. Kers**[2], G. Loop[3]
[1]Beemster Trading Industriestraat AA Heerhugowaard Netherlands
[2]Croppings bv Boterbloem MV Berghem Netherlands
[3]Avantes bv Soerense Zand Noord Eerbeek Netherlands

P 69.

PERFORMANCE EVALUATION OF SEVERAL TYPES OF SENSORS APPLIED IN THE GREENHOUSE ENVIRONMENTAL CONTROL AND MANAGEMENT

J. Chen and C. Chen
Department of Bio-industrial Mechatronics Engineering, National ChungHsing University, Taichung Taiwan

P 70.

USE OF BIOSIGNAL ANALYSIS TO INDICATE CHRYSANTHEMUM (*CHRYSANTHEMUM MORIFOLIUM*) RESPONSE TO PAR INTENSITY

Ch. Lykas[1], K. Kalovrektis[2], V. Pigadas[3]
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[2]University of Piraeus, Informatics Department, Piraeus, Greece
[3]Universtiy of Central Greece, Department of Computer Science and Biomedical Informatics, Greece

P 71.

EDDY COVARIANCE MEASUREMENTS OF WATER VAPOR, HEAT AND CO_2 FLUXES IN A PEPPER SCREENHOUSE: CORRECTIONS OF RAW DATA

U. Dicken, **J. Tanny**
Institute of Soil, Water and Environmental Sciences, Agricultural Research Organization, Volcani Center, Israel

09.00-09.10 **Keynote Lecture III**
Chairs: C Kittas, T. Bartzanas,N. Katsoulas
Good agricultural practices in greenhouse production
Dr. Muien Muhamad Qaryouti

09.40-10.00 **Coffee Break - Visit to Poster & Exhibition Area**

10.00-12.40 **Morning Sessions**

Plenary Room

10.00-12.00 **Oral Presentations 13 "GROWING MEDIA AND HYDROPONICS I"**
Chairs: D. Savvas - D.Schwarz

GHI 1.
REMOVAL OF PLANT PATHOGENS IN RECYCLED GREENHOUSE EFFLUENT USING ARTIFICIAL WETLANDS
N. Gruyer[1], M. Dorais[1], G. J. Zagury[2], B. Alsanius[3]
[1]Agriculture and Agri-Food Canada, Horticultural Research Centre, Laval University, Quebec, QC, Canada
[2]Civil, Geological, and Mining Engineering Dept., École Polytechnique de Montréal, Montréal QC, Canada
[3]Department of Horticulture, SLU. Alnarp, Sweden

GHI 2.
CAN SUPER ABSORBANT AFFECT ON EFFICIENCY OF HYDROPONIC SYSTEMS?
M.Delshad, M.Ahrar, M.Babalar
Department of Horticultural Science, University College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran

GHI 3.
COCONUT FIBER: A PEAT-LIKE SUBSTRATE FOR ACIDOPHILIC PLANT CULTIVATION
A. Berruti[1], V. Scariot[1]
1 - Department of Agronomy, Forest and Land Management, Faculty of Agriculture, University of Turin, Grugliasco, Torino, Italy.

GHI 4.
GROWING MEDICINAL PLANTS IN HYDROPONIC CULTURE
R. Maggini[1], C. Kiferle[1], A. Raffaelli[2], L. Guidi[1], A. Pardossi[1]
[1]Dipartimento di Biologia delle Piante Agrarie, Università di Pisa, Pisa, Italy
[2]Istituto di Chimica dei Composti Organo Metallici, Consiglio Nazionale delle Ricerche, Pisa, Italy

GHI 5.
MODELLING CROP GROWTH AND NUTRIENT UPTAKE IN GREENHOUSE GERBERA (*GERBERA JAMESONII* H. BOLUS) GROWN IN SOILLESS CULTURE
D. Massa, G. Carmassi, L. Incrocci., A. Pardossi
Dipartimento di Biologia delle Piante Agrarie, Università di Pisa, Pisa, Italy

GHI 6.
TOMATO GROWTH, YIELD AND WATER USE EFFICIENCY AS AFFECTED BY SALINITY AND DEFICIT IRRIGATION UNDER GREENHOUSE CONDITION
A. R. AlHarbi[1], A. M. Al-Omran[2], M. A. Wahb-Allah[1]
Plant Production Dept.[1] and Soil Science Dept.[2] Faculty of Food and Agricultural Sciences, King Saud University, Saudi Arabia

10.00-12.40 **Oral Presentations 14 "PLANT PROTECTION"**
Chairs: Ch. Lykas - Ch. Papaioannou

PP 1.
ASSESSING SPIDER MITE DAMAGE TO GREENHOUSE CAPSICUM LEAVES
I. Herrmann[1], M. Bernstein[2], A. Sade[3], A. Karnieli[1], D.J. Bonfil[4], P.J. Weintraub[5]
[1] The Remote Sensing Laboratory, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede-Boker, Israel.
[2] Dpt. of Geography and Environmental development, Ben-Gurion University of the Negev, Beer-Sheva, Israel.
[3] Biobee Ltd, Sde Eliyahu, Israel.
[4] Field Crops and Natural Resources Department, Agricultural Research Organization, Gilat Research Center, Israel.
[5] Dpt. Of Entomology, Agricultural Research Organization, Gilat Research Center, Israel.

PP 2.
THE USE OF CROP SPECIFIC COCKTAILS OF PARASITOIDS AGAINST APHIDS – A NEW TOOL FOR IPM
V. Rosemeyer, N. de Menten
Viridaxis S.A., Gilly, Belgium

PP 3.
A NEWLY DEVISED ELECTRIC FIELD SCREEN FOR AVOIDANCE AND CAPTURE OF GREENHOUSE INSECT PESTS
Y. Matsuda[1], T. Nonomura[1], J. Kimbara[2], S. Kusakari[3], H. Toyoda[1]
[1]Dep.of Agricultural Science and Technology, Kinki University, Nara, Japan
[2]Research Institute, Kagome Company, Tochigi, Japan
[3]Agricultural, Food and Environmental Sciences Research Center of Osaka Prefecture, Osaka, Japan

PP 4.
EPIDEMIOLOGY AND MANAGEMENT OF DOWNY MILDEW, A NEW PATHOGEN OF COLEUS IN THE UNITED STATES
B.R. Harlan, M.K. Hausbeck
Department of Plant Pathology, Michigan State University, East Lansing, MI, USA

PP 5.
EFFECT OF RHIZOBACTERIA SELECTED FOR PLANT GROWTH PROMOTION AND BIOLOGICAL CONTROL OF FUSARIUM OXYSPORUM F. SP. RADICIS-LYCOPERSICI ON YIELD OF HYDROPONICALLY GROWN TOMATO PLANTS
A. Gul[1], H. Ozaktan[2], L. Yolageldi[2], B. Cakir[1], M. Sahin[3], S. Akat[3]
[1]Dpt. of Horticulture, Agricultural Fac., Ege University, Bornova, Izmir, Turkey
[2]Dpt. of Plant Protection, Agricultural Fac., Ege University, Bornova, Izmir, Turkey
[3]Graduate School of Natural and Applied Sciences, Ege University, Bornova, Izmir, Turkey

PP 6.
THE OCCURRENCE OF FUSARIUM CROWN AND ROOT ROT OF TOMATO IN SOUTH AND SOUTHERN WEST OF TURKEY
L. Yolageldi[1], A. Gul[2], H. Ozaktan[1], B. Cakir[2]
[1]Dpt. of Plant Protection, Agricultural Fac., Ege University, Bornova, Izmir, Turkey
[2]Dpt. of Horticulture, Agricultural Fac., Ege University, Bornova, Izmir, Turkey

PP 7.

EVALUATION OF THE TECHNICAL EFFICACY OF SPRAY GUNS AND WHEELED MANUAL SPRAYERS FOR PHYTOSANITARY TREATMENTS IN GREENHOUSES

F.C. Páez[1], V.J. Rincón[1], J. Sánchez-Hermosilla[1], M. Fernández[2]
[1]Departament of Agricultural Engineering, University of Almería, Almería, Spain.
[2]Instituto de Investigación y Formación Agraria y Pesquera (IFAPA), La Mojonera, Spain.

PP 8.

AN ELECTROSTATIC INSECT EXCLUSION TECHNIQUE ENABLES GERMFREE CULTIVATION OF TOMATO PLANTS IN OPEN GREENHOUSES

H. Toyoda[1], Y. Matsuda[1], T. Nonomura[1], J. Kimbara[2], S. Kusakari[3]
[1]Dep.of Agricultural Science and Technology, Kinki University, Nara, Japan
[2]Research Institute, Kagome Company, Tochigi, Japan
[3]Agricultural, Food and Environmental Sciences Research Center of Osaka Prefecture, Osaka, Japan

Hall II

10.00-12.40 **Oral Presentations 15 "CROP MANAGEMENT AND CULTURAL PRACTICES I"**
Chairs: S. de Pascale - A. Papadopoulos

Session Keynote V

GREENHOUSE CROP MANAGEMENT: NEW APPROACHES TO AN OLD CHALLENGE

S. De Pascale[1], C. Leonardi[2]
[1]Dept. Agricultural Engineering and Agronomy, University of Naples Federico II, IT
[2]Dept. Agriculture and Food Science, University of Catania, IT

CPI 1.

GROWTH RESPONSES OF TWO *ANTHURIUM ANDREANUM* GENOTYPES TO ELEVATED CARBON DIOXIDE CONCENTRATION

N. García Victoria[1], D. Fanourakis[1, 2]
[1] Wageningen UR Glasshouse Horticulture, MV Bleiswijk, The Netherlands
[2] Wageningen University, Department of Plant Sciences, Horticultural Supply Chains Group, Wageningen, The Netherlands

CPI 2.

EFFECTS OF OXYGEN SUPER-SATURATED NUTRIENT SOLUTIONS ON GREENHOUSE TOMATO

A.P. Papadopoulos[1], E.S. Yaganza[1], D.L. Ehret[2], M. Dorais[3], X. Hao[1], W. Lin[2], S. Khosla[4], A. Martynenko[1], M. Ramadoss[1], U.K. Saha[5]
[1]Greenhouse and Processing Crops Research Centre, Agriculture and Agri-Food Canada, Harrow, Ontario, Canada
[2]Pacific Agri-Food Research Centre, Agriculture and Agri-Food Canada, Agassiz, British Columbia, Canada
[3]Centre de Recherche et de Développement en Horticulture, Agriculture and Agri-Food Canada, Envirotron bldg, Laval University, Québec, Canada
[4]Ontario Ministry of Agriculture, Food and Rural Affairs, Harrow, Ontario, Canada
[5]Soil and Water Science Department, University of Florida, USA

CPI 3.

CONTRIBUTION OF PHYTOHORMONES IN ALLEVIATING THE IMPACT OF MODERATELY SUBOPTIMAL TEMPERATURE STRESS ON GRAFTED TOMATO

G. Ntatsi[1,2], D. Savvas[2], D. Schwarz[1]
[1]Leibniz-Institute of Vegetable and Ornamental Crops Großbeeren /Erfurt e.V., Großbeeren, Germany
[2]Dpt. of Crop Science, Lab. of Vegetable Crops, Agricultural University of Athens, Athens, Greece

CPI 4.
YEAR-ROUND MINI-CUCUMBER PRODUCTION WITH SUPPLEMENTAL LIGHTING: ADDITIONAL BLUE LIGHT, GROW PIPE HEATING AND FERTIGATION
X. Hao[1], J.M. Zheng[1], J. Brown[1] and S. Khosla[2]
[1]Greenhouse and Processing Crops Research Centre, Agriculture and Agri-Food Canada, Harrow, Ontario, Canada
[2]Ontario Ministry of Agriculture, Food and Rural Affairs, Harrow, Ontario, Canada

CPI 5.
DEVELOPMENT OF A GENOTYPE-TO-PHENOTYPE CROP SIMULATION MODEL FOR CAPSICUM ANNUUM L.
A.M. Wubs[1,2], E. Heuvelink[1], J.A. Dieleman[3], J.J. Magan[4], A. Palloix[5], L.F.M. Marcelis[1,3], F.A. van Eeuwijk[2]
[1] Chair Group Horticultural Supply Chains, Wageningen University, Wageningen, the Netherlands
[2] Biometris, Wageningen University and Research Centre, Wageningen, the Netherlands
[3] Wageningen UR Greenhouse Horticulture, Wageningen, the Netherlands
[4] Estación Experimental Fundación Cajamar, Almeria, Spain
[5] INRA, Avignon, France

CPI 6.
YIELD COMPONENT ANALYSIS OF SALINITY RESPONSE FOR SELECTED BACKCROSS INBRED LINES OF *SOLANUM LYCOPERSICUM* 'MONEYMAKER' X *SOLANUM CHMIELEWSKII*
Ep Heuvelink[1], Paul Dijkhuis[2], Vincent Kock[1], Charis Kontopoulou[1], Sherge Tolessa Kassaye[1], Meng Yi[1], Nikita Trotta[2], A.W. van Heusden[2]
[1]Horticultural Supply Chains group, Wageningen University, P.O. Box 630, 6700 AP Wageningen, the Netherlands
[2]Wageningen UR Plant Breeding, P.O. Box 386, 6700 AJ Wageningen, the Netherlands

12.40-14.30 **Light Lunch**

Plenary Meeting

14.30-15.30 **Oral Presentations 16 "GROWING MEDIA AND HYDROPONICS II"**
Chairs: N. Castilla - G. Mavrogiannopoulos

GHII 1.
A CONTINUOUS RECIRCULATING DRIP SYSTEM FOR GROWING IN SOLUTION CULTURE
G. Mavrogianopoulos, P. Aglogalos, I. Lycoskoufis
Department of Natural Resources Management & Agricultural Engineering, Agricultural University of Athens, Athens, Greece

GHII 2.
USE OF PHENOLIC FOAM AS A GROWING MEDIUM FOR COMMERCIAL CULTIVATION OF TOMATO 'SUPERDOTAERANG'
S.J. Hwang[1,2*], J.E. Park[1,2], J.H. Kang[1], J.S. Jeong[1,2], S.H. Park[3], Y.J. Cheon[3], and K.S. Kim[3]
[1]Dpt. of Horticulture, Gyeongsang National University, Jinju, Korea
[2]Institute of Agriculture and Life Sciences, Gyeongsang National University, Jinju, Korea
[3]Smithers Oasis Korea Co., Ltd., Seoul, Korea

GHII 3.
THE EFFECT OF UNEQUAL DISTRIBUTION OF NaCl SALINITY ON TOMATO GROWTH AND POTASSIUM ABSORPTION
G. Mavrogianopoulos, F. Lymberopoulos, M. Pelekanos, **I. Lycoskoufis**
Department of Natural Resources Management & Agricultural Engineering, Agricultural University of Athens, Athens, Greece

15.50-16.10 **Coffee Break - Visit to Poster & Exhibition Area**

Plenary Room

16.30-16.50 **COMMISSION OF HORTICULTURAL ENGINEERING MEETING**

Plenary Room

16.50 **ISHS Presentation and Overview - Awards**

Hall I

14.30-16.10 **Oral Presentations 17 "PRODUCT QUALITY"**
Chairs: C. Kubota - E. Heuvelink

Session Keynote VI

ENVIRONMENTAL CONTROL TECHNOLOGIES TO IMPROVE PRODUCT QUALITY
C. Kubota
School of Plant Sciences, The University of Arizona, Tucson, AZ, USA

PQ 1.

CAN GRAFTING ENHANCE FLAVOUR AND HEALTH PROMOTING COMPOUNDS IN TOMATO FRUITS GROWN AT SUBOPTIMAL TEMPERATURE?
A. Krumbein, D. Schwarz
Leibniz-Institute of Vegetables and Ornamental Crops Grossbeeren/Erfurt e.V., Grossbeeren, Germany

PQ 2.

POST-HARVEST BLUEING OF SPATHA IN *ANTHURIUM ANDREANUM* 'TROPICAL' AS AFFECTED BY PRE-HARVEST CONDITIONS
N. García Victoria, M. Warmenhoven,
Wageningen UR Glasshouse Horticulture, MV Bleiswijk, The Netherlands;

PQ 3.

ZINEG – THE LOW ENERGY GREENHOUSE: IMPACT OF REDUCED IRRADIATION ON GROWTH AND FLAVONOID SYNTHESIS OF LETTUCE
C. Becker[1], A. Krumbein[1], L.W. Kroh[2], H.P. Kläring[1]
[1] Leibniz-Institute of Vegetable and Ornamental Crops Grossbeeren/Erfurt e.V. Grossbeeren, Germany
[2] Institute of Food Technology and Food Chemistry. Technische Universität Berlin, Germany

15.50-16.10 **Coffee Break - Visit to Poster & Exhibition Area**

Hall II

14.30-15.50 **Oral Presentations 18 "CROP MANAGEMENT AND CULTURAL PRACTICES II"**
Chairs: Y. Tuzel - A. Dieleman

CPII 1.

CASE STUDIES OF A MODIFIED BIOLOGICAL SIMULATOR (TOMGRO) ACCORDING TO SHORT CROPPING PERIOD
G. Dimokas[1], C. Kittas[1] and M. Tchamitchian[2]
[1] University of Thessaly, School of Agricultural Science, Department of Agriculture Crop Production & Rural, Environment, N. Ionia, Greece
[2]Écodéveloppement, I.N.R.A., DomaineSaint-Paul, Site Agroparc, France,

CPII 2.
CROP PHYSIOLOGY IN SEMI-CLOSED GREENHOUSES
J.A. Dieleman[1], A. de Gelder[1], T. Qian[1,2], A. Elings[1], L.F.M. Marcelis[1,2]
[1] Wageningen UR Greenhouse Horticulture, AP Wageningen, The Netherlands
[2] Wageningen University, Horticultural Supply Chains, AP Wageningen, The Netherlands

CPII 3.
GROWTH OF TOMATOES UNDER HYBRID LED AND HPS LIGHTING
T.A. Dueck, J. Janse, B.A. Eveleens, F.L.K. Kempkes & L.F.M. Marcelis
Wageningen UR Greenhouse Horticulture, MV Bleiswijk, The Netherlands

CPII 4.
OPTIMUM PLANT CANOPY: HOW CANOPY ARCHITECTURE AND CULTIVATION STRATEGIES CAN AFFECT LIGHT INTERCEPTION AND PHOTOSYNTHESIS
V. Sarlikioti[1], P. H. B. de Visser[1] and L.F.M. Marcelis[1,2]
[1]Wageningen UR Greenhouse Horticulture, AP Wageningen, The Netherlands.
[2]Horticultural Supply Chains, Wageningen University, AP Wageningen, The Netherlands

15.50-16.10 Coffee Break - Visit Poster Area & Exhibition

Hall II

16.10-16.50 Oral Presentations 18"CROP MANAGEMENT AND CULTURAL PRACTICES II"
Chairs: Y. Tuzel - A. Dieleman (Continued)

CPII 5.
PREDICTING THE DEVELOPMENT AND EXTERNAL QUALITY OF LILY GROWN IN A TRADITIONAL CHINESE SOLAR GREENHOUSE
W. Luo, C. Zhou, W. Du, G. Li, J. Dai
College of Agriculture, Nanjing Agricultural University, Nanjing 210095, P R China
e-mail of corresponding author: lwh@njau.edu.cn

CPII 6.
EVALUATION OF SALINE TOLERANCE OF TOMATO UNDER HIGH CO_2 CONCENTRATION WITH STABLE ISOTOPES
F.M. del Amor, P. Cuadra-Crespo, M.C. Piñero
Dpt. of Citricultura y Calidad y Seguridad Alimentaria, Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario (IMIDA), La Alberca, Murcia, Spain

Poster Area

Posters Session 3

P 72.
EFFECT OF SALINE CONCENTRATIONS ON THE GROWTH OF MELON CULTIVATED UNDER PROTECTED ENVIRONMENT
T.S. Duarte[1], R.M.N. Peil[2], S. Bacchi[2]
[1] Experimental Station of Ituporanga, EPAGRI, Ituporanga SC, Brazil
[2] Dpt. of Crop Science, UFPel, Pelotas RS, Brazil

P 73.
GROWTH, WATER CONSUMPTION AND USE EFFICIENCY OF SUMMER SQUASH CROP IN CLOSED RICE HUSK MEDIUM GROWING SYSTEM
R.M.N. Peil, A.S. Strassburger, L.A. da Fonseca
Departamento de Fitotecnia, Universidade Federal de Pelotas, Pelotas RS, Brazil

P 74.

DAILY AND SEASONAL VARIATION OF NITRATE CONTENTS IN LETTUCE CULTIVARS IN HYDROPONIC SYSTEM IN THE SOUTH OF BRAZIL

R.M.N. Peil[1], L.A. da Fonseca[1], A.S. Strassburger[1], K. F. Strassburger[2], C.A.B. Medeiros[3]
[1]Departamento de Fitotecnia, Universidade Federal de Pelotas, Pelotas RS, Brazil
[2]Departamento de Solos, Universidade Federal de Pelotas, Pelotas RS, Brazil
[3]Embrapa Clima Temperado, Pelotas RS, Brazil

P 75.

EFFECTS OF GRAFTING AND SALINITY ON AGRONOMIC CHARACTERISTICS AND ION UPTAKE BY CUCUMBER PLANTS GROWN IN A CLOSED HYDROPONIC SYSTEM

S. A. Petropoulos, C. Olympios, G. Ntatsi, D. Savvas, C. Akoumianakis, H. Passam
Agricultural University of Athens, Laboratory of Vegetable Production, Athens, Greece,

P 76.

EFFECT OF PGPR APPLICATION AND NITROGEN DOSES ON BABY LEAF LETTUCE GROWN IN A FLOATING SYSTEM

V. Balanza[1], J.A. Martínez[1], C. Egea-Gilabert[2], D. Niñirola[1], J. Lopez-Marín[3], A. González[3], **J.A. Fernández**[1]
[1] Dept. Producción Vegetal. Technical University of Cartagena. Cartagena, Spain
[2] Dept. Ciencia y Tecnología Agraria. Technical University of Cartagena. Cartagena, Spain
[3] Dept. Hortofruticultura. IMIDA. La Alberca. Murcia. Spain

P 77.

PESTICIDES APPLICATION IN GREENHOUSE CROPS USING A FOG SYSTEM, STUDY OF DEPOSITION, UNIFORMITY AND LOSSES TO THE GROUND.

V.J. Rincón, F.C. Páez, J. Sánchez-Hermosilla, A. Callejón
Departament of Agricultural Engineering, University of Almería, Almería, Spain

P 78.

COMMUNITY LEVEL PHYSIOLOGICAL PROFILING AS A METHOD TO MONITOR HEALTH STATUS OF TOMATO PLANTS IN CLOSED HYDROPONIC GROWING SYSTEMS

A.K. Rosberg[1], N. Osman[1], M. Hultberg[1], W. Wohanka[2] & B.W. Alsanius[1]
[1]Dpt. of Horticulture, Swedish University of Agricultural Sciences, Alnarp, Sweden
[2]Dpt. of Phytomedicine, Research Center Geisenheim, Germany

P 79.

EFFECT OF APPLICATION OF *PSEUDOMONAS FLUORESCENCE* ON YIELD AND YIELD COMPONENTS OF WHEAT UNDER DROUGHT TOLERANCE

R. khalili, H.A. Alikhani, M. zarei, L. Mohammadi
Dpt. of Soil Science, University College of Agriculture & Natural Resources,
University of Tehran, Karaj, Iran

P 80.

***MICROCEPHALOTHRIPS ABDOMINALIS* (THYSANOPTERA: THRIPIDAE) DISCOVERED IN SOUTHERN FRANCE**

J. Pizzol[1], P. Reynaud[2], C. Poncet[1]
[1] INRA – UR 880, URIH - France
[2]LNPV – Station d'Angers – France

P 81.

SURVEY OF THRIPS SPECIES IN HORTICULTURAL GREENHOUSES IN SOUTHERN FRANCE

J. Pizzol[1], P. Reynaud[2], C. Poncet[1], D. Nammour[1], N. Desneux[1], S. Voisin[1], J.P. Ziegler[1]
[1]INRA – UR 880 URIH, France
[2]LNPV, France

P 82.
MECHANICAL DISTRIBUTION OF *PHYTOSEIULUS PERSIMILIS* ON CHRYSANTHEMUM
L. Zappala, G. Manetto, G. Tropea Garzia, G. Emma, S. Failla
Department of Agri-food and Environmental Systems Management, University of Catania, Italy

P 83.
S-ABA EFFECTS ON EVAPOTRANSPIRATION AND LEAF BURN IN *SALVIA FARINACEA*
J.E. Barrett, A.E. O'Donoughue, C.A. Bartuska
Dpt. of Environmental Horticulture, University of Florida, Gainesville FL, USA

P 84.
EFFECT OF CROWN SIZE AND CULTIVAR ON STRAWBERRIES FRESH BARE ROOT PLANTS YIELD AND QUALITY IN SICILY
F. D'Anna, G. Caracciolo, A. Moncada, F. Vetrano
Dpt. Agronomia Ambientale e Territoriale Sez, di Orticoltura e Floricoltura
Università degli Studi di Palermo. Italy

P 85.
INFLUENCE OF DIFFERENT DOSES OF NITROGEN ON PRODUCTION AND QUALITY OF STRAWBERRY FROM FRESH PLUG PLANTS
F. D'Anna, G. Caracciolo, A. Moncada, A. Parrinello, R. Alessandro
Dipartimento di Agronomia Ambientale e Territoriale Sez. di Orticoltura e Floricoltura (DAAT), Università degli Studi di Palermo

P 86.
CULTURE PRACTICES FOR SELECTING AND GROWING WILD BELLFLOWER (*CAMPANULA RAPUNCULOIDES* L.) COMMERCIALLY
V. Scariot, W. Gaino, M. Devecchi
Department of Agronomy, Forest and Land Management, Faculty of Agriculture, University of Turin, Grugliasco (TO), Italy

P 87.
USE OF SHADING NETS TO IMPROVE QUALITY CHARACTERISTICS OF COMPACT GARDENIA (*GARDENIA JASMINOIDES* ELLIS) POTTED PLANT
Ch. Lykas, N. Katsoulas
University of Thessaly, School of Agricultural Science, Department of Agriculture Crop Production & Rural, Environment, N. Ionia Magnesias, Greece

P 88.
PRODUCTION OF HIGH-QUALITY ALOE PLANTLETS THROUGH TISSUE CULTURE
M. Cardarelli[1], D. Borgognone[1], Y. Rouphael[2], G. Colla[1]
[1]Dipartimento di Geologia e Ingegneria Meccanica, Naturalistica e Idraulica per il Territorio, Università della Tuscia, Viterbo, Italy
[2]Department of Crop Production, Faculty of Agricultural Engineering and Veterinary Medicine, Lebanese University, Dekwaneh, Beirut, Lebanon

P 89.
IMPLEMENTATION OF MANAGEMENT PRINCIPLES ON GREENHOUSE VEGETABLES NEAR THE CITY OF THESSALONIKI
P. Nikolaidou[1], G. Dimokas[2] and M. Martika – Vakirtzi[1]
[1] Aristotle University of Thessaloniki., School of Agriculture, Department of Agricultural Economics, University City AUTH, Thessaloniki, Greece
[2] University of Thessaly, School of Agricultural Science, Department of Agriculture Crop Production & Rural, Environment, N. Ionia, Greece

P 90.

EFFECT OF LIGHT REGIME ON GROWTH AND FLOWERING OF *PHALAENOPSIS* ORCHID

R. Paradiso, G. Colonna and S. De Pascale
Department of Agricultural Engineering and Agronomy - University of Naples Federico II, Portici - Naples (Italy).

P 91.

THE EFFECTS OF ARBUSCULAR MYCORRHIZAL FUNGI ON OSMOTIC ADJUSTMENT SYSTEM OF TOMATO UNDER SALINE STRESS

Z.B Zhang , C.X He , X.C. Yu
Institute of Vegetables and Flowers, Chinese Academy of Agricultural Science, Beijing, P.R. China

P 92.

GRAFTING EFFECTS ON EARLINESS, YIELD AND FRUIT QUALITY OF TWO TOMATO CULTIVARS

P. Tsouvaltzis[1], A.S. Siomos[1], N. Barbayiannis[2]
[1]Dpt. of Horticulture, Aristotle University, Thessaloniki, Greece
[2]Dpt. of Hydraulics, Soil Science and Agricultural Engineering, Aristotle University, Thessaloniki, Greece

P 93.

THE EFFECT OF SUPLEMENTARY LED LIGHTING ON THE ANTIOXIDANT AND NUTRITIONAL PROPERTIES OF LETTUCE

G. Samuolienė, A.Brazaitytė, R.Sirtautas, A.Novičkovas, P. Duchovskis
Institute of Horticulture, Lithuanian Research Centre of Agricultural and Forestry Sciences, Kaunas distr., Lithuania

P 94.

EFFECT OF *Ocimum basilicum* L. BIOLOGICAL PREPARATION ON TOMATO FRUIT QUALITY GROWN IN GREENHOUSE

S. Sakalauskienė[1], **S. Sakalauskien**ė[1], J. Pinikienė[2], R. Karklelienė[1], A. Radzevičius[1], Č. Bobinas[1], A. Brazaitytė[1], J. Sakalauskaitė[1], P. Viškelis[1], G. Samuolienė[1], P. Duchovskis[1]
[1]Institute of Horticulture, Lithuanian Research Centre of Agricultural and Forestry Science, Babtai, Kaunas distr., Lithuania
[2]Center for Classical Homeopathy, Nemenchine, Lithuania

P 95.

GREENHOUSE BABY LEAF PRODUCTION IN SEMI-ARID CLIMATE: SEASONAL EFFECTS ON YIELD AND QUALITY

M. Kroggel, W. Lovichit, C. Kubota
School of Plant Sciences, The University of Arizona, Tucson, AZ, USA

P 96.

ANTIOXIDANT COMPOUNDS AND NITRATES IN BABY LETTUCE AS AFFECTED BY NITROGEN AND CALCIUM FERTILIZATION AND HARVESTING TIME DURING THE COURSE OF THE DAY

A. Koukounaras, A.S. Siomos, S. Neveskiotis
Department of Horticulture, Aristotle University, 54124 Thessaloniki, Greece

P 97.

EFFECTS OF DIFFERENT ROOTSTOCKS ON YIELD, QUALITY AND PLANT VIGOUR OF WATERMELON GROWN IN GREENHOUSE

G.B.Oztekin[1], **Y.Tuzel**[1], N. Uysal[2]
[1]Department of Horticulture, Faculty of Agriculture, Ege University, Bornova, Izmir-Turkey
[2]Graduate School of Natural and Applied Sciences, Ege University,Bornova,Izmir-Turkey

P 98.
ROOTING AND GROWTH OF CUTTINGS FROM ETHYLENE-LOW OR ETHYLENE-HIGH SENSITIVE MINIATURE ROSE GENOTYPES
N. Ahmadi
Department of Horticultural sciences, Tarbiat Modares University, P. O. Box 14115-336, Tehran, Iran

P 99.
EFFECT OF SILICATE APPLIED DURING CUTTING PROPAGATION ON ROOTING AND GROWTH OF TWO ROSE CULTIVARS
Y.G. Park[1], C.H. Ko[1], S.B. Lee[1], and B.R. Jeong[1,2*]
[1]Dpt. of Horticulture, Division of Applied Life Science (BK21 Program), Graduate School of Gyeongsang National University, Jinju, Korea
[2]Institute of Agriculture & Life Sciences, Gyeongsang National University, Jinju, Korea

P 100.
GROWTH OF BLUEBERRY CULTIVARS IN NFT HYDROPONIC SYSTEM
M.W. Schuch[1], R.M.N. Peil[1] , D.C. Nascimento
Departamento de Fitotecnia, Universidade Federal de Pelotas, Pelotas RS, Brazil

P 101.
SOILLESS CULTIVATION SYSTEMS: A NEW APPROACH IN FRUIT PLANTS PROPAGATION IN THE SOUTH OF BRAZIL
M.W. Schuch[1], R.M.N. Peil[1]
Departamento de Fitotecnia, Universidade Federal de Pelotas, Pelotas RS, Brazil

P 102.
CULTIVATION OF VEGETABLE TRANSPLANTS USING SOLID-STATE LAMPS FOR THE SHORT-WAVELENGTH SUPLEMENTARY LIGHTING IN GREENHOUSES
G. Samuolienė, A. Brazaitytė, P. Duchovskis, A. Viršilė, J. Jankauskienė, R. Sirtautas, A. Novičkovas, S. Sakalauskienė, J. Sakalauskaitė
Institute of Horticulture, Lithuanian Centre of Agricultural and Forestry Sciences, Babtai, Kaunas district, Lithuania

P 103.
ENHANCING NITROGEN USE EFFICIENCY IN *CUCURBITACEAE* CROPS BY GRAFTING
G. Colla[1], Y. Rouphael[2], M. Cardarelli[1], E. Rea[3]
[1]Dipartimento di Geologia e Ingegneria Meccanica, Naturalistica e Idraulica per il Territorio, Università della Tuscia, Viterbo, Italy
[2]Department of Crop Production, Faculty of Agricultural Engineering and Veterinary Medicine, Lebanese University, Dekwaneh, Beirut, Lebanon
[3]CRA-Centro di ricerca per lo studio delle relazioni tra pianta e suolo, Roma, Italy

P 104.
GREENHOUSE MIST SYSTEM CAN IMPROVE ROOTING AND PROVIDE GREATER FLEXIBILITY IN ROOTING CUTTINGS OF GRAPEVINE IN ALBANIA
E. Kukali[1], H. Ismaili[3], E. Kongjika[2], A. Merkoci[4]
[1]Agricultural University of Tirana, Departament of Hortikultur
[2]Akademia e Shkencave e Shqiperise
[3]Agricultural University of Tirana, Genetic Bank
[4]Institute of Energy Water & Enviroment, Polytechnic University, Department of Climate and Environment

P 105.
IMPACT OF SALINITY DUE TO A HIGH CONCENTRATION OF NACL OR TO A HIGH CONCENTRATION OF NUTRIENTS ON TOMATO PLANTS
I. Lycoskoufis[1], G. Mavrogiannopoulos[1], D. Savvas[2], **G. Ntatsi**[2]
[1]Department of Natural Resources Management and Agricultural Engineering, Agricultural University of Athens, Athens Greece
[2]Department of Crop Science, Laboratory of Vegetable Crops, Agricultural University of Athens, Athens, Greece

General/ Scientific Information

Oral Presentations
Each oral presentation should be presented in the designated hour and session, as stated in the Final Program and should last 15 minutes, followed by 5 minutes discussion.

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Each Poster should be mounted between 08.30-09.00 hrs in the morning of the day of their presentation that has already been communicated to the authors and is stated in the Final Program.
Presenting authors should stand next to their poster during the coffee breaks (morning and afternoon) for discussion with the Scientific Committee and/or the other participants.
Posters should be dismounted in the end of the same day. Posters that will not be collected by their authors, they will be gathered by the Secretariat and discarded.

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The official Symposium language is English.

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Registration / Hotel Accommodation

Registration

Type of registration	March 1st and before	After March 1st
ISHS MEMBER	€ 550	€ 600
NON-MEMBER	€ 610	€ 660
STUDENT*	€ 250	€ 250
SCIENTIFIC TOUR – June 9th	€ 75	€ 95
ACCOMPANYING PERSON	€ 180	€ 180

The registration fees for DELEGATES cover:
- Non Member registration fee includes one year membership to ISHS
- Admission to the scientific sessions and exhibition area
- The delegate's bag and documentation
- Welcome Reception on June 5th
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- Applicable taxes

The registration fees for STUDENTS cover:
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- The delegate's bag and documentation
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- Lunches and coffee breaks according to the congress program
- Certificate of attendance
- Applicable taxes

The registration fees for the SCIENTIFIC TOUR cover:
- Transfer with private bus to agricultural area of North Greece
- Visit to the Agricultural Bee Keeping Co-Op of Nikiti - Halkidiki SITHON
- Visit and guided tour in local greenhouse
- Refreshment break during the tour
- Visit to Petralona Cave
- Lunch in local restaurant
- Visit to Porto Carras winery and wine tasting
- Applicable taxes

Hotel Accommodation

Hotelname	Cat.	Type of room	Distance from meeting venue	Single room (1 Person)	Double/Twin room (2pers)
Porto Carras (Meliton Hotel)	5*	Standard	0m	€ 135	€ 135
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Daily rates per room, including breakfast & taxes

Cancellation Policy

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- Cancellation requests must be made to the Congress Secretariat in writing. For cancellation received by March 31st, 2011, a refund of the total fee, less € 80 as administration charge, will be made
- After that date refunds will not be possible. If the conference is cancelled for any reason, GreenSys 2011 shall not be held liable for airfare, hotel, or other costs incurred by conference registration.

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All changes or cancellations have to be made in writing to ERA Ltd. Please do not contact the hotel directly.

- Written cancellation received by December 31st, 2010: Full refund less 25 € administration fees will be charged.
- Written cancellation received by March 31st, 2011: 1 night cancellation fee applies.
- Written cancellation received by May 15th, 2011: 2 nights cancellation fees apply.
- Written cancellation received from May 16th, 2011 and onward: No refund.
  In the event of non-arrival, the hotel will automatically release the reservation and payment will be non-refundable.

Cancellation policy for organized tours

- Written cancellation, for organized tours, received by May 15th, 2011: Full refund less € 20 administration fee.
- Written cancellation, for organized tours, received after May 16th, 2011: No refund & full charge will apply.

Scientific Tour / Social Events / Tours

Scientific Tour / Social Events

Welcome Reception (incl. in Registration Fees)

Sunday, June 5, 2011

The Welcome Cocktail of the Greensys 2011, will be held at the pool of Meliton Hotel, Porto Carras Grand Resort, on June 5th at 20:00 hrs.

Dress: Smart Casual

Included in registration fees of registered participants and accompanying persons

Beach Dinner (Optional)

Monday, June 6, 2011

On Monday June 6th, at 20:30 hours, our beach party will start at the beach of Porto Carras Grand Resort.

Dress: Casual (a sweater might be useful in case of a chilly night).

Price: €65 per person

Gala Dinner (Optional)

Wednesday, June 8, 2011

The Gala Dinner will be held on Wednesday June 8th, at 20:00 hours, at the Porto Carras Grand Resort.

Dress: Business Casua

Price: €80 per person

Limited admission. Book now!

Scientific Tour (Optional)

Thursday, June 9, 2011

09.00 Departure from Porto Carras Hotel. Shortly afterwards visit to "the Agricultural Bee Keeping Co-Op of Nikiti – Halkidiki SITHON" to know the procedure and honey tasting
Visit to the Nursery Mavromatis in a farmstead located in "Local Water" of Ormylia. Coffee/ Refreshment
Visit to Petralona Cave
Lunch in a local tavern
After lunch we will visit Porto Carras Winery for tour and wine tasting!

Dress: Casual

Price per person: €75 until March 1st/ €95 after March 1st

Tours

Mount Athos Full Day Cruise (optional)

Monday, June 6, 2011

08:15 Pick up from Porto Carras Hotel and 1 hour later arrival in Ormos Panagias port
09:30 The cruise Starts: Sail to MT. Athos. The guests can clearly see the monasteries as they are just 100m from the beach. While sailing there is a guide explaining the history and giving information about the monasteries Dohiariou, Xenofontos, Dionysiou, Simon Petras, Panteleimonos or Russian, Limani Dafnis, Grigoriou, Pavlou Nea Skiti, Ag. Annas. Information is given in Greek, German and English language.
13:30 Stop in Ouranoupolis town for lunch and shopping there are several Greek art shops where the clients can buy icons and items of folk art
16:00 Sailing for Ormos Panagias port and arrival 45 minutes later. Board on the bus
18:30 Arrival back to the hotel

Price per person: €70

Vergina Full Day Cultural Tour (optional)

Friday, June 10, 2011

07:45-08.30	Pick up from Porto Carras hotel. 1 hour later arrival at Thessaloniki to pick up the guide
10.15	Coffee Break
10.40	Departure for Vergina
11.10	Arrival at Vergina. Archeological site visit.
11.45-12.45	Visit the Tombs – Museum of Vergina
13.30-15.30	Lunch at local restaurant. Departure from Vergina.
18:00	Arrival at Chalkidiki – end of the tour

Price per person: €60

Important Notes:

- For tickets please contact the Congress Secretariat
- Admission to all social events/ tours will be against tickets **only**.
- All bus departures will be from Porto Carras / Meliton Building, parking area.
- "Thessaloniki Full Day Tour" and "Petralona Cave & Ancient Olynthos Half Day Tour" will not be operated due to lack of participation.

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Abstracts of Keynote Lectures

JUNE 6th — KEYNOTE LECTURE I

EFFICIENT USE OF NATURAL RESOURCES IN GREENHOUSES

A.J. Both
Department of Environmental Sciences - Rutgers University, New Brunswick - USA

Over the last decade, greenhouse growers have been hit hard by significant increases in energy prices and a world-wide financial recession. Many have investigated or even switched to alternative energy sources, but are often still struggling financially. Alternative energy sources for greenhouse applications include solar (photovoltaic and thermal), wind, biomass, industrial waste heat, and in special cases hydro power. Specialized technologies are applied to convert alternative energy sources in electricity and heat energy, including solar panels, solar collectors, wind turbines, biomass boilers, combustion engines powering generators, and hydroelectric generators. In some cases, these technologies have been amended with storage and conversion systems that further enhance conversion efficiencies, such as insulated storage vessels, heat pumps, high efficiency heat exchangers, variable speed pumps and motors, LED lighting systems, and combined heat and power systems. On the other hand, many growers have realized significant energy savings by first applying energy conservation strategies, including improved insulation where possible, multi-layer cladding materials, energy curtains, and innovative environmental control strategies (e.g., temperature integration). Energy conservation can be a simple and effective tactic to increase the viability of a greenhouse operation and should therefore always be considered first. Typically, greenhouses are designed for maximum light transmission, a design criteria that often conflicts with the desire to reduce energy consumption. But with new materials and innovative approaches, energy consumption does not have to be one of the biggest cost components for greenhouse crop production. Efficient use of natural resources in greenhouses is a challenge for both large and small operations. While large operations often are better able to fund capital investments, smaller greenhouse businesses can also benefit from improved resource utilization efficiencies and often do so by incorporating a more efficient use of available labor. This presentation will attempt to address resource use efficiencies for differently sized greenhouse operations, under different climate conditions, and employing different levels of technology.

JUNE 7th — KEYNOTE LECTURE II

AUTOMATION AND ROBOTICS IN GREENHOUSES

E.J. van Henten[1,2]
[1]Farm Technology Group, Wageningen University, The Netherlands, [2]Wageningen UR Greenhouse Horticulture, The Netherlands

Labour costs rank high on the list of production costs in West European countries. Besides the absolute costs, scale enlargement of production facilities, problems with the availability of skilled and motivated labour forces, health problems of the workers and more emphasis on specialization of crop production and individualization of plant treatment, demand a stronger focus on labour aspects of protected cultivation. Improving labour efficiency will be one of the critical success factors in the Netherlands as well as in Western-Europe the next decades.
Solution directions to deal with these trends, as also visible in horticultural practice, are:
1. More effective layout of the company,
2. Proper or preferably optimized scheduling of labour,
3. Support, alleviation or even replacement of human labour by machines and robots.
This key-note will shortly review the current trends in greenhouse crop production that can be identified as driving forces for developments towards improved labour efficiency. Secondly, the state-of-the-art in mechanisation will be described to identify available technology. This will be followed by the description and exploration of some research lines that are currently being followed to fill in the gaps between existing and required technology for the future. Finally, key challenges for research will be addressed.

JUNE 8th — KEYNOTE LECTURE III

GOOD AGRICULTURAL PRACTICES (GAPS) PRINCIPLES FOR GREENHOUSE VEGETABLE PRODUCTION IN THE MEDITERRANEAN REGION

M. Qaryuti
National Center for Agricultural Research and Extension (NCARE), Amman - Jordan.

Over the last years, Near East and North Africa countries (NENA) adjacent to the Mediterranean Sea region have developed a sizeable greenhouse industry, covering an estimated area of about 145,000Ha. (2008-2009 estimates). The NENA greenhouse crop sector is characterised by a predominance of small-scale farmers who produce a large range of horticultural crops for local consumption and export. Due to the growing significance of greenhouse sector to the economy, these countries have - with the assistance of FAO - set up a regional working group on greenhouse horticultural Production since 1993, to exchange know-how on "Integrated Production and Protection" (IPP) practices, which has subsequently developed to Good "Agriculture Practices" (GAP). In order capitalize on the experiences gained so far, in this region within the framework of GAP, the group has decided to produce and publish a GAP guideline for greenhouse vegetable production in the NENA countries.
The proposed publication will address the quality and quantity aspects of greenhouse production of horticultural produces in the Mediterranean Region. It is intended to be a crowning achievement of joint efforts between the International Society for Horticulture Science-Commission for Protected Cultivation and FAO regional working group on GAP in the NENA countries.
The contents of this proposed publication addresses a large audience of beneficiaries such as farmers, extension officers, scientists, policy makers, etc. in their pursuit to improve the greenhouse horticulture production management and to strengthen regional cooperation in this regard.
The established working Group continues to hold regular bi-annual meeting(s) in rotation in the member countries in order to discuss developments, exchange of information, and develop common research and extension programmes for greenhouse crop production in the region, covering a broad range of thematic issues related to areas like: greenhouse design and climate control, crop management including IPM and GAP, production economics and marketing. So far, several meetings of the working group have been conducted, showing that common links in research and development leading to the implementation of joint projects with the assistance of a network of scientists from Belgium, Spain, France, Germany, and Greece.

Abstracts of Oral Presentations

Oral Presentations 1 - GREENHOUSE DESIGN

SESSION KEYNOTE I

GREENHOUSE DESIGN: CONCEPTS AND TRENDS

M. Teitel[1], J.I. Montero[2], E.J. Baeza[3]
[1]Institute of Agricultural Engineering, Agricultural Research Organization, the Volcani Center, Bet Dagan, Israel.
[2]Institut de Recerca i Tecnología Agroalimentaries Centre de Cabrils, Barcelona, Spain.
[3]Fundación Cajamar, Estación Experimental, El Ejido, Spain.

Greenhouses are constructed all around the world to provide fresh vegetables and ornamentals throughout the year. The prevailing greenhouse type and equipment, in a specific region, are generally suited to the weather in that region, the availability of construction materials and the type of crop that is grown. In each region, elements such as structure, cover materials, climate control systems and irrigation and fertilization equipment are routinely inspected by growers, designers and researchers, with aim to improve their efficiency, reduce inputs and minimize undesired effects on the environment. The term "greenhouse design" considers many aspects and can't be covered in one paper. Therefore, this paper mainly considers developments related to the possible effects of manipulations in structure and cover materials on microclimate. In addition, it emphasizes the main concepts and trends that were observed during the last decade in greenhouse horticulture. The major driving forces in improving greenhouse design have been: the desire to achieve a sustainable greenhouse that is energy neutral, consumes the minimal essential amount of water, has the lowest negative impact on the environment while maximizing net financial return. Consequently, we have witnessed in recent years the development and expansion of tall and large structures, innovative cover materials, closed and semi-closed greenhouses and progress in solar greenhouses that harvest solar energy for heating. Most recently the incorporation of arrays of photo voltaic cells for power generation in protected cultivation became popular, a trend that still has to be carefully evaluated. In warm climates we have witnessed the expansion of screenhouses and innovative insect proof screens that provide a reasonable environment for various crops, with a much lower capital investment than fully-equipped greenhouses. Progress was also made with the development of tools for better and faster design of structures for protected cultivation. For example, CFD (computational fluid dynamics) simulations were extensively used to investigate the effect of structure shape, ventilator size and arrangement (with or without insect proof screens) on microclimate. The studies indicated that there is still scope in improving the design of current prevailing structures and their components.

GD 1.

HORIZONTAL FLOW AND VERTICAL TRANSFER IN AND ABOVE AN INFINITE SCREENHOUSE

I. Seginer
Civil and Environmental Engineering, Technion, Israel Institute of Technology, Haifa, Israel

The ever increasing size of greenhouses aggravates the natural ventilation problem by reducing the efficacy of the side vents. Design improvements are often explored by using computational fluid dynamics (CFD) to analyse flow patterns. However, computations for very large structures still require significant computing resources, thus limiting the number of tests for new design configurations. Recent results show that the central area of very large greenhouses is environmentally uniform, suggesting that solving for a repetitive single module (span), could be used to represent most of the greenhouse area, saving considerably on computational resources. To launch this approach, a further simplification would be to consider a horizontally uniform structure, where the exchange of momentum and energy is strictly vertical through the roof. Recently, solutions of such a configuration have been produced with the mixing length methodology applied to an 'infinite' screen-house. In that study, the screen roof is characterised by two aerodynamic parameters: mixing-length and drag-coefficient, both of which can be determined from measured flow profiles above and under the roof. The model has been extended to accommodate an anisotropic (corrugated) roof and a row crop, as well as to solve for the temperature and humidity profiles in and above the screenhouse. Sample calculations with the model mimic expected responses, such as the cooling effect and the negative Bowen ratio resulting from a dry atmosphere, and the improved ventilation under sparse screens. Sparse screens can not, however, block the entrance of small insects, so that a compromise must be struck, or a more elaborate roof geometry must be explored, which could be done with CFD. Less expected is the prediction that Increasing the height of the roof (of an infinite screenhouse) results in *less* favourable indoor conditions.

GD 2.

LESSONS LEARNED FROM EXPERIMENTS WITH SEMI-CLOSED GREENHOUSES

H.F. de Zwart
Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands.

In the past decade, a large number of experiments with semi-closed greenhouses have been carried out. Technical, horticultural and engineering problems were solved and high production levels were achieved. Due to the capture of condensate and the reduced air exchange, water and CO2 demands can be reduced significantly. However, the investments for a semi-closed greenhouse are high. Moreover, the running costs can be high as well, especially in situations where seasonal heat storage is difficult.
This paper gives an overview of the results obtained in different countries and shows the key parameters that affect the economical viability of semi-closed greenhouses.

GD 3.

SYSTEM DYNAMICS AND PERORMANCE FACTORS OF UA-CEAC LUNAR GREENHOUSE PROTOTYPE BIOREGENEATIVE LIFE SUPPORT SYSTEM

M. Kacira[1], G. Giacomelli[1], L. Patterson[1], R. Furfaro[2], P. Sadler[3], G. Boscheri[4], R. Wheeler[5], C. Lobascio[4], M. Lamantea[4], S. Rossignoli[6]
[1]Agriculture and Biosystems Engineering, University of Arizona, Tucson, AZ, USA.
[2]Systems and Industrial Engineering, University of Arizona, Tucson, AZ, USA
[3]Sadler Machine Company, Tempe, AZ, USA
[4]Thales Alenia Space Italia, Torino, Italy
[5] NASA Kennedy Space Center, FL, USA
[6] Aero Sekur, Aprilia, Italy

To elaborate a vision for globally coordinated space exploration, NASA Global Exploration Strategy identified the Moon (and subsequently Mars) as the primary targets to further human presence in the Solar System. Future habitation of space, including lunar outposts will necessitate engineering of special systems capable of performing critical tasks such as revitalizing atmosphere (liberate oxygen and fix carbon dioxide), purifying water (via plant transpiration), and growing human food. Bioregenerative Life Support Systems (BLSS) represent a solution to the problem of sustaining human presence in space. Centered on using plants to sustain a continuous vegetarian diet for astronauts, a typical BLSS employs plants and crop production to provide air revitalization, water recycling, resource recycling, and food production for the crew. The lunar greenhouse (LGH) prototype project funded by NASA Steckler Phase 1 Space Grant supported collaboration from a multidisciplinary and multinational team of experts to study and evaluate the scientific and technical merit and feasibility of a lunar greenhouse prototype as BLSS. The LGH module was constructed to be light-weight, collapsible for transport, autonomous deployment, modular for expansion with a hydroponic multi-cropping system that could produce lettuce, strawberry, sweet potato, and tomato. The module was instrumented to continuously monitor all primary resource inputs (feed water, nutrient solution, CO2, labor, and energy) as well as, desired outputs (biomass, water harvested, oxygen generated). This presentation will provide data obtained from a 155 day closure evaluation period on the system dynamics of production output and resource input, including: biomass production (2.19 ± 0.17 kg/day), dry fertilizer salts (0.07 ± 0.11 kg/day), water balance (17.4 ± 6.6 kg/day harvested, 23.5 ± 14.1 kg/day consumed), electrical and radiation energy use (378, 115.2 MJ/day, respectively) as well as labor use (19.03 ± 40.36 min/day), and propose overall production and consumption ratios to describe system performance.

GD 4.

MODEL-BASED OPTIMAL GREENHOUSE DESIGN: A CASE STUDY FOR SOUTH SPANISH CONDITIONS

B.H.E. Vanthoor[1,2], C. Stanghellini[1], E.J. van Henten[1,2], P.H.B. de Visser[1]
[1]Wageningen UR Greenhouse Horticulture, Wageningen, The Netherlands
[2]Farm Technology Group, Wageningen University, Wageningen,The Netherlands

We have developed a generic method to design the optimal greenhouse under a variety of climate and market conditions around the world. The optimal greenhouse is defined as the design that maximises the difference between economic crop yield and the costs associated with construction, maintenance and operation of the greenhouse facility. To determine this trade-off, a greenhouse climate model, a tomato yield model and an economic model were integrated in the generic method. Finally a controlled random search algorithm selected the greenhouse with the maximal net return among a huge number of possible combinations. In this study the method is applied to find the optimal design for the conditions of Almeria, South Spain, for a long tomato production period from August to June. The design alternatives that were considered contained all possible combinations among different climate modification techniques (i.e. greenhouse structure, cover material, ventilation surface, various indoor/outdoor screens, whitewash, heating systems, cooling systems and CO_2 enrichment systems). Results demonstrated that a light greenhouse covered with glass and equipped with a direct air heater of 50 Wm^{-2} ensured the largest profit. Besides natural ventilation only seasonal whitewash was used to decrease the indoor temperature. The distribution curves for the best set of greenhouses (all greenhouses for which the net result differed less than € 0,50 m^{-2} with respect to the best greenhouse) revealed that most greenhouses had a light (Venlo-type) structure with a specific ventilation area of 20% (72% of the greenhouses in the best set) and they were equipped with: glass (69%); seasonal whitewash (69%); a direct air heater (100%); a thermal screen (73%); a fogging system (43%) and without CO_2 enrichment (57%). It is concluded that the present method is a powerful tool to select the design elements that are most apt to given climate and market conditions.

GD 5.

A 3D MODEL FOR CROP AND GREENHOUSE TO IMPROVE ILLUMINATION STRATEGIES IN GREENHOUSE CROPS

P.H.B. de Visser[1], G.H. Buck-Sorlin[2], **L.F.M. Marcelis**[1]
[1]Dept. of Greenhouse Horticulture, WUR, Wageningen,The Netherlands
[2]Biometris, WUR, Wageningen, The Netherlands

For the use of assimilation lamps in greenhouse horticulture there is a need to find the optimal balance between increasing light levels for growth and restricting the use of energy for lighting. For this, a 3D model for crop and greenhouse environment was developed. The model simulates the spatial distribution of light and the resulting light absorption and photosynthesis for each leaf. Light distribution was modeled using a Monte Carlo based inversed ray tracer. The crop structure was modeled as a branching system according to the so-called extended L systems grammar. Both the inversed ray tracer and the crop structure were modeled inside the interactive modeling platform GroIMP. Modeling results show that the current designs for lamp grids and reflector types can be further improved to increase light interception by the given crop structures. Adaptation of the plant positions in row crops is also shown to enhance light

capture, as will be illustrated for tomato and rose. The 3D model may help growers and advisors to find a more efficient way to use the energy input for illumination systems without giving in on crop production. Further possibilities to use 3D models of plants in interaction with their environment will be discussed.

GD 6.

DESCRIPTION, OPERATION AND PRODUCTION OF THE SOUTH POLE FOOD GROWTH CHAMBER

R.L. Patterson[1], P.D. Sadler[2], R.M. Wheeler[3], M. Kacira[1], and G.A. Giacomelli[1]
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The South Pole Food Growth Chamber (SPFGC) is an automated hydroponic climate controlled chamber located inside the Amundson-Scott South Pole station, which produces fresh vegetables and herbs, as well as a psychologically pleasurable environment for station personnel. The objective of this study was to document automated control practices, telepresence support, and resource utilization and production. Resources included: input of energy, water, plant nutrients, carbon dioxide, labor, and maintenance materials; and output was food production. Data collected from January through October 2006 was used to document the performance. Plants ranging from vegetative greens to flowering fruit crops to herbs were grown within a hydroponic polyculture cropping method within one common controlled environment. Consumables included: 1.1 kg d^{-1} carbon dioxide, 0.21 kg d^{-1} dry plant fertilizer salts, 1012 MJ d^{-1} (281 kWh d^{-1}) electrical energy, and production included: 0.8 kg d^{-1} oxygen, and 2.8 kg d^{-1} edible food products. The primary system components and the control elements of the SPFGC are described, and an energy balance was performed. A Resource and Production Model was developed based on the SPFGC operations.

ENI 1.

NEXT GENERATION, ENERGY-EFFICIENT, UNIFORM SUPPLEMENTAL LIGHTING FOR CLOSED-SYSTEM PLANT PRODUCTION

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This report describes the first in a series of luminaires that Cycloptics Technologies, LLC, is developing for plant growth chambers, and research and commercial greenhouses. Controlled Environment Agriculture (CEA) farming in cloudy climates is an obvious application that can benefit from energy efficiency, beam control, and PPF uniformity provided by the Cycloptics innovative reflector technology. The CEA challenge is to implement supplemental lighting systems at a cost making local plant production competitive with large, centralized farms and long-distance shipping. Cycloptics reflector technology has been demonstrated to reduce supplemental lighting energy for plant growth dramatically, making it a potential enabling technology for local, CEA farming to expand throughout the world. These luminaires were designed to deliver high and uniform levels of PAR, with high electrical efficacy (μmol s^{-1} W^{-1}). Cycloptics selected the Philips Elite Agro 315W ceramic MH lamp because of its 2.0 μmol s^{-1} W^{-1} efficacy and 30000 hour life. In tests conducted in a 8.9 m^2 (96 ft^2) walk-in plant growth chamber at Cornell University, fourteen luminaires were mounted on the top of the chamber with each reflector's aperture flush mounted through the ceiling. Using Cycloptics One Bounce and Out® reflector technology, 95% of the 630 μmol s^{-1} of PAR energy produced by each lamp was indirectly radiated throughout the chamber, producing average PPF of 1105 μmol m^{-2} s^{-1}, with Max/Min and Avg/Min uniformity to within six-inches of the sidewalls no greater than 1.27 and 1.10, respectively. Compared to identical chambers outfitted with T12 and T5 fluorescent lamps providing an average of 700 μmol m^{-2} s^{-1}, the MH chamber consumed 58% and 30% less energy, respectively, with significantly better horizontal uniformity over a range of distances from the ceiling. Lettuce (*Lactuca sativa*) growth was used to calibrate and quantify light integral uniformity and plant growth under the lighting system.

ENI 2.

DEVELOPING LED LIGHTING TECHNOLOGIES AND PRACTICES FOR GREENHOUSE CROP PRODUCTION

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A USDA Specialty Crops Research Initiative project has begun involving collaboration among the Universities of Arizona, Michigan State, Purdue, and Rutgers, as well as ORBITEC and CCS, Inc. The focus is to develop hardware, practices, and standards for economically feasible, energy-efficient use of light-emitting diodes (LEDs) throughout the greenhouse industry. LEDs are solid state, robust, very long-lived, and can be selected to emit narrow-spectrum wavelengths that match pigment absorption for desired plant responses. Waste heat can be removed separately from light-emitting surfaces, so emitters can be placed close to crop surfaces without risk of overheating tissues. The hypothesis to be tested is that less electrical power is needed to achieve the same or better plant responses using LEDs rather than traditional lighting systems. New system designs for LED lighting will minimize shading of crops from solar irradiation as the sun tracks across greenhouses. LED systems will control floral initiation and development photoperiodically and photomorphogenically in a variety of bedding-plant species, will control rooting and development of seedlings, cuttings, and grafted vegetable and ornamental transplants photomorphogenically and photosynthetically in preparation for grow out, and will irradiate indeterminate high-wire crops photosynthetically with mobile intracanopy / side-lighting arrays. Metrics of performance related to flowering, transplant vigor, and fruit yield using LED lighting will be compared with controls using traditional lighting technologies and correlated with metrics of electrical energy utilization and daily light integral. Following preliminary testing at academic institutions, commercial stakeholders will test LED prototype hardware in production settings. Each laboratory and commercial stakeholder will contribute data and information for economic, life-cycle assessment, and best-practice components for improved LED hardware design and operation. Procedures will be established for standardized testing of LED lighting arrays for the greenhouse industry. A robust education / outreach program will be developed for stakeholders and the general public.

ENI 3.

A CONCEPT FOR REDUCED ENERGY DEMAND OF GREENHOUSES: THE NEXT GENERATION GREENHOUSE CULTIVATION IN THE NETHERLANDS

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In high tech greenhouse cultivation as in The Netherlands, a lot of fossil energy is used for optimizing climate conditions like temperature and humidity. For more sustainable greenhouse horticulture, a considerable reduction of the use of energy is needed, but trade offs with production and quality are not accepted. An approach in which proven technology is combined enables growers to implement the elements step by step, leading to an easy acceptance. We developed a novel cultivation system for tomato to meet the goal: to reduce the energy input by 40 % from 1.2 GJ/m^2 to 0.75 GJ/m^2 with a normal production level (60 kg/m^2) and quality. Prior to experiments, the

ways to achieve this goal were examined by model simulations. Then, the set of promising options were tested, and showed good results.
The Next Generation Greenhouse Cultivation is based on (a) the intensified use of thermal screens combined with control of humidity (b) maximizing the use of the integration capacity of the crop (c) growing with high humidity and (d) improved efficiency of CO_2 dosing by reduction of ventilation. In this approach, the main element is the prolonged use of screens with a high insulating value (> 70%) to reduce the energy demand combined with a forced ventilation system that injects relatively dry outside air in the greenhouse. By forced ventilation it is not necessary to use a fixed minimum temperature of the heating pipes as an insurance to avoid plant diseases. This contributes to the reduction of energy consumption. The maximal use of the integration capacity of the crop involves a strong relation between daily radiation sum and diurnal mean temperatures and large difference between night and day temperature on sunny days. This reduce the energy input and ventilation rate. Growing with increased humidity, achieved by misting, reduce ventilation rates because of the increased enthalpy of the greenhouse air. When applying CO_2-supply, reduced ventilation results in higher CO_2 concentrations, and hence a higher energy efficiency. The Next Generation Greenhouse Cultivation is a concept for energy saving, consisting of modules that can be implemented step by step into practice. This concept and the positive results of the first experiment with tomato will be presented. In the Netherlands, this concept is currently applied to several other crops.

ENI 4.

PERFORMANCE AND TECHNO-ECONOMIC ANALYSIS OF A COVERED CLOSED LOOP GEOTHERMAL HEAT PUMP FOR GREENHOUSE HEATING

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A great variety of heating applications are being used nowadays in order to cover the greenhouse thermal needs. During the last decade a significant increase in installation of closed loop Geothermal Heat Pump (GHP) systems has been observed. GHPs are highly efficient, renewable energy systems for greenhouse heating and cooling. The main advantage of this system consists on the simplicity of the application, the low cost of structure and the fact that no drilling is required. GHP system exploits the underground stored heat. The external air temperature variations interact directly only with the surface soil temperature, due to the heat capacity of soil. As a result, the effect of the external air temperature variations is being reduced at deeper ground layers. The underground temperature value remains almost constant at a depth greater than 5 m, while in 2 m depth the underground temperature value has been proved that do not change significantly if the ground is under cover. Therefore, a fluid of a more or less constant temperature can be supplied to the primary GHP circuit by installing a ground heat exchanger. GHPs, operating with such a system, consume less energy than air-to-air heat pumps which are widely used. The present study investigates the possibility of greenhouse heating using a covered closed loop GHP system, without an auxiliary conventional heating system. The innovation of the examined system relies on the fact that the ground surface, beneath which the piping installation is located, is covered by polyethylene film (greenhouse simulation) or it is located inside a greenhouse. This cover material method proved experimentally that can improve the heating performance of the GHP. Also, this study presents a techno-economic analysis and the depreciation period for this system compared with a conventional heating system.

ENI 5.

PERFORMANCE OF COMBINED HEATING AND DEHUMIDIFICATION SYSTEM FOR GREENHOUSES

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The proposed Combined Heating and Dehumidification (CHD) system is intended to provide the desired climatic conditions in closed greenhouses, as expressed in temperature and humidity. The proposed CHD system is based on a heat pump for drying the air, and an addition heat exchanger for heating. This framework offers an innovative approach to the solution of the problem of excess humidity, combined with the application of methods for insulating the greenhouse. As a result, expensive energy will be saved, on the one hand, and the conditions in the greenhouse will be optimized, on the other hand. In order to provide the required conditions and for the purpose of efficiency and saving of energy consumption in greenhouses, it is suggested to apply the following two approaches: Heat consumption decreasing – through improvement of the greenhouse insulation. Improvement of the greenhouse insulation may be achieved through the use of a double, inflated covering, and a thermal screen. These means were developed and examined in the 1970s, because of the energy crisis. Heat pump using – to dry the greenhouse air artificially while maintaining the desired humidity. For that purpose, it is suggested to activate a heat pump in the greenhouse, so that the air which is initially cooled and releases water, is subsequently heated. This means that there is a process of conversion of energy from latent heat into sensible heat with no losses to the surroundings. This procedure will allow condensation of all of the water vapor emitted from the foliage and the ground. Prototype of the proposed CHD was designed, constructed and examined. The CHD prototype was installed in the experimental greenhouse (1100 m^2) which comprising common heating (hot water pipes) system, thermal screen and force ventilation system. This greenhouse was examined under several operation modes. The proposed and comparable greenhouse operation modes were intended to maintain temperature of 18 ^oC and relative humidity of 80%. The experimental results indicate that under the proposed greenhouse operation mode, the CHD prototype capability of removing up to 500 kg of water per night (40 kg/hour); energy saving of about 80% in comparison to without thermal screen and with ventilation greenhouse operation mode and 60% in comparison to with thermal screen and with ventilation greenhouse operation mode.

ENI 6.

DEVELOPMENT OF AN ASSESSMENT MODEL FOR GREENHOUSE USING GEOTHERMAL ENERGY SYSTEMS

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In the farming industry, controlled horticulture is an essential prerequisite in producing crops whole year round with equally high quality. However, this requires more energy supply especially for heating which account considerable proportion of the total maintenance costs from approximately 19~58 percent. This is largely from oil which supplied 92 percent of heating energy. To significantly reduce the cost of heating, energy-self sufficient facilities which utilize alternative fuel such as natural source like geothermal are promising. Operations of geothermal energy system are always stable and are affected by the external change in the temperature throughout the year making it favorable for agricultural facilities. However for greenhouse, a design standard to utilize geothermal energy system is complex and difficult to establish. This is because the internal environment inside the greenhouse is affected by a various components such as the scale, location, climate, ground's condition, cultivated crops, cropping season and heating facilities. Furthermore, the geothermal systems that were domestically introduced were not designed according to the climatic conditions of the country. This resulted to problems like inefficient operation of facilities or excessive spending of maintenance costs. To solve the problem, this study was conceptualized. The objective is to compute the energy load of the internal facilities present inside the greenhouse using the Building and Energy Simulation (BES) Programs such as TRNSYS. The operational practices inside the facility and crop growth will be strongly considered. Also, the capacity required for the geothermal system and energy load reduction will be calculated using heat exchanger modules. The energy assessment model for greenhouse and techniques to calculate design standards for the existing greenhouse facilities will be established. Based on the results, new greenhouse design utilizing geothermal system will be developed.

ENI 7.

GREENHOUSE ENERGY CONSUMPTION FOR TOMATO PRODUCTION IN THE IBERIAN PENINSULA

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Greenhouse climate models are a powerful tool which allows simulating inside environmental conditions as a function of external conditions, construction and environmental control equipments characteristics. They also permit to evaluate the energy consumption necessary to obtain the predefined conditions. A Greenhouse Climate Simulator (GCS) was used to analyse the energetic behaviour in different regions in the Iberian Peninsula. GCS uses mensal mean data of several years of solar radiation, temperature, wind speed and relative humidity. A climate generator computes the median hourly climatic data of a typical day for each month and location. As inputs GCS requires data related with the greenhouse characteristics, environmental control equipment and the crop. For the energy balance a static complex model is used which is based on the physics of heat and mass transfer. The results show the energy consumption due to the heating system in each of the studied locations, as well the heat dissipated by the cooling system along a mean year, for year round production in plastic greenhouses. This is used to estimate energetic consumption indicators which allow generating predictive maps. It is an interesting tool which may contribute to the grower's decision making and to the reduction of energy consumption, helping to lower production costs and environmental impacts.

ENI 8.

INTRODUCTION AND POTENTIALS OF EXERGY ANALYSIS IN PRIMARY ENERGY SAVING RESEARCH FOR GREENHOUSES

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Until now, research on primary energy savings in greenhouse systems is primarily based on analysis of energy and enthalpy state variables. It has been proven that these state variables are very useful for greenhouse climate modeling. However, the theory of thermodynamics indicates that these state variables are rather in-accurate for assessing primary energy saving options. To that respect, an analysis based on the second law of thermodynamics using the concept of exergy (free energy) is preferred. Our exergy analysis of different processes in greenhouses (like heating, heat conductance in the cover, mixing of air with different CO_2 concentrations and transpiration) reveals possibilities for important primary energy savings in greenhouse systems. Furthermore, some recent primary energy saving research based on energy/enthalpy analysis, like closed greenhouse systems and dehumidification systems, were compared with the exergy analysis. This clearly demonstrated the lower performance of the energy/enthalpy approach. The Institute for Agricultural and Fisheries Research (ILVO) will use this exergy analysis as a basis for the development of an exergy efficient greenhouse prototype (EXE-kas). Climate modeling and simulation for the EXE-kas in the Northern latitude predicts a primary energy consumption which is an order of magnitude lower than in classical greenhouse systems. Similar energy savings are achieved in the civil building industry by application of the exergy-efficient passive house technology. These findings strengthen our conviction that further development of the EXE-kas can lead to sustainable greenhouses for the future.

WA 1.

PREDICTING THE IMPACTS OF SUBSTRATE WATER POTENTIAL ON EXTERNAL QUALITY TRAITS OF LILY GROWN IN GREENHOUSE

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Water is one of the important environmental factors affecting the external quality of Lily. The aim of this study was to quantitatively investigate the effects of substrate water supply on external quality traits of lily (*Lilium* spp.). Experiments of Lilium oriental hybrids (*Lilium* spp. cv 'Sorbonne') with different planting dates and different levels of water treatment were conducted in a greenhouse in Naijing () from March 2009 to January 2010. The integrated photo-thermal index (PTI), defined as daily total PAR intercepted per plant multiplied by daily average normalized thermal time, was used as a driving variable to describe the seasonal dynamics of the external quality traits (plant height, number of leaves per plant, length and diameter of flower bud). Effects of substrate water potential on the dynamics of the external quality traits were quantified based on the experimental data. Based on these quantitative relationships, a model for predicting the impacts of substrate water potential on the external quality traits of Lilium oriental hybrids. Independent experimental data were used to validate the model. The results showed that the coefficient of determination (r^2) and the relative prediction error (*RE*) between the predicted and the measured values were, respectively, 0.96 and 4.67% for plant height, 0.96 and 1.38% for number of leaf unfolding per plant, 0.97 and 3.67% for length of flower bud, 0.97 and 6.15% for diameter of flower bud. The model developed in this study gives satisfactory predictions of the external quality traits of Lilium Oriental Hybrids, hence, may be used for optimizing water management for Lilium Oriental Hybrids production in greenhouses. Further evaluation is needed if the model is applied to wider range of lily cultivars.

Keywords: model, photosyntheticcally active radiation, temperature, planting date

WA 2.

TOMATO PLANT WATER STATUS AND FRUIT GROWTH DYNAMICS IN RESPONSE TO WATER AVAILABILITY IN THE GROWING MEDIUM

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Current irrigation strategies for tomato are often based on the amount of solar radiation, as it is a major climatic driver for crop transpiration. However, glasshouse climate is expected to change drastically with new approaches of energy saving in glasshouse climate control. It is therefore expected that the relationship between crop transpiration and solar radiation will change, and the current strategies might consequently result in inappropriate irrigation. Because of the limited water buffering capacity of soilless growing media such as rockwool, this could have adverse effects on fruit production and quality. This research presents an overview of tomato (*Solanum lycopersicum* L.) plant ecophysiological responses to substrate water availability, using a unique set of substrate moisture and plant based sensors. The impact of the water availability on plant water status was characterized to allow the formulation and testing of mechanistic hypotheses. The hydraulic properties of the growing medium were therefore taken into account and plant water uptake, stem diameter variations and the dynamics of fruit growth were intensively studied. This study indicated that a small decrease in substrate matrix potential (h) caused a sharp decrease in hydraulic conductivity (K) of the growing medium, which had a significant effect on the water availability for plant roots. Therefore, taking into account the hydraulic properties of the growing medium is of utmost importance for water uptake by plants. The unique combination of plant sensors and soil moisture sensors offers great possibilities to increase the knowledge about plant responses to varying water availability. Finally, this study has shown that tomato plants are able to extract water from their fruits into the stem under conditions of high transpiration and low water availability.

WA 3.

GREENHOUSE CUCUMBER PRODUCTION UNDER DEFICIT IRRIGATION CONDITIONS

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Study was carried out in Yeniköy-Menderes/İzmir (38˚13' N, 27˚03' E, elevation 176 m) during the summer seasons of 2007, 2008 and 2009 in greenhouse cucumber production at farmers' condition. In the first year long cycle crop production was realized while it was two consecutive short cycle crop production in the remaining two years. By using innovative sensor technologies, a full irrigation (no stress) and two deficit irrigation treatments in which soil water content was allowed to be depleted to 40% (deficit 1) and 60% (deficit 2) of the available water content in the plant root zone, were compared with the local farmer's practice. According to the average of three years, the highest yield was obtained from the full irrigation treatment (29.0 kg/m^2) followed by farmer's treatment (25.40 kg/m^2). Recorded amount of irrigation water were 683 mm for Full Irrigation, 545 mm for Deficit 1, 495 mm for Deficit 2 and 717 mm for Farmer's treatments. During the automated irrigation period in growing season, drainage water was only received from full irrigation (11 mm) and farmer treatments (94 mm). The Water Use Efficiency based on marketable yield and irrigation water applied was the highest in Deficit 1 (43.7 kg/m^3) whereas it was the

lowest in Farmers' treatment (35.4 kg/m^3). Calculated water-saving ratio (based on irrigation water applied to obtain one kg yield per m^2) in controlled irrigation treatments in comparison with farmer practice showed that it could be obtained 17%.19% and 17% water saving with full irrigation, deficit 1 and deficit 2, respectively.

WA 4.

MODEL-BASED ESTIMATION OF MOISTURE CONTENT OF ROOT MEDIUM AND IRRIGATION CONTROL FOR SOILLESS CULTURE OF PAPRIKA PLANTS

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Optimum irrigation control with model-based prediction of moisture content of root medium (rockwool) was studied for efficient soilless culture of paprika plants. A continuous measurement system of irrigation, drainage, water content of the medium, transpiration with six paprika plants was developed for the experiment. Environmental factors of radiation, temperature, relative humidity were measured. Two models were developed for estimating transpiration by plants and drainage from root media. The transpiration model included growth (leaf area index) and environment parameters (radiation integral and VPD) and the drain model included physical property of growth medium (container capacity) and current moisture content. A model for estimating moisture content of the medium was developed using two models as above. Under various conditions of irrigations, the moisture contents of the medium and drain ratio could be predicted. Therefore we can develop adequate irrigation strategies applicable to practical situations based on these simulated results.

WA 5.

TRANSPIRATION MODELS FOR GREENHOUSE GERBERA (*GERBERA JAMESONII* H. BOLUS)

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Day-time transpiration rate (E) was modelled in gerbera plants grown in semi-closed soilless (rockwool) culture in the typical greenhouse conditions of Mediterranean region in autumn and spring season. Fresh (1.0 mM NaCl) or saline (9.0 mM NaCl) water was used to prepare the nutrient solution in order to investigate the crop's response to moderate salinity conditions. The use of saline water did not influence significantly crop growth and E in autumn while it reduced considerably leaf area index (LAI), shoot dry matter accumulation, flower production and transpiration under the higher evaporative conditions of the spring. In both seasons, leaf stomatal resistance was not affected by NaCl salinity. Penman-Monteith (PM) equation and a regression model (with global radiation and vapour pressure deficit as independent variables) were used to predict diurnal and nocturnal E, which was measured with a weighing gutter. Several sub-models were implemented to estimate: the evolution of LAI, which was measured by a non-destructive method; the contribution of radiation to crop transpiration; leaf stomatal resistance as function of irradiance and vapour pressure deficit. Regression model was calibrated using different procedures and validated with independent data sets. The best predictions of the PM equation were obtained when heat transfer was considered a result of free convection. Both models allowed good estimation of E in both growing seasons and under different salinity conditions as the model explained more than 90% of the variation of E and the slope of the linear

WA 6.

WIRELESS SENSORS NETWORKS FOR PRECISION IRRIGATION SCHEDULING TO BECOME THE FIRST IoT SERVING THE ENVIRONMENT

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The time is coming when Wireless Sensor Networks (WSNs) will crowd farms to supply information on specific farming variables and to precisely tune operations based on field variability. A market-ready water management system is focused on: (a) a new and maintenance free dielectric tensiometer and (b) the low-power communication protocol for the wireless nodes. The software to process information and take optimal decisions, is focused on the complete Decision Support System (DSS, expert planner, irrigation scheduler and crop response model) and functions as a Web service, accessible from any place on the world with nearby internet connectivity or even through satellite networks can reach any place.
The main deliverable is a water management system that can generally be used at farm level in those situations where the water availability and quality is limited. It is configurable by the farm operator to control water at different scales, and deal with multi-source water management and deficit irrigation. The system, developed by Geomations SA under FLOW-AID, a finished EU FP6 project, is currently in the commercialization phase. In demo sites (Turkey, Jordan, Lebanon, Netherlands) the system applied deficit irrigation scenarios and was compared to conventional methods of irrigation scheduling. It was found to save 5-10% water while, due to regularity of operations, it guaranteed better quality and quantity of produce.
1. The Problem: Agriculture water share varies markedly and can reach up to 80 % in parts of southern Europe, where irrigation of crops accounts for virtually all agricultural water use (EEA, 2009). In arid and semi-arid areas of the EU, including much of southern France, Greece, Italy Portugal, Cyprus and Spain, irrigation allows for crop production where water would otherwise be a limiting factor. "…But when water is scarcer than land, maximizing water productivity is more important. This implies applying less irrigation water in a smarter way, in order to give a higher yield per cubic meter of water evaporated".

2. The solution

This proposed system consists of the following parts:

2.1. Monitoring and Control Hardware (irrigation controller nodes)

This hardware can locally, in each farm plot, monitor all relevant weather and soil parameters like soil moisture (available amount of water in soil), soil hydraulic pressure (extractability of water from soil), soil temperature (evaporation) and electrical conductivity (water quality). It can perform a local (plot) scheduling task, which can be downloaded from the central irrigation scheduler. All controllers in the field today can communicate with the central computer by using telemetric devices (radio transmitters or GSM- modems, WiFi or bluetooth).

2.2. A decision support system (DSS-software for a PC)

This decision support system should help the farmer to optimise the scheduling tasks for the monitor and control nodes in each plot. That is, the farmer will obtain the optimal planning of the use of the water per plot (crop distribution, irrigation scheduling, etc.), in agreement with the characteristics of his farm (area, availability of machinery, water availability, etc.), their production costs and preferences, incorporated like restrictions in the model. The Decision Support System does not need to be installed on the farm, but can be web-based as well, for central maintenance. To evaluate the potential crop yield and so the economic profit, with respect to the amount of water and specific water quality, the irrigation scheduler and crop planning expert make use of a crop salinity and water stress response model. This crop response model is a library containing all relevant data for a number of crops and soil types.

As a result, the irrigation scheduler DSS chooses a specific irrigation program out of a database of predefined programs, calculates the settings of parameters for it, and downloads this set into the irrigation executing nodes for each individual plot. The irrigation nodes will ensure that the optimal amount of water per plot is allocated according to real-time available data.

This web service constitutes a complete system that starts from wireless sensors in the field and sends data on the Internet, where Intelligence is added to the information conveyed by data from the farm and sends back commands to manage a resource. This is the present reality of the Internet of Things (IoT), which is becoming commercial for agricultural applications, while the WSNs cards (nodes) are becoming low cost and mainstream as a high value technology in near future.

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SESSION KEYNOTE II

RECENT TRENDS IN GREENHOUSE MICROCLIMATE STUDIES

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Based on a bibliographic analysis on the recent trends in greenhouse micro-climate studies, it is first shown that the rate of publications about greenhouse micro-climate still increases whereas CFD studies about greenhouses have a tendency to stagnate or slightly regress. Most of the published studies (57%) have been based on a dual modeling plus experimental approach, whereas the remainder concern pure experimental methods. Generally all these studies deal, according to similar proportions, with the questions of greenhouse heating, cooling, screening and crops transpiration.
Substantial advances are observed in the fields of experimental characterization using wireless sensors and exploitation of these data by means of geostatistical methods for climate and plant activity. The progress in CFD assisted characterization of the phenomena occurring in greenhouses is also very sensible, particularly concerning : (i) the characterization of the distributed climate in very large scale (1 hect or more) greenhouses, (ii) the CFD modeling of very intricate geometries such as weaved screens or cellulose evaporative cooling pads or (iii) complex phenomena involving coupled mechanisms such as fogging and ventilation, fungal spores transfer in air or algae's in algae reactors used in greenhouses.
The question of radiative transfers within greenhouses prompts renewed interest on modeling radiative transfers within greenhouses. It aims either to a revisit of the description of the general relations for estimating the amounts of solar energy absorbed by the greenhouse components or to a numerical modeling of the radiative transfers. The first approach highlights the considerable amount of incident radiation which is lost to outside the greenhouse and should be considered in the thermal analysis of greenhouses, whereas the numerical approach ends at a numerical coupling of radiative and convective transfer equations and a very detailed and precise description of climate conditions at levels of greenhouse and crop cover.
Finally, the contributions of these recent progresses are examined with respect to the improvement of the climate conditions in the major production systems designed to cope with greenhouse sustainability: the closed energy saving greenhouses for northern latitudes and the simple Canarian type shelters for southern ones.

GM 1.

THE EFFECT OF SHADING NETS ON GREENHOUSE MICROCLIMATE AND CROP PERFORMANCE

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A major problem confronting the Mediterranean greenhouse horticulture is the excess of heat during the summer. One of the methods to alleviate the heat load is shading with nets. Shading nets can either be fixed or mobile. They can be external (above the greenhouse) or internal (inside the greenhouse above the crop). Experiments were carried out in a greenhouse in which a tomato crop was grown. The greenhouse was divided into two compartments of three spans each. In one compartment a 30% shading net was applied above the greenhouse, on top of the polyethylene cover, while in the other compartment it was stretched inside the compartment, at gutter height and parallel to the soil. Solar radiation outside and inside the greenhouse and light intensity above the crop and at soil level, and air temperature and humidity were measured over the growing period continuously. In addition, leaf temperature, photosynthesis and transpiration were measured on several days. In each treatment crop yield and quality was monitored together with LAI and plant height. The results show that net position does not significantly affect the values of most measured parameters. Few parameters however, appear to be affected by the different net position.

GM 2.

MODELING THE EFFECT OF THE POSITION OF COOLING ELEMENTS ON THE VERTICAL PROFILE OF TRANSPIRATION IN A GREENHOUSE TOMATO CROP

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The advantages of reducing greenhouse ventilation are reduced pest pressure; the chance of maintaining a higher carbon dioxide concentration; reduced heating requirements; which, altogether lead to a higher productivity. However, even at the latitude of The Netherlands, ventilation can be significantly reduced only by applying other means of cooling and only mechanic (rather than evaporative) cooling is compatible with reduced ventilation. With respect to the position of the cooling elements there is a trade-off to be made between positioning above the crop (which would warrant the most uniform vertical profile of temperature) and positioning below (which prevents light loss). The research question addressed here is: can we quantify the effect of the positioning of the cooling elements on the vertical profile of transpiration within the crop canopy? In this work we use the energy balance of each crop layer to develop a modified "big leaf" model for its temperature and transpiration. The model is then validated with data from a large greenhouse experiment (tomato) involving two positions of the cooling elements; two temperature set-points; and a control (not cooled and naturally ventilated) compartment. For the validation we used measurements of crop temperature at different heights in the canopy and of transpiration of the whole crop. Finally we used the model to determine and discuss the effect of the various types of air conditioning on the profile of transpiration within the crop. The compartment with natural ventilation had the highest simulated transpi-

ration (which agreed with the measurements) and the largest uniformity of distribution of transpiration among layers. As expected, the least homogeneous distribution was with the cooling elements below, which had also the smallest transpiration. The difference in total crop transpiration brought about by the position of the cooling elements, however, was only about 5%.

GM 3.

CLIMATE CHANGE EFFECTS ON GREENHOUSE TOMATO PRODUCTION FOR A SPECIFIC REGION IN MEXICO

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One of the sectors more vulnerable to climate change in Mexico is agriculture, in which there is a combination of extreme climate conditions and vulnerability due to weak infrastructure. Greenhouses reduces the negative effects of climate but requires high investments; therefore, an important research area in the development of greenhouses is energy which constitutes a high percentage in production costs. Because, the future impacts of climate change are subject to regional variations, this work is concentrated in greenhouse tomato production for a specific region located close to Pacific Ocean in Mexico. Some indices related to climate change are calculated for the last years, and the monthly temperature and relative humidity dispersion diagrams are depicted for the study period in order to identify if climate conditions have changed in the last years and compare this results with the comfort zone for tomato production. Also the enthalpy inside and outside of the greenhouse is calculated under the four climate change scenarios expected by 2020, this could be an indicator of the energy required to maintain optimal conditions for production. The results will allow us to identify the most critical months and planning seasonal tomato production to save water and energy, which can imply changes in planting schedules and crop management.

GM 4.

EFFECT OF THE HETEROGENEITY OF THE RADIATION DISTRIBUTION ON THE CROP ACTIVITY

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The crop activity inside a greenhouse is strongly affected by the local microclimatic conditions (radiation, temperature and humidity of air in particular). In order to reduce the consumption of energy and water, the control of these parameters is of prime interest. The objectives of the present study are: (i) to analyse the evolution of the microclimate in the vicinity of the canopy all day long and (ii) to assess the impact of the spatial heterogeneity of the radiation distribution on the air humidity and evapotranspiration of the crop. A 100 m^2 greenhouse compartment located in Angers (47° 28' N, 0° 33' E) was equipped with a set of sensors including temperature and humidity probes as well as solar silicium cells and pyranometers. The evapotranspiration was measured at two locations with balances. Under rather clear sky conditions, the horizontal distribution of the radiation reaching the crop was analysed and its impact on the evapotranspiration, the humidity and the temperature inside the crop was investigated. The values of the climatic parameters averaged over time (from 9 am to 5 pm) evidence the role played by the heterogeneity of the radiation distribution on the crop response and on the microclimatic conditions in the vicinity of the plants. At a shorter time scale (2 hours), strong heterogeneities are also observed : different evolutions of their characteristics all over the day have been noticed. Knowing both the spatial distribution and temporal evolution of the crop activity could help identify the plant requirements and adapt a strategy for heating and irrigation.

GM 5.

VERTICAL TEMPERATURE GRADIENTS IN A CROP: A PHYSIOLOGICAL EXPLORATION

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Microclimate management currently opens avenues for more specific crop management. The positioning of SON-T or LED lamps, cooling ducts and heating pipes all influence the vertical temperature gradient in rising crops, with consequences for organ temperature and therefore development rate, and for transpiration rates. Only strong temperature differences have consequences for photosynthesis rates.
Experiences and model calculations with temperature gradients will be summarized, and the consequences for growth and development will be explained on the basis of underlying physiological mechanisms. Taking tomato as an example crop, a change in surrounding air temperature affects organ temperatures in the top of the canopy and consequently truss and leaf appearance rates. An increase in air temperature somewhere along the canopy profile results in earlier fruit ripening in terms of days (not in terms of degree-days). The cumulative effect over all trusses is a reduced plant load (if truss appearance rate is not increased). The increased temperature also causes a larger fruit sink strength. The impact on production depends on the balance between the latter two mechanisms. If leaves remain removed around the moment of truss harvest, which will occur earlier, then LAI, light interception, growth rate and ultimately production will be lower. This mechanism introduces at least for tomato a production risk. This does not apply to crops of which the leaves are not removed, such as sweet pepper and cucumber. Here, increased maintenance respiration rate may play a more dominant role.
To determine the desired temperature profile, the change in temperature must be integrated over canopy depth. This value is a direct measure for the time to fruit maturity measured in days, and also for the moment of leaf removal. Operational actions to balance physiological processes, and optimize production can be adjustment of the height or temperature of heat sources.

GM 6.

MEASUREMENT AND ANALYSIS OF AIR FLOW AND AERIAL ENVIRONMENT OF RICE PLANT CANOPY IN A CLOSED PLANT PRODUCTION SYSTEM

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A completely closed plant production system has been developed to produce genetically modified (GM) rice plant. In this system, the rice plant, expressing an exogenous antigen protein in seeds which can induce mucosal immune responses, is cultivated. Since these rice seeds are for medical use, a stable expression and high accumulation of the targeted protein in the seeds are required. The expression of exogenous protein is widely influenced not only by plants' genetic background but also by growth environment. Thus, the closed system is required to achieve highly controlled environment and to grow the GM rice plants under uniform optimal conditions. In this paper, the detail of this system and spatial and time-series measurement of aerial environment of the plant canopy are presented. The system includes a cultivation room (3.73m W x 3.93m L x 2.00m H) and 12 hydroponic containers (60cm x 90cm). 56 x 400 W metal halide lamps mounted on the ceiling give 1000 μmol m^{-2} s^{-1} PPF on the cultivation bed surface. The air, of which temperature and humidity are controlled by an air-conditioning system, flows through plant canopy in a horizontal direction from the outlet of room wall. Rice plants were grown at a planting density of 120 m^{-2} from seedling stage to harvesting time. Measurement of horizontal profile of air temperature inside plant canopy showed that the temperature was highest at the middle part of canopy. Although the absolute humidity was high at the downstream part during seedling stage, it became high at the middle part during and after tillering stage. The result indicates that air movement in and out the canopy depends on plant canopy structure and that precise control of air flow based on plant canopy development is necessary to create uniform aerial environment of plant canopy for photosynthesis and transpiration.

GM 7.

MICROCLIMATE INSIDE GREENHOUSE VERSUS SCREENHOUSE

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Abstract
Cultivation in controlled climate has increased in recent years in arid and semi-arid countries like the Sultanate of Oman. This type of cultivation has shown its positive outcome in terms of corps's quantity and quality in these countries where harsh weather and scarce water are prevailing conditions. However, optimizing the structure of the controlled environment has become a major concern for the purpose of saving electrical energy and water consumption. The biophysics of two types of agricultural controlled environment, currently used in Oman, has been evaluated. They are a fan-pad cooling greenhouse covered with a 200 micron UV plastic and a 100% natural ventilation screenhouse covered with an 80 micron insect proof screen. Relative humidity and air temperature have been monitored horizontally and vertically across both structures. Inside solar radiation was monitored at center of both structures below the covers. Preliminary analysis shows that although the temperature near cooling pad side of greenhouse was colder than it is near the opposite (door) side, maximum by 4 °C at midday, the relative humidity at this side was lower than the door side. The temperature at the center of screenhouse became higher than both front and back sides of the screenhouse especially at the midday. However, there was no big difference in relative humidity between relative humidity inside all sides of the screenhouse. There was no difference in inside air temperature between the greenhouse and screenhouse during night time however the difference increased during the day and reached its maximum at midday. This difference increased when the outside air temperatures increased. Relative humidity was always lower than inside the greenhouse where the difference between them reaches 48% especially after midnight. Overall, although screenhouse did not use any forced cooling system as in greenhouse, it has created an inside climate that was suitable for vegetable production until the end of spring season.

Keywords: greenhouse, screenhouse, microclimate, controlled environment, natural ventilation

ENII 1.

CONTROL STRATEGY FOR THERMAL SCREENS OPENING IN GREENHOUSES: AN ALGORITHM FOR MINIMIZING HEAT LOSSES

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Thermal screens are known to reduce heating requirements of greenhouses and therefore are now becoming widely implemented. Previous studies have found that delaying the thermal screens opening after sunrise can increase energy savings. Energy efficient glass with low emissivity (low-e) coating can now be combined with anti reflective (AR) coating thus offering better thermal performance without reducing significantly solar radiation transmission. The objective of this paper is to test different combinations of double glazing and thermal screens and to develop an algorithm defining the optimal opening of thermal screens for minimizing heat losses. Regular clear double glass, AR double glass and AR with low-e double glass are considered. Up to two thermal screens are modelled: one opaque and highly reflective with low emissivity integrated within the window panes and another one with a high transmittance installed on a separate structure, closer to the crop. A transparent thermal screen is useful because it can be used during the day while allowing light to reach the plants. Combining two thermal screens softens the rather abrupt temperature change that can be observed at the opening of the thermal screen when only one screen is present. Simulations are carried out for an east west oriented solar greenhouse located in Montreal. An insulated and thermally massive north wall acts as a passive thermal storage and buried piped in the ground are used for additional thermal storage.

ENII 2.

THE CLOSED SOLAR GREENHOUSE – TECHNOLOGY AND EVALUATION OF ENERGY HARVESTING UNDER SUMMER CONDITIONS

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For energy generation from thermal solar radiation greenhouses are usable in case of closed operation and cooling technology. Beside the problem of long time energy storage, the closed run of greenhouses, the assembly and capacity of cooling and heating systems, and the operation control of the micro climate and energy management system are in the focus of research. A new prototype of solar greenhouse was built up at Humboldt University Berlin. In a 300 m^2 Venlo type greenhouse a cooling fin system under the roof was connected to a heat pump and a low temperature storage tank. By a new technology for integration of the heat pump into the hydraulic pipe system several operation modes are possible for heating and/or cooling the greenhouse and charge or discharge the thermal storage. First results of operation behavior will shown by using typical evaluation parameter like cooling capacity, collector efficiency, and coefficient of performance for the heating and cooling operation. With the cooling fin system (surface 680 m^2) the cooling capacity comes up to 250 W/m^2. The latent to sensible heat exchange ratio is about 30% to 70%. The among of water witch was condensate on the fin surface was at a maximum of 1.2 $l/(m^2d)$. Condensation was increasing with daily solar radiation sum (600 to 1200 kWh). Inside this interval the collector efficiency of the solar greenhouse is at 0.6 to 0.7. The heat pump is working for greenhouse cooling with a seasonal energy efficiency ratio of 4.9 and within the heating operation the heating season performance factor is 4.6.

ENII 3.

UP SCALING AND TEST RESULTS OF AN ADVANCED FRESNEL GREENHOUSE

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At Wageningen UR a Fresnel greenhouse was developed with a set of 12 linear Fresnel lenses mounted in the south side of the cover of a 6 x 6 m^2 test prototype greenhouse. In April 2010 was started with an up scaled version with a total size of 500m^2. The system was improved by using an asymmetric covering, antireflection coated glass and lenses with in increased aperture. With this size it will be possible to keep illumination and indoor temperature at the appropriate level for pot plants and beside the energy yield measurements also reel cultivation experiments could be performed with this greenhouse.
The Fresnel lenses are able to separate direct and diffuse light. All focussed direct radiation can be used for the generation of energy by linear photovoltaic modules (PV module) in the focal line and the non focussed diffuse light can still be used for plant growth. At high radiation conditions in summer the capture of all direct radiation intensities results in better climate conditions in greenhouses. Especially for pot plants, often needing lower light intensities, this offers interesting possibilities.
First the properties of the new linear Fresnel lenses were tested on concentration factor, focal distance and light transmission. Linear Fresnel lenses with sizes of 1x1.6 m were chosen and mounted between an AR coated double glass structure to avoid water condensation and pollution on the lenses. The use of the AR coating on glass will keep the total light transmission on a high level. For the stand regulation only the collector has to move in two dimensions. In total about 40m PV/T modules are used in this greenhouse to generate electrical and thermal energy (hot water). The other receivers are carried out as a heat water collector tubes for the generation of hot water. They are controlled in the correct horizontal and vertical position. The energy output, short circuit current (I_{sc}) and open cell voltages (V_{oc}) are measured during clear days.

References: Tripanagnostopoulos Y., Siabekou Ch., Tonui J.K., 2007, The Fresnel lens concept for solar control of buildings, Solar Energy, 81, p.661-675

Keywords: Fresnel lens, Greenhouse, solar energy, photovoltaic

ENII 4.

THE EFFECT OF FRESNEL LENS-SOLAR ABSORBER SYSTEMS IN GREENHOUSES

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Fresnel lenses can be mounted stationary on the greenhouse roof combined with linear absorbers to receive and convert the concentrated solar radiation into heat, electricity or both. The linear Fresnel lenses can separate direct from diffuse solar radiation and this advantage makes them suitable for lighting and temperature control of the greenhouse interior space. The incident beam solar radiation is concentrated on the tracking PVT absorbers and can be taken away from the glazed space. In this way, lower illumination level is achieved while avoiding overheating of the interior space. Furthermore, in low intensity solar radiation, the absorbers can be out of focus leaving the light to come in the interior space and keep the irradiation at an acceptable level for the plants. The proposed system can cover a great part of greenhouse thermal as well as electrical load and seems to be a promising solution. Apart from the above mentioned contribution to greenhouse energy needs, Fresnel/PVT influence greenhouse interior space by the heated linear thermal absorbers, which are in higher temperature than the rest greenhouse components and plants. These absorbers work as linear "heat sources" of infrared radiation and influence mass and heat transfer (HT) as well as fluid flow (FF) phenomena in the greenhouse. In the frame of the present study, a greenhouse with Fresnel/PVT, operated under some defined conditions of solar radiation input and ratio beam to total, ambient temperature and wind speed, is considered. Regarding roof operation modes, configurations with and without roof openings are investigated and results for both cases are given. Computational Fluid Dynamics (CFD) methodology is used for the simulation of HT and FF phenomena involved in the above mentioned cases. Results such as FF fields and temperature contours are presented. In addition, some horticulture aspects provide a wider view of the studied issues by considering the effect of HT and FF patterns on plant processes.

ENII 5.

EXPERIMENT ANALYSIS OF HEAT RELEASE AND STORAGE WITH WATER FOR TEMPERATURE RISING IN SOLAR GREENHOUSE

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Wall and ground play an important role in heat storage in greenhouses. Studies showed that the amount of heat stored in wall accounts only 35% ~40% of the total stored energy in the coldest month in a solar greenhouse. The north wall was always designed too thick, and a large number of construction materials was used, which cause the waste of land resources and the increasing of the cost. In this study, to transfer the heat stored in the wall into the soil may be the key to simplify the wall. Solar energy is used as heat source, water is used as heat exchange medium and shallow soil in greenhouse is used as the thermal mass. The heat was collected and stored in shallow soil through water circulation during the day, and the greenhouse temperature increased at night due to the soil heat releasing. The results showed that: this method increased the heat storage of greenhouse. The temperature difference began to increase after covered the insulation. The average air temperature in experiment greenhouse is 4.0 ^{0}C higher than in normal greenhouse. The soil temperature at 0cm,30cm,60cm in the experiment greenhouse is 3.0 ^{0}C,3.0 ^{0}C, 5.0 ^{0}C higher than in the normal greenhouse respectively. Therefore, this method not only increased the air temperature, but also increased the temperature of soil around which crops grow.

ENII 6.

PROTOTYPE DEVICE FOR FLUID FLOW MANAGEMENT IN COAXIAL PIPES OF ROOT ZONE HEATING SYSTEMS

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The soil or the soil-less substrates for horticultural greenhouse cultivations need to be heated during the winter. Usually the ground is heated by means of an hydraulic system associated with a boiler.
A prototype of an innovative hydraulic system, consisting of coaxial pipes, was designed and tested in 2008 and 2009 with the aim to reduce energy consumption and to obtain a higher temperature uniformity along the baseline in the substrate, compared with a traditional root zone heating system. The innovative system showed very interesting results during the winter season, but during the early spring and autumn tests, when the greenhouse was heated only during the night, the system resulted slow in reaching the set temperatures and consumed more energy.
This suggested the design and test of a prototype for the management of hydraulic fluid flows in the coaxial pipes of the innovative root zone heating baseline. The preliminary trials were carried out in march-april 2010 under the Italian Research Project "F.LO.R.ENER."
In relation to the external environmental conditions and to the requirements of the new heating system, the device allowed the management of the flow of fluid streams in the coaxial tubes from a countercurrent flow system to a concurrent flow. This feature allowed better operating conditions for the innovative heating system, i.e. higher heating uniformity and energy saving, also in spring.

The tests showed the positive features of the prototype that, in comparison to the conventional root zone heating baseline, led to a better temperature homogeneity in the crop substrate and showed a mean 28% reduction of energy consumption.
Further trials will be conducted for longer periods during the next autumn and spring 2010-2011.

ENII 7.

SENSIBLE AND LATENT HEAT RATIO IN CONTROLLED AGRICULTURE

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The main objective of this paper is to show the total energy found in controlled agriculture as a function of its components under different conditions located in Germany and Mexico. The strong differences of heat capacity between dry air and vapor makes feasible to storage a significant amount of energy as temperature increases. Since rational knowledge of the laws of the nature and the technological limitations requires to know the role temperature and humidity, thus the enthalpy with three different diagrams are used, including Mollier and Carrier diagrams in a 3D framework. As a result, decisions to handle an intensive agricultural system inside the ideal levels of production are suggested.

SESSION KEYNOTE III

COVERING MATERIALS FOR SUSTAINABLE GREENHOUSE ECOSYSTEMS

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World-wide the availability of natural resources is decreasing (water, gas/oil, fertilizers), while the world population is growing. That makes is necessary to move more and more from open filed production to simple protective structures up towards advanced technology greenhouses in order to increase crop production and quality, make production highly predictable and to reduce scarce resource use. Covering materials enable to protect the crop from harmful events (extreme temperatures, extreme rainfall or drought, pest and diseased etc.).
Current research is focussing on creating the right microclimate for the crop and save water and pesticides (e.g. Skirvin et al, 2011). Light transmission of materials remains a challenge (SuarezRay et al, 2011) in all climates next to condensation properties (e.g. Kitta et al., 2011). Further improvement of crop yield and quality in low tech and mid tech greenhouses is expected from photoselective coverings in warm climates (e.g. Alsina et al. 2011). The effect of the covering on the greenhouse inside temperature is an important research question (e.g. Ma et al. 2011; Kitta et al, 2011). Reducing greenhouse temperature by materials with NIR decreasing properties are still a challenge (e.g Stanghellini et al, 2011) in order to see if they give possibilities for improving greenhouse microclimate. In modern greenhouse industry materials with a long lifetime and very high light transmission are required. Nanotechnology is used to reach that goal. Research is developing glass with modern coatings, anti-reflective coatings, diffuse light. Double glass with low emission coatings (Hemming et al., 2011) and double plastic (Sim at al, 2011) is investigated in order to save energy. Diffuse light has been proven to be valuable for an increased crop production (Hemming, 2009; Stanghellini et al. 2011).
The challenge for research remains since several years the same: Finding the right covering material combing a high light transmission, low energy and water consumption, creating the ideal microclimate for a high quality crop production, which is economically interesting for growers. A future challenge would be to develop materials with are able to adapt to seasonal changes in outside conditions. Developing the right covering material for a given local climate condition and crop requirement is the first step towards sustainable greenhouse ecosystems.

Keywords: light transmission, light quality, energy saving, microclimate, anti-reflective coating, low-emission, NIR reflection, photoselective, plastic film, glass

CM 1.

GLOBAL, PAR AND DIFFUSIVE RADIATION TRANSMISSION OF AGRICULTURAL SCREENS: PRELIMINARY REPORT

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The use of low-cost greenhouse frames covered with screens (nets) for growing vegetables and other crops is spreading in the Mediterranean area. Agricultural screens are commonly characterized, in commercial terms, by the degree of shade that they provide. Measuring this shading degree, that is not representative of normal growing conditions, requires expensive equipment and is quantified by the global radiation transmissivity at incidence angle of zero. A low-cost and simple metal framework prototypeâ was designed to quantify global, PAR and diffusive radiation transmission of agricultural screens in the open air, determining their characteristic transmission curves for global radiation and PAR (Photosynthetically Active Radiation), and the diffuse radiation transmission characteristics of the screens. Several commercial screens were tested. The global radiation and PAR characteristic transmission curves of the tested screens, measured with this framework prototypeâ, will be presented. Complementary information on the diffuse and direct components of the radiation transmitted through these screens will be presented.

CM 2.

VALIDATION COMPARISON OF TWO TYPES OF PLASTIC COVERING MATERIALS UNDER MEDITERRANEAN GROWING CONDITIONS: NIR ABSORBING POLYETHYLENE VS. STANDARD POLYETHYLENE

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In some geographic areas, during the warmer season, it is very frequent to avoid the excessive heating of the greenhouse using interior shading screens or whitening the exterior face of the cover, both solutions at the expense of loosing Photosynthetically Active Radiation (PAR). This problem could be solved by cutting-off the transmission of solar thermal energy (near infrared; NIR), comprised between 760 and 2500 nm, approximately. Interference pigments, which cause reflection of the NIR radiation, or other nanoparticles that cause its absorption, can be added in the formulations of flexible film covering materials. Evaluating the effect of such selective filtering is developed as an activity of the Euphoros European collaborative project. Simulations have been performed first to evaluate a priori the effect of two prototypes with two different NIR absorbing pigments, applied with two density levels. All pigments did have some absorption in the PAR (Photosynthetically Active Radiation) as well. The simulations sug-

gest that many factors (for instance modified ventilation requirement, absorption by the cover of the radiation reflected by the crop) may combine to determine the overall effect of the filter on winter crop production. Therefore the most promising among the simulated prototypes has been implemented in an experimental greenhouse in Almer a, and its performance compared with a standard polyethylene test film. The experiment is in progress and the paper will describe and discuss the results.

Keywords: radiation balance, filter films, greenhouse cooling, optical properties.

CM 3.

EFFECTS OF ANTI-DRIP POLYETHYLENE COVERING FILMS ON MICROCLIMATE AND PRODUCTION OF A GREENHOUSE TOMATO CROP

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One important issue for greenhouse producers to deal with is the management of high humidity levels during the cold period of the year. Recent endeavors on greenhouse heating energy saving have resulted in an increase in the air relative humidity, due to the use of even more airtight greenhouses. It has unequivocally shown that a high level of humidity is a factor that directly affects the fruit yield and quality of greenhouse crops by pre-disposing these crops to fungal diseases. Recent year's concerns about food safety, environmental pollution, worker's safety, resistance to chemicals and the need for rational use of energy stimulated extensive research concerning the development of sustainable humidity management techniques. Such a technique is the use of anti-drip (AD) and anti-fog (AF) cover materials. Aim of this work was to study the effects of two AD PE cover materials on greenhouse microclimate and on growth and production of a hydroponic tomato crop. The experiments were carried out from February to May of 2007 in three similar greenhouses, covered by different cover materials. A standard polyethylene (PE) film covered one of the three greenhouses (C-PE). The other two greenhouses were covered: the first by a PE film with anti-drip (AD) and anti-fog (AF) properties (AD+AF-PE) and the second one by a PE film with AD properties (AD-PE). The greenhouse and outside microclimate parameters along with crop growth and production were recorded. The results showed that the relative humidity levels were higher in the AD-PE covered greenhouse. The crop development and production was similar in the three greenhouses.

Keywords: anti-fog, relative humidity, condensation

CM 4.

NEW GREENHOUSE CONCEPT WITH HIGH INSULATING DOUBLE GLASS WITH MODERN COATINGS AND NEW CLIMATE CONTROL STRATEGIES – MODELLING AND FIRST RESULTS FROM A CUCUMBER EXPERIMENT

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The goal of the Dutch horticultural sector is to build new greenhouses in 2020 without the use of fossil energy and reduce CO_2-emissions with 45% compared to 1990. Research is therefore focused on reducing energy losses through the covering and to develop new energy saving growing strategies.
Until now, energy losses through the covering are reduced by closing energy screens, mainly during night time. However, even higher insulation values can be reached by insulating double covering materials. Hemming et al. (2009) presented a study with new developed coverings using anti-reflection coatings to increase light transmission and low-emission coatings to reduce energy losses of double glazing.
The study has lead to an integration of one of those glasses in a total greenhouse concept of 500 m^2, realized in summer 2010 at the research station of Wageningen UR Greenhouse Horticulture in Bleiswijk. The glass used has light transmission of 89.0% perpendicular and 79.6% hemispherical and an u-value of 1.1 $Wm^{-2}K^{-1}$ (compared to 6.7 $Wm^{-2}K^{-1}$ of a single glass greenhouse).
In order to develop the optimum growing strategy scenario calculations of greenhouse climate (temperature, humidity, CO_2) and energy consumptions year-round were carried out with a validated dynamic climate model. Effects on cucumber production (dry matter) were calculated. That way the optimum growing strategy in terms of low energy consumption combined with a high cucumber yield was developed. Model calculations showed that a cucumber production of 75kg/m^2 and year should be possible with a gas consumption of 12 m^3/m^2, an electricity consumption of 8kWh/m^2 and a CO_2 consumption of 43 kg/m^2. That way the energy consumption per kg cucumber would be reduced from 0.53 m^3 gas equivalents to 0.19. The theoretical strategy is currently tested in an experiment in the new built greenhouse in Bleiswijk. Cucumbers were planted at 5th of August, the first crop will end in November.
The paper will describe details of the new growing strategy and results of the model calculations compared with real experimental results.
The research is carried out together with Scheuten Glass, Boal Systems, Maurice greenhouse builder, Climeco Engineering and is financed by the Dutch Ministry of Agriculture, Nature and Food quality and the Productboard of Horticulture.

Keywords: energy saving, covering material, coatings, u-value, climate control strategies, cucumber, greenhouse design

CM 5.

COLOURED COVERING MATERIALS FOR PEACH PROTECTED CULTIVATION

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Spectral wavelength distribution and quantity of solar radiation influence plant photosynthesis, photomorphogenesis, phototropism and photoperiod. With regard to photomorphogenesis, vegetative and reproductive growth processes are influenced by the photoreceptor phytochrome and by the cryptochrome. In literature the phytochrome response is characterized in terms of radiation rate in the red wavelengths (R, 600-700 nm) to that in the far-red radiation (FR, 700-800 nm), i.e. the R/FR ratio. The effects of the blue radiation (B, 400-500 nm) on the morphogenetic responses of plants can be investigated by studying different ratios between the blue radiation and the photosynthetically active radiation (PAR, 400-700 nm), i.e. the B/PAR ratio, and between the blue radiation and the far-red radiation, i.e. the B/FR ratio.
Aim of this paper is to investigate the influence of coloured nets on peach trees. A 40% shading blue net, a 40% shading red net, a 40% shading yellow net, 40% shading pearl net, 40% shading grey net and a 12% shading neutral net were installed on steel greenhouses (6 m x 6m) at the experimental farm of the University of Bari, latitude 41° 05' N. Peach trees were located in pots inside the greenhouses and in open field.
The growth of the peach trees cultivated in open field was lower in comparison to the growth of the trees cultivated under the coloured nets. The red and blue nets influenced the spectrum of the solar radiation passing through the nets modifying investigated radiation ratios. Both the nets increased the growth of the trees more than the neutral, pearl and grey. The nets influenced positively the fruit characteristics, such as size, colour and sugar content, in comparison to open-field.

CM 6.

PHOTOSELECTIVE FILMS IN PEST AND DISEASE CONTROL

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Plastic covered horticulture is a rapidly growing industry, though major challenges in pest and disease control remain. A number of factors contribute to this; in Europe the removal of products from the market as a result of the European Commission directive 91/414/EEC (resulting in a loss of 74% of chemicals available in 1993), increased pressure to reduce crop residues in a consumer market with an increasing preference for environmentally friendly produce and economic pressure to reduce both costs and carbon footprints. An alternative to chemical control is the use of photoselective films. Altering the light environment has been shown to have beneficial impacts for pests and diseases. Developments in the production of photoselective polytunnel cladding have meant that their use is now cost effective and can form an important part of IPM programs. The wavelengths with most potential for crop protection are those in the UV region. Altering these wavelengths has been shown to reduce disease pressures through the disruption of key morphogenic processes, direct damage, host-mediated responses and vector interference. Mechanisms for reduction in arthropod pest pressures through altered UV levels occur through deterrence, disruption of navigation, both direct and indirect damage, and through the attraction of biocontrol agents to UV-induced plant signals. This talk will present the results of work to determine the effects of five photoselective films active in the UV region on two common pest and disease systems. The first assessed the population dynamics of *Tetranychus urticae* (two-spotted spider mite) and the control efficacy of its biocontrol agent, *Phytoseiulus persimilis*, on rose. The second assessed the disease development and sporulation rate of *Oidium neolycopersici* (tomato powdery mildew) and the control efficacy of its biocontrol agent, *Bacillus subtilis*, on tomato. These suggest a role for such plastics in areas with high incidence of UV radiation.

CM 7.

GREENHOUSE CLIMATE AS AFFECTED BY A DIFFUSE GLASS COVER: FIRST RESULTS FROM A ROSE EXPERIMENT

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High energy use in rose cultivation at higher latitudes is caused by the need for artificial light to supplement scarce sun radiation. On the other hand, too high radiation levels are known to reduce flower quality. Therefore shading is widely applied during spring and summer, either through movable screens or seasonal whitewash. In both cases damage to the crop is avoided at the cost of reducing potential assimilation.
Recent research on cucumber (Hemming et al., 2008; Dueck et al., 2009) has shown that diffusing cover materials have the potential of improving the uniformity of vertical light distribution in a crop, therefore decreasing the energy load on the uppermost crop layer to the advantage of underlying crop layers. Diffusion, however, usually implies a loss of overall transmission. This drawback can be avoided by antireflection coatings and diffusive glass covers have recently become available with the same transmission as standard glass.
The potential energy savings of such a cover on roses are based on a decreased need for shading (less artificial light requirements). Therefore, an experiment is in progress on a rose crop (cv Red Naomi) at the research station of Wageningen UR Greenhouse Horticulture in Bleiswijk in two compartments, one covered with normal horticultural glass; the other covered with diffuse glass with anti-reflection coating. The resulting properties of this diffuse glass are as follow: light transmission of 93% perpendicular and 83% hemispherical with a haze factor of 72%
The paper will describe in detail the effect of the diffusing cover on the greenhouse climate (air- and plant-temperature, humidity and ventilation requirement), water balance and energy use compared to the greenhouse covered with standard glass. The research is financed by the Dutch Ministry of Agriculture, Nature and Food quality; the Dutch Horticultural Board and the European cooperation project EUPHOROS.

CCI 1.

TOWARDS A MORE SUSTAINABLE, WATER EFFICIENT PROTECTED CULTIVATION IN THE GULF REGION

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Water scarcity is becoming a major problem all-round the world. Specially in the Gulf region where rainfall is minimal, current agriculture relies on deep water resources. The main source of water for agriculture is coming from groundwater. As these resources are depleting, alternative resources have to be exploited and the remaining water has to be used more efficiently.
Cooling of greenhouse in arid regions is done by evaporative cooling. The transpiration of the crop forms a important part of the cooling usually in combination with a mechanical system such as pad and fan. The evaporated water is not reclaimed for the air and is therefore lost. The only alternative method of cooling is convective cooling where a cold surface is used. Through the application of this method the greenhouse can be closed meaning not air exchange between the greenhouse and the outside is needed.
Closed greenhouses are the ultimate production systems since the greenhouse climate can be regulated optimally. Furthermore all the water used will be recycled in the system, drastically increasing the water efficiency. Carbon dioxide enrichment can be applied in these greenhouses which can increase production by 40% given the proper climate. More than 100 kg of tomato per square meter of greenhouse is possible given the amount of solar radiation available in the Gulf region and the reference cases in the Netherlands. Carbon dioxide can be supplied by pure CO2 or by burning natural gas. Finally pesticide use is decreased as insects are kept outside.
The cooling need depends on the solar heat load inside the greenhouse and the convective heat load as the outside temperature is higher than the greenhouse temperature. Dynamic simulation results using the climatic data of Riyadh showed that a conventional greenhouse needs a maximum of 650 W of cooling capacity per square meter of greenhouse. Through the application of spectral selective covering materials and insulation the maximum cooling capacity can be reduced to less than 500 W per square meter of greenhouse. On an annual base 4GJ of heat has to be removed from the total of 7 GJ of solar energy.
Though the investment costs of a high tech greenhouse are considerable. The economic evaluation shows that a high tech greenhouse is economically more attractive than the traditional greenhouse.

CCI 2.

ZINEG - THE LOW-ENERGY GREENHOUSE: THE EFFECT OF HIGH HUMIDITY ON TOMATO PRODUCTION IN SEMI-CLOSED GREENHOUSES

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Greenhouses with a low consumption of primary energy are designed to collect and store the heat energy obtained from solar radiation for use at night or in the cold season. Keeping the greenhouse ventilation closed for the longest possible time during sunny periods maximises the heat energy extraction. It is known that high temperatures can be harmful to plants, particularly because pollen may become sterile above 33 °C. In a previous experiment, however, the fruit set was also significantly hampered at a ventilation set point of 30 °C, probably combined with high relative air humidity. For this reason, we studied the effect of high humidity combined with high temperature on tomato growth. Tomato plants were grown from June to September in six greenhouse compartments. The set points for ventilation during the day were 70, 85, and 95 % relative humidity in two compartments each. In addition, ventilation opened at 30 °C and at 75 % relative humidity at night in all compartments. Extremely high humidities during the day occurred in August/September, when the leaf area was fully developed and air temperature in the greenhouse seldom exceeded 30 °C. Hence ventilation seldom opened in the 85- and 95-% humidity treatments. These conditions resulted in marked reductions in the fruit set, which fell by about 50 % at the ventilation set point 85 % compared to set point 70 %, and to almost zero at set point 95 %. Photosynthesis, however, remained virtually unaffected by humidity. Moreover, yield was not reduced by high humidities as long as fruit from flowers pollinated during lower humidities in June/July was harvested. At high humidities, however, the pollen agglutinated, inhibiting pollination.

CCI 3.

EVALUATION OF EVOLUTIONARY ALGORITHMS IN PARAMETER ESTIMATION OF A GREENHOUSE CLIMATIC MODEL

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In the current research were carried out the analysis, calibration and validation of a mathematical model to describe the main climatic variables (air temperature and humidity) of a greenhouse under semi-arid environmental conditions of the Mexico central region. Data were collected from a greenhouse which is part of Universidad Aut noma de Querétaro's biotronica laboratory. Model's input variables were the outside temperature, relative humidity, wind velocity and solar radiation. The mathematical model took into account the main physical processes that happen inside a greenhouse such as: radiation, convection, conduction, and also crucial process in the crop such as transpiration. A local sensitivity analysis was performed in order to identify model's parameters that more affect temperature and humidity inside the greenhouse. Afterwards, a comparison of three evolutionary algorithms (EAs), such as Genetic Algorithms (GA), Evolutionary Strategies (ES) and Evolutionary Programming (EP) to calibrate the

model, was carried out. The objective was to determine which algorithm provides best values to the parameters in order to get the best fit among model's predictions and measurements. Results showed better fit among model predictions and measurements in case of Evolutionary Programming to the air temperature during spring-summer than in case of autumn-winter season. In the case of the relative humidity, an over estimation of simulated data to the measurements was found for all evolutionary algorithms. However, all evolutionary algorithms outperformed the fit of local optimization algorithms such as nonlinear least squares for both studied variables.

CCI 4.

EFFECTS OF HIGH LIGHT INTENSITY, HIGH HUMIDITY AND WIDE TEMPERATURE REGIMES ON CROP GROWTH AND ENERGY CONSUMPTION ON POTTED PLANTS

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Some tropical plants are grown with very little sunlight in Holland (5 mol/m2/dag). Growers use screens and chalk to keep out a lot of the sunlight in spring, summer and autumn. The growers are afraid of high light levels in combination with high temperatures and low humidity because they can lead to leaf damage, growth problems and bad plant quality. In The Netherlands, a lot of research is done on crop growth in closed greenhouse systems. Herein, 'new' climate combinations can be made compared to normal "open" greenhouses. For instance combinations of relative high humidity, low or high temperature, high [CO_2] and high light intensity. Experiments in a closed greenhouse for commercial pot plant production (project 'Greenhouse as energy source'), showed that pot plants grow faster and with more quality with more sunlight, high humidity and high CO2-levels. Based on this observation, a research project was started with the aim to answer two questions: Is it possible to tolerate more sunlight on pot plants that are normally grown under low sunlight levels and what happens with the growth and quality if plants are grown with wide temperature regimes? The experiment is carried out from September 2009 till October 2010. The used pot plants are Anthurium, Areca, Calathea, Dracaena, Ficus, Guzmania en Oncidium and the results show that there are possibilities to save a lot of energy without losing crop growth most of the time.

CCI 5.

GLOBAL SENSITIVITY ANALYSIS OF GREENHOUSE CROP MODELS

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Sensitivity analysis is part of the study of mathematical model's behaviour. For greenhouse crop models, mostly, local approaches based on the calculation of partial derivatives are applied. However, the main drawback of local approaches is that derivatives provide only information at the base point where they are computed and do not take into account the rest of the variation range of the input factors. Nowadays, several global sensitivity analysis approaches such as standardized regression coefficients, scatter plots, elementary effect test, variance-based methods and Monte Carlo Filtering are in developing. In the present work a global sensitivity analysis based on variance calculations, for parameters of a greenhouse crop model, was carried out. The paper stresses the methodological issues concerning a global sensitivity analysis for model's parameters. The global sensitivities of all parameters of a dynamic model of a lettuce crop were calculated. Firstly, uniform probability density functions (PDFs) were assigned to each of the model's parameters. Secondly, several thousands of Monte Carlo simulations were carried out in order to calculate both the first-order and the total-order sensitivity indices. A combination of the SimLab (ver 3.2) software and Matlab environment was used to carry out all the simulations. Also the scatter plots for all model's parameters were generated. The global sensitivity approach was applied to two lettuce crop models. The first was a simplified model, which considers dry weight and leaf area index (LAI) as state variables and also synthetic climatic data. The second test case was a lettuce crop model with structural and non-structural dry weight as state variables. In the second case actual data were collected from a Mexican greenhouse with natural ventilation. Results showed that the global approach is feasible and advantageous over the local sensitivity methods, provided one can determine PDFs to all model parameters.

CCI 6.

DYNAMIC TEMPERATURE INTEGREATION WITH TEMPERATURE DROP TO IMPROVE EARLY FRUIT YIELD AND CONSERVE ENERGY IN GREENHOUSE TOMATO PRODUCTION

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High early fruit yield is very important in greenhouse tomato production in cold regions because of shortage of fresh produce and high price in the market. However, tomato plants are usually vegetative during the winter in these regions (due to low temperature and weak light). Increasing greenhouse temperature to promote early fruit production may not be feasible since it not only uses more energy but also may deplete the limited carbohydrates in the plants. A series of greenhouse trials were conducted in last 4 years to evaluate various dynamic temperature integration strategies with pre-night or pre-morning temperature drop to increase early fruit yield. The temperature integration with pre-night or pre-morning temperature drop down to 13.5°C resulted in higher fruit temperature (relative to leaf temperature) and showed a good potential in promoting early fruit production. The temperature integrations with temperature drop also reduced the energy consumption from March to May by 3% to 8%, respectively. It was also found from these trials that water condensation and high humidity during the temperature drop periods can be eliminated with the use of grow pipes (a small heating pipe placed inside crop canopy). The optimum low temperature for the drop varied with cultivars. Therefore, we also conducted a series of growth

chamber trials to determine the low temperature threshold and the optimum low temperature drop for various greenhouse tomato cultivars. Based on the results from these growth chamber trials and the greenhouse trials, we can conclude that a temperature integration regime with proper low pre-night or pre-morning temperature drop in conjunction with grow pipe heating can be an effective greenhouse climate control strategy for improving early fruit yield and energy use efficiency in greenhouse tomato production.

CCI 7.

SIMULATION OF FIXED AND VARIABLE PRESSURE FOGGING IN A NATURALLY VENTILATED GREENHOUSE, WATER AND ENERGY SAVINGS AND STABILITY OF CLIMATE

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Previous studies on high pressure fogging have shown their capability for maintaining acceptable climate for crop production most of the year in greenhouses located in semiarid regions. A well defined control strategy should account for the varying heat load, and therefore cooling demand, inside the greenhouse during the day and throughout the seasons, as well as the plant's contribution on cooling and humidification, which is also variable. Thus, it may be advantageous to use a variable pressure fogging (VPF) system, where specific fog rates can be supplied based on the cooling demand. However, the absence of effective cooling strategies is one of the drawbacks limiting the extensive use of these systems. A crop evapotranspiration model was calibrated and a greenhouse climate model was developed and validated with measured data to make predictions for greenhouse relative humidity and temperature. Preliminary results for a typical summer day based on the computer simulation comparing a proposed control algorithm for VPF, based on fixed pressure fogging system using vapor pressure deficit (VPD) and relative humidity based control for the VPF showed that VPD based fixed pressure fogging strategy consumed more water (12.4%) and energy (6.2%) compared to the VPF system. Cycling of the pump was smaller (25.4%) and higher stability of temperature and relative humidity were achieved by the operation of the VPF system. Moreover, the results showed that reducing the number of nozzles by 20% further improved the stability of greenhouse temperature and relative humidity. The presentation will provide further details and comparisons of control strategies on water and energy savings for variable pressure fogging based greenhouse cooling in naturally ventilated greenhouse.

Oral Presentations 8 - CFD

SESSION KEYNOTE IV

STATUS AND FUTURE OF CFD FOR AGRO-ENVIRONMENTAL APPLICATIONS

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Computational fluid dynamics is the science of predicting fluid flow, heat transfer, mass transfer, chemical reactions, and related phenomena by solving the mathematical equations which govern these processes using a numerical process. Since 1960s, there has been considerable growth in the development and application of CFD to all aspects of fluid dynamics. As a result, CFD has become an integral part of the engineering design and analysis environment of many companies because of its ability to predict the performance of new designs or processes.
In agriculture, farmers have struggled with natural environment to achieve annually stable production of high qualified vegetables as well as livestock using various technologies of protected cultivation. Internal environmental control such as heating, cooling, ventilating, and air-conditioning as well as structural design considering time-dependent wind and snow loads are very important topics for engineers and scientists in agriculture field. Moreover, local dispersion of aerosol, spore, disease, odor and various gases from and around the facilities are also very important. Understanding of the flow of mass and energy became serious in agricultural environment.
The present state of CFD has already shown popularity in almost any field in the agri-environment. Although most studies are still in atmospheric environment such as odor dispersion, inside and outside agricultural facilities, greenhouses, air pollution, etc, the application of CFD in the land and water engineering, renewable energy and bio-energy are fast emerging. A rapid increase of published papers on the use of CFD in agricultural science and engineering has been observed.
In this paper, the past and present of CFD applications in agriculture will be introduced with the statistics for various uses of CFD. Since CFD still holds more possibilities, the application of CFD agri-environment in the future looks very bright. In the future, it is expected that more up-and-coming researchers in various research fields will collaborate actively with each other, share useful information, and develop new areas of study for the advancement of agriculture and CFD applications.

CFI 1.

INFLUENCE OF DIFFERENT AIR TREATMENT SYSTEMS TO THE ENVIRONMENT OF SEMICLOSED GREENHOUSES: SIMULATION STUDY OF COMMERCIAL GREENHOUSES WITH POT PLANTS

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Semi closed greenhouse concepts are a powerful tool in a strategy towards independency of fossil energy sources. The main characteristics of a semiclosed greenhouse is the lack of ventilation, leading to continuous high CO_2 concentrations and the possibilities of temperature and humidity control using air treatment units (ATU). Optimization of climate factors creates the possibility to increase production, although air temperature and humidity differences could be occurred due to operation of heat exchangers and fans. Aim of the present study is to simulate in terms of CFD the environment of commercial semiclosed greenhouses with phalaenopsis crop. The greenhouses are equipped with different ATU, concerning the capacity, the distribution system and the location of the units inside the greenhouses. For each greenhouse a 3D simulation model was set up integrating, the greenhouse structure, the external and internal climatic conditions, the crop and the operational characteristics of ATU. As the air flow is of great importance, preliminary calculations were carried out, using the virtual wind tunnel technique, to specify the air flow resistance of the pot plants. The computational results, concerning the spatial air temperature distribution, were compared with experimental data collected by a wireless sensor network installed in each greenhouse. Even if there is a qualitatively good agreement in average terms, the simulation models were not able to predict accurately the vertical air temperature distribution and the hot spots occurred on the crop level. Useful conclusions were obtained concerning the set up of simulation models, as the details of it, mainly concern the air distribution systems, are proved to be the most important limitation factors in order to improve the accuracy of computational predictions. Despite the capability to investigate the greenhouse environment using CFD, more experimental work is needed to evaluate the accuracy of simulation predictions for commercial greenhouses under different climatic conditions.

CFI 2.

COMPUTATIONAL FLUID DYNAMICS SIMULATION OF HERBIVORE-INDUCED PLANT VOLATILES AROUND GREENHOUSES

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Plants emit volatile organic compounds (VOCs) in response to herbivory. One of the ecological functions of herbivore-induced plant VOCs (HIPVOCs) is to attract carnivorous natural enemies of the herbivores. Such carnivore attractants are applicable to conservation biological pest control because this system of pest control utilizes indigenous agents, rather than mass-reared exotic agents, around sites of interest. To use carnivore attracting VOCs, their concentration would be one of the important factors, as it should be maintained at an appropriate level to attract a

sufficient number of natural enemies in greenhouses. VOC concentration is usually determined by small-scale tests like the wind tunnel test, but the designed value does not always reflect the anticipated performance in an open field. However, the detection of concentration in the field is rather difficult. Thus, computational fluid dynamics (CFD) would help design attractants from the standpoint of reducing development lead time. In this study, the diffusion of VOCs generated from attractants in greenhouses was simulated by using CFD to re-evaluate the successful as well as unsuccessful results of a field test at Miyama in Kyoto for the attraction of natural enemies. For attractants in a film pack, the generation rate was estimated by weighing, and the diffusion coefficient and density were derived from the molecular weight. Furthermore, the minimum number of attractants, which ensures a sufficient level of natural enemies, was determined by using CFD.

CFI 3.

A CFD MODEL TO STUDY EXTERNAL SHADING AND ON-COVER SHADING OF GREENHOUSES

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Shading, ventilation and crop transpiration play a major role on the refrigeration of a greenhouse. Shading, ventilation and crop transpiration are closely linked, and a change in any of them produces a change in the other two. Previous research works have studied the relationship between these three variables under a number of external weather conditions. While most of the previous studies are based on analytical models of the greenhouse climate, this paper presents a numerical model (CFD model) to study the effect of shading on the greenhouse climate and transpiration rate. Two shading methods were considered and compared: external shading consisting of a porous screen above the greenhouse structure and fixed shading done with a porous screen directly placed over the greenhouse cover. Especial attention was paid to the implementation of the transpiration model into the CFD model. Crop transpiration was modelled by using a simplification of the Penmann-Monteith equation. For this purpose, the radiation absorbed by each cell of the computational domain was calculated by using absorption models and extinction coefficients available in literature. Stomata resistance corrections for extreme high temperatures and low VPD were incorporated to the transpiration model. 3D simulations of a three span arched roof greenhouse are currently being done to study the distribution of humidity, temperature and air speed of externally and on-cover shaded greenhouses versus non shaded greenhouses. Comparisons are made for leaf area indexes ranging from 0 to 4 and for different ventilation rates. Comparing both shading methods, preliminary results showed that the external shading increased slightly the ventilation rate, but it produced minor changes on the greenhouse temperature and humidity distributions. In agreement with previous studies, shading generated a stronger reduction in temperature for less ventilated greenhouses and for low transpiration rates. For each greenhouse-type under consideration, attempts are being made to establish regressions between the main involved variables: temperature, crop transpiration and greenhouse humidity versus ventilation rate, incident radiation and Leaf Area Index.

CFI 4.

NUMERICAL ESTIMATION OF PRESSURE COEFFICIENTS OVER SINGLE AND MULTISPAN PITCHED ROOF GREENHOUSES

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The greenhouses have usually metal frame covered by glass or plastics and therefore are light structures, which make them sensitive to dynamic loads such as the air load. The air flow over a greenhouse is a complex phenomenon. The pressure coefficients are used to calculate the wind load on the building's roof. The eurocode for wind actions EN 13031-1:2001 gives values for external pressure coefficients on the greenhouses, however, many manufacturers have complain that these values will lead to heavy structures of greenhouses with high construction costs. The proper design of the greenhouses would have to ensure not only the functionality and the static safety of the structure but also to keep the construction cost at low level. In the light of the above and taking into consideration that the adjustment of national regulations to eurocode is expected to be completed in 2011, the present work is focused on the calculation of the pressure coefficients on single and multispan pitched roof greenhouses. The study of an incompressible two-dimensional, steady, viscous air flow takes place in a hypothetical wind tunnel with the Navier – Stokes and continuity equations. The equations have been solved numerically, using the Galerkin Finite Element Method. The Reynolds numbers are varied from 0.02 to 2000 for all the structures. The numerical results of pressure coefficients are compared and discussed with data of eurocode's for wind actions. The pressure coefficients given by the eurocode in the leeward area of the roof are close to the results derived from this numerical estimation, in most cases. While, in the windward area the results show that a further segmentation of the pressure coefficients would be better.

CFI 5.

OPTIMIZATION OF VENT CONFIGURATION DURING VENTILATION FOR DEHUMIDIFICATION PURPOSE USING COMPUTATIONAL FLUID DYNAMICS TECHNIQUE

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Abstract High humidity, which can often affect the crop growth and lead to plant diseases and insects, etc, usually occurs in the prolonged closed greenhouse under winter climate conditions of eastern china. Natural ventilation is the most widely used for dehumidification despite of the fact that it may lower temperature in the greenhouse. A great challenge, therefore, is raised on how to maintain the desired temperature level when ventilation is needed for dehumidification purpose. The optimization of vent configuration for multi-span greenhouses, which was mainly to compromise between ensuring dehumidification effectives and preventing excessive heat loss was attempted by Computational Fluid Dynamics (CFD). A three-dimensional (3-D) CFD model was developed based on the solution of the Navier-Stokes equations with Boussinesq assumption and a k-ε closure. The crop and insect-proof were considered as porous medium in the model. Validation of the model was made by comparing with the experimental data obtained from in a 1980m^2 11-span plastic-covered greenhouse divided into two compartments separated into a plastic partition. The validated model was then used to investigate the distribution of temperature and humidity, variations of climatic parameter and the corresponding heat loss in the ventilated greenhouse under different vent configurations (i.e. side, roof and side plus roof) through unsteady simulation. Following this, the effect of size of ventilation openings on the dynamic response of temperature and humidity in the greenhouse was evaluated. Simulations showed that, under the same conditions, the reduction of average temperature in the greenhouse for the roof vent configuration is 4°C lower than other vent configurations after the dehumidification. It is then concluded that roof ventilation configuration tends to be the best for the purpose of thermal insulation and dehumidification under winter climate conditions and the optimal opening range for the roof ventilation is suggested to be between 0.2m and 0.8m.

CFI 6.

ANALYZING VENTILATION EFFICIENCY USING AGE OF AIR THEORY AND CFD TECHNOLOGY

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In agricultural buildings, environmental conditions are influenced by the ventilation system. Understanding of ventilation process is important to improve condition of growth environments. "Age of air" which has been used to investigate ventilation efficiencies has not yet been applied in agricultural fields. LMA and LMR concepts based on this theory were used to evaluate the distribution of fresh air and the potential for eliminating contaminants inside the structure. However, the experimental methods for measuring these values have limitations due to shortage of experimental devices. In addition, laboratory experiments are always laborious, time consuming and expensive. In this study, the "Age of air" theory and CFD were both employed. As a basic step, a 3-dimensional chamber with narrow width was designed to verify the theory in the CFD analysis. The inlet was fixed while the outlet was varied in order to find the differences and characteristics of the ventilation efficiencies. The CFD results were compared with the results of laboratory experiment which was conducted via tracer gas approach. In validating the computation of the LMAs and the LMRs, the results showed that they had a similar tendency of distribution and the average time difference was 39s. Considering the condition of the experimental environments, it could be concluded that the simulation for the "Age of air" was designed reasonably. When the ventilation rate was increased, the values of the LMAs and the LMRs were smaller while the air exchange efficiency had an opposite tendency. It showed that the efficiency of total air exchanges was 0.31 in Case 3-1 and was superior to the other cases. Based on the results of this study, the research could be upgraded to determine the overall and local ventilation efficiency quantitatively in the agricultural facilities such as greenhouses and livestock houses.

ET 1.

PLANTLAB, THE NEXT GENERATION OF GROWING

M. Kers
PlantLab

Developed from the perspective of the Plant

Out of the perspective of a plant and all known plant physiological knowlegde PlantLab created a patented new growing surrouding for plants, the so called Plant Production Units. In these Multilayer Nurseries all kind of available technology is used. For example Light Emitting Diodes (LED), Infra Red (IR) and different technologie, depending the size of a Plant Production Unit, according to control humidity, air temperature, root temperature, airflow, CO2, water and nutrients. A new R&D facility was built in 's-Hertogenbosch in the Netherlands and also two practical Plant Production units of 100 square meter, with one and two layers in where lettuce and Fittonia (small pottedplant) are grown. With this new oppertunity it is possible to grow plants without sunlight and harvest crops according to a strictly time scedule. The PlantLab achievement so far is that production has been increased by a factor 2, compared to the production in a modern glasshouse, when at the same thime the water and carbon footprints a decreased significantly. Thus a total new way of growing is possible, that will change our current way of growing crops. Due to the combination of a variety and a growing recipe, the nutrient and phytochemical values can be tuned and fixated, enabling us to grow high quality food and medical herbs 365 days a year, anyplace, without the necessity of using any pesticides

History

The PlantLab engineers developed unique mathematical prediction models between 1989 and 2006. These models enable producers to the mostexact planning and management of plant production process, so that the moment of harvesting, the yield quality and quantity can be strictly managed, thus ensuring the best possible link between supply and market demand. After PlantLab prooved the principle growing crops under totally balanced circurmstances without using daylight, they patented the technology of their invention in 2008, Since then next step followed in an increasing speed. PlantLab's R&D home base is the new Centre for Growing Concepts at the University of Applied Sciences HAS in 's-Hertogenbosch in the Netherlands. This hypermodern research centre developed by PlantLab, includes 8 climate chambers in which plant research can be carried out under 56 different environmental combinations simultaneously. The PlantLab R&D facility was opened by the Minister of Agriculture, Nature and Food Quality of the Netherlands on the 27th of June 2010.

The next generation

Coming from the high end horticulture, the next Generation of Growing was a natural next step to take for PlantLab. An environment where you can grow ornamentals and food 24 hours a day, 365 days a year. A new type of multilayer nursery where corps are protected from unpreditable and harmfull weahter. And where the water us is reduced with over 90% compared to the current horticulture. Due to the lack of diseases no pesticides are being used and the local for local production decreases the fossil fuel consumption needed for transporting our food from A to B. A lot of different companies are involved to explore the oppertunities of the Next Generation of Growing. Imtech as a technical services provider in Europe expressed her Social Responsable aspiration by enabling the sustainable cultivation of flowers, plants, vegetables and fruit in well balanced high-tech closed nurseries. Philips is involved for optimizing the needed LED technologie and Hereaus for optimizing the used IR technologie. And a lot of other companies and Universities are involved.

We are close to the market introduction of innovative Plant Production Units that will allow efficient and sustainable 'footloose' (i.e. at any given location) production of plants. This concept enables us even to start multi layer nurseries in the center of our cities.

Keywords: multilayer production, plant production without daylight, Plant Production Unit, controlled production, LED, IR, CO2, carbonfootprint, waterfootprint, sustanable production, local for local.

ET 2.

ENVIRONMENTAL ACCEPTABILITY OF GREENHOUSE TOMATO PRODUCTION IN FRANCE: PRELIMINARY RESULTS

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Environmental acceptability of greenhouse production with respect to its intensification is a controversial question as it decreases with the use of impacting inputs such as heating energy, while it increases with the intensification of the system which raises the productivity per unit input . Then, which is the right equilibrium between the necessary limitation of the inputs on one side and the necessary intensification of the system on the other side. Few studies have dealt with this important question, with contradictory results, often depending on the considered impacts.

Based on Life Cycle Assessment of greenhouse tomato production in France, in heated greenhouses as well as in cold high tunnels, we have addressed this crucial question by considering all the potential impacts of greenhouse production on the environment. As the spatial scale of the toxicological assessment used within LCA does not make allowance for the confined character of greenhouses, where toxic exposure is very local we have completed this approach by an occupational indicator study, developed for evaluating the exposure of operators and workers to the active substances in plant protection products.

Preliminary results of these studies are briefly presented, then discussed with respect to more or less intensive tomato production systems such as cold tunnels or heated greenhouses.

Keywords: greenhouse, tomato, LCA, exposure, environmental impact

ET 3.

INFLUENCE OF THE USE OF DRIP IRRIGATION SYSTEMS AND DIFFERENT MULCHING MATERIALS ON ORNAMENTAL SUNFLOWERS IN GREENHOUSE CULTIVATION

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Keywords: chitosan and galactomannans-based sprays, soil thermal behaviour, irrigation water productivity, sustainable floriculture.

Abstract
This research, conducted during the 2010 spring-summer seasons in a plastic greenhouse Mediterranean type environment, investigated the effects of drip irrigations and conventional films and bio-degradable sprays as mulching, on soil thermal behaviour, IWP, yield and quality features of ornamental sunflower cut stems. The sprays are two pre-competitive research materials, prepared using natural polymers. The thermal analysis showed that the mulching plastic films increased the soil temperatures around of 2°C, compared with the un-mulching soil, at 20cm depth; instead the mulching spray degradable materials didn't influence significantly the thermal soil behaviour. The agronomic results showed that I1 had more advantage than I2 and that both PM2 e BM1 had the highest IWP values. Among the different mulches the values were, in order, PM1>PM2>BM2>BM1>UM for yield and qualitative characteristics of the cut stem.

ET 4.

A WEB-SERVER-EMBEDDED ENVIRONMENTAL CONTROL SYSTEM FOR CLOSED GREENHOUSE

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Recent decade, low environmental control level and high energy consumption of greenhouse were main reasons in restricting sustainable development of protected agriculture in China. To solve the above problems, a web-server-embedded environment control system for a closed greenhouse was developed to improve the environment control level and decrease the power consumption. In this study, 6 demonstrated web-server-embedded environment control systems each with closed greenhouse using double-layer hollow tempered glass as enclosure covering materials were performed for two years. The good performance of the greenhouse in environment control at middle summer and winter were shown by utilizing its closed loop ventilation structure and predictive control algorithm.

Keywords: Closed system, Loop ventilation, Predictive control algorithm, Protected agriculture

ET 5.

IMPLICATIONS OF SUSTAINABLE GREENHOUSE SYSTEMS FOR PEST AND DISEASE CONTROL

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The protected crop industry faces growing economic, governmental and market pressures to increase sustainability and reduce carbon footprints. New greenhouse designs and management systems are being developed to ameliorate these concerns. As new greenhouse systems are being devised for greater energy efficiency it is also pertinent to give consideration to pest and disease (P & D) control, both in terms of the direct impacts these new systems will have on P & D pressures and in minimising the need for chemical control chemicals. The EUphoros project has developed sustainable greenhouse systems and established sites around Europe to assess their effectiveness. Two P & D systems have been considered as part of the project; *Tetranychus urticae* (two-spotted spider mite) and its biocontrol agent *Phytoseiulus persimilis* on ornamentals, and *Oidium neolycopersici* (tomato powdery mildew) and its biocontrol agent *Bacillus subtilis* on tomato. Using data from the test sites, models of these systems have been developed to assess how changes in temperature and humidity, due to the novel management regimes, impact on pest and disease pressures. These have also been compared to traditional greenhouse management systems. A novel model for *O. neolycopersici* has been developed and an existing model of *T. urticae* dynamics has been modified to incorporate temperature and humidity effects on pest and biocontrol agent biology. Novel experimental work was conducted to parameterise the two models. This included assessment of *O. neolycopersici* development and sporulation and the control efficacy of *B. subtilis* at a range of temperature and humidity regimes relevant to greenhouse climates. As part of this image analysis software was developed to allow diseased leaf area to be assessed. The functional response of *P. persimilis* to humidity and crop host was also assessed. The data from the experimental work and the predictions from the models will be presented.

ET 6.

DEVELOPMENT OF THERMAL ENVIRONMENT MODELING & ENERGY SAVING TECHNIQUE IN CHINESE SOLAR GREENHOUSE

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The Chinese Solar Greenhouse (CSG) is an original type in china. It possesses the structure of the back wall to preserve heat during daytime and release heat at night, so the crops can normally grow up in CSG in winter without any heating system. In this paper, the characterization and modeling of the research progresses on the thermal environment of the CSG are reviewed. The energy-saving methods and their technological level in the CSG are also reviewed. Energy-saving methods include optimizing structure of the back wall, using phase change materials to improve the CSG's capability of heat storage and preservation, water cycling equipment installed on the wall and buried under the soil to retain heat, heat isolation curtain to control heat releasing rate from the back wall, water heat pump for heat applying and so on. As the back wall of the CSG built with earth is too much thick, that resulted in the waste of cultivated land resources. In some areas the low air temperatures in the CSG in winter causes in the freeze injury to crops. The development trend of improvement in the structure of the CSG and possible new energy sources for heat supplement in the CSG are discussed based on these problems.

ET 7.

HYDROLYZED PROTEIN BASED MATERIALS FOR BIODEGRADABLE SPRAY MULCHING COATINGS

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Low density polyethylene (LDPE) films are widespreadly used in agriculture for soil mulching. The use of LDPE mulching films causes the serious drawback of huge quantities of waste to be disposed of. Over the last years the growing environmental awareness has been prompting the research to develop a new generation of mulching products starting with raw materials from renewable origin. These materials have to retain their physical and mechanical properties while in use and have to be compostable or biodegradable at the end of their life, degrading via micro-organisms into carbon dioxide or methane, water and biomass.
The research is focused on the development of novel biodegradable polymeric materials based on hydrolyzed proteins, derived from waste products of the leather industry. Biodegradable soil mulching coatings were realized with these biodegradable polymeric materials by means of spray techniques; the coatings were tested in a *Ligustrum Ovalifolium* cultivation carried out inside a greenhouse.
This paper describes the mechanical and the radiometric properties and the functionalities of the new bio-based mulching coatings, which were developed and tested in real scale field cultivation tests. Laboratory tests were carried out in order to study the relevant physical and mechanical properties of the coatings, and the decay of these properties in field. During their life in field, the biodegradable soil mulching materials showed suitable mechanical and radiometric properties for an efficient and profitable use in agriculture. The innovative biodegradable spray coatings lasted in field up to 9 months. During the cultivation cycle, the mulching films showed a soil fertilizing effect, due to the slow release of proteinaceous material, as a result of the biodegradation process.
The biodegradable materials could be the environmentally friendly alternatives to synthetic petro-chemical polymers and could contribute to a sustainable agriculture.

ET 8.

HIGH-TEC GREENHOUSES FOR ORGANIC FARMING?

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Heated greenhouses, which are consuming fossil fuels, are for many organic farmers a real problem. Most of them therefore prefer simple and cheap unheated "shelters", which by principle bear the risk of humidity problems, unsuitable temperatures and bad labour conditions etc. The Technische Universität München and the Experimental Station Qeckbrunnerhof have setup a research and demonstration project for finding a scientific answer to the question whether high-tec greenhouses may be a good alternative also for these growers. The general aims of the project are: - Reduction of energy consumption by highest insulation
- Optimization of energy efficiency by most effective cropping systems
- Reduction of CO_2 emission by a non fossil fuel heating system
The experimental greenhouse block has a size of 1000 m^2 in three compartments with different energy saving equipment (screens), double polythene inflated covers (2), F-clean inflated cover (1). All compartments have roof ventilators; one has additionally an insect proof forced ventilation. The control system is computerized (RAM) and a special process documentation software has been designed and installed (e.g to monitor the measured heat consumption). The heating system consists of a wood pellet burner with an attached warm water heat storage (for optimizing the efficiency). The research subjects are planned in a systems approach with the mutual investigation of cropping results, technical data and ecological and economical evaluation. At the moment intensive climate measurements (summer conditions) have been carried out and will be presented; in winter 2010/2011 the measurement of the technical data will follow. First cropping experiments (salads and later in spring tomatoes, the cultural schedules follow the "Bioland" rules) are also ongoing and the results also will be presented at greensys 2011.

CCII 1.

REVIEW OF ENERGY EFFICIENT LIGHTING TECHNOLOGIES IN THE GROWING OF PLANTS AND VEGETABLES

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The paper examines reaction of plants towards the artificial lighting of different spectrums as well as investigates newest and most effective lighting technologies in the growing of plants and vegetables.
The paper focuses on the plant reaction towards the artificial lighting of different spectrums. There are described standard lamps widely used in the gardening and new non-standard lighting devices and are performed comparative technically-economical calculations for the determination of energy efficiency at different classifications of lamps. A defected filament lighting device was developed during the stage of the patent. Introduced in the production is also the device of spectral LED diodes of our own made construction. In the greenhouses of the Latvia University of Agriculture is performed research of plant growth at different versions of artificial lighting.

CCII 2.

APPLICATIONS OF FAR-RED LIGHT EMITTING DIODES IN PLANT PRODUCTION UNDER CONTROLLED ENVIRONMENTS

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Light emitting diodes (LEDs) are a potential supplemental light source to provide select light quality in plant production. Far-red (FR, 700 – 800 nm) LEDs, despite the plant biological significance, have limited availability in the market, compared with that of red (600 – 700 nm) or near infrared (~800 nm or longer) LEDs. This is because FR light has no value in human or industrial applications (such as machine vision). However, with possible future bans against the use of incandescent lamps (the conventional source of FR), greater demand is expected for FR LEDs in horticultural applications. Moreover, the LED technology that allows pure FR light permits applications beyond traditional applications of FR rich lighting to control flowering. Our research group has worked on applications of FR lighting in food crop and transplant production, including morphology control of grafting rootstock seedlings or promoting growth of baby leaf lettuce plants. Using FR lighting at end of day (EOD), tomato and squash rootstock hypocotyls were elongated to a desirable length (124-162% of non-treated control) and the response was saturated at a small dose of pure FR (2-4 mmol m^{-2} d^{-1}). This FR dose requirement was translated to various combinations of FR light intensity, duration, and light-delivery methods, suitable for a greenhouse plant production system. We also demonstrated that supplemental FR lighting in baby leaf production enhanced the fresh and dry mass of lettuce plants grown in the growth chamber (115-128% of the control), caused by the increased light interception as a result of extending leaf area. However, EOD-FR did not cause significant growth promotion for lettuce in greenhouse. More research is necessary to develop feasible FR lighting system to make the technology readily available in specialty crop industry.

CCII 3.

NEURAL NETWORK PREDICTIVE CONTROL IN A NATURALLY VENTILATED AND FOG COOLED GREENHOUSE

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Passive ventilation in greenhouse production systems is predominant worldwide, limiting its usability and profitability to specific regions or for short production cycles. Evaporative fogging systems have increasingly been implemented in Arid and Semi-Arid regions to extend the production cycle during the warmest season, and also to achieve near-optimum environments for year-round production. However, appropriate control strategies for evaporative fogging systems are still lacking or limited despite its reported benefits in terms of environmental uniformity and potential savings in water and energy usage, when compared to fan and pad systems. The present research proposes a neural network predictive control approach for optimizing water and energy usage in a naturally ventilated and fog cooled greenhouse while providing a near-optimum and uniform environment for plant growth. As a first step the dynamic behavior of the greenhouse environment, defined by air temperature and relative humidity, was characterized by means of system identification using a recurrent dynamic network (NARMX). The multi-step ahead prediction capability of NARMX allows for the optimization of the control actions (vent configuration and fogging rate) for its implementation in the NN predictive control scheme. Greenhouse environmental data from a set of experiments consisting of several vent configurations (0/50, 0/100, 50/50, 50/100 and 100/100, percent opening of the side/roof vents) and three fogging rates (0.29, 0.37 and 0.45 g m^{-2} s^{-1}) during several days throughout the year were used in the system identification process as well as for the validation of a mechanistic model. Both models are compared and incorporated into the NN predictive control scheme. This presentation will present results and discuss the feasibility of the NN predictive control scheme in a naturally ventilated greenhouse equipped with a variable-rate fogging system, while achieving a greenhouse environment within defined permissible ranges of air temperature and relative humidity.

CCII 4.

MODELLING GREENHOUSE TEMPERATURE AND HUMIDITY DYNAMICS IN ORDER TO DEVELOP AN ENERGY SAVING MODEL-BASED CONTROL STRATEGY

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The horticultural industry in northern Europe is facing the economic reality that quality products should be produced at low costs to remain competitive with mass production in other countries. This fact implies pressure on the horticultural industry and development. Also from a political/social perspective pressure is applied because of the impact of the consumption of fossil fuels on the environment, which resulted in the Kyoto Protocol.
In this paper, the aimed strategy is to open roof windows to maximum (30°) opening level during late evening and/or early morning for short periods (from 5 to 10 min) when the thermal screen remains closed. The latter takes care of the fact that the inside temperature under the screen is very little influenced. When the windows are closed, the thermal screen could be opened to decrease inside humidity. Both inside temperature and humidity will be influenced by roof window opening and thermal screen opening. To quantify these dynamic responses of inside temperature and humidity two models are identified based on data obtained from a set of step experiments conducted in greenhouses of the Venlo type in Leuven and Beitem (Belgium) during winter and spring. Outside temperature, humidity and wind speed are disturbance variables in the considered model.
Windows were opened to maximum level when thermal screen was closed. One hour after closing the windows, the thermal screen was opened. If the window opening step (0-30°) is applied and wind speed is 0.5 m/s, the time constant of the drop of the inside humidity above the thermal screen is around 300 seconds and the time constant of temperature is around 500 seconds. When the wind speed is around 4 m/s, the time constants of humidity and temperature are nearly equal (around 150 seconds). A linear decay is found between the time constants and the wind speed. This result indicates that exchange of humidity is faster than exchange of temperature and this difference decreases when higher outside wind speeds are noted.
Based on the observations and the models in this paper, an energy saving model-based control strategy for the greenhouse climate can be developed.

Keywords: greenhouse; greenhouse climate; thermal screen; data-based modelling

CCII 5.

CLIMATE MODELLING IN A GREENHOUSE WITH PROPORTIONAL ENVIRONMENTAL CONTROL SYSTEM

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Performance of greenhouse environmental control systems can be evaluated by means of predictive climate models. In this work a model for prediction environmental parameters such as temperature and humidity based on energy and mass balances was developed and validated for a greenhouse controlled with proportional environmental control system. Viveiros do Furadouro is a forestry nursery to propagate *Eucaliptus globulus* Labill, and the Venlo type covered with glass greenhouse of the present study is the vegetative propagation unit (minicutting), with an area of 1632 m^2. The *Eucalyptus globulus* Labbil is characterised by having low rooting ability, so the environmental control has to be very accurate and requires the use of multiple control equipments, such as heating, cooling (pad or fog), thermal/shade screens, natural and dynamic ventilation. The proportional control of each equipment such as fan and wet pad for cooling, is difficult and needs good knowledge of the dynamic of greenhouse environmental parameters as well as the influence of individual equipment, but has the advantage of allowing different alternatives to achieve the set points. The climate data was recorded at 8 minutes intervals and daily means were calculated to establish a climatic model based on energy and mass balances, which allows prediction of internal environmental parameters. Information about the activation (percentage) of the environmental control systems was also recorded. The extraction of the coefficients for the balances combines direct calculation and interaction using Microsoft Excel® SOLVER®, until reaching the minimum absolute difference between simulated and measured inside temperature and humidity. This model will permit simulation of internal environmental conditions without damage the plants and the establishment of proper set points for reaching maximum root ability and the maximum efficiency of greenhouse environmental equipments.

CFII 1.

NUMERICAL ANALYSIS OF WIND LOADS ON AN INTEGRATED SYSTEM CONSISTED OF A GREENHOUSE AND A NET-COVERED WINDBREAK

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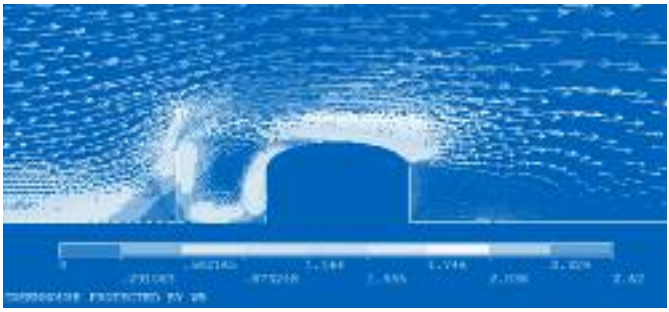
Protecting greenhouses by windbreaks is an expanding practice. Such windbreaks are usually raised near the greenhouse side walls, thus they reduce wind loads and minimize heat losses by suppressing wind velocity along the walls. As a result, there is a strong aerodynamic interaction between the windbreak and the greenhouse structure. Therefore, the two neighbouring structures have to be studied as an integrated system and optimised with respect to both the height and porosity of the windbreak and its distance from the greenhouse. Plastic nets are widely used in agricultural windbreaks for the protection of both crops and light structures, gradually replacing the traditional tree windbreaks, which require a long growing period. For this reason, the windbreaks considered in the present study are made of three different plastic nets, particularly designed for windbreak applications. The detailed experimental analysis of the airflow characteristics around an integrated windbreak-greenhouse system requires long and tedious wind tunnel experiments. An easier to use, low-cost alternative is Computational Fluid Dynamics (CFD) simulations. CFD method was proven efficient in simulating airflows through net covered structures (Giannoulis et al, 2010) and estimating the corresponding aerodynamic pressure coefficients (Briassoulis et al, 2010). The following typical system of a greenhouse protected by a windbreak was investigated by 2-D CFD simulations and optimised: An arch-roof greenhouse with height of 3 m at the gutter and 4.5 m at the ridge was protected by a net windbreak of height 3, 4, or 5 m, located at 2, 3, 4, or 5 m upstream from the greenhouse windward wall. Three different nets of optical porosity in the range between 35-65% were considered as covering materials of the windbreak, while the greenhouse was covered an impermeable plastic film. An impermeable windbreak was also studied for comparative purposes. The airflow was numerically analysed in all studied cases and the corresponding aerodynamic pressure coefficients were calculated. The present results show that there is a decrease with respect to wind loads on both the greenhouse windward wall and the windbreak. This decrease can exceed 50% for certain configurations of the system. An optimal location and height of the windbreak can be selected depending on the aerodynamic properties of the net. Furthermore, the optimal configuration can be selected based not only on wind loads bur also on energy saving considerations and on ventilation optimisation under the new aerodynamic conditions. CFD simulations can easily investigate a large number of structural design configurations with respect to airflow characteristics and wind loads. In this way, they can be used for a preliminary analysis of problems requiring an intensive experimental work, which can offer guidance for an optimal efficient technical solution.



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CFII 2.

UNSTEADY COMPUTATIONAL STUDY OF AIR FLOW CHARACTERISTICS AROUND AN AGRICULTURAL STRUCTURE MODEL

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Agricultural structures are affected by the ambient air conditions, both on the external surface and the internal environment. The complexity of the air flow led to a large number of experimental investigations and numerical simulations of air flow around full scale agricultural and urban buildings or around a structure model inside a wind tunnel, as reported in the literature. The purpose of this work is the detailed analysis and visualization of complex air flow around agricultural structure models. The structure model, either with rectangular or arched geometry, is placed in a wind tunnel. The two dimensional laminar or turbulent, separated or reattached air flow, around a wind tunnel model is investigated with the direct solution of transient Navier-Stokes and continuity equations using

Galerkin finite elements. The Reynolds numbers are calculated with respect to the model height and the inlet free stream velocity. In this work, a two dimensional air flow is studied for several Reynolds numbers. A uniform free stream flow is used as boundary condition at the entrance of the computational domain. The non-slip boundary conditions are imposed along the walls of the wind tunnel and the building model. The outlet boundary condition is a free boundary condition that permits the fluid to leave the computational domain freely without any distortion. The main emphasis of this paper is the study of vortex generation and its effect on agricultural building wall surfaces. Moreover instantaneous values of both velocity components and pressure are obtained from the direct solution of Navier-Stokes and continuity equations. These values are used in the study of dynamic and statistical analysis of this transitional flow. The detailed simulation of air flow and the intense production of vortices will be presented with animation of instantaneous stream lines and velocities of external air.

CFII 3.

OPTIMUM DESIGN OF BUBBLE-COLUMN PHOTO-BIOREACTOR FOR MICROALGAE CULTIVATION USING COMPUTATIONAL FLUID DYNAMICS

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Renewable energy is urgently needed because of fossil energy depletion and carbon dioxide reduction. Bio-diesel is one of the most desirable renewable energy because it can alternate transportation energy. However, the bio-diesel from soybean or corn, etc. can be confronted with food crisis. Microalgae, therefore, has recently been spotlighted as a new source which not only contains high oil lipid with high growth rate but also can be used value-added products such as cosmetics, health functional food or pharmacy from the residue. Because pond production system is limited in distinguishable four seasons as well as insufficient land availability in Korea, photo-bioreactor (PBR) is a good alternative way for microalgae cultivation. PBR can be controlled the internal environments such as light, nutrients, temperature, carbon dioxide, and so on, artificially. In this study, computational fluid dynamics (CFD) was used to find an optimum bubble-column PBRs for mass cultivation of the microalgae. A three dimensional CFD model was designed and validated based on the multi-phase models including bubble movement and meshes & time step independent tests. The model was also compared with the field experiments by conducting particle image velocimetry (PIV) tests. A new evaluation method of mixing efficiency in the PBRs was developed by tracing the movement of each particle in the PBRs connected with the growth model according to the light intensity. Various types of PBRs were compared quantitatively with consideration of a microalgae growth model adaptable for the CFD model. The results showed that the productivity and the uniformity in the 20 L of plate type PBRs can be enhanced by 17% and 55% in maximum, respectively when the baffle was installed in order to guide the fluid flow using bubble injection.

CFII 4.

RADIATION-CONVECTION COUPLING USING CFD IN A TUNNEL GREENHOUSE WITH A LETTUCE CROP : PRELIMINARY RESULTS

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This paper presents the numerical simulation based on Computer Fluid Dynamics (CFD) software (ANSYS/FLUENT v 12.1) of a 22x8 m^2 polyethylene tunnel with a lettuce crop. The main originality of this work lies in the realism of the model which both considers a numerical coupling between radiation and convection and between physical exchanges and crop activity, particularly transpiration.
More particularly, the main features of the model are as follows:
- Radiation transfers are simulated by means of a Discrete Ordinates model with a dual-band model comprising short wavelengths, from 0 to 2.4 micrometers, and long waves from 2.4 to 200 micrometers.
- Air turbulence is modeled by a standard k-epsilon procedure.
- The dynamics of air within the crop is simulated by an equivalent porous medium.
- Crop-air interactions are considered by simulating the energy balance equation within each mesh of the crop cover:
Net radiation = Q sensible +Q latent.
A subroutine calculates the net radiation, then solves the crop mass and energy balances. The CFD program is customized to compute these sources and sinks of sensible energy and water vapour and to numerically solve simultaneously the climate state variables. For validating the coupling of convection and radiation in greenhouse tunnel conditions, the numerical results were finally compared with previously published (Boulard and Wang 2002) experimental results for a lettuce crop in a tunnel in Avignon (South of France) on March 23th.
Comparison of various measured and simulated climate patterns are presented (air speed, short and long waves radiations and leaf temperature and humidity within the crop, air temperature and humidity within the whole tunnel). These results are discussed and various procedures aiming at improving both the coupling between radiative and convective transfers and between climate and crop activity are finally proposed.

Keywords: CFD, greenhouse, crop transpiration, lettuce, radiative transfers, convective transfers

CFII 5.

ASSESSMENT OF SIDEWALL AND ROOF VENTS OPENING CONFIGURATIONS TO IMPROVE AIRFLOW INSIDE GREENHOUSES

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In recent years many scientist have proved the existence of important gradients of temperature associated to changes in the airflow inside greenhouses. In tropical conditions, greenhouses are ventilated through side and roof vents that are operated manually; thus generating areas of high temperature. The aim of this study was to improve ventilation and climate homogeneity inside the greenhouse. This was carried out evaluating different side and roof vents opening configurations, and applying computational fluid dynamics (CFD) methods to simulate the airflow inside the greenhouse. A five span greenhouse (7 m high and 40 m long) was modeled and placed in the center of a 2D computational domain of 20 x 240 m, high and long respectively. The greenhouse was provided with five permanent continuous ridge vents, two mobile continuous gutter to ridge roll-up vents (spans 2 and 4), and two mobile continuous side roll-up vents. Nine configurations were evaluated, varying the percentage of aperture in the mobile vents and opening or closing the permanent vents. The Navier-Stockes equations were solved using the software Fluent 6.3. Wind velocity was employed to evaluate the airflow across the horizontal profiles (1.5 m above the surface). These air velocity profiles show that air velocity decreases in the first span and increases near the leeward wallside. The vents opening configuration with the highest wind speeds (0.77 ± 0.25 m/s) was provided by the total opened configuration. The vents opening configuration of permanent roof vents and sidewall vents opened, and no mobile roof vents, presented lower values for wind speeds (0.70 ± 0.21 m/s), highlighting the natural ventilation improvement reached with the continuous mobile gutter to ridge roll-up vents. The other configurations showed not improvement in natural ventilation, but differences in climate homogeneity. The areas near the roof presented the lowest air velocities and consequently may explain high temperature spots.

AR 1.

A REAL TIME MONITORING AND CONTROL SYSTEM TARGETED TO SUPPORT GREENHOUSE AUTOMATION & INTERNET CONNECTIVITY

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The next phase of the farm computerizing evolution will be the creation of Remote Agricultural Monitoring Services (RAMS) or Farm Automation Networks (FANs). FANs are networks that use different technologies for different services: agro data and control. Today, an increasingly wide range of farm electrical and electronic devices (sensors, actuators) contributes to the comfort and safety in agricultural production, by controlling heating systems, irrigating systems, etc. These farm automation systems provide an increasing number of functions of growing complexity, while at the same time open up the possibility to develop entirely new applications. In this paper, we present a real-time monitoring and control system, which allows remote end-users to access and manage agro data through a computer network. Our aim is based on using low cost components, minimizing system complexity and implementing a user-friendly environment. Related to this point, we have used the current network infrastructure of the Biosystems Engineering Department (T.E.I. of Larissa/ Greece). Data sources are video signals taken with a video camera, temperature measured with digital thermometers and soil water content detected with dielectric probes. In remote agricultural monitoring services the video and data transmission is crucial due to heterogeneous hardware and software environments and the fact that in many rural areas the existing telecommunication infrastructure cannot support applications requiring high data transmissions speed. The highest priority was to implement a system on an experimental teleworking platform for workstations, to collect and manage real data. Therefore we have investigated the evaluation of a new "User Interface" in order to be considerably more comfortable and friendly for end users. The development and testing of the system was also satisfactory. The system worked consistently with no failures throughout the test period.

AR 2.

EFFECT OF STEM AGE ON THE RESPONSE OF STEM DIAMETER VARIATIONS TO PLANT WATER STATUS IN TOMATO

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Current irrigation strategies in glasshouse crops such as tomato (*Solanum lycopersicum* L.) are often based on solar radiation. However, new energy-efficient climate control technologies have led to modified (micro-)climatic conditions inside glasshouses. Due to these new technologies, the glasshouse climate has become less dependent on solar radiation. As a result, plant water uptake could be expected to become less dependent on radiation. Therefore, it has been suggested to monitor the plant water status with plant based methods. In fruit trees, irrigation schedules have been developed, based on stem diameter measurements. Recently, interest has grown to use this type of measurements in horticultural crops such as tomato. Although stem diameter changes are very informative about the plant water status on a short term, the implementation of this technique for longer periods (an entire growing season) has some constraints, because stem diameter variations are dependent on other factors than water status, such as sugar content of the stem, fruit load and stem age. This study aims to gain more knowledge about how stem age influences stem diameter growth. Measurements of water uptake and stem diameter variations of an entire growing season were therefore studied and analyzed using a mechanistic model of water flow and storage. Calibration of this model in different periods of the growing season allowed us to determine which parameters were plant age dependent. These parameters could then be adapted to time-dependent variables, which in turn could serve to develop irrigation protocols based on stem diameter changes.

AR 3.

EXAMINATION OF THE SURFACE RENEWAL TECHNIQUE FOR SENSIBLE HEAT FLUX ESTIMATES IN SCREENHOUSES

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Screenhouses are widely used in arid and semi-arid agriculture to protect crops from direct solar radiation and to increase water saving. However, accurate estimation of crop water use under screens is still a challenge. The most reliable method that directly measures evapotranspiration, the Eddy Covariance (EC), is both expensive and complex in data collection and processing. This renders it unfeasible for day to day use by farmers. A simpler alternative is the Surface Renewal (SR) technique which utilizes high frequency temperature readings of low-cost fine-wire thermocouples, to estimate the sensible heat flux. Assuming energy conservation and employing relatively cheap complementary measurements, the evapotranspiration can be estimated. The SR technique uses a structure function mathematical analysis that involves a time lag parameter and provides amplitude and time period of a ramp-

like temperature signal. This behavior arises from the detachment of air parcels that have been heated or cooled near the surface and sequentially renewed by air parcels from above. While the SR technique is relatively simple to employ, it requires calibration against direct measurements. The aim of this research is to investigate, for the first time, the applicability of the SR technique in screenhouses. Experiments were carried out in a vineyard screenhouse within which EC and SR systems were deployed, to simultaneously measure sensible heat flux. To optimize the SR operation, 6 fine-wire (40 gauge) exposed T-type thermocouples were placed at 3 heights above the canopy and below the screen and an additional thermocouple was placed above the screen. Thermocouple output was continuously recorded at 10 Hz during a period of 11 days. Preliminary results for day time hours revealed temperature ramp amplitudes of up to 0.8 ^{0}C. The ramp time period was found to increase with the time lag chosen for the analysis, and was of the order of tens of seconds. Best linear correlations between EC and SR sensible heat fluxes were obtained for the thermocouple located at 1.15Hc (where Hc is the canopy height), approximately at the mid-height between the canopy top and the screen. Time lags associated with these results were typically larger than those reported in the literature for uncovered plantations.

AR 4.

TOWARDS PHENOTYPING AND HIGH THROUGHPUT SCREENING USING LED INDUCED CHLOROPHYLL FLUORESCENCE TRANSIENT IMAGER

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Measurement of chlorophyll fluorescence of plants provides a non-invasive technique to monitor the photosynthetic apparatus. Studies of biotic stress using chlorophyll fluorescence imaging showed heterogeneous responses over the leaf. There is great interest for an imager that can measure whole plants within a short time combined with a xy-table to be able to measure hundreds of plants at multiple positions. Here we present a phenotyping platform that consists of a computer controlled xy-table with dimensions of 3.80x1.70 m^2 equipped with an chlorophyll fluorescence imager that is capable of imaging an area of 24x18 cm^2. The camera was developed for performing measurements in dark but also at high light conditions of 1500 µmol/(m^{2}s). It will be demonstrated that for these two light conditions different measuring protocols have to be used. The measurement is based on a saturating light pulse from high intensity LEDs to excite chlorophyll-a fluorescence yielding at the start of the pulse F_0 and to achieve F_m at the end of the pulse. Typically 30 images within 0.15-0.8 s are being captured within this single pulse. From these sequential fluorescence images two images are calculated: F_v/F_m which correlates with the maximal quantum yield of PSII photochemistry efficiency for dark adapted plants or with the effective quantum yield of PSII photochemistry F_v'/F_m' for plants subjected to light. For measurements at high light conditions a special LED illumination was developed capable of inducing pulses with an intensity of 8500 µmol/(m^{2}s) at 1 m distance from the plant. Another feature of this camera is that using an eight position filter wheel different spectral bands can be imaged with the same camera as used for the chlorophyll fluorescence images. This yields information on a pixel to pixel basis at multiple wavelengths, for instance for imaging the heterogeneous distribution of chlorophyll and anthocyanins within a plant. Using this instrumentation correlation will be shown with the PAM-fluorometer measurements. Furthermore, first results will be discussed on the phenotyping platform using the combination of xy-table and the newly developed chlorophyll fluorescence camera.

AR 5.

MEASURING LEAF MOTION OF TOMATO BY MACHINE VISION

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For a better understanding of growth and development of tomato plants in three dimensional space, tomato plants were monitored using a vision system. It is commonly known that leaves of tomato plants do not have a fixed position and orientation during the day; they move in response to changing environmental conditions such as the position of the sun. For better understanding, it was desired to quantify this motion. Using a stereovision concept, two cameras were mounted in an experimental greenhouse a short distance apart from each other to enable depth measurement. Markers were placed on strategic spots on the tomato plant branches and leaves in the field of view of both cameras. Images were taken every ten minutes during daytime on several consecutive days. In the greenhouse, a virtual 3D coordinate system was defined and camera and tomato plant position and orientation were defined in this coordinate system. Image processing techniques were used to trace the markers and the 3D position coordinate of each marker in each image was calculated to obtain the course of a marker during several days. Stems, branches, and leave nerves were considered as kinematic mechanical, robot like, links and corresponding theory was used to model and calculate the motion of stems and leaves of a tomato plant. Analysis of the images showed both small (1-2 degrees) and large rotations (10 degrees or more) of the branches and the different leaves on a branch during the course of a day. Leaves on one side of a branch showed a parallel motion in the same direction; the leaves on the opposite site of the branch showed a mirrored motion. However, deviating patterns occurred too. The developed method proved to be able to precisely quantify the motion of stems, branches and leaves of tomato plants during several days.

AR 6.

USING A WIRELESS SENSOR NETWORK TO DETERMINE CLIMATE HETEROGENEITY IN A GREENHOUSE ENVIRONMENT

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Climate control in greenhouses is necessary for attaining high crop growth, yield and quality. Most control actions are based on temperature and humidity measurements made at a representative point in the greenhouse. Even in control systems based on a temperature integration concept, where fixed temperature bandwidths and integration intervals are commonly used, signals are obtained from specific regions. The use of a single ventilated RH-T monitoring box per control group is by far not sufficient, since the information provided is related to only one spot inside the greenhouse. To determine the control limits, more info about the micro-climate and the spatial distribution of climatic parameters are needed, especially when high temperature or humidity gradients occur. This info can be obtained by using un-ventilated, low-cost wireless sensors equipped with solid-state RH-T sensing elements, recently available in the market. As climatic parameters are spatial correlated, they can be handled as regionalized variables. To predict the values of these variables, the knowledge of error or uncertainty of the prediction is quite essential. The easiest way to obtain predictions is to use an average of the measurement data. Another way is to weight the data according to the distance between locations. This idea is implemented by geo-statistical analysis which is based on using a measurement of a regionalized variable at one location to gain information about values of the variable at another location by constructing variograms. In this study the climate heterogeneity of the greenhouse environment is analyzed by using a geo-statistical method. Six experiments were performed in commercial greenhouses observing the micro-climate with 100 wireless sensors under different conditions and for different crops. Sensors were placed near the growing tip of the crop in a horizontal grid of about 10x10 m^2. Data was acquired every minute, and 10-minute averages were used for plotting 2D-graphs and performing analyses. From the data the spatial and temporal distribution of RH and T was obtained. Instantaneous spatial differences varied up to ±5°C for T and ±20% for RH, depending on location, time of day and season. Significant differences of ±2°C for T and ±12.5% for RH, while averaging data over longer periods (5 days), have been observed. A sensor density of at least 10 sensors per hectare is needed to not miss cold or wet spots in real-time. Further research is needed to investigate the way the info regarding the spatial and temporal distribution of climatic parameters can be integrated in the control systems and finally to quantify the energy saving potential.

Keywords: relative humidity; air temperature; geostatistical methods; microclimate

Oral Presentations 13 - GROWING MEDIA AND HYDROPONICS I

GHI 1.

REMOVAL OF PLANT PATHOGENS IN RECYCLED GREENHOUSE EFFLUENT USING ARTIFICIAL WETLANDS

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Due to the lack of quality water and potential pollution of groundwater by leached nutrients, recirculation of nutrient solutions for greenhouse cultures is now unavoidable. Even though closed growing systems offer several advantages from an environmental point of view, risks associated with pathogen spread, unbalanced nutrient solutions and build up of phytotoxic compounds are major concerns for growers. Artificial wetland is a low-cost alternative for treating agricultural wastewaters. Therefore, the objective of this study was to evaluate the effectiveness of three types of artificial wetland to reduce the population of *Fusarium oxysporum* and of *Pythium ultimum* in greenhouse effluents. To do so, an experiment was conducted under greenhouse conditions using horizontal subsurface flow artificial wetlands (HSSF-AW) filled with pozzolana and implanted with common cattail (*Typha latifolia*). Wetland units contained either a 1- simple, 2- complex or 3- no external carbon source. The experimental design was a complete randomized block design with four replicates (total of 12 e. u.) and a rentention time of 5 days. Wetland units received a reconstituted greenhouse effluent and, were weekly inoculated with a suspension of *Fusarium oxysporum* (10^6 CFU per mL) or of *Pythium ultimum* (10^6 CFU per mL). Daily samples of AW-effluent were collected and *Fusarium oxysporum* and *Pythium ultimum* concentration was evaluated using the selective Komoda and PDA-PARP media, respectively. Total organic carbon, biofilm, enzyme activities and populations of mesophilic bacteria, *Pseudomonas* spp., and *Bacillus* spp. were also evaluated. Results have shown that each type of HSSF-AW was efficient to reduce by 99% measured population at the effluent level. It is possible that the indigenous population present in HSSF-AW could potentially play a role in the biological control of *Fusarium oxysporum* and *Pythium ultimum*. Biological control in the HSSF-AW will be explain in this presentation.

Keywords: marshland, pond, *Fusarium oxysporum*, *Pythium ultimum*, recycling drainage solution

GHI 2.

CAN SUPER ABSORBANT AFFECT ON EFFICIENCY OF HYDROPONIC SYSTEMS?

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Hydroponics culture has developed rapidly in recent years. Different materials are used as cultural medium substrate and one of the most common one is perlite. Despite the beneficial properties of perlit, it has low water holding capacity (WHC). As a result, the considerable volume of solution can be wasted daily and decrease the efficiency of hydroponic system. In order to improve WHC of perlite this experiment was performed in an experimental glasshouse. We explored the effect of a locally produced hydrogel as a medium amendment on yield, water/fertilizer use efficiency and fruit quality of grafted and non-grafted greenhouse cucumber plants. The results showed that hydrogel enhanced yield and water/fertilizer use efficiency but did not affect on fruit quality. Grafted plants onto *Cucurbita pepo* rootstock had higher yield and water/fertilizer use efficiency just in non-amendment substrate and could not get better records in hydrogel amended media. The possibility of using hydrogel in soilless culture and differences between grafted and non-grafted cucumber plants will be further discussed.

GHI 3.

COCONUT FIBER: A PEAT-LIKE SUBSTRATE FOR ACIDOPHILIC PLANT CULTIVATION

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A remarkable topic related to pot cultivation is the increasing need for suitable peat alternatives. Recent studies emphasized the interest in using environmentally friendly substrates with good quality, low cost, and high availability, with a view to sustainable floriculture. Peat is widely used for container plant production. Due to its high ability to preserve acidic pH through cultivation phases, high water holding capacity and porosity, and generally inertness, peat quite meets acidophilic plants needs. Physicochemical analyses performed on several peat substitute candidates elected coconut fiber as the most peat-like material. Hence, a first experimentation was conducted replacing 30% peat with coconut fiber in *Camellia japonica* L. cultivation. Positive results on growth and ornamental values led to a second greenhouse experiment on camellia where coconut fiber was raised up to 50%. Results on growth and flowering were in line with those of the standard substrate, with the exception of chlorophyll content in leaves which resulted lower, but still in the acceptable range. An eventual experimental design regarded the use of 50% coconut fiber on azalea, *Pieris* and *Leucothoe*, so as to evaluate transferability among different acidophilic species. Suitability of coconut fiber was confirmed as generally growth values did not differ statistically in *Pieris* and *Leucothoe*, while in azalea vigor and health status were even improved. It can be concluded that peat can be partially substituted by coconut fibers up to 50% without adverse effects on plant health and appearance. Considering both technical and economic factors, large-scale use of coconut fiber as peat alternative could lead to a more environmentally friendly and sustainable acidophilic plants production.

GHI 4.

GROWING MEDICINAL PLANTS IN HYDROPONIC CULTURE

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Medicinal plants are increasingly cultivated on a commercial scale to satisfy the large demand for natural remedies. These species are generally grown in open field, which results in large year-to-year variability in both biomass production and the content of active principles. Hydroponic technology may be applied to produce high-standard plant material all year-round in consideration of the possibility to control growing conditions and to stimulate secondary metabolism by appropriate manipulation of mineral nutrition because it provides a strict control of the growing conditions and should provide high-standard plant material all year round. A series of experiments were conducted between 2005 and 2010 at University of Pisa to investigate the application of floating raft growing system for the greenhouse cultivation of echinacea (*Echinacea angustifolia* DC) and basil (*Ocimum basilicum* L), which are typically cultivated for their roots and leaves, respectively. Growth and the content of distinctive caffeic acid derivatives (CADs), specifically echinacoside in echinacea and rosmarinic acid in basil, were determined. Both species grew rapidly and healthy and in two to four months they accumulated large biomass with minimal contamination. Nevertheless, in echinacea the high biomass production was not associated with high levels of CADs and the concentration of echinacoside (the marker compound used for quality standardization) never reached the minimum standard (1% on a dry weight basis) for the industrial production of dry extract. In contrast, basil accumulated very high content of rosmarinic acid. One additional advantage was the possibility to harvest also the root system of basil, which contained higher levels of rosmarinic acid compared to the leaves.

GHI 5.

MODELLING CROP GROWTH AND NUTRIENT UPTAKE IN GREENHOUSE GERBERA (*GERBERA JAMESONII* H. BOLUS) GROWN IN SOILLESS CULTURE

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A climate-based model was developed and tested to predict the daily rate of dry matter accumulation and nutrient uptake in gerbera plants grown in closed-loop soilless culture. The main input variables and parameters are indoor radiation, temperature, nutrient content of both leaves and inflorescences and a partitioning coefficient between reproductive dry matter and total aboveground dry matter. The was calibrated and validated using the results of a few experiments conducted with gerbera plants grown in semi-closed soilless (rockwool) culture in the typical greenhouse conditions of Mediterranean region in autumn and spring season in autumn and spring. In general, the model simulated satisfactorily both crop growth and nutrient uptake. The possible application of the model in the management of closed growing systems is discussed.

GHI 6.

TOMATO GROWTH, YIELD AND WATER USE EFFICIENCY AS AFFECTED BY SALINITY AND DEFICIT IRRIGATION UNDER GREENHOUSE CONDITION

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Agriculture is facing a major worldwide problem with lack of adequate water resources. Deficit irrigation is an optimization strategy which allows a crop to sustain some degree of water stress during certain stage of crops or the whole season without a significant reduction in yield in order to reduce water amounts. A greenhouse experiment was conducted during the 2008/09/ and 2009/10 growing seasons to study the effects of water salinity and deficit irrigation program at different stages of growth on yield and quality of tomato (*Lycopersicon esculentum* Mill. cv. Red Gold). Two salinity levels (irrigation water with electrical conductivity (EC) of 0.9 and 3.8 dS m^{-1}) were combined with nine irrigation treatments in a 2x9 factorial combination. The nine irrigation treatments have been applied as follows: (a) three fixed water regimes constant and regular over the whole crop cycle, it performed re-establishing 100, 80 and 60% of the maximum crop evapotranspiration (ET_C),(b) three irrigation treatments supplied a deficit amount of water as 80% of ET_C at vegetative, flowering and fruiting growth stages and (c) deficit amount of water as 60% of ET_C at the three growth stages, respectively. Vegetative growth, flowering and yield traits were measured while water use efficiency (WUE) was determined. The obtained results detected a significant effect of water salinity on yield and water use efficiency (WUE). The decrease in yields was 22% and 24% for the first and second seasons, respectively. All vegetative and fruit traits decreased significantly as deficit irrigation levels increased. WUE increased significantly as the volume of irrigation water decreased. The relationship between production and water volume was a second-degree polynomial. The interaction between water salinity and deficit irrigation treatments exerted significant effects for most of the studied parameters. The high irrigation frequency significantly mitigated the deleterious salinity effects. Deficit amount of water as 80% of ET_C at fruiting growth stages with non saline water gave the best results.

Keywords: Lycopersicon esculentum Mill., deficit irrigation, salinity, water saving, water use efficiency.

PP 1.

ASSESSING SPIDER MITE DAMAGE TO GREENHOUSE CAPSICUM LEAVES

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Spider mites are causing significant damage to crops and yields, in greenhouses as well as in fields. The Two-spotted spider mites (*Tetranychus urticae* Koch; TSSM) feed on the under-side of the leaf. Leaf age, food availability and mite density as well as climatic conditions are factors affecting vertical migration of TSSM up the plant to younger and more nutritious leaves. Since optimal plant and climatic conditions can be achieved in a greenhouse, it is hypnotized that, spectral monitoring of the upper leaves of the plants, can lead to TSSM damage identification even in early stages of infestation. By early identification of TSSM damage and early implementation of treatment, there is a possibility of minimizing damage to yield as well as decreasing the expense on acaricides applied and/or the natural enemies released. Ninety seven pepper leaf samples were randomly collected in a greenhouse of Kibbutz Nirim (31° 20′ N; 34° 24′ E) in the northwest Negev region, Israel. The samples were classified to four levels of TSSM damage: no damage; light damage; medium damage; and high damage. The leaf samples were spectrally examined in the lab by a Licor, 1800-12s, external integrating sphere connected by optic fiber to ASD FieldSpec Pro FR spectrometer. The spectral data were used for calculating several known vegetation indices. One way ANOVA analysis of vegetation indices values were applied to coupled TSSM damage levels. The ANOVA analysis resulted in ability to significantly ($p<0.001$) separate between the no damage and low damage levels. Therefore it is concluded that there is a potential for early identification of TSSM infestation in greenhouse pepper plants. The next phase of work to be done during the coming winter/spring, is to apply hyperspectral line scanner in pepper greenhouse in order to explore the above results spatially in greenhouse conditions.

PP 2.

THE USE OF CROP SPECIFIC COCKTAILS OF PARASITOIDS AGAINST APHIDS – A NEW TOOL FOR IPM

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Viridaxis is a Belgian company which developed a new way of mass-rearing aphid parasitoids. Due to its innovative and unique technology, Viridaxis has been able to develop and produce one new parasitoid species every year. The principal problem in commercial cultures is to detect and then identify the aphids present in the crop. This problem has been slowing down IPM strategies for a while now. By the time the aphids are spotted by the grower and then identified by himself or a specialized technician, it is usually too late. Chemical treatment has to be done, ruining the rest of the IPM strategy used in the crop (predatory mites, predators and other beneficials). Viridaxis developed a new concept of aphid control, based not on the species identified but on the crop treated. For each crop, the aphids present are well known. What was needed was a product controlling any aphid species possibly present in the crop. Starting with strawberries, Viridaxis studied the aphids attacking the cultures in various regions and over many years, and developed a unique cocktail of parasitoids species (FresaProtect) parasitizing and controlling all aphids. The releasing points have been adapted to this mix and the result is a fast and easy to handle product. FresaProtect is used as a preventive agent with perfect integration into an IPM scheme. After three years of R&D in the lab and in the field and two years of large scale field trials in Belgium and Europe, FresaProtect has been proven to be an efficient treatment for aphid control. After the strawberries, Viridaxis is expanding this concept to other protected crops such as other soft fruits (raspberries, blueberries, currants), ornamentals, and vegetables.

PP 3.

A NEWLY DEVISED ELECTRIC FIELD SCREEN FOR AVOIDANCE AND CAPTURE OF GREENHOUSE INSECT PESTS

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A bifunctional electric field screen was proposed to physically exclude insect pests from greenhouses. The screen consists of insulated iron wires (ICW) arranged in parallel and two earthed conductor nets placed on both sides of the ICW. A negative charge (0.1 to 8.0 kV) was applied to the insulated wires with a voltage generator to polarize an insulator sleeve used to cover the wire, negatively on the outer surface and positively on the inner conductor wire surface of the sleeve. The negative surface charge of the ICW caused an electrostatic induction in the earthed nets and an opposite charge on the net surfaces facing the ICW. An electric field formed in a space between the ICW and the earthed net, and the field strength increased in direct proportion to increasing voltages applied to the ICW. Adults of the test insects (whitefly, western flower thrips, green peach aphid and tomato leaf minor) reaching the outer surface of the earthed net were deterred from entering the inside of the charged screen, whereas all insects immediately passed through the screen when the ICW was not charged. This avoidance was directly proportional to the increase in the voltage. In addition, the capability of the screen to capture insects that enter inside the screen was proven by introducing insects into the space between the ICW and the earthed net. Strong capture was observed when the ICW was negatively charged with more than 4.0 kV. A test in screen-installed greenhouses sho-

wed that the insects were completely prevented from passing through the charged screen, in contrast to a rapid transfer of all insects when the screen was not charged. Thus, the present results show that the described screen is a promising physical tool for controlling insect pests in open greenhouses.

PP 4.

EPIDEMIOLOGY AND MANAGEMENT OF DOWNY MILDEW, A NEW PATHOGEN OF COLEUS IN THE UNITED STATES

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Coleus (*Solenostemon scutellarioides*), a herbaceous bedding plant, has been prized by gardeners for its bright colorful foliage since Victorian times, and in recent years has seen a resurgence in popularity in the United States. Coleus plants exhibiting disease symptoms were observed in New York and Louisiana in 2005 and throughout much of the United States by 2006. This pathogen was determined to be *Peronospora* sp. Epidemiological studies were conducted at Michigan State University to determine the optimal environmental conditions for sporangial release in the greenhouse. Additionally, host resistance and reduced-risk fungicides were investigated as management tools. Concentrations of airborne sporangia were monitored by placing a 7-day volumetric spore sampler in a greenhouse with coleus infected with *Peronospora* sp. Coincident hourly leaf wetness, temperature, and relative humidity data were collected. Two years of spore trapping in a greenhouse with downy mildew-infected coleus showed that a period of high relative humidity (>95%) followed by lower relative humidity (70%) prompted the release of especially high numbers of sporangia into the atmosphere. Coleus were screened for downy mildew susceptibility in trials that included 21 cultivars which were rated for disease severity and pathogen sporulation. 'Volcano' and 'Dragon Black' consistently showed susceptibility to downy mildew. None of the cultivars included in the study showed disease resistance. 'Fairway Red Velvet' had limited downy mildew symptoms and pathogen sporulation. Reduced-risk fungicides that controlled downy mildew on inoculated plants when compared with inoculated plants that were not treated included fenamidone, cyazofamid, and azoxystrobin. Selected, new and experimental fungicides that are not yet labeled were also effective. The results of and experimental approach that defines the environmental parameters that favor downy mildew sporulation, identifies coleus cultivars that offer disease resistance, and tests reduced-risk fungicides will offer growers an effective management program.

PP 5.

EFFECT OF RHIZOBACTERIA SELECTED FOR PLANT GROWTH PROMOTION AND BIOLOGICAL CONTROL OF FUSARIUM OXYSPORUM F. SP. RADICIS-LYCOPERSICI ON YIELD OF HYDROPONICALLY GROWN TOMATO PLANTS

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Plant growth-promoting rhizobacteria –PGPR- have great importance among the beneficial microorganisms that are naturally occurring in the rhizosphere. They increase resistance of plants against to various abiotic and biotic stress conditions, plant growth and yield. In this study, PGPR selected for the ability of plant growth promotion and biological control of crown and root rot caused by Fusarium oxysporum f. sp. radicis-lycopersici (FORL) were tested in tomato production in substrate under greenhouse conditions. Four PGPR isolates (TR 2/1, TR 18/1, TR 21/1, 14/1y) selected according to the results of in vitro and in vivo tests from a collection of fifty PGPR strains were compared with control treatment (no PGPR inoculated). As plant material, a resistant and a sensitive tomato varieties against FORL were used. Plants were grown under healthy conditions without FORL inoculation. Rhizobacteria inoculation took place three times; before sowing as seed coating and two times after transplanting as substrate drenching (one day and one week after transplanting). Bacterial suspensions with a final concentration of 10^9 CFU.ml^{-1} were used. Seeds were sown on 11 January 2010 and transplanting was realised on 26 February 2010. Harvest period lasted six weeks from 24 May up to 2 July. Cumulative fruit weight and number were evaluated weekly. The main effects of varieties and rhizobacteria were significant; no interactions between experimental factors were detected. Tomato plants inoculated with rhizobacteria TR 2/1, TR 18/1 and TR 21/1 gave higher yield compared with the control treatment.

PP 6.

THE OCCURRENCE OF FUSARIUM CROWN AND ROOT ROT OF TOMATO IN SOUTH AND SOUTHERN WEST OF TURKEY

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Crown and root rot of tomato caused by Fusarium oxysporum f.sp. radicis-lycopersici was first detected in Turkey in 1998. Since then, it has been observed to become a common disease in commercial greenhouses in south and southern west part of Turkey. In order to gain an opinion about the incidence of the disease and obtain isolates of the pathogen for further studies, a survey was conducted in the greenhouses of two major tomato growing provinces, namely Antalya and Muğla on May of 2008. Diseased plant samples were collected from greenhouses where the crown and root rot has been suspected to occur and such plants were counted. Fifty three Fusarium oxysporum isolates were obtained from forty one tomato greenhouses and twenty eight of them were selected to use in pathogenicity test. For the pathogenicity tests two tomato cultivars 'Newton F1' and 'Kardelen F1' which were common in commercial greenhouses where the disease symptoms existed, were inoculated by root-deep technique

with conidial suspension of those isolates. Based upon their pathogenicity reaction eighteen isolates were identified as F. oxysporum f.sp. radicis-lycopersici. The presence of the pathogen was also confirmed by re-isolations from infected tomato plants on selective media for Fusarium spp. As a result, the incidence of the disease was determined as 26.1% and 85.1% in commercial tomato greenhouses from where the pathogen could be isolated and identified, in Antalya and Muğla, respectively.

PP 7.

EVALUATION OF THE TECHNICAL EFFICACY OF SPRAY GUNS AND WHEELED MANUAL SPRAYERS FOR PHYTOSANITARY TREATMENTS IN GREENHOUSES

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The main objective of this work is to evaluate and compare the technical efficacy of the distribution of the spray applied with spray guns vs. wheeled manual sprayers in greenhouse tomato cultivation. The test conditions of the spray gun were established taking into account the routine farming practices of applying a volume of around 1500 l/ha at pressures of about 20 bar (in completely developed crops). The wheeled sprayers were tested with two types of nozzles (conventional fan and anti-drift fan) at a pressure of 12 bars, distributing approximately 1500 l/ha. The 3 treatments were compared by placing artificial collectors (paper filter strips) in 12 zones (3 heights and 4 depths) of 5 pairs of plants. In addition, collectors were placed on the ground, coinciding with the 4 depths. For all tests, the lines were sprayed from both sides with a colorimetric tracer (tartrazine). With the resulting data, the deposition was calculated as a function of the amount of tracer per unit area. The results indicated that the depositions from the spray gun were significantly inferior to those of the wheeled manual sprayer. Specifically, the spray gun resulted in a deposition of 42.2% and 31.3% less than that of the wheeled sprayer with conventional fan and induction nozzles, respectively. In addition, the uniformity of the distribution in the plant mass was worse, with a coefficient of variation of 72.39% and high losses to the soil. Regarding the assays made with the wheeled manual sprayer, the results indicate that the conventional nozzles offer somewhat better performance than do the induction ones. The conventional nozzles provided better deposition (14.3% greater), a higher recovery rate (87% as opposed to 78%) and lower losses to the soil (41% as opposed to 45%).

PP 8.

AN ELECTROSTATIC INSECT EXCLUSION TECHNIQUE ENABLES GERMFREE CULTIVATION OF TOMATO PLANTS IN OPEN GREENHOUSES

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An electrostatic insect exclusion technique is our environment-friendly method for physically controlling insect pests of crop plants. Our long-distant desire in our greenhouse tomato production is to integrate this electrostatic method in crop protection measures and to reduce the use of fungicides and insecticides. The first device used to capture flying insect pests was a dielectric screen in which paired insulator conductor wires were arranged in parallel and oppositely charged with equal magnitude using two separate electrostatic voltage generators. This type of screen utilized electric lines of force that move a positively charged particle from the positive to the negative pole. The force was strong enough to capture adult whiteflies, and therefore is potentially applicable to other flying insect pests of similar body length (0.8 to 1.3 mm), such as thrips, aphids, and leaf miners. However, the screen was ineffective in capturing much larger insects, as larger insects are stronger and therefore more able to escape from the screen trap. The second device was a three-layered version of the electric field screen, in which the earthed metal meshes were placed on both sides of single-layered insulated conductor wires to make dielectric poles. This screen was found to be able to strongly capture larger insects with body lengths of 2 to 4 mm and could be applied to the control of all pest insects of open greenhouses. Our incremental attempt was to apply this screen to the greenhouse to achieve germfree tomato production. For this purpose, the present work was performed to demonstrate an effectiveness of the present screen for capturing air-borne conidia of the powdery mildew and gray mold pathogens that have been most serious in our greenhouse tomato production. The results obtained indicate that the screen can create germfree and pest-free space in open greenhouses.

SESSION KEYNOTE V

GREENHOUSE CROP MANAGEMENT: NEW APPROACHES TO AN OLD CHALLENGE

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Protected cultivations need a continuous adaptation of their configuration from different points of view, for matching a changing scenario, dealing particularly with globalization, evolution of consumers expectations, increasing attention to environmental impact. Therefore, being the crop the basic component of the greenhouse agro-system it is necessary to improve its productivity and ability to use the available resources. From a purely plant physiological approach, these objectives are accomplished by dry matter production and partitioning. However, high product quality (both nutritional and marketing) and low-external-inputs farm management systems appear nowadays to be even more relevant objectives than crop yield. As a matter of fact, customers are generally willing to pay more for food which is of a high ecological quality but inferior in appearance and technological quality. This is particularly important for Mediterranean greenhouses where plants are often exposed to diverse abiotic stresses, including heat and salinity. In this respect, better crop management and more suitable cultural practices may be effective for the above purposes. The several aspects which could be considered, assume different levels of importance in relation to the specific biotic and environmental variables that can change over time. There are many approaches that could be considered in greenhouse crop management to identify innovative strategies to both optimise resource use efficiency and to reduce the environmental impact of greenhouse production. The main crop management innovations will be presented and discussed with respect to the Mediterranean greenhouse. Attention will be addressed to agronomic improvements and crop management innovations aimed at increasing greenhouse production sustainability.

CPI 1.

GROWTH RESPONSES OF TWO *ANTHURIUM ANDREANUM* GENOTYPES TO ELEVATED CARBON DIOXIDE CONCENTRATION

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CO_2 enrichment is not a year round practice in the cultivation of cut *Anthurium Andreanum* in The Netherlands, but is mostly related to the heat demand in the greenhouse, which means that there is only sufficient CO_2 available (above ambient) when the heating is operating. Because of great efforts on energy saving measures, the number of heating hours, and thus CO_2 dosing, has been only declining in the recent years. The expected benefits of CO_2 dosage, based on growers' experience, are too low to justify the investment and running costs of a system with continuous CO_2 dosage, especially in times of very low flower prices. To evaluate whether the actual cost of continuous CO_2 supply can be paid back by extra production and/ or improved quality characters, a one year lasting greenhouse experiment was designed in which 3 levels of CO_2 (380, 500 and 800 µmol mol^{-1}) were realized to two cut *Anthurium* cultivars ('Tropical' and 'Midori'). This ongoing study, currently in its ninth month, shows that elevated carbon dioxide significantly increases the number of harvested flowers, flower fresh weight and decreases generation time as compared to the ambient CO_2 level in both cultivars. Moreover, the quality characters (flower diameter and stem length) are highly improved. However, the two studied genotypes respond differently to the CO_2 enrichment. 'Midori' is found to be more responsive than "Tropical", a difference possibly related with observed differences in stomatal density at the different CO_2 levels. The implications of these results on the economics of continuous CO_2 fertilization (separated from the heating demand) in cut *Anthurium* cultivation for different genotypes are discussed.

CPI 2.

EFFECTS OF OXYGEN SUPER-SATURATED NUTRIENT SOLUTIONS ON GREENHOUSE TOMATO

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The effects of varying levels of nutrient solution oxygenation on greenhouse tomato (*Lycopersicon esculentum L.* cv. Macarena) was investigated in 2006 and 2007 using rockwool, coir and perlite growing media. In 2006, early marketable (and total) yield was higher with 75 ppm O_2 in the nutrient solution (14.5 kg m^{-2}; 1.8 kg wk^{-1}), than the control (12.8 kg m^{-2}; 1.6 kg wk^{-1}) and compressed air (12.9 kg m^{-2}; 1.6 kg wk^{-1}) treatments. The seasonal yield followed the same trend, i.e. higher values were obtained with 75 ppm O_2 (28.9 kg m^{-2}) than with the control (27.1 kg m^{-2}) and compressed air treatments (26.2 kg m^{-2}). Yield in 2006 was generally comparable at all levels of oxygen supersaturation (20 ppm, 30 ppm, 35 ppm and 75 ppm). The seasonal average weight of marketable fruit was significantly higher with 35 ppm O_2 (206.5 g) than with the control (195.8 g) and compressed air treatments (194 g). In 2007, in general, the late-season and seasonal marketable yield with all oxygen treatments was either equal to or higher than

the control. Except for the 30 ppm treatment, the usual decline in marketable yield across the season was slower with oxygen super-saturated nutrient solution (24-29% between the mid and the last season) than with the control (i.e. a corresponding 40-45% reduction), indicating that oxygen can sustain productivity under ageing stress condition. The 60 ppm O_2 treatment resulted in higher total seasonal yield than the control on the rockwool medium. These results suggest that application of nutrient solution oxygenation under certain conditions can improve greenhouse tomato productivity. Differences in climatic conditions may explain partly the differences in crop performance between the two seasons.

Key words: hydroponics, root-death, yield.

CPI 3.

CONTRIBUTION OF PHYTOHORMONES IN ALLEVIATING THE IMPACT OF MODERATELY SUBOPTIMAL TEMPERATURE STRESS ON GRAFTED TOMATO

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Low temperature is one of the most important environmental stress factors that inflict plant growth and development. The root system has a strong impact on the susceptibility of plants to low temperature and this has been attributed to several root functions, including production of phytohormones, their upward transport, and root-to-shoot signaling which change shoot physiology and thus growth and productivity. Grafting might be used as an efficient tool to modify root gene expression, thereby increasing temperature stress tolerance of fruit vegetables. In order to test whether rootstocks are capable of alleviating negative effects of low temperature by altering the biosynthesis of hormones at the root level, reciprocal grafting of cultivars and their mutants was applied. Mutants expressing or lacking a specific hormone, particularly auxin, ethylene, absicic acid (ABA) and salicylic acid (SA) were selected. In the case of ABA, two different mutants where used, specifically 'Sitiens' and 'Notabilis'. After two weeks of regular growth in a greenhouse at a mean air temperature of 22 °C, the latter was lowered to a suboptimal level (15 °C) for two weeks and then raised again to 22 °C to test plant adaptation. Growth and physiological characteristics, such as leaf area, shoot length, leaf dry mass, photosynthesis, transpiration, and stomatal conductance were examined. The levels of proline and chlorophyll were also measured. Results confirmed the negative impact of low temperature on growth characteristics. Auxin- and ethylene-deficient mutants did not respond differently to suboptimal temperature, while ABA- and SA-deficient mutants were more severely affected than the control plants. Results indicate that rootstocks producing higher levels of some phytohormones than the self-rooted scion improve significantly growth and physiological characteristics of the grafted plant under suboptimal temperature conditions. Such rootstocks may be commercially used to alleviate suboptimal temperature stress by operating at the hormonal level.

CPI 4.

YEAR-ROUND MINI-CUCUMBER PRODUCTION WITH SUPPLEMENTAL LIGHTING: ADDITIONAL BLUE LIGHT, GROW PIPE HEATING AND FERTIGATION

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The effects of additional blue light, grow pipe heating and mineral nutrition supply (K, Ca, and N: K ratios) on plant growth and fruit yield of mini-cucumbers were investigated in 4 winter greenhouse trials from 2006 to 2010 for improving fruit yield and quality under supplemental lighting. High pressure sodium (HPS) lamps are the most commonly-used light source and were used as the main lighting source in these trials. Because HPS lamps are short of blue light (in comparison to solar radiation) and blue light is essential in chlorophyll formation and photo-morphogenesis, we evaluated the effects of additional blue light on mini-cucumber production in two of the trials. The additional blue light (6 to 12 µmol/m^2/s PAR (photosynthetically active radiation), in addition to the 180 µmol/m^2/s PAR provided by HPS) was supplied with blue LED above crop canopy. The addition of blue light significantly alleviated leaf chlorosis but only resulted in 0% to 3% yield increase, which was less than the PAR increase (3% to 6%). The plants in the greenhouses might have received sufficient blue light from solar radiation and thus increasing the proportion of blue light in supplemental light did not improve response of plants to supplemental lighting. Grow pipe heating increased leaf and fruit temperature, and fruit yield. No interaction between lighting and the supply of Ca or K was detected in our trials; the highest fruit yield was achieved with 400 mg/L K and 210-260 mg/L Ca regardless of the use of lighting or not. Supplemental lighting had a significant interaction with N: K ratios; the highest fruit yield was achieved with an N: K ratio of 1:3 (mg/L: mg/L) under supplemental lighting (110 to 180 µmol/m^2/s) while N: K ratios did not affect fruit yield under ambient light (no supplemental lighting).

CPI 5.

DEVELOPMENT OF A GENOTYPE-TO-PHENOTYPE CROP SIMULATION MODEL FOR CAPSICUM ANNUUM L.

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Yield is determined by many underlying component traits as well as the environmental conditions. Prediction of yield of a specific genotype is therefore difficult. However, the underlying traits of yield are assumed to be more stable (less dependent on environmental conditions) than yield itself. Likewise, QTL of the underlying component traits are expected to be more stable, i.e. less environment dependent, than QTL of yield itself. Crop growth models enable us to use underlying component traits to simulate final crop yield in different environments. In the EU-project SPICY (Smart tools for Prediction and Improvement of Crop Yield), one of the aims is to develop a genotype-to-phenotype model. The model parameters are based on the QTL for the component traits instead of the phenotypic parameters for the components. As a first step, a simple crop growth simulation model was developed with three parameters that were genotype specific (Light Use Efficiency, leaf area development rate, partitioning). In the model, leaf area expansion is linearly related to temperature sum. Light is intercepted and converted to dry matter by means of Light Use Efficiency (LUE). Partitioning into the fruits is regulated by partitioning index. To derive the genotypic component traits, the model parameters, a Recombinant Inbred Line (RIL) population (149 lines) of the cross Yolo Wonder x Serrano Criollo de Morelos-334 (both *Capsicum annuum* L.) was grown at two different locations (Wageningen and Spain) in two different seasons (spring, summer-autumn). The above mentioned parameters were obtained for the four environments. Simulations were first done with the model parameters obtained for each environment to ensure that the model principles worked. Next, QTL analyses were performed on the parameters determined for the four environments. The results of these analyses were used in the simulation model instead of the genotype specific model parameters. The perspectives of this approach for predicting yield of a specific genotype will be discussed.

CPI 6.

YIELD COMPONENT ANALYSIS OF SALINITY RESPONSE FOR SELECTED BACKCROSS INBRED LINES OF *SOLANUM LYCOPERSICUM* 'MONEYMAKER' X *SOLANUM CHMIELEWSKII*

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Eight lines and 'Moneymaker' (parent cultivar), selected from the backcross inbred lines (BIL population) of *Solanum lycopersicum* 'Moneymaker' x *Solanum chmielewskii* were grown on stonewool from July till November in a greenhouse at two salinity levels (EC = 3 dS m^{-1} and EC = 8 dS m^{-1}). High EC was obtained by adding sodium chloride to the nutrient solution with EC = 3 dS m^{-1}. This experiment aimed at determining possible differences between these genotypes in their response to salinity and to link this to their genetic background. Furthermore, morphological and physiological parameters were determined which might explain possible differences in salinity response.
Genotypes differed significantly in their yield response to salinity. Fresh yield was reduced at high salinity for most genotypes, with some genotypes being sensitive (43-45% yield reduction) and one genotype being tolerant (no yield reduction). Also 'Moneymaker' did not show yield reduction at high salinity, however, its yield was only 72% of the yield of the tolerant genotype. Yield component analysis revealed that contrasting genotypic behavior mainly resulted from differences in dry matter production and in fruit set at high EC. The salt tolerant genotype seems very promising, not only because of its high yield and salinity tolerance in the present experiment. When growing all 62 genotypes from the BIL population at moderately high temperature stress, the salt tolerant genotype showed the highest pollen germination and fruit set percentage, number of ripe fruits, total biomass and yield. Future research aims at further unraveling the physiological and genetic basis behind these favorable characteristics of this genotype.

GHII 1.

A CONTINUOUS RECIRCULATING DRIP SYSTEM FOR GROWING IN SOLUTION CULTURE

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Conventional Nutrient Film Technique system (NFT) is used for long time for growing short-term crops like lettuce, Spinach et.al. Using NFT for long-term crops such as, tomatoes, cucumbers and peppers presents disadvantages. Extended measurements sow that the oxygen content along the bed in NFT decreases from inlet to outlet. Also, the deferent oxygen content along the bed seems to influence nutrient uptake. A modified system using continuous recirculating drip system for growing in solution culture (NDT) was designed to provide precise nutrient control, consistent water potentials, and well oxygenized root environment for long-term crops. Tomato plants grew in the NDT for seven months vigorously and were healthy and more productive than in the conventional NFT system. Photosynthesis and stomatal conductance were enhanced in NDT compared to NFT. The measurements of oxygen concentration in nutrient solution near by the roots was high and uniform along the channel of NDT, but not in the NFT, where was decreasing along the channel. The results indicated that all plants grown in the NDT did not suffer from any hypoxic symptoms. Thus, the NDT appeared to approximate a well-drained porous substrate and was ideal for long-term greenhouse growth of vegetables. For a commercial culture, this system provides a better root environment control and independence of porous materials. For experimentation this system maintains the advantages that solution culture provides, like a better controlled abiotic-stress and easiness of root harvest.

Key words: hydroponic systems, hypoxia, nutrient oxygen concentration, vegetables

GHII 2.

USE OF PHENOLIC FOAM AS A GROWING MEDIUM FOR COMMERCIAL CULTIVATION OF TOMATO 'SUPERDOTAERANG'

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This study was conducted in a glasshouse to compare growth and performance of 'Superdotaerang' tomato in various growing media in a slab form, rockwool (the control), coir, phenolic foam LC, phenolic foam RC, phenolic foam run 3813-4, and phenolic foam 3813-4W. Each slab was sealed in a plastic package (100 cm x 7.5 cm x 15cm). Plug seedlings obtained from a commercial nursery in Jinju, Korea which had been grown for 40 days in 40-cell plug trays were transplanted to slabs on 19 May 2010. The experiment included six plants per replication with three replications. At 55 days after planting, growth parameters such as plant height, stem diameter, number of leaves, plant fresh weight, plant dry weight, and stem length between clusters were measured. Plant height and number of leaves were not significantly affected by the medium. Plant height was the greatest in phenolic foam LC. The greatest fresh and dry weights of the top were obtained in rockwool. In phenolic foam 3813-4W, plants showed the smallest plant height, stem diameter, fresh and dry weights, and soluble solids content. Each treatment showed similar results as compared to the control. The results obtained suggest that phenolic foam LC and phenolic foam RC may be used as a new material in a commercial scale production of tomato.

Additional key words: cocopeat, rockwool, slab, soluble solid content
This research was supported by Technology Development Program for Agriculture and Forestry, Ministry for Food, Agriculture, Forestry and Fisheries, Republic of Korea (Project No. 110023-3).

GHII 3.

THE EFFECT OF UNEQUAL DISTRIBUTION OF NaCl SALINITY ON TOMATO GROWTH AND POTASSIUM ABSORPTION

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The growth and relative potassium (K^+) absorption of Tomato plants was studied, when grown in unequal distribution of NaCl salinity. The plants were grown in closed hydroponic system (NFT), after split of their root system in two compartments. The experiment consisted of three treatments: In the first treatment (A, control) both compartments of the root were supplied with standard nutrient solution, of electric conductivity 2 dS m^{-1}. In the second treatment (B) the half of the root system was supplied with the above standard nutrient solution, while the other half of the root system was supplied with saline nutrient solution (standard nutrient solution + 40 mmol/l NaCl) of 6 dS m^{-1} electric conductivity, in which Rubidium (Rb) was added (used as a tracer to examine K^+ uptake from the saline compartment). In the third treatment (C) both the two compartments of the root system were supplied with saline nutrient solution (standard nutrient solution + 40 mmol/l NaCl) of 6 dS m^{-1} electric conductivity, while in one compartment Rb was added (used as a tracer to verify the relative rate of Rb / K^+ uptake). The results indicate that, in treatment C the exposure of both root compartments in salinity resulted significant reduction of leaf area and yield, the growth of root system in each compartment was equal, as it was in the control treatment, and the absorption of Rb^+, K^+ was at the same ratio. In treatment B, the use of a standard nutrient solution to one compar-

tment of the root system alleviated the effects of salinity, with regard to the leaf area and yield. The part of the root system which was supplied with the standard nutrient solution had double dry weight, compared to the part of the root which was in the saline nutrient solution; however the sum of the root dry weight in the two compartments did not varied from that in the control treatment. In treatment B, the Rb^+ tracer proved that K^+ was not absorbed proportionally from both root parts, not even proportionally to the root mass. Most of the K^+ was absorbed from the root part that was in the standard nutrient solution. This was attributed to antagonistic effect of K^+ with Na^+, in the presence of NaCl.

Key words: salinity, potassium absorption, Tomatoes

SESSION KEYNOTE VI

ENVIRONMENTAL CONTROL TECHNOLOGIES TO IMPROVE PRODUCT QUALITY

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Greenhouse and controlled environment (CE) technology was traditionally developed to extend the crop cycle into the seasons that are not suitable for open-field production. CE technologies have also focused on optimizing environmental conditions to maximize plant growth and development rate as well as product quality. Today, product quality is a critical factor due to the increasingly competitive nature of the market for greenhouse products. Recognizing the unique opportunity to improve overall or specific product quality, various research has shown that the greenhouse environments could be tailored so that the products gain extra value such as improved vigor, nutritional quality or extended postharvest shelf life. For example, our research at the University of Arizona demonstrated that application of moderate salt stress to tomato plants could enhance soluble solids, lycopene and other antioxidant concentrations in fruit throughout the experimental year-round production. Tomatoes produced under salt stress generally exhibited a longer shelf life. However, it is also recognized that environmental conditions that maximize the biomass production are not necessarily the same as those that enhance the product quality. Therefore, economic analysis needs to be conducted and effective marketing strategy to promote and educate consumers must be developed to profitably introduce such CE technologies that enhance specific quality attributes by sacrificing overall yields. In addition to pre-harvest CE technologies, researchers should consider possible effects of postharvest handling, storage CE technologies and distribution methods to ensure delivery of high product quality to the consumers. Researchers and extension personnel must take a transdisciplinary systems approach that considers all factors involved from greenhouse production to consumption to successfully introduce such technologies that support sustainable development of greenhouse industry.

PQ 1.

CAN GRAFTING ENHANCE FLAVOUR AND HEALTH PROMOTING COMPOUNDS IN TOMATO FRUITS GROWN AT SUBOPTIMAL TEMPERATURE?

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Grafting of existing elite commercial cultivars onto selected low-temperature tolerant rootstocks is regarded as a promising tool to produce vegetables at suboptimal temperature. Recently, the effectiveness of grafting with respect to upgrading fruit quality is increasing. However, no information on fruit quality of grafted tomato at suboptimal temperature is available. 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 at two air temperatures (17, 21°C). Health promoting compounds (lycopene, ß-carotene, ascorbic acid) and flavour compounds (sugars, titratable acids, aroma volatiles) were analysed in red-ripe tomatoes at three harvest dates.The results show that the concentration of lycopene and ascorbic acid was lower in 'Classy' and 'Piccolino' at 17°C compared with 21°C and grafting had no effect on these health promoting compounds. Furthermore, lower concentrations of taste compounds (titratable acids, sugars) were found at lower temperatures. However, grafting increased acid concentration but decreased sugar concentration. Interestingly, the concentration of 14 aroma volatiles was higher in tomatoes grown at 17°C than at 21°C. On the other hand, the concentration of 9 aroma volatiles was lower. Grafting increased five lipid-derived, two lignin-related and two amino acid-related aroma volatiles and decreased the carotenoid-derived ß-damascenone, the terpenoid-derived linalool and the lipid-derived (*E,E*)-2,4-heptadienal. Surprisingly, no interaction between grafting and temperature was found for most of compounds investigated. Deductive, the rootstock 'Maxifort' was able to compensate the decreased concentration of titratable acids and of one aroma volatile ((*E,Z*)-2,4 decadienal) at low temperature.

PQ 2.

POST-HARVEST BLUEING OF SPATHA IN *ANTHURIUM ANDREANUM* 'TROPICAL' AS AFFECTED BY PRE-HARVEST CONDITIONS

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Post-harvest blueing of Anthurium spatha has recently become a serious quality problem in red Anthurium varieties in The Netherlands. Although the first signs of blueing can show already at harvest, allowing timely flower rejection, blueing mostly becomes visible during and after the trading channel, leading to quality claims. By means of a nursery comparison between 10 growers and a parallel greenhouse experiment, it was investigated how different circumstances during greenhouse cultivation (including climate, nutrition factors and crop management) contribute to blueing within the first 12 days after harvest. Blueing was observed in all nurseries in varying degrees depending on the harvest date. A good correlation was found with the time that the RH is over 80% during the six weeks previous to harvest. The effect of high RV on blueing was increased by high CO_2 concentrations, both suggesting reduced transpiration as the main cause. The greenhouse experiment confirmed these findings and also showed that the recently introduced crop management method of breaking young leaves increased the chances for blueing. A higher calcium supply in the nutrient solution contributed to a slight increase of the calcium content in the spatha tissue, but could not prevent blueing. The increase of the nutrition EC as a method to prevent blue coloration, widely used by growers, was found to make the problem more severe and to reduce strongly the concentration of Calcium, Magnesium, Manganese and Boron in the spatha tissue.

PQ 3.

ZINEG – THE LOW ENERGY GREENHOUSE: IMPACT OF REDUCED IRRADIATION ON GROWTH AND FLAVONOID SYNTHESIS OF LETTUCE

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Thermal insulation shields save energy in greenhouses but are likely to decrease PAR-intensity and thereby (1) constrain plant growth due to reduced photosynthesis and (2) lower the plants' flavonoid content as their biosynthesis is induced by light. It may (3) play an important role in which growth period the light intensity is reduced because plant metabolism alters during ontogeny. To test these hypotheses Red Oak Leaf lettuce (*Lactuca sativa*) was grown in phytochambers under average light intensities of 410 ("unshaded") and 226 µmol/m² s PAR ("shaded"), respectively. After two weeks some plants were harvested, some others were transferred between treatments. After four weeks all plants were harvested. Weight, maximum diameter of heads and number of leaves were noted and flavonoid concentration was analyzed (HPLC-DAD-ESI-MS²). The examined growth characteristics showed no significant differences after two weeks. After four weeks plants grown unshaded or "shaded-unshaded" developed the heaviest heads (289.5 and 308.1 g FM, respectively). Those grown shaded showed the least weight (273.9 g FM) and possessed on average 9.7 leaves less than the other treatments. The differences in quercetin and luteolin concentration were also not significant after two weeks of growth. Nevertheless, after four weeks plants grown unshaded or "shaded-unshaded" contained higher quercetin concentrations (1.02 and 1.17 mg/ 100 g FM, respectively) than those grown "unshaded-shaded" (0.81 mg/ 100 g FM). Similar results were found for luteolin: Plants grown unshaded and "shaded-unshaded" contained more luteolin (both 0.07 mg/ 100 g FM) than those grown "unshaded-shaded" or shaded all the time (both 0.04 mg/ 100 g FM). Our study indicates that light conditions have a stronger impact on growth and flavonoid biosynthesis of lettuce in the two weeks prior to harvest than in the weeks before.

CPII 1.

CASE STUDIES OF A MODIFIED BIOLOGICAL SIMULATOR (TOMGRO) ACCORDING TO SHORT CROPPING PERIOD

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The aim of this work was the analysis of sensitivity of a modified biological simulator (TOMGRO) in tomato crop during winter period. The modified biological simulator (TOMGRO) that used for case studies of the experiment has been developed and validated according short cropping period, cultivation techniques and climate conditions of the countries and growers near Mediterranean. Analysis of sensitivity was necessary in order to test simulator's behavior according different climate data. Case studies were focused in the influence of temperature in tomato growth and production. For this purpose experiments were carried out in the farm of the University of Thessaly in the region of Velestino. Climate data were recorded inside and outside of the greenhouse area. Simultaneously biological data for tomato growth and production were recorded. Results showed that climate variation inside the greenhouse area causes modification in tomato growth rate and production. It was found that temperature increasing leads to: i). increasing the number of nodes, leaves and trusses of the plants, ii). reduction of dry weight of leaves, stems, fruits and leaf area plant, iii). simultaneously reduction of mature fruits number and iv). early production. The management of greenhouse climate can be made more efficient by using the case studies results from the biological model. A part of the conclusions will contribute to balance of earnings of a product's nominal value into the market, according to the management cost of the greenhouse equipment during the production process.

Key words: Biological simulator, TOMGRO, decision-making systems, case studies, growth, tomato production.

CPII 2.

CROP PHYSIOLOGY IN SEMI-CLOSED GREENHOUSES

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In energy efficient greenhouse concepts, durable energy sources should be included. In the recently developed concept of (semi-)closed greenhouses, the excess of solar energy in summer is collected and stored in aquifers to be reused in winter to heat the greenhouse. The combination of cooling and reduced rates of ventilation allows high CO_2 concentrations throughout the year. Other specific climate characteristics in semi-closed greenhouses with cooling ducts below the gutters are: improved temperature control, vertical temperature gradients, high humidities, high CO_2 concentrations even under conditions of high light intensities and increased rates of air movement. Aim of this research was to establish the effects of these new climate conditions on yield and underlying physiological processes. Tomato is used as a model crop. Experiments on a range of open to fully closed greenhouses, vertical temperature gradients, CO_2, diurnal temperature patterns and humidity were performed. In these experiments, assimilate production, partitioning, elongation and fruit development as well as transpiration at different crop levels were investigated. Leaf photosynthesis was measured under a wide range of light intensities, CO_2 concentrations, temperatures and humidities. Instantaneous leaf photosynthesis rates were integrated over canopy depth and time to instantaneous and daily crop photosynthesis rates. The data obtained will be integrated in a crop growth model, with which scenario studies will be performed to optimize climate conditions to fully exploit the potential of semi-closed greenhouses.

CPII 3.

GROWTH OF TOMATOES UNDER HYBRID LED AND HPS LIGHTING

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The use of LEDs can be promising for greenhouse horticulture, but before it can be put into practice on a large scale more knowledge must be acquired on effects of LED lighting on crops. Furthermore, the growers will have to learn to grow their crops under LEDs and the efficiency of LEDs must increase even more.
In order to gain more insight into the influence of LEDs on crop growth and production, an experiment was performed in the Wageningen UR greenhouses with a small cocktail plum tomato (cv Sunstream) from October 2009 to June 2010. Four lighting treatments were applied, with each treatment in a separate greenhouse compartment: top lighting with HPS (1) or LED (2), and hybrid lighting with HPS above the crop in combination with LED lighting above the crop (3) or in between the canopy (interlighting) (4). The light intensity from the lamps in all treatments was maintained at 170 µmol m^{-2} s^{-1}. The light was 50/50 divided between HPS and LED in the hybrid treatments. The climate in each treatment was adapted to the needs of the crop in each lighting system. The various lighting systems resulted in different greenhouse climates, in which more heating was required in the LED treatment and the least heating in the hybrid with interlighting. A strong crop developed under LED alone, and to maintain a proper crop balance the fruit load was altered by maintaining an extra tomato fruit per truss and increasing the stem density relative to that under HPS. The leaves of tomato grown under HPS were thinner and aged more rapidly than in the other treatments. Leaves lower in the canopy under LED alone or hybrid treatments had a higher photosynthesis capacity in the winter than leaves developed under HPS lighting. Differences in production were small, although the production under LEDs was lower. There were only small differences in fruit quality. The amount of energy required per kilogram tomato was highest in the LED treatment and hybrid with top LED lighting. This was

primarily due to the fact that a higher air temperature was necessary and these LEDs were cooled and the cost of cooling added to the use of energy. The consequences and future perspectives of the different types of supplementary lighting for crop growth and production as well as for crop management practices will be discussed.

CPII 4.

OPTIMUM PLANT CANOPY: HOW CANOPY ARCHITECTURE AND CULTIVATION STRATEGIES CAN AFFECT LIGHT INTERCEPTION AND PHOTOSYNTHESIS

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The last decades, a number of process based tomato models have been proposed, their main challenge being the correct simulation of fruit yield. For that reason, an accurate simulation of photosynthesis, and thus light interception, is of primary importance. Light interception is dependent on canopy structure. Recently a functional structural plant model (FSPM) for tomato has been developed that simulates in detail both architectural characteristics of the crop as well as important physiological processes that determine crop growth and yield. In this study this model is used to test the effect of various aspects of plant architecture on vertical as well as horizontal distribution of light and photosynthesis in the canopy. Sensitivity analysis was performed on leaf elevation angles, leaf azimuth angle, leaf length to width ratio, internode length, within row plant distance and plant density. Simulations were performed under summer and winter light conditions. Input radiation data were a ten years average of Dutch conditions. The model assumed an infinite canopy. Light calculations were based on a nested radiosity approach. Photosynthesis was calculated based on Farquhar type of photosynthesis model. Increase of leaf length to width ratio and decrease of internode length increased total light interception up to 5% and 3% and photosynthesis up to 11% and 12% respectively. The original distribution of leaf elevation angles proved to be optimal for photosynthesis. Leaf azimuth angle had no effect on either parameter. Increase of plant density (from 4.1 to 6.3 stems per m^2) and decrease of row spacing (from 0.4 to 0.2 m) led to an increase in photosynthesis by 12% and 2%. Even if total light interception was not affected, changes on light distribution were often observed. This study showed that changes of either phenotypic plant characteristics or cultivations strategies can have a strong effect on canopy photosynthesis. FSPMs can become a useful tool in exploring and quantifying these effects.

Keywords: 3D tomato model, virtual plant, plant density, canopy architecture, light, photosynthesis

CPII 5.

PREDICTING THE DEVELOPMENT AND EXTERNAL QUALITY OF LILY GROWN IN A TRADITIONAL CHINESE SOLAR GREENHOUSE

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Photosynthetically active radiation (PAR) and temperature are two of the most important environmental factors affecting the development and the external quality of ornamental crops. The aim of this study was to develop a model for the effects of PAR and temperature on the development and the external quality of oriental lily (*Lilium* spp.) in order to optimize PAR and temperature management for its production in Chinese traditional solar greenhouses. Experiments of Lilium oriental hybrids (*Lilium* spp. cvs 'Siberia' and 'Sorbonne') with different planting dates and densities were conducted in a Chinese traditional solar greenhouse located at Lianyungang (34°36 N, 119°10 E), China from 2008 to 2009. The integrated photo-thermal index (PTI), defined as daily total PAR intercepted per plant multiplied by daily average normalized thermal time, was used as a driving variable to predict the development stages and to describe the seasonal dynamics of the external quality traits (plant height, number of leaves per plant, length diameter of flower bud). The quantitative relationship of these traits with PTI was either exponential or expo-linear. Using independent experimental data, the model was found to give satisfactory predictions of the development stage and the external quality traits of the two experimental cultivars grown under different season and planting density conditions. The coefficient of determination (r^2) and the root mean square error (RMSE) between the predicted and measured results were, respectively, 0.95 and 5.8 days for flowering date, 0.94 and 0.078m for plant height, 0.92 and 4.3 for number of unfolding leaves per plant, 0.87 and 7.59mm for length of flower bud, and 0.87 and 2.44mm for diameter of flower bud. The model developed in this study may be used for optimizing planting date and density for lily production in greenhouses. Further evaluation is needed if the model is applied to wider range of planting densities and lily cultivars.

Keywords: model, flowering date, photosyntheticcally active radiation, temperature, planting density

CPII 6.

EVALUATION OF SALINE TOLERANCE OF TOMATO UNDER HIGH CO_2 CONCENTRATION WITH STABLE ISOTOPES

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Salinity is an important concern as global demand for fresh water is increasing. Nowadays, of the current 230 million ha of irrigated land, 45 million ha (20%) are salt affected. Additionally, future climate predictions indicate the increased frequency of drought years that could aggravate salinisation of groundwater reservoirs, especially in the Mediterranean region. The use of CO_2 application in greenhouses is a common practice in Northern Europe to increase revenues, but salinity usually is not a crop limiting factor. The four major constraints of salinity on plant

growth are osmotic effects, restriction of gas exchange, ion toxicity and nutrient imbalance. Elevated CO_2 concentration often improves photosynthesis while reducing stomatal resistance, thus increasing water use efficiency, but decreasing photorespiration and oxidative stress. Thus, it is envisaged that increasing atmospheric CO_2 concentration can partly ameliorate the negative effect of salinity on plant growth. However, the extent to which varieties differ in their response to salinity and CO_2 should be evaluated. Natural abundances of ^{13}C and ^{15}N in plant material have recently been used as physiological traits to determine time-integrated parameters associated with CO_2 assimilation, and as an index of genotypic performance under given stress conditions. Therefore, a study was conducted in a computer-regulated climate chamber with fully-controlled environmental conditions. Five common tomato (*Lycopersicon esculentum* Mill.) cultivars used in the greenhouse industry in SE Spain were evaluated: Daniela, Delizia, Huracán, Martina and Zahorí. Plants were grown in 12-L black containers filled with coconut coir fibre and were irrigated with a modified Hoagland solution with the addition of 0 (control), 60 or 120 mM NaCl. Plants were grown at 400 or 800 ppm CO_2. Plant growth (height and fresh weight) and isotopic composition were measured after each growing period. Results indicate: i) the beneficial response of increasing CO_2 - with regard to ameliorating saline stress, ii) a differential response according to the variety and iii) new possibilities for using stable isotopes to identify stress.

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Abstracts of Poster Presentations

P 01.

GREENHOUSE SECTOR ASSESSMENT IN AZERBAIJAN AND PROSPECTS FOR SUSTAINABLE DEVELOPMENT

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Azerbaijan has three major greenhouse vegetable production areas: the western part of the country (mainly Ganja and Shamkir regions); the central region (mainly Absheron peninsula); and the southern region Lankaran and Astara area. Of the about 280 hectares of greenhouses in Azerbaijan, about 20% are antiquated Soviet style greenhouses, many of which are currently being updated and repair by their owners. New structures of Israeli, Dutch, Turkish and Italian companies have been built or are in the planning stages of construction. Finally, about 30% home built polyethylene covered greenhouses with mixed wooden and steel frame materials, and low tunnels exist in the regions. The majority of greenhouse cultivation systems in Azerbaijan, regardless of geographic location, consist of fundamental climate control components, and depending on their design and complexity, they can provide a greater or lesser amount of climate control, and subsequent plant growth and productivity. The climograph of Baku shows that greenhouses in Bacu, if all year round cultivation is needed, will have to be equipped at least with heating and ventilation systems while cooling systems during summer period would be also preferable. The main constraints for greenhouse cultivations in Azerbaijan are heating and cooling since it is considered that climate conditions inside the rudimentarily equipped greenhouses do not meet crop needs for optimal growing. No absolute solutions are available since variations in design and past maintenance may exist. Energy conservation is also necessary. In this paper, an effort to suggest the appropriate design of greenhouses and their equipment suitable for the region is made, and guidelines on the step up of the supply chain management for the sustainable development of the greenhouse sector in Azerbaijan are given.

P 02.

GREENHOUSES IN LANDSCAPE ARCHITECTURE AND URBAN HORTICULTURE - A DEVELOPING RELATIONSHIP

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The first practical greenhouses were built during the 17th century as components of private and public gardens. These glass structures -where architectural style and botanical needs were often in conflict- are known as orangeries, conservatories etc. As time passed greenhouses strengthened their role in botanical gardens but their main evolution concerned more and more functional structures focused in agricultural production. In our time the augmented need to incorporate plants in urban environments in order to ameliorate the microclimate and foster the contact between city people and nature, leads to the development of novel urban landscape applications. At the other hand the continuous growing of cities makes the need for urban food production imperative and thus urban horticulture is expected to expand and become more effective. In this framework the development of urban greenhouses in various scales (from small gardens to commercial setups) and forms is already a reality. Vertical farming, sky farms and green skyscrapers are contemporary terms to describe ideas about future urban glasshouse applications. In the present review the main design and application trends concerning the development of glass protected landscapes and horticultural setups inside cities are presented. Also their expected effects in the on going effort for sustainable urban environments (in climatic, social, aesthetic and productive terms) are discussed.

P 03.

EVALUATION OF DROUGHT TOLERANCE OF PEPPER GENOTYPES UNDER HIGH CO_2 CONCENTRATION

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Drought reduces pepper yields and limits cultivation areas, especially in arid or semiarid regions, where agriculture is still by far the greatest consumer of water. Agriculture in these areas is often characterised by widespread depletion of non-renewable groundwater. Increasing water scarcity is becoming more difficult to manage because of growing demand and requirements for activities other than agriculture. Additionally, global climate warming will probably increase drought periods in these areas, aggravating the existing problems. Therefore, production per unit of land needs to be replaced by production per unit of water (water productivity). We need to increase the efforts to adapt crops and irrigation strategies, including the use of more-drought-tolerant varieties. Therefore, a study was conducted in a computer-regulated climate chamber with fully-controlled environmental conditions. Four common sweet pepper (*Capsicum annuum* L.) cultivars used in the greenhouse industry in SE Spain were evaluated: Herminio, Coyote, Vélez, and Tallante. Plants were grown in 12-L black containers filled with coconut coir fibre and were irrigated with a modified Hoagland solution. Plants were either irrigated every day (control) or 1 day of irrigation was followed by 1 or 2 days of non-irrigation (moderate or severe drought stress, respectively). Plant growth (fresh weight and height) was determined after each growing period at different CO_2 concentrations. The results show that increasing CO_2 (from 400 to 800ppm) produced a different response according to the variety considered. Thus, for variety Herminio, plant FW increased by 32 % in well-watered conditions, but at moderate stress the advantage

of supplying CO_2 was increased by 47% (compared with the standard CO_2 concentration). Increasing CO_2 concentration did not further improve the plant growth response under severe stress (compared to the standard CO_2 concentration). Coyote, Vélez and Tallante had a lower response. This study could help growers to identify the most-tolerant cultivars regarding drought when using elevated CO_2 concentrations to partly mitigate stress.

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P 04.

AGRONOMICAL AND PHYSIOLOGICAL RESPONSE OF GERANIUM TO SALINITY AND BORON TOXICITY

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High salinity and boron often occur together in irrigation water in arid climates. A greenhouse experiment was conducted to evaluated: 1) the effects of high salinity and boron (B) on growth, water relations, gas exchange, photochemical performance and ion uptake in geranium (*Pelargonium x hortorum* Bailey); and 2) the interaction of both factors on these process. Potted plants were irrigated in a factorial combination of B (1 and 10 mg L^{-1}) and NaCl (2 and 9 dS m^{-1}). Toxicity by B reduced aerial part dry weight and caused edge burn in the mature leaves, while salinity decreased the aerial growth and caused little visible damage on foliar blade. At high salinity, B excess was less detrimental, both visually and quantitatively, than it was at low salinity. A strong accumulation of B, Cl and/or Na in the leaves was the determining factor of damage to this species. At the two concentrations of B studied, increased salinity reduced leaf B content. Salinity induced plant growth reduction principally due to a smaller leaf area available for photosynthesis rather than to a reduced rate of photosynthesis, while both aspects participated under B toxicity. The photochemical apparatus of geranium was not damaged by excess B or high salinity. Overall, the interaction of salinity with B concentration had an antagonistic effect; however, an additive effect was observed when we studied evapotranspiration.

P 05.

EFFECTIVENESS OF PASSIVE BIOREACTORS FOR TREATING GREENHOUSE EFFLUENT CONTAMINATED BY PATHOGENS AND NUTRIENT POLLUTANTS

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Due to the lack of quality water and potential pollution of groundwater by leached nutrients, recirculation of nutrient solutions for greenhouse cultures is now unavoidable. Even though closed growing systems offer several advantages from an environmental point of view, risks associated with pathogen spread, unbalanced nutrient solutions and build up of phytotoxic compounds are major concerns for growers. The objective of this study was to evaluate the effectiveness of two types of passive bioreactor to reduce the population of pathogens (*Fusarium oxysporum* and *Pythium ultimum*) and the content of SO_4^{2-} and NO_3^- in greenhouse effluents. To achieve this objective, an experiment was conducted using passive bioreactors, proved to be an effective technology for the treatment of acid mine drainage. Bioreactor units contained either a 1) none sterile and 2) sterile reactive mixture. The experimental design was a complete randomized block design with three replicates (total of 6 e. u.) and a rentention time of 5 days. Passive bioreactors received a reconstituted greenhouse effluent composed of 500 ppm of SO_4^{2-} and 300 ppm of NO_3^- and, were weekly inoculated with a suspension of *Fusarium oxysporum* (10^6 CFU per mL) or of *Pythium ultimum* (10^6 CFU per mL). Daily samples of bioreactors-effluent were collected and *Fusarium oxysporum* and *Pythium ultimum* concentration was evaluated using the selective Komoda and PDA-PARP media, respectively. Weekly samples of bioreactors-effluent were collected to evaluate the removal rate of SO_4^{2-} and NO_3^-. Dissolved organic carbon, ORP, and populations of mesophilic bacteria and sulfate-reducing bacteria were also evaluated weekly. From our experimental results, we can make the difference between biological (with non sterile bioreactor) and physical (with sterile bioreactor) factors that explain the high removal rate of pathogens and nutrient pollutant removal.

Keywords: *Fusarium oxysporum*, *Pythium ultimum*, SO_4, NO_3

P 06.

AIR DEHUMIDIFICATION INSIDE A DOUBLE INFLATABLE FILM GREENHOUSE (POTTED PLANTS)

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In heated greenhouses attempts have been made to produce potted plants while reducing the amount of energy used. In fact, improvements in greenhouse structure and equipment (double walls, etc.) have led to better insulation and tightness. Moreover, this tightness also induces microclimatic changes, especially on night-time humidity levels. The increase of inside humidity leads to the development of condensation and dripping and consequently, to the increase in the occurrence of fungal diseases and physiological disorders. The air dehumidification becomes necessary. To decrease humidity, growers have to dehumidify by ventilation-heating, involving a major increase in energy consumption. Humidity control is therefore a limiting factor for saving energy. Therefore, it becomes essential to propose alternatives to the ventilation-heating method to reduce indoor humidity. Thus, we propose to analyze the effectiveness of a multifunction dehumidifying heat pump installed in a 2500m^2 double inflatable film

greenhouse located in northwestern France, during spring 2010. Hydrangeas in containers are placed on the ground (heated). The temporal evolution of climate, thermodynamic and ecophysiological data will be presented and analyzed. The thermodynamic efficiency of the machine will also be deducted. Depending on the weather outside, the energy consumption of the device (power: 10kW) used to dehumidify is three to four times lower than that which would have been induced by the ventilation-heating method. By condensing about 30 liters of water per hour during night-time the machine balances the crop evapotranspiration and avoided the occurrence of fungal diseases.

P 07.

THERMAL PERFORMANCE OF AN UNHEATED GREENHOUSE UNDER SEMI-ARID CONDITIONS DURING THE NIGHT

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The aim of this work is to analyze the thermal performance of a greenhouse by investigating experimentally the heat transfers occurring through the walls and ground. The study focuses on the effects of (i) the thermal inertia of the soil, (ii) the radiative losses through the cover, and (iii) the convection mode and flow regime on the heat transfer coefficients. Measurements of microclimatic and thermal performances were performed for a closed unheated Venlo greenhouse without crop in the semi-arid area of Batna (southern Mediterranean basin). Experiments were conducted from January to March 2008 under clear or cloudy skies, and low or high wind speeds. From the results, it is concluded that the heat stored in the ground of the greenhouse represents a significant heat source which can compensate the energy losses through the walls, especially during a night preceded by a significant diurnal insulation This process can maintain an average inside - outside temperature difference during the night within the range [1,59 -2,81] K. Results also show that the radiation losses are the main component of the energy losses of the greenhouse, mainly through the outside wall surface of the cover. This phenomenon is enhanced under clear sky conditions. Conversely, the radiative heat exchange along the inner wall represents the main heat supply to this wall. The convection mode inside the greenhouse induced by the air movement seems to play a significant role on the convective exchange coefficient inside the greenhouse. These coefficients both inside and outside the greenhouse were estimated and analyzed, and a good agreement with the models reported in the literature was found. This study could help growers define and adapt their heating strategy to avoid undesired low temperatures which may damage their crops at night.

P 08.

DESIGN AND TEST RESULTS FOR CPV SYSTEMS IN A NIR CONCENTRATOR INTEGRATED IN A GREENHOUSE

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In this investigation a concentrated photovoltaic (CPV) system based on a spectral selective linear Fresnel reflector with adjustable lamellae is developed. The lamellae of the linear Fresnel reflector are provided with an integrated filter for blocking near infrared radiation (NIR) in order to diminish the heat load to the greenhouse and exploiting this radiation in a solar energy system. Due to the spectral selective properties of NIR reflecting materials a part of the NIR radiation is reflected. This will reduce the need for cooling of the greenhouse under summer conditions. For the horticultural application a material combining high PAR (Photosynthetically active radiation) transmission and maximal NIR reflection was chosen.
With a simulation model based on ray tracing computer program the optimal geometry of the spectral selective reflecting lamellae was designed with respect to concentration factor and the maximum power level. The positions of the lamellae are controlled with high resolution linear actuators. Highly accurate prepositioning is achieved with a preset shaped form. The CPV system contains a hybrid type photovoltaic/thermal collector (PV/T-system) based on monocrystalline Silicon to convert the concentrated solar radiation into electrical and thermal energy. Water cooling in the photovoltaic modules will remove excessive heat during the collection of concentrated radiation. An important issue was the effect of an irregular light distribution on the PV module due to the blocking of light by construction parts such as glazing bars. This will result in the appearance of shadow bands on the PV-module. Methods will be shown to prevent large disadvantages on the PV yield due to the effect of this shadow bands. The typical daily and yearly yields are determined from the measurements of the energy output, short circuit current (Isc) and open cell voltages (Voc). The efficiency and economic achievement of this conversion system is investigated.

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Keywords: Greenhouse, NIR selective covering, concentrated radiation, solar energy

P 09.

A MODEL FOR PREDICTING ENERGY CONSUMPTION AND CO_2 RATE IN GLASSHOUSES

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The total glasshouse area for vegetables in France is about 1600 ha, mainly for tomato and cucumber crops. Glasshouse heating is the second operating cost after the labor cost and can reach 20 to 40 % of the overall cost.

As a consequence, energy is a major concern for growers, especially with the fuel price increase. Thus, energy consumption optimization is becoming crucial, in order to make energy savings while maintaining potential yields. To evaluate the impact of energy saving strategies on energy consumptions and CO_2 rate in glasshouse by comparison and simulation, heat and mass equations were calibrated with data gathered at the Ctifl center of Carquefou (Nantes). Heat exchange predictive calculations take into account gain and loss by day and night radiation, air exchange (enthalpy variation), plant transpiration, wall and soil exchanges. CO_2 rate predictive calculations take into account CO_2 mass supply, exchange through the vents and consumption by plants. The model validation was made at the scale of both the total glasshouse area and the experimental cell, with energy and CO_2 rate measurements in different conditions, by taking into account the heating system management.

P 10.

PHOTOVOLTAIC ARRAY SHADING EFFECTS ON WELSH ONION GROWTH

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The use of renewable energy for greenhouse-environment control to replace or reduce the consumption of fuel and power-line electricity is an important objective for sustainable greenhouse crop production. This study was undertaken to apply a solar photovoltaic (PV) array to supply electricity for the greenhouse-environment control. The PV array was mounted inside the south roof of an east–west single-span greenhouse. Effects of PV array shading on the growth of Welsh onion (*Allium fistulosum* L.) were investigated. Two PV array arrangements were tested: straight-line and checkerboard formations. For both arrangements, the PV array covered 12.9% of the greenhouse-roof area. Another greenhouse with identical dimensions and orientation to the PV greenhouse was built near the PV greenhouse; this greenhouse with no PV array was used as the control greenhouse. Then Welsh onion were cultivated hydroponically in both PV and control greenhouses. The straight-line arranged PV array (PV_S array) continuously cast shadows on a specific area of the cultivated Welsh onion during the cultivation period. The fresh weight and dry matter weight of Welsh onion cultivated under the shadow of PV_S array were significantly less than those of Welsh onion cultivated in the control greenhouse. The checkerboard arranged PV array (PV_C array) intermittently cast shadows on a specific area of the cultivated Welsh onion during the cultivation. Consequently, the inhibitory effects of the PV array shading on the fresh weight and dry-matter weight accumulations of Welsh onion were diminished. The electrical energy generated by the PV_C array was comparable to that of the PV_S array, which further supports the advantageous characteristics of the PV_C array.

P 11.

WATER BALANCE AND ENERGY PARTITIONING IN A SEMI CLOSED GREENHOUSE

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The concept of a closed (or semi closed) greenhouse that is used to harvest the solar energy can be attractive for water use efficiency or in order to reduce the fossil fuel input. To examine the concept, a 550 m^2 greenhouse was built in The Netherlands and experiments were carried out. The greenhouse is equipped with overhead cooling units, an air treatment unit that blows air via sleeves that are located below the gullies, a heating system, CO_2 supply and a fogging system. All systems are used to allow a proper control of the greenhouse microclimate. Present paper concentrates only on the water balance during the summer period of such a greenhouse and examines the energy partitioning of the solar radiation. For that purpose, solar radiation, air temperature and humidity were measured inside and outside the greenhouse. In addition, the amount of water used for irrigation and fogging and the amount of drainage were continuously monitored over a period of 64 days in the months of July August and September. The results reported here relate to experiments with a mature pepper crop. During the growing period the irrigation rate was set proportional to the solar radiation and was equal to 0.162 liters m^{-2} per MJ m^{-2} which complies with common practice of Dutch growers. The percentage of drainage out of the irrigation changed significantly among the days but was on average 34%. The major water input to the greenhouse came from irrigation and only a small fraction was due to fogging in some of the days. The remainder of irrigation minus drainage was transpired by the plants. On average, 15% of the vapour was removed from the greenhouse by infiltration and air exchange with the ambient air via the air treatment units. The rest condensed on the heat exchangers of the cooling units, the roof and the side walls. The results show that the global radiation inside the greenhouse was on average 0.57 ±0.06 of the outside radiation. In summer, the heat load on the greenhouse is mainly removed by the overhead cooling units who remove sensible and latent heat with an average latent to sensible ratio of 0.62. This ratio changed among the days and increased approximately linearly with solar radiation. The energy extracted by the coolers was about 0.73 ±0.18 of the solar radiation entering the greenhouse.

P 12.

DESIGN AND APPLICATION OF A CONCENTRATED PHOTOVOLTAIC SYSTEM WITH SEASONAL THERMAL STORAGE FOR APPLICATION IN HIGH TUNNELS

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Solar energy systems are recently developed and incorporated in agricultural structures to reduce or even completely cease the use of fossil fuels. A literature survey shows that concentrated photovoltaic systems may offer many

advantages with regard to energy saving in protected crops. Combined with a near infrared reflective film that replaces the conventional polyethylene cover, it can reduce the heat load on the crop by reducing IR transmission to the tunnel, and at the same time use the reflected radiation to produce electricity and thermal energy. The current work reports on the design of a system for low temperature thermal energy production with a seasonal thermal storage that is used for heating and electricity generation in high tunnels. Structural simulations are made to develop a new type of tunnel which efficiently incorporates a system for solar energy capture. CFD simulations are carried out to determine heat transfer and fluid flow in the solar energy system. A computer application has been programmed to simulate ray tracking and system control.

P 13.

ATTITUDE-BASED MODEL FOR THE IMPLEMENTATION OF ENERGY EFFICIENT TECHNOLOGIES IN THE BAVARIAN HORTICULTURAL SECTOR

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The Bavarian horticultural industry is very heterogeneous in its structure. In addition to numerous smaller directly selling companies, highly specialized greenhouse producers with an indirect distribution concept exist in the field of vegetable growing and ornamental plants. Especially for small and medium-sized enterprises (SMEs), the energy costs are an increasing cost factor and thus enhanced energy efficiency is an important approach to improving competitiveness. Especially in smaller companies, the technical equipment is often not up to date. Therefore, it is of interest to locate the influencing factors which hinder or fasten implementation of innovative energy-saving techniques, to give instructions to overcome these barriers and improve energy efficiency. Within the Bavarian State funded research association FORETA, which pools eleven academic projects related to energy-efficient technologies and applications, an econometric model has been developed for the identifying promoting and inhibiting factors of innovation in Bavarian horticulture. On the basis of reviewed literature and a survey of experts in horticulture, a multi-attribute model has been developed, which illustrates intentions and behaviors of decision makers in horticulture. This theoretical model is being assessed on the basis of an empirical investigation in more than 100 horticultural companies in Bavaria which took place in summer 2010. Managers of different horticultural areas were asked for rating various statements to innovative techniques using a five-point Likert scale. The assessment of the developed structural equation model is being examined by appropriate software using the collected data.

P 14.

EXPERIMENTAL STUDY OF IMPROVING THE COEFFICIENT PERFORMANCE VALUE OF A GROUND SOURCE HEAT PUMP USED FOR GREENHOUSE HEATING AND COOLING

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A convenient and economic method for greenhouse heating and cooling is the installation of Ground Source Heat Pumps (GSHPs). GSHPs are attractive alternatives to conventional heating and cooling systems due to their higher energy utilisation efficiency. The technique relies on the fact that GSHP utilises the earth as a heat source in heating mode and as heat sink in cooling mode operation. In heating mode, GSHP absorbs heat from the ground and uses it to heat the greenhouse. In cooling operation mode, heat is absorbed from the internal greenhouse air and is transferred to the ground through its ground heat exchanger. The heating performance of a GSHP is expressed by a dimensionless unit called Coefficient of Performance (COP). COP value depends on many factors, most important of which are: (a) the temperature difference (DT) between the generated heat pump thermal fluid and heat source. COP value increases as the temperature difference decreases and (b) the temperature stability of the heat source particularly between 0 ^{o}C and 30 ^{o}C. The main objective of this research is to study the temperature variations among different depths and soil covering materials in order to maintain higher COP value. The different soil covering materials; bare ground, ground covered by insulation material (fibran), ground covered by polyethylene film (greenhouse simulation) affects the underground temperature, even at a depth of 2 m. This can lead to an improved COP value caused by the minimisation of the temperature difference between the heat pump thermal fluid and the ground and also by the fact that in 2m depth the temperature value does not change significantly.

P 15.

ENERGY SAVING IN TOMATO GREENHOUSES EQUIPPED WITH A VENTILATION SYSTEM WITH AND WITHOUT HEAT RECUPERATION

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Tomato production in Western Europe is a high energy-demanding industry. To maintain profitability, new energy-saving techniques are necessary. Newly introduced systems, such as the Closed Greenhouse, often demand large investments with high payback times as result. Also the impact on the crop complicates the introduction of such systems in practice. New, interesting systems have to fulfil the following requirements: decrease of energy consumption with maintenance of yield and quality and an acceptable payback time. A promising innovative energy-concept has been tested in practice in two compartments. Both compartments are equipped with double screens, which reduces the energy demand. The upper screen is a high insulating screen with aluminium strips. The second

screen is an anti fog screen in Compartment 1 and a regular energy screen in Compartment 2. By keeping the greenhouse more closed, energy can be saved. However, this also increases the humidity in the greenhouse, which can lead to a higher incidence of fungal diseases such as *Botrytis*. Therefore, in both compartments a ventilation unit is installed, which can add outside air in a controlled way in order to reduce the humidity inside the greenhouse. Both ventilation units are similar in the way they are used, but the second one is equipped with a heat exchanger which enables to transfer energy from outgoing air on incoming air in a very efficient way. Energy consumption is registered in order to evaluate both systems on their energy saving capacity. Therefore, both compartments are compared with a reference compartment without ventilation unit and equipped with only one thermal screen. Furthermore, yield, plant and fruit characteristics are monitored and the management of the system is optimised.

P 16.

« ENERGY SUSTAINABLE GREENHOUSE » Project: REDUCTION OF ENERGY CONSUMPTION AND ENERGY STORAGE IN AQUIFER

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In France, the total expanse of vegetable crops in heated greenhouses represents approximately 1 400 ha, mainly tomato and cucumber. Heating is the second largest item in the budget (from 25 to 40% of total costs), after labour. It is therefore a major concern for growers, especially with rising fuel prices, which could call into question the very existence of this sector. The environmental context has also to be considered; the greenhouse sector has to reduce its environmental impact, particularly greenhouse gas emissions. The only chance of maintaining this activity lies in the development of a tool that would be more energy-autonomous.
The greenhouse is a solar energy captor which is however not fully exploited because part of the captured energy is expelled outside by ventilation. In addition, the greenhouse has a very low thermal inertia, which gives rise to important thermal losses. The "Energy Sustainable Greenhouse" project therefore aims to:
- reduce the thermal losses: double plastic cover with F-Clean® is tested, double thermal screens on the roof and thermal screens on the walls are installed,
- improve dehumidification by heat pump,
- develop a greenhouse equipped to store and use excess energy through reversible air conditioning devices (Aquifer Thermal Energy Storage-ATES).
50% energy savings are expected. The first year of tests has shown promising results.
The project has been labelled by the PEIFL (European Innovation Pole for Fruits and Vegetables) and is expected to last 5 years. It was financed by the French Ministry of Industry, ADEME, FranceAgriMer, and Conseil Régional Languedoc-Roussillon. The project has nine partners, which include INRA, Brgm, Aprel, and HoogenDOORN.
Keywords: cooling, closed greenhouse, plastic cover, heat pump

P 17.

EFFECTS OF A CLOSED GREENHOUSE ON PLANT GROWTH AND SECONDARY PLANT COMPOUNDS OF TOMATOES (*SOLANUM LYCOPERSICON* L.)

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The German Advisory Council on Global Change predicts a global temperature increase of 0.6 °C from 2006 to 2030. Other studies have shown that the greenhouse production area increased dramatically during the last few years, where the energy requirement in winter and the prices of fossil fuel increased too. Therefore, it will be necessary to develop new technologies, in order to control the cost of plant production and the climate conditions in greenhouses. Recently, a new cooperation project (ZINEG) was started in Germany. A closed greenhouse will be used as a solar collector, in order to collect the energy-rich water vapour of the plants, which is converted into thermal energy using cooling fins in the roof region and stored in a rain-water tank. On the one hand, a combined application of the latter purpose, a high pressure fog system, and CO_2 enrichment was used to reduce the temperature, the ventilation opening, and the losses of CO_2, especially in summer. On the other hand, the stored thermal energy will be used for heating in cooler periods, where a lower water temperature in the rain-water tank can be increased by a heat pump. As such, the microclimatic conditions (relative humidity and temperature) will be changed dramatically. Furthermore, it is possible that the cooling fins in the roof region influence the light conditions adversely. Therefore, a part of the main objective of this study was to investigate the effects of the closed greenhouse on plant growth and secondary plant compounds with antioxidant properties of tomatoes.

P 18.

EXPERIMENTAL VALIDATION OF A MATHEMATICAL MODEL FOR THE ESTIMATION OF ENERGY REQUIREMENTS IN INFRARED HEATED GREENHOUSES

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A simplified model for the estimation of energy heating requirements in infrared heated greenhouses is presented and validated, based on experimental results obtained in a production greenhouse. Recent results provided previously by the authors on the use of infrared heating in small scale experimental greenhouses have shown significant energy savings in comparison to conventional forced air or pipe heating. Radiation allows directional control of the

heating flux, which can be used to maintain canopy temperature within a specified temperature range, compensating losses by convection to greenhouse air and by radiation to cover and soil. Thus in IR heating the concept of a greenhouse with uniform inside air temperature is not applicable and therefore energy fluxes and the overall energy balance have to be reconsidered in comparison to conventional greenhouse heating analysis. The mathematical model developed for the estimation of the energy needs in IR heated greenhouses is based on a set of two equations representing the energy balance of greenhouse air and cover respectively, used to estimate the corresponding temperatures. Total heat losses, including conduction through the soil, infiltration losses, convection and radiation losses from the cover are calculated based on the temperature estimates. In the present work experimental results obtained in an infrared heated greenhouse are used to validate the model. A single span greenhouse unit (span width 9.60 m, length 12.5 m, gutter height 4.00 m and ridge height 6.50 m) equipped with gas fired IR radiators has been used. Experimental data include systematic measurements of all parameters determining the interior microclimate. The exterior climatic conditions were also recorded by a properly equipped meteorological station. Experimental results are in good agreement with the mathematical model estimations, indicating a potential of more than 30% savings in IR heated greenhouses in comparison to forced air heated ones.

P 19.

ASSESSMENT OF ENERGY USE AND GROWTH EFFECT OF LIGHTING SYSTEMS (HPS AND LED) IN CUT ROSE CULTIVATION

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Cut rose cultivation necessitates the addition of supplemental lighting during production periods in Northern Europe. Commonly, growers use High-Pressure Sodium (HPS) lamps to create more light in their greenhouses since they have a high degree of light photosynthetic efficiency (PAR). However, Light Emitting Diodes (LED) are more energy efficient then HPS lamps. The aim of this research was to compare energy consumption and growth parameters of HPS and LED light in cut rose cultivation. A comparative study on cut rose (*Rosa hybrida* 'Avalanche') was set up in three identical greenhouses. Three lighting treatments were used in this study: HPS, blue/red LED and red LED light. Lights were positioned at a height of 2m above growing medium and produced 80-90 µmol/m s at plant level. Data was collected on growth, production, energy consumption, quality and heating requirements.
Measurements indicated that the amount of photosynthesis for rose plants under LED light increased with almost 57% in comparison with HPS light. However there were no significant differences in production or plant development between all treatments. During 8 months the energy use of all three treatments was registered. Since LED lights do not produce heat radiation, a compensation by heating was necessary. This resulted in a total energy use of 21,57MWh for HPS light compared to 31,54MWh for red LED and 33,80MWh for blue/red LED light. Due to the lack of LED heat radiation a decrease of temperature was noticeable in plant temperature which could exert an influence at the development of the plant and the risk of infection of *Botrytis*.

P 20.

NEW METHOD FOR COOLING GREENHOUSES IN ARID AREAS

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Traditionally in Saudi Arabia, which has desert climate in most of parts, greenhouses are cooled using pad and fan system. Warm dry air is forced through a wet mattress making the air humid and thereby cooler. However, this method is not efficient when the outside temperature exceeds 45 °C.
In winter time (September – April), Crop production inside greenhouses is higher than in summer (May - August) due to higher summer temperatures in Saudi Arabia.
Two sources of heat affect plants growth and productivity in greenhouses:
1. Hot air surrounding greenhouse, which needs to be cooled through the cooling pads to reduce the temperature inside greenhouse.
2. Radiation across the cover leads to increased temperature in the upper part of greenhouse,

To solve these problems, field study was carried out for many years to design new cooling system depending on raised cooling pads in the middle of the greenhouse and suction fans on both side of greenhouse near the ground. Proven cooling efficiency was obtained with this system as compared with traditional fan and pad cooling located at the same level.

P 21.

THE INFLUENCE OF A HYBRID SOLAR ENERGY SAVING SYSTEM ON THE GROWTH AND THE YIELD OF TOMATO CROP IN GREENHOUSES

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The use of solar energy saving systems contributes to the reduction of greenhouse heating cost for the off-season crop production. Moreover, the improvement of the microclimate conditions can result in higher yields and product quality. At the northern latitudes of the Mediterranean region, the greenhouse cultivation period is mainly starting at early spring time, as a result of the high thermal needs during the winter, even though the solar radiation levels may be acceptable on plant growth. For these reasons a research project was conducted during the winter period, to investigate the effect of a hybrid solar energy saving system on plant growth and production in greenhouses. Water filled transparent polyethylene sleeves have been used as a hybrid solar system in a conventionally

heated part of a greenhouse at Northern Greece, (plot A), were tomato plants were hydroponically cultivated above the polyethylene sleeves. Another part of the greenhouse (plot B) operated only with conventional heating and the tomatoes were placed on plastic gutters. During the experiment, the following plant growth parameters were measured: a) the tomato plants growth rate, b) the rate of fruit settings and c) the total yield, for both parts of the greenhouse. Also, microclimatic data were recorded concerning: 1) the interior air temperature and humidity of the greenhouse plots, 2) the temperature of the rockwool slabs, 3) the water temperature in the sleeves, and 4) the intensity of solar radiation. The results showed that the application of the hybrid solar energy saving system in plot A led to qualitative differences on the plant growth while the crop yield was almost equal compared to plot B.

P 22.

INFLUENCE OF CO_2 ENRICHMENT IN GREENHOUSES ON THE YIELD OF THE PEPPER PLANT (CAPSICUM ANNUUM L.), UNDER HIGH TEMPERATURE CONDITIONS

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Enrichment of greenhouses with CO_2 is a method of increased plant growth and productivity and it is applied successfully in many regions in the world. However, in places where during the main cultivation period high temperatures occur, special application of the CO_2 enrichment is needed due to the fact of high ventilation needs which reduce the available time for CO_2 application leading to a lower performance. In this work, the effect of artificial CO_2 application on the optimum increase of productivity of pepper plants under high temperature conditions was examined. This study was performed in two identical greenhouses (experimental and control greenhouse) and was repeated three times, twice in the spring cultivation period and once in the autumn. During this study, a characteristic property of plant physiology was exploited. It is known that increasing the CO_2 concentration at levels higher than normal the optimum temperature of the C_3 plants growth is also increased. This results in a reduction of time needed for ventilation of greenhouses allowing the application of CO_2 for longer period.
The results showed that the method of CO_2 enrichment under high temperatures confers beneficial outcomes, like all the other enrichment methods known. In the experimental greenhouse, where the enrichment was applied, plants were absorbing CO_2 at high rates and were showing an improved growth and production of about 27% compared to the ones in the control greenhouse regardless of higher than optimum temperature levels in the experimental greenhouse.

P 23.

EVAPOTRANSPIRATION MEASUREMENTS AND MODELLING IN A VINEYARD COVERED WITH A SHADING SCREEN

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In arid and semi-arid regions many crops are grown under shade in order to protect them from supra-optimal radiation. The modified microclimate under the shade may reduce crop water requirement. Hence accurate tools to estimate crop water use are necessary to improve the irrigation management and increase the water saving in such regions. The most common and reliable method that directly measures evapotranspiration (ET) is the Eddy Covariance (EC) which employs fast response wind speed, temperature and water vapor concentration measurements. The use of this method is well established for open canopies but its use under screen constructions has only recently been explored. The aim of this research was to measure ET in a vineyard covered with a shading screen and to compare the measurements with several ET models. Experiments were carried out in a vineyard located in the Jordan Valley region of eastern Israel. The vineyard was covered with a transparent screen, with 10% nominal shading. An EC system was deployed in the middle of the vineyard, along with net radiation and soil heat flux sensors which facilitate the energy balance closure analysis. Measurements were conducted during 28 days (non continuous) on April, May and June 2010. Three ET models were examined: reference ET under the screen (PETin), reference ET for outside conditions (PETout) and a Penman-Monteith model modified for screenhouse conditions by the inclusion of additional boundary layer resistance (PM-sc). Energy balance closure analysis presented as a linear regression between half hourly values of consumed energy (Y = sum of latent and sensible heat fluxes) and available energy (X = net radiation minus soil heat flux), resulted with the regression $Y = 1.04X - 6$ ($W\ m^{-2}$), with $R^2 = 0.87$ (1344 data points). Average daily measured ET under the screen was 5.5 mm d^{-1}, in general agreement with the models predictions and the applied irrigation. Models of reference ET showed that PETout was on average larger by 30% than PETin, implying on significant potential water saving in irrigation of vineyards under screens.

P 24.

MISTING COOLING TECHNIQUE OF PROTECTED CULTURE FOR ONCIDIUMS ORCHIDS IN SUBTROPICAL REGIONS

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Oncidiums are planted in the open protected culture or shading nets in subtropical regions. Because of the lack of cooling controlling technique for inside microclimate, the production period was limited. Without ventilation, higher humidity and higher temperature induced the serious growth problems of orchids. In this study, a microclimate model incorporated to the plant physiological conditions was developed and validated. Mechanical ventilation fans with intermittent misting were applied to modify the internal microclimate of internal environment of protected structure. The cooling technique can keep the interior air temperature lower than outside air temperature. The

plant temperatures could maintain near to the web temperature. The intermittent misting function with the best evaporative cooling efficiency was controlled with interval function calculated with microclimate model. Similar technique can be applied to others open protected structures of Oncidiums and others orchids.

Keywords: Shading nets, misting cooling, open structure, Oncidiums

P 25.

TEMPERATURE AND HUMIDITY RELATIONSHIP UNDER COPULA THEORY

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The main objective of this paper is to show the marginal distributions in controlled agriculture as a function of its temperature and humidity in different conditions located in Germany and Mexico. Normal distributions generally used, are contrasted with experimental information by using eigenvalues as part of the principal components. Copula theory analysis has become an important ingredient in many fields of science and engineering, until it is finding connection among discrete data. Even when programs exist to calculate the temperature and humidity relationship by using the physics of air-water mixtures, a Matlab ® program under PC platform is utilized to develop the linked distributions involved. Finally, decisions to handle an intensive agricultural system inside the ideal levels of production are recommended under statistical probability.

P 26.

APPLYING COOLING BELOW OR ABOVE THE CROP: AN EXPERIMENTAL STUDY IN SEMI-CLOSED GREENHOUSES

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The concept of semi-closed greenhouse has been a well promising technology the last decade in Dutch horticulture sector. As one of the main characteristics of semi-closed greenhouses are the high levels of CO2, which is mainly realized by minimizing ventilation losses, cooling is needed to dispose of the excess heat. Air treatment units (ATU), mainly consisting of a heat exchanger and air distribution system, are used in order to remove and store this heat. Despite the ambitious expectations of this innovative concept, regarding the environmental control, the application of ATU may produce vertical and horizontal temperature and humidity differences, since the air movement is dominated by their design, installation and operational characteristics. This might cause differences in plant growth and development.
An experimental study of two similar semi-closed greenhouse compartments, equipped with the same type of heat exchanger but different air distribution system is presented. Air was blown in either above or below the crop. Both compartments were monitored constantly by an extended network of sensors. By processing the experimental data using geostatistical techniques, both air temperature and humidity maps were produced. The results showed that at the top of the crop, the average air temperature in the compartment with coolers located above the canopy is lower than the compartment with coolers located below (dT=0.68°C). The coolers above resulted in better horizontal air temperature distribution than coolers below (differences ranged from 0-2.0°C and 0-3.5°C for the two compartments respectively). These differences were mainly due to the ventilator opening area (slightly higher in the second compartment), and the buoyancy effect. Mean air humidity in the compartment with coolers above was lower than the second one. Finally, the CO2 concentration in average terms was similar in both compartments even though in the second one (coolers below) the horizontal variation was higher.

Keywords: air treatment units, air temperature distribution, air humidity, CO2 concentration

P 27.

EFFECT ON ROSE PRODUCTION AND QUALITY OF A DIFFUSE GLASS GREENHOUSE COVER

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High energy use in rose cultivation at higher latitudes is caused by the need for artificial light to supplement scarce sun radiation. On the other hand, too high radiation levels are known to reduce flower quality. Therefore shading is widely applied during spring and summer, either through movable screens or seasonal whitewash. In both cases damage to the crop is avoided at the cost of reducing potential assimilation.
Recent research on cucumber (Hemming et al., 2008; Dueck et al., 2009) has shown that diffusing cover materials improve the uniformity of vertical light distribution in a crop, therefore decreasing the energy load on the uppermost crop layer to the advantage of the underlying leaves. These properties lead to a 10% increase in production. The application of such a cover on roses could decrease the need for shading so that a desired radiation sum could be achieved with less need for artificial light. Moreover, if the light distribution improvement on the crop leads to an increase in production, the same production could be achieved with less supplemental light, increasing the potential energy saving.
Diffusion, however, usually implies a loss of overall transmission. This drawback can be avoided by antireflection coatings so that most recently diffusive glass covers have become available with the same transmission as standard glass.
A rose crop (cv 'Red Naomi') is being cultivated since august 2010 at the research station of Wageningen UR Greenhouse Horticulture in Bleiswijk in two compartments, one of them covered with diffuse, anti-reflection coated glass. The paper will describe in detail the effect of the diffusing cover on the photosynthetic properties of the crop and bud temperature and the resulting production and quality (stem length and weight; bud size).

The research is financed by the Dutch Ministry of Agriculture, Nature and Food quality; the Dutch Horticultural Board and the European cooperation project EUPHOROS

P 28.

THE EFFECT OF COLORED PLASTIC FILMS ON THE GROWTH AND YIELD FORMATION OF TOMATOES

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Experiments were carried out to investigate the effect of colored plastic films on the growth, development yield formation and yield quality of tomatoes. Red, yellow and blue colored polyethylene plastic films were used. Control was colorless polyethylene film. The transparency of films during vegetation period was detected at the wave length 400- 700 nm (photosyntheticaly active radiation). The ration between red (600-700 nm) and blue(400-500 nm) spectrum for new plastic films is 1.01 for transparent cover, 1.04 for yellow, 1.08 for red, but 0.95 for blue plastic film. During vegetation period plastic film transparency and the the ratio between red and blue spectrum was changed. Tomatoes variety 'Maximka' was used for experiments. Plants were grown in vegetation pots placed in greenhouse or in soil covered with plastic tunnel. Plant length, number of leaves and leaves pigment content was determined during plant growth. Chlorophylls and carotenoides content was determined spectrophotomericaly in the ethanol extract of plant leaves. Tomatoes fruits fresh and dry weight and carotenoides content was defined. Experiments showed the influence of plastic film color on plant and fruit pigment content. The increase of chlorophyll content as effect of red and yellow colored plastic film was observed in plant leaves. The increase of carotenoides in tomatoes fruits under yellow plastic film was detected. No effect of plastic film color on number of leaves was observed. Decrease of tomatoes yield and number of fruits under blue cover was detected.

P 29.

INFLUENCE OF TWO NEW GREENHOUSE COVERING MATERIALS ON GREENHOUSE MICROCLIMATE AND COOLING LOAD

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Aim of this work was to study the effects of a new polyethylene (PE) film with high reflectance and absorption in near infrared radiation (NIR-PE film) and of a PE film with low transmittance in infrared radiation IR (IR-PE film), on greenhouse microclimate and cooling load of an hydroponic tomato crop. Films were evaluated in the laboratory and experimentally in three similar arched roof greenhouses, two covered with the new covering materials and the third one by a C-PE film. The greenhouse and outside microclimate parameters along with crop growth and production were recorded. Laboratory measurements show that the NIR-PE film has 13% lower transmissivity in total radiation band than the other two films and 57% higher absorbtivity than the C- PE film. Experimental results show that the NIR-PE covering material reduce substantially the solar radiation entering the greenhouse and resulted in a temperature drop up to 2°C than the air temperature of the C-PE covered greenhouse. The total production per m^2 was 12.12 kg m^{-2}, 12.00 kg m^{-2} and 10.25 kg m^{-2} under the under the IR-PE, the NIR-PE and the C-PE covered greenhouses, respectively with no significant differences between the three greenhouses

P 30.

EFFECT OF CONDENSATION ON LIGHT TRANSMISSION AND ENERGY BUDGET OF EIGHT GREENHOUSE COVER MATERIALS

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Calculations and the few data that are available show that over 100 liters water condense yearly on each square meter of the greenhouse cover. It is known that the presence of condensation reduces light transmission.This undesired side-effect is suppressed to some extent by adding film-forming (anti-drop) additives to plastic film covers and surface structures or coatings on hard cover materials. There is a need, therefore to assess the effect of the surface treatment on the loss of light. On the other hand, condensation releases the energy that was used for evaporation, thereby warming-up the cover and somewhat decreasing the heating requirement of the greenhouse. The amount of condensation energy that is not lost may be expected to depend on the external and internal climate conditions. Therefore the Dutch Horticultural Board financed this project whereby the effect of condensation on light transmission and energy budget has been investigated on a small greenhouse (about 3 x 4 m), placed in a climate chamber, and covered in turn with 8 different materials. Each experiment was repeated for two temperature differences between inside and outside (10 and 20 °C) and two air movements in the greenhouse. Light transmissivity was reduced by 9% on average, with large differences among materials. Anti-drop coatings did suppress this effect, as did a surface structure meant to increase diffusivity of the material. As far as energy is concerned, the U-value of the greenhouse increased by an average of 16% (single layers) or 12% (double layer covers) when wet. Obviously there was an effect of the temperature difference on the U-value, which was found to be consistent with the heat transfer theory, whereas little effect was found of the air movement within the house.

P 31.

MONOCHROMATIC LED-LIGHT AND ITS INFLUENCE ON DEVELOPMENT AND FLOWERING OF PETUNIA HYBR. AND LYCOPERSICON ESCULENTUM

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LED-technology seems to be a promising light source for assimilation light as well as photoperiodic light, both as a supplement when growing plants in greenhouses or as sole light source when growing in confined spaces such as growth chambers or "plant factories". Low radiant heat and the freedom of choice regarding the spectral distribution of the light are advantages that are often highlighted in this context. In order to examine the effect of various wavelengths on the growth and development of the long-day plant *Petunia* hybr. and the day-neutral Tomato, experiments were carried out in a growth chamber. Five different light treatments were used, monochromatic red, yellow, green and blue light, and the polychromatic white light, all at 60 $\mu molm^{-2}s^{-1}$, during 16 h day^{-1}. Results showed that for *Petunia* the red, yellow and green light gave very compact plants with suppressed flower initiation, whereas white and especially the blue light gave more open plants, rich in flowers. For tomato, results were quite different with compact plants in blue and white light and elongated plants in yellow and green light. The influence of monochromatic light on plants appears to be strongly dependent on plant species.

P 32.

LOCAL AND GLOBAL SENSITIVITY ANALYSIS OF A GREENHOUSE CROP TRANSPIRATION MODEL

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Both a local and a global sensitivity analyses were carried out to the Baille's greenhouse crop transpiration model. The model parameters are the radiative coefficient (A), the advective coefficient (B) for the day (Bd) and night (Bn), and the solar radiation extinction coefficient (K). Data were collected from a greenhouse located at the Experimental Station of the Cajamar Foundation "Las Palmerillas", El Ejido, Almería (Spain). The experiment was carried out during the winter 2004 for a tomato crop. Input variables for the model were global radiation, leaf area index (LAI) and vapour pressure deficit (VPD) measured every min. A total of 104831 samples (about 70 days) were used. The output variable was the transpiration rate of the crop, measured with a weighting micro-lysimeter. A combination of the SimLab (ver 3.2) software and the Matlab environment was used in all the simulations. In case of the local sensitivity analysis, derivatives were calculated analytically in order to estimate the relative sensitivities and also a local sensitivity index. On the other hand, to the global sensitivity analysis, firstly, uniform probability density functions (PDFs) were defined for all four parameters, and then, several thousands of Montecarlo simulations were performed to calculate the first order sensitivity indexes using both the Fourier Amplitude Sensitivity Test (FAST) method and also the Sobol variance-based method. Results showed that according to local sensitivity analysis the most important parameter was the advective coefficient during the day (Bd), then the radiative coefficient (A), the extinction coefficient (K) and the advective coefficient during the night (Bn) was irrelevant. However, the advective coefficient during the day (Bd) appears as the most important parameter and the others were no significant in case of the global methods. The scatter plots generated for all model parameters results coming from a global sensitivity analysis are more reliable than those obtained using the local approach.

P 33.

GREENHOUSE CLIMATE CONTROL BASED ON `SPEAKING PLANT APPROACH - SYSTEM DEVELOPMENT TO DETECT NEGATIVE CONDITIONS

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ZINEG, a joint venture project of several universities and research institutes in Germany aims at maximum possible reduction of energy consumption and carbon dioxide emissions of greenhouses. A research greenhouse (960 m^2) with maximum thermal insulation, mainly closed method of operation and the use of solar energy is built in Hannover. This is done in a cooperation of the Leibniz University Hanover and the Lehr- and Versuchsanstalt Hanover-Ahlem. Energy saving climate control strategies will be developed and tested on ornamental potted plants. These will take a significant influence on the climate conditions in the greenhouse in view to eventually occurring negative stress situations for plants. In highly insulted greenhouses the humidity and temperature inside the greenhouse differs partly very strong from conventional greenhouses. When the main focus is set on reducing the energy input dehumidification has to be prevented when possible. Therefore an online monitoring system is being developed and used in order to get phytosignals (measured and calculated) and thereby information concerning the condition of the plants. In a plant cuvette entire intact plants will be positioned and the gas exchange of the plants is measured. This gives information about the opening of the stomata that serve as an adjustable barrier for the gas exchange and react directly to negative climate conditions for the plants. The measured data give an input to a model that runs parallel and describes the development.

P 34.

A KALANCHOË PHOTOSYNTHESIS MODEL FOR CLIMATE CONTROL

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For decision support systems (DSS) and for optimising greenhouse climate control various simulation models are more and more used. Crop specific models for crop growth and crop development and their sub-models as e.g. microclimate or photosynthesis are needed to predict the crop performance to the climatic results induced by the greenhouse actuators. Especially crop gas exchange models for CO_2 and water, i.e. photosynthesis and transpiration, are important bases. As most cultivated greenhouse horticultural production crops metabolise using the C3 pathway most attention in model attention was put on developing models and well performing photosynthesis models exist for those crop types. For greenhouse crops with CAM metabolism only few model studies have been done. For the economically important greenhouse crop, the short day pot plant kalanchoë, only development and quality model approaches were done. For greenhouse climate control purposes, though, crop gas exchange models are needed. At full functional CAM metabolism the plants CO_2 uptake starts at nighttime and carbon is stored as malate for later usage at daytime. At daytime, this malate pool is used for the C3 pathway while stomata are closed until the pool is empty. An empty pool then induces the regular C3 pathway with opening the stomata. For this, four phases in a cycle within 24 hour can be distinguished. During its production cycle, however, kalanchoë is shifting from C3 to CAM metabolism and thus the climate control when based on photosynthesis and transpiration models needs to be adjusted to that. In the current paper we developed photosynthesis and transpiration models for the CAM metabolism for different stages of kalanchoë based on measurements of photosynthesis on a commercially grown crop and validated on a 2nd set of measured data. The models were incorporated in a crop growth model and validated on the same commercially grown cultivar. The models are implemented in the climate control system and a DSS.

Keywords: DSS, model, simulation, software

P 35.

DEVELOPMENT OF A CONTROLLED PLANT GROWTH MODULE WITH CHANGEABLE RATIO OF R-G-B AND W LED SPECTRA AND ANALYSIS OF ENERGY AND PPFD EFFICIENCY

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As alternative artificial light sources, light-emitting Diodes (LEDs) for plant production and plant research have attracted significant attention because of its high efficiency, longevity, and wavelength specificity. Unlike common light sources such as fluorescent lamp, LEDs emit specific wavelength and are available in various wavelengths. Radiation of specific wavelengths with LEDs may increase photosynthesis, stimulates physiological responses, morphology, and accumulation of phytochemicals. To investigate these facts, we designed and constructed a plant growth system that utilizes LEDs as artificial light source. This system consists of integrated air conditioner, six nutrient solution reservoir, and nine growth modules with red-green-blue LEDs, six growth modules with red-white LED, and three growth modules with fluorescent lamps. This system is able to control light intensity (and quality) of each wavelength, duration and duty ratio of pulse in wireless, inside temperature, relative humidity, and CO_2 concentration. In terms of PPFD and energy, efficiency of combined ratio of LEDs was analyzed.

P 36.

PAD-AND-FAN COOLING SYSTEM CAPABLE OF EASILY INSTALLING AND COMBINING WITH NATURAL VENTILATION IN GREENHOUSES

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Since fine-mesh screens of vents for exclusion of insect pests induce significantly restriction of ventilation and rising air temperature in a greenhouse, cooling systems are required to maintain the desired growing conditions during hot summer. However, the existing cooling systems, namely, i) the pad-and-fan system and ii) the fogging system have disadvantages to adopt in small commercial greenhouses equipped with fine-mesh screens as fellows: i) the system installation is too expensive, and exhaust of the hot and humidified air depends on mechanical ventilation; ii) small natural ventilation due to airflow resistance of screens is subject to the failure of fog evaporation, as a consequence the risk of wetness of plant foliage is high. In this study, the pad-and-fan cooling system capable of easily installing and combining with natural ventilation, is proposed to spread evaporative cooling into described above greenhouses in Japan, where the climate is high radiation, hot and humid in summer. This cooling system consists of an air supplying fan, a perforated tube, an irrigation pipe and cool pads. The fan (airflow rate 72 m^3 min^{-1}) with attached perforated polyethylene tube (diameter 48cm) was installed on the inside central ground along length of the greenhouse (width 5m, length 10m, ridge height 3m). The cool pad unit (width 90cm, height 30cm, thickness 10cm) was composed of alternating layers of cellulose cubes and water-absorbing sheets, and six pads were closely-spaced to polyethylene tube. Irrigation to cool pads was performed intermittently above cool pads. The air temperature and relative humidity in center of the greenhouse (height 1.5 m), which side openings were covered by fine-mesh screens (0.3mm-mesh size, porosity of 0.52), were lowered average 5 °C and humidified 20~30% compared with the treatment greenhouse on summer daytime. No significant temperature and humidity gradients were created along the greenhouse length.

P 37.

EFFECT OF THE SHADING AND GRAFTING TECHNIQUE ON GROWTH AND FRUIT PRODUCTION OF SWEET PEPPER PLANTS

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Horticultural cultivation in Mediterranean greenhouses requires the implementation of refrigeration systems to avoid stress situations, particularly under spring-summer conditions. The effects of using aluminised screens offering different degrees of shading combined with two transplant types (grafted or ungrafted) were analyzed in sweet pepper plants. Simultaneous comparisons were made among greenhouse that were either not shaded (control) or covered with reflective aluminized shadecloth that attenuated 40% (T40) and 60% (T60) of direct sunlight. The shadecloth was applied at the start of warm weather in May. The greenhouses were shaded for the rest of the summer, and fruit was picked until August. The results showed that only the T60 treatment returned significantly different results compared to the control: the T60 had a lower production. And non-grafted plants produced yields slightly lower than grafted.

Key words: *Capsicum annum* L., grafting, rootstock, greenhouse

P 38.

IMPROVING INPUT RESOURCE UTILIZATION EFFICINCIES FOR PLANT FACTORIES OF PLANT FACTORY AND GREENHOUSES

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For improving input resource utilization efficiencies (IRUE), which is defined as a ratio of the amount of input resource fixed or held in produce or in plants to the amount of corresponding resource input to the plant production system. In reality, this efficiency is defined for each resource component such as light energy, water, CO2, a fertilizer, plant biomass (from seeds or cuttings to whole plants or produce), money and so on. Similarly, COP (coefficient of performance) of heat pump systems and other performances of environmental control systems are defined. These efficiencies and system performances are estimated and analyzed considering various factors such as greenhouse environment, amounts of input resource and CO2 emission, cultivation systems, plant species and cultivars, weather, and operation methods of environmental control equipments, and cost. In order to analyze the IRUE, we developed a system to estimate diurnal changes in the rates of net photosynthesis, transpiration and ventilation based on mass balances of water and CO2, with respect to the plant production system. About one thousand sensors in total including IC chips and barcode readers are installed for measuring environments, equipment operations, fluxes of energy and mass, flows of consumption goods and personnel, etc. The concept and ongoing experiments and preliminary outputs will be introduced at the symposium site. This research is a part of plant factory R & D project recently initiated at Chiba University, Kashiwa city, Japan. A plant factory with artificial light with a floor area of 1, 000 m2 and a greenhouse complex with a floor area of 1 ha, installed with heat pumps for heating, cooling, dehumidification, enhanced air circulation, were completed in March 2011, with related facilities for transplant production, plant residue processing, rain water storage, etc. Main target crops are lettuces and tomatoes for production under artificial and natural lights, respectively.

P 39.

EMISSIONS OF PLANT PROTECTION PRODUCTS FROM GREENHOUSES TO THE AIR

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Aim of the present study is to provide scientific information to be used by European Food Safety Authority (EFSA) for the development of new EU guidance on emissions of plant protection products (PPPs) from protected crops (greenhouses and cultivations grown under cover). Protected crop systems require ventilation to control temperature and other growing conditions. PPPs are thus likely to be carried to the outside air once they are present in the air within the system. In addition, concentrations of PPPs in air within covered structures can be greater than outdoors, due to higher temperatures and the enclosed structure preventing dissipation. In order to calculate the emissions of PPPs to the air, two structures were considered, one with fully controlled ventilation (multi span greenhouse) and one with uncontrolled ventilation (walked in tunnel). For both types of structures, calculations were performed by simulating the growing period of two crops (tomato and lettuce) for the regions of Murcia (Spain) and Sicily (Italy). Using an hourly weather data set for 13 years (1997-2009), the emissions of PPPs from greenhouses to the air were estimated in two steps. Firstly, the simulation model 'KASPRO' was used to calculate the indoor climate conditions regarding, air temperature, air humidity, inside solar radiation and ventilation rate. Secondly, by using the indoor climate data as initial conditions the emissions of PPPs to the air were calculated with the simulation model 'IDEFICS'. The results showed the influence of the indoor climate conditions and the type of structure to the emissions of PPS to the air. In most of the cases the transfer of PPPs to the air is not exceed the 10% of the initial quantity of PPPs applied.

P 40.

GREENHOUSE INSIDE CLIMATE: A DATA-BASED MODELLING APPROACH REFERRING TO THE PREDICTION OF INSIDE TEMPERATURE AND RELATIVE HUMIDITY

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Mathematical modelling is used in greenhouse research to control a wide range of variables that are normally difficult to manipulate. Besides the existence of numerous types of models, data-based models are possible to predict the dynamic behaviour of the greenhouse climate in an accurate way. In contrast with the mechanistic models, data-based models do not involve the mechanistic character which renders them often difficult to use. The prediction of the greenhouse climate can be used for the improvement of greenhouse structure design and control of the environment. Greenhouse air temperature and relative humidity are two important variables that can be influenced and controlled by many parameters. The present research refers to the prediction of these two variables along a greenhouse, and a dynamic data-based model approach is proposed, which incorporates the use of a heating system and two window openings. Measurements were performed in an experimental polyethylene covered arched roof greenhouse of ground area of 160 m^2 located in the experimental farm of the University of Thessaly in Central Greece. Model inputs were the outside air temperature and relative humidity and model outputs were inside air temperature and relative humidity. To model the effect of window opening and heating tube temperature, those effects were decoupled from other effects such as day/night fluctuations (diurnal effect). The resulting transfer function, including inside air temperature as output and outside air temperature as input, was a first order model with a structure [1 2 3 0], an average coefficient of determination R_T^2 of 0.94 and a value for Young information criterion (YIC) of -11.667. Also, the transfer function, including outside air relative humidity as input for the same output, was a first order model [1 2 0 0], with R_T^2 of 0.84 and YIC of -10.583. The resulting models can be further used for greenhouse system control purposes and energy use optimisation.

P 41.

EVALUATION OF COST-EFFICIENT LIGHT CONTROL BASED ON WEATHER FORECASTS AND ELECTRICITY PRICES ON GROWTH AND FLOWERING IN CAMPANULA

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A cost-efficient light control system based on weather forecasts, electricity prices and daily photosynthesis integral (DPI) was evaluated for commercial production of the long-day (LD) plant *Campanula porten-schlagiana* 'Blue Get Mee' and *C. cochlearifolia* 'Blue Wonder'. Experiments were conducted under both autumn and spring conditions and included four treatments. Three treatments were controlled by the software system DynaLight which automatically defined the most cost-efficient use of supplemental light based on a predefined set point of DPI, forecasted solar irradiance and the spot market price on electricity. The set point of DPI in the three treatments was 300, 450 and 600 mmol m^{-2} leaf d^{-1}, respectively, and the treatments were compared with a traditional LD treatment of 19 h day. The alternative light control strategies resulted in very irregular light patterns including daily periods of solar irradiance combined with supplemental light in low light periods and a night period interrupted by irregular light breaks (NB-lighting). Both Campanula species flowered in the irregular light patterns during spring, but flowering was impaired in plants grown in irregular light during autumn. This impairment was caused by a combination of the irregular light and low light intensities and could be restored by maintaining a consecutive 19 h day with incandescent light (<5 µmol m^{-2} s^{-1}). The results illustrated that day length was an important factor for flowering in LD species grown under low light intensities. Growth in terms of carbon gain was only little affected by irregular light, and a 30% reduction in electricity costs were achieved without major reductions in plant quality. Our results presented here are novel and illustrates a potential to maintain plant production of LD species in protected systems where the energy used for light is controlled by a cost-efficient light control system based on weather forecasts and electricity prices.

P 42.

HIGHER PLANTS IN CLOSED LIFE SUPPORT SYSTEMS - REQUIREMENTS FOR FUTURE RESEARCH

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Future long term mission to the Moon and Mars rely on a life support system capable of regenerating all the essentials for survival. As identified through MELiSSA (Micro-Ecological Life Support System Alternative), such regenerative life support systems need to include a compartment for production of higher plants. Plants provide a regenerative food source, aid in oxygen production, and contribute to purification of air and water. In the Literature Study of Higher Plants in Space for MELiSSA (LiRHiPliSME) project, contributing to the MELiSSA Phase 2 - Preliminary Flight Experiments, literature has been reviewed to assemble the relevant knowledge within space plant research. Focus has been on the effects of gravity, space radiation, magnetic fields and ultimately a combined effect of these factors on plant growth and development. The main objective of LiRHiPliSME was to establish an understanding of the current knowledge within space plant biology and identify the need for future scientific research activities required before higher plants can be included in regenerative life support systems. In general, the available information regarding effects of the space environment on plants is inconclusive, and suffers from limitations in available flight hardware, sensor technology and research facilities that simulate space conditions. Development

of hardware and sensor technology should complement the research activities. In addition, more work is necessary on the canopy scale and with food crops relevant for life support. On the whole, the available literature seems to prove that plants can grow and reproduce in space when provided with a well stirred atmosphere and grown at moderate light levels. Based on the LiRHiPLiSME study, future research activities required before higher plants can be implemented in closed life support systems on the Moon or Mars are presented and placed in a timeline.

P 43.

GROWING PLANTS IN THE EUROPEAN MODULAR CULTIVATION SYSTEM (EMCS) ON THE INTERNATIONAL SPACE STATION

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The European Modular Cultivation System (EMCS) has been operational on the International Space Station since 2006. The Norwegian User Support Centre (N-USOC) has been assigned by the European Space Agency as responsible for the EMCS. The plants are grown in Experiment Containers (ECs) that are installed on two centrifuge rotors. The rotors allow for microgravity and acceleration studies with variable g-levels from 0.001*g* to 2.0*g*. The atmosphere control systems supplying adjustable CO_2, O_2 and N_2 levels combined with the temperature control system is providing extensive environmental control in the EMCS incubator. The Rotor Based Life Support System connected to a fresh water reservoir is supplying each EC with water and humidity controlled air. Together with the illumination system (LED) the EMCS has the feature to provide the ECs with fully controlled environmental conditions. The EMCS has advanced observation capabilities by means of a camera system, and multiple sensors for monitoring and control through dedicated power and data lines to each EC. Until today 7 plant experiments has been conducted in the EMCS. Experiment unique equipment integrated in the ECs are designed and developed to support the dedicated experiments. The experiments performed so far are the two US TROPI experiments, the French GRAVI-1 experiment, the Norwegian MULTIGEN-1 experiment, the Japanese experiments Cell Wall and Resist Wall and finally the French GENARA A experiment. The MULTIGEN-1 was a long duration experiment lasting for 84 days. To support a full life cycle of *Arabidopsis thaliana* a Plant Cultivation Chamber was especially developed with optimised water and nutrient supply. Through the EMCS experiments basic knowledge are revealed on how plants grow and develop in the microgravity environment. The experience gained by remotely controlling the plant cultivation system, can be transferred to greenhouse applications on ground and in future human exploration to Moon and Mars.

P 44.

GREENHOUSE CLIMATE IDENTIFICATION BASED ON DYNAMIC NEURAL NETWORK

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The greenhouse climate is a complex system and the development of mechanistic models is a time-consuming task and resources expensive activity. Design of advanced control systems of greenhouse climate requires a state feedback. When the physical model of the plant is not available one strategy of solution consists of accomplish the control action based on a mathematical model provided by the online identification of the plant. In such cases, an artificial neural network (ANN) could be a good option. Dynamic neural networks (DNN) exploits the feedback properties of the applied DNN and permits to avoid many problems associated with static neural networks such as global extreme search and consequently they have better approximation properties. A very successful scheme to accomplish control of unknown nonlinear systems consists of identifying the unknown dynamics using differential neural networks and on the basis of the so obtained mathematical model, to develop an appropriate control law. In the present work a differential neural identifier with an online learning law which guarantees the boundedness for both the weights and the identification error is used in order to approximate the temperature and humidity air dynamics inside a Mexican greenhouse. Based on the developed neural identifier, a control law to guarantee the boundedness of the tracking error was developed to force the system to track the desired setpoints. Simulation results justify the proposed approach.

P 45.

INFLUENCE OF TWO DIFFERENT THERMAL SCREEN MANAGEMENTS ON YIELD, QUALITY AND ENERGY CONSUMPTION OF A SOILLESS TOMATO CULTURE

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To save energy in glasshouse culture, one possibility is to use thermal or shading screen during the night but also during the day. The purpose of this study was to identify the effects of thermal screen management on yield, quality and energy consumption of a soilless tomato culture. The trials were performed during the seasons 2009 and 2010 in two similar greenhouses with each an area of 358 m^2, located in Switzerland. The greenhouses have two screens: a thermal screen (SLS 10 Ultra Plus by Svensson) and an aluminised screen (shading screen, XLS 15 by Svensson). In one of the greenhouse, the shading screen was removed half an hour after sunrise, and the thermal screen one hour after sunrise if the outside temperature was higher than 5°C and if the light intensity was higher than 3 klux, if not it remained closed (Test management). In the other one, the screens were opened at sunrise (Control). For the season 2009, tomatoes cv. 'Climberley', 'Komeet' and 'Plaisance' were planted on February 12th in coir, at a density of 2.5 stems/m^2. Thereafter shoots were selected to reach 2.8 stems/m^2. In 2010, cv. 'Climberley' and 'Komeet' were planted on February 9th, at the same density as in 2009. The energy consumption was measured by thermal energy meter (Multical® 601 by Kamstrup) with Pt 500 sensors. The test management allowed an energy saving of 23% for the 2009 season. The 21th July 2010, the energy saving in the greenhouse with the test man-

agement achieved 27%. No significant incidence on yield and on analytical quality of tomatoes was noted. This results confirm that screen management can allow energy saving without negative impact on the amount and quality of the yield.

P 46.

IMPLEMENTATION OF AN ALGORITHM FOR OPTIMAL FERTILIZATION WITH PURE CARBON DIOXIDE IN MEDITERRANEAN GREENHOUSES

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There is little doubt that widespread carbon fertilization, made possible by the direct application of heating fumes is one of the factors leading to the high productivity of Dutch glasshouse horticulture. The chance of using bottled CO_2 in the unheated greenhouses of the Mediterranean region has been made possible only recently by the price decrease caused by the Kyoto protocol. However, the large ventilation requirement of greenhouses in the region ensures that an economic management of fertilisation is badly needed. Allowing for a higher than external concentration under ventilation obviously imply that some of the supply will end up outside the greenhouse, rather than in the crop. This increases the cost of getting a given amount of CO_2 into the crop, but it does not necessarily reduce profit. By applying some economics to a simple assimilation model, an optimisation algorithm was developed, that calculates each time the economically optimal set-point concentration of CO_2, in view of the external conditions, the need for ventilation, the price of CO_2 and the expected value of the yield. We discuss the feasibility and the results of the implementation of this optimisation algorithm in a commercial greenhouse, in the framework of the EU-financed cooperation project EUPHOROS.

P 47.

ADDITIONAL ROOF VENTILATORS TO IMPROVE LEEWARD VENTILATION SYSTEMS

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Compared to lee ventilation, windward ventilation increases ventilation rates in greenhouses. However, in areas such as the Canary Islands tomato greenhouses use to be large and, furthermore, are located in areas with hard-blowing winds which involves wind damage to crops (through side vents) and to windward roof vents. For this reason leeward ventilation is preferred to windward ventilation. Nevertheless some improvements are needed for large span greenhouses with leeward ventilation to eliminate hot areas and thus increase temperature uniformity. For this purpose CFD simulations were run on a three-span experimental greenhouse with lee ventilation. CFD simulations showed that there was an area of negative air pressure near the gutter of the first span. Therefore a ventilator was built on this location in order to act as an air outlet. In this report we present the results of the study of this additional vent. Three sonic anemometers were placed outside and inside the greenhouse in different positions. The experimental data agreed with the general flow pattern shown by CFD simulations: the additional ventilator acted as an efficient air outlet and the internal air movement was as predicted by simulations. Preliminary analysis has shown a good correlation between outside wind velocity and the velocity outlet through the additional vent. The correlation between outside wind velocity and air velocity in the centre of the greenhouse was lower for higher wind speeds.

P 48.

ECOPHYSIOLOGIC AND ENERGY-EFFICIENT CULTIVATION OF TOMATOES IN AN INTELLIGENT AND SMART CONTROLLED GREENHOUSE

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Greenhouse plant cultivation is one of the most energy intensive ones of agricultural production. Energy consumption, investments and operational costs are aiming at a higher yield and year round production. New energy-efficient climate control technologies were introduced and led to new climatic conditions inside the greenhouse. The reactions of the plant to these new climatic conditions is totally different than generally is known in greenhouse cultivation. Therefore, it has been suggested to monitor the plant (water) status with plant based methods and sensors and to couple these measurements with the energy installation. In this research project (4 years period), the interaction between plant and energy consumption in a tomato greenhouse is investigated. In order to reduce costs and save energy, various innovative energy systems were evaluated. Two pilot installations based on an innovative ventilation concept were built at 2 research centres. In these greenhouses the behaviour of the plant was measured with plant sensors during almost 2 years. These data were analyzed and brought into a mechanistic model of water flow and storage. At the end of the project an intelligent and smart greenhouse will be controlled by this integrated model. This poster will give an overview of the project Smartkas and give the first results.

P 49.

AIRFLOW AND MICROCLIMATE PATTERNS IN ENERGY SAVING GREENHOUSES: AN EXPERIMENTAL AND CFD ASSISTED STUDY

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This study analyses airflow circulation and microclimate distribution in experimental energy saving greenhouses with a tomato crop in South France. Two types of energy saving greenhouses are considered, one based on heating energy conservation by means of an inflatable Teflon double skin and a thermodynamic air humidity control, and the other based on the closed greenhouse concept, with inter seasonal storage.
Distributed micro-climate investigations inside the greenhouse are based on both experimental measurements and numerical simulations to solve the mass, momentum and energy conservation equations of the heat and mass transfers.
In addition to the newness of the energy saving greenhouses, the novelty of the simulation lies in the realism of the 3D modelling of these greenhouses with (i) a coupling of convective and radiative exchanges using Discrete Ordinate (DO) modelling, a procedure which is taken into account for (ii) the simulation, in each mesh of the crop canopy, of the sensible and latent heat exchanges between greenhouse air and tomato crop.
The dynamics of the sources and sinks of heat and water vapour deduced from experimental and modelling studies are presented and analysed. The distributed climate and flow fields within the greenhouse are also revealed by the experimental and numerical approaches. The most characteristic patterns are presented and ways for improving micro-climate distributions are suggested and discussed.

Keywords: Greenhouse, CFD, Modelling, Airflow, Climate, Tomato, Closed Greenhouse, Dehumidification, Cooling, Heating.

P 50.

CFD SIMULATION TO PREDICT THE IMPACT OF THE SUN PATH ON THE LOCAL CLIMATE AND CROP ACTIVITY INSIDE A GREENHOUSE

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Optimizing irrigation in greenhouses is one of the main concerns of growers. Improving water management requires an accurate knowledge of the crop needs. In this prospect, Computational Fluid Dynamics (CFD) is a way to predict the influence of the local microclimatic conditions on the crop evapotranspiration. Up to now, the interactions between the climate and the crop have been scarcely studied in distributed climate approaches. Moreover, the models only consider the steady state conditions and little is known on the impact of the radiation distribution evolution on the crop activity. The objectives of this study are (i) to develop a model of the crop activity which takes account of the spatial and temporal heterogeneity of the radiation by simulating the path of the sun and (ii) to quantify the influence of the solar radiation on the crop activity and therefore on the climate in the vicinity of the plants. A commercially available CFD code was considered and a crop submodel was implemented. The computational domain was restricted to a volume close to the canopy and the unsteady 2D Navier Stokes equations were solved using the standard k-e turbulence model. The model was validated from experiments conducted inside a 100 m^2 glasshouse. Results evidence the crucial role played by the spatial and temporal variation of the radiation intensity on the crop transpiration and on the microclimate which establishes inside and around the crop. In particular, strong horizontal gradients of relative humidity are predicted during the day. The developed approach may help growers improve their irrigation strategy or reconsider the plant arrangement inside the greenhouse.

P 51.

PARAMETRIC STUDY OF NATURAL VENTILATION OF GREENHOUSES CLUSTERS

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Greenhouse production involves major environmental impacts. The increasing demand for higher quality products, in particular of environmentally friendly quality, and the actual various rules and standards (European to local) that define the agricultural sector do require, therefore, a restructuring of the greenhouse horticulture production sector. In recent years numerous projects have been carried out to try to identify and solve environmental issues. Life Cycle Assessment (LCA) has been the basic tool to identify critical points in the production chain thus helping to implement sustainable (development) policies. Nowadays, imported from industrial ecology, the concept of "clustering" has begun to be considered in agriculture. It can be defined as the geographical concentration of different companies and institutions that are interrelated with common objectives. In agriculture, this kind of sites is known as Food-Parks or Agroparks. This approach is certainly applicable and of great interest to Spain. Indeed, due to increased competition, protected cultivation infrastructures are in the process of improvement and transformation. In this context of creating Agroparks, or transforming old fashion protected cultivation areas, it is of key importance the improvement of joint or overall greenhouse natural ventilation. To do so, a parametric study of the separation distances among greenhouses within a greenhouse cluster was carried out. The basic greenhouse module was 50 x 48 x 6 m^3. Natural ventilation was operated by means of double ridge vents. The basic configuration studied was

4 greenhouse modules in a row. Separation distances of greenhouse height (H), 1.5 H, 2H and 4H were simulated with a general purpose fluid analysis code (Fluent). Isothermal simulations were run since only wind driven ventilation is affected by other buildings or greenhouses proximity. A RANS approach was also considered because, with design purposes, just the mean physics involved in the ventilation process, and not their dynamics, are needed. Natural ventilation efficiency was determined through mass balances between greenhouses and air velocities in the greenhouses. Finally, minimum and maximum distances between greenhouses for optimum overall greenhouse natural ventilation within a greenhouse cluster are proposed.

P 52.

NATURAL AND FORCED VENTILATION: NUMERICAL SIMULATION OF AN EXPERIMENTAL GREENHOUSE LOCATED IN A COMPLEX ENVIRONMENT

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Aim of the present study is to simulate numerically both natural and forced ventilation processes of an experimental greenhouse located in a complex environment. The 3D computational domain was designed in detail in order to represent the real greenhouse's surrounding environment. The crop (tomato) was simulated using the equivalent porous medium approach by the addition of a momentum source term, due to the drag effect of the crop. Wind characteristics, temperature and humidity of outside air and operational characteristics of fans were specified to set up the CFD model. The numerical analysis was based on the Reynolds-averaged Navier-Stokes equations in conjunction with the RNG k-ε turbulence model using the finite-volume numerical method. Two sets of calculations were carried out. In the first one, both natural and forced ventilation was simulated using experimental data as boundary conditions. The validation of these simulation models was accomplished using data collected over summer periods of 2006 and 2007. In the second one, natural and forced ventilation were simulated considering wind velocity of 1, 3 and 5 m/s and wind direction from 0° - 360° with step of 30° for each value of wind speed. The ventilation rate for every case, which was calculated according to the simulation of the decay tracer gas method, expressed as a function of wind speed and wind direction. The computational results obtained by the first set of calculations, were in a qualitatively good agreement with experimental data concerning the air temperature and the air velocity inside the greenhouse. The results obtained by the second set of calculations show that the ventilation rate could be expressed as a function of wind speed and wind direction, even if the greenhouse is located in a complex environment. The numerical model is proved to be a useful tool, as the customized ventilation functions, which predict the ventilation rate under different environmental conditions, could be integrated in control systems for each greenhouse.

P 53.

COMPARATIVE ANALYSIS OF A BIG SCALE SCREENHOUSE WITH PLANE AND MULTISPAN ROOF BY USING COMPUTATIONAL FLUID DYNAMICS (CFD)

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The structural adaptations that the greenhouses have had to take to adapt itself to the tropical and semi-arid regions, it has happened through the substitution of the plastic cover by a porous cover that allows a better air exchange without exposing to the culture to the damages of biological agents (plagues and diseases), porous structure is commonly called "screenhouse". Based on the numerical simulations by using Computational Fluid Dynamics (CFD), in this work the set up the natural ventilation that happens in one screenhouse of 245 length x 110 width, with two types of roof study, plane and multispan (20 spans). The simulations were done for 5 speeds of outer wind (1-5 m s^{-1}), screen porous with a 0.33 porosity (16.1x10.2 threads cm^{-2}), and simulating a crop of tomato totally developed (IAF=5). The graphical results indicate that screenhouse with roof in multispan presents uniform landlords of flow due to the differences in the pressure gradients that happen between the outside and the zone of span, notwithstanding the speeds of wind they behave of similar way to screenhouse with flat roof. Comparatively the thermal gradients in the interior around the crop (2 m) are also similar in both, plane and multispan roof.

Keywords: Thermal gradient, wind behavior, screen porosity, air exchange.

P 54.

EXPERIMENTAL RESULTS AND NUMERICAL MODELING OF SOLAR RADIATION DISTRIBUTION IN A NATURALLY VENTILATED GREENHOUSE

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The effect of solar radiation distribution in a naturally ventilated greenhouse was experimentally and numerically investigated, taking into account the thickness of the cover, its spectral optical and thermal properties. Measurements of solar radiation distribution, in terms of transmissivity, were carried out in an experimental tunnel arc type

greenhouse, located in Central Greece. The measurements were carried out using the LI-1800 spectroradiometer in 3 points along the length of the greenhouse and in 3 points along its width. For the numerical part a two dimensional mesh was used to render the greenhouse's geometry, and the Discrete Ordinate (DO) model for simulating the radiation, taking into accounts its spectral distribution in three wavelength bands. Mean values for the experimental part was used to adopt realistic initial and boundary conditions. The flow recirculation, due to the buoyancy effect, showed the importance of internal temperature gradients, although forced convection which resulted from natural ventilation was dominant. It was concluded that cover material with high absorptivity deteriorate the natural ventilation increasing the air temperature by convection, and favouring the development of secondary recirculation where the air is trapped. In general a good agreement was found between the experimental and numerical results. The CFD model can be further used in order to improve the homogeneity of solar radiation distribution in greenhouses according to the used covering materials and ventilation openings.

P 55.

3D NUMERICAL INVESTIGATION OF A FAN VENTILATED GREENHOUSE TAKING INTO ACCOUNT EVAPO-TRANSPIRATION AND RADIATION

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The effects of solar radiation distribution during fan ventilation in an arc type tunnel greenhouse in specific hours of daylight were numerically investigated taking into account the plants' evaporo-transpiration mechanism. Inside the greenhouse a tomato crop 1.5 m tall was considered in four rows arrangement. For the simulation's needs a 3D mesh is used to describe the real geometry, and the finite volume method was adopted for the solution of the fully elliptic partial differential equations. Climatic data from experimental values were used in order to approach realistic conditions of typical summer day. Special parameters, like the optical properties of covering material and of tomato plants as well as the plant's resistance to the flow, the rate of tomato transpiration. Various values of relative humidity of the inlet air stream were examined. The numerical results are validated against experimental measurements. The distribution of PAR inside the greenhouse depends strongly on the angle of incidence of incoming solar radiation and so from the greenhouse shape. Although the dominance of the forced convection, resulted from the mechanical assisted ventilation, flow recirculations are presented and buoyancy effects appear in areas where forced convection is limited via to the crop's rows presence.

Key words: CFD, radiation, evaporo-transpiration, 3D, greenhouse

P 56.

INCREASING ENERGY EFFICIENCY OF GREENHOUSES BY THE USE OF ROTARY SPEED REGULATED CIRCULATING PUMPS

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Circulating pumps in heating systems are, apart from assimilation lights, the main electrical loads within heated greenhouses. With the heating power typically being influenced by seasonal and daily cycles, most conventional pumps can only be operated on one power level, always generating the same delivery head regardless of heating periods. Modern, rotary speed regulated pumps are able to solve this problem by permanently adjusting their rotary speed (and therewith their delivery height) to the current heat demand. Long-term measurements of effective energy and heat flow at the University of Applied Sciences Weihenstephan-Triesdorf revealed that the annual power consumption - and consequently the costs of operation - can be lowered up to 70% by the use of rotary speed regulated pumps. These kinds of pumps have additionally been installed in the heating systems of several nurseries in order to prove these values under different industrial conditions. This approach could be realized via the research project "Increasing energy efficiency of greenhouse-nurseries in Bavaria", which is part of the "Bavarian Research Association Energy Efficient Technologies And Appliances". The calculations are based upon long-term measurements of power consumption, extrapolated with specific annual heating load charts for each company. Currently, at the University of Applied Sciences Weihenstephan-Triesdorf, two different kinds of systems are operated. In one system the calculation of the demanded delivery volume bases on an output signal generated by the climate-control-computer, in the other systems it bases on the difference between flow- and return-temperature. To widen the range of application of rotary speed regulated pumps, a circuit will be designed that allows the regulation of the pumps directly by an output signal of the mixing valve. Besides the conservation of energy, the attention hereby must be concentrated on the consistent horizontal heat distribution within the greenhouse.

P 57.

ESTIMATING THE SURFACE OF CANOPY IN GREENHOUSES USING IMAGE ANALYSIS

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Most of the climate variables inside of the greenhouses in southeast Spain are controlled. Therefore, the biomass of the intensive crops achieves high densities and uniform shapes when the crops are completely developed. However the dose of the sprayed treatments must be directly conditioned by the variation of the density of the canopy in the growing period. A low cost accurate method for surface canopy estimation is critical for optimization of treatments and environment efficiency. Some vegetation indexes have been used as indirect estimators of biomass

obtained from multi-spectral images for others applications. The well known Leaf Area Index is a direct estimator of biomass witch is highly correlated with Vegetation Index, based on differential radiometric response from health canopy in red and infrared spectral bands. The main aim of this work was the design of a low cost methodology for indirect estimation of surface of canopy based on digital images of a tomato intensive crop in greenhouse. Efficiency and precision of the proposed estimator was tested comparing it with some other indirect estimators, characterized by the higher cost or low accuracy.

P 58.

PERFORMANCE OF ORGANIC TOMATO (Lycopersicon esculentum Mill.) UNDER INCREASING COMPOST AND WATER LEVELS IN GREENHOUSE

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The growth, yield and fruit quality of the most widely popular tomato (Lycopersicon esculentum Mill.) indeterminate hybrid `Neuton` were evaluated under two seasonal watering regimes (400 and 800 mm) and four levels of compost fertilizer (0, 20, 40 and 60 t/ha) in the Jordan Valley during (2008). Plant height, stem diameter and number of leaves were significantly the highest under the lower water (400 mm) regime with the highest compost (60 t/ha) level. Tomato yields (160 t/ha) under the highest compost level (60 t/ha) of the lower water regime (400 mm) were the highest and significantly similar to those obtained under the higher water regime (800 mm) with the (40 t/ha) compost level which yielded 163 t/ha. On the other hand, the lowest significant total yield was obtained at 0 t/ha of compost under either watering level. While pH of the fruit juice was not affected, TSS was significantly the highest at 400mm water x 60t/ha compost, as well as, at 800mm water x 40t/ha of compost.

Keywords: *Lycopersicon esculentum*, water, compost, yield, TSS, Jordan.

P 59.

DIGESTED LIVESTOCK MANURE AS ORGANIC N-FERTILIZER FOR GREENHOUSE LETTUCE

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In Italy, lettuce is extensively grown in greenhouse. Maintaining adequate nutrition is one of the most critical aspects of producing greenhouse crops: as an example, for greenhouse lettuce produced on soil substrate, an excessive mineral N-fertilization could lead to luxury consumption, with dangerous effect on plant healthiness and on environmental quality.
The possibility to fertilize lettuce by applying organic fertilizers, as digested livestock manure, able to supply nitrogen and other nutrients by optimizing their use efficiency represents a promising approach. In our work, we evaluated the agronomical performances of a solid fraction of pig livestock manure, previously digested under anaerobic conditions or not-digested, as organic fertilizers for lettuce production.
In the greenhouse experiment, plantlets of *Lactuca sativa* L. (cv. Cappuccina) were transplanted in pots containing two soils with different textural, physical and chemical characteristics. A digested and a not-digested solid fraction of pig livestock manure, at two increasing N rates (200 and 400 mg N/kg_{soil}) were applied as N-organic fertilizers, taking the granular urea as reference mineral fertilizer. Irrigation was managed in relation to plant water-demand. After 6 weeks, lettuce fresh and dry weight (g $plant^{-1}$), dry matter (%), total leaves' area (cm^2), number of leaves, leaf tissues N, P, K, Mg content (mg kg^{-1}), residual soil N, soil available $N\text{-}NO_3^-$ and $N\text{-}NH_4^+$ and related N-use efficiency (%) were determined.
Agronomic performance of the organic fertilizers were influenced by both the soil characteristics and the organic fertilizers. The biomass production and agronomical parameters related to lettuce showed that the digested livestock manure gave results comparable to those obtained by applying the mineral fertilizer urea, together with a better N-use efficiency. Moreover, the application of both the organic fertilizers determined a significant decrease of soil leachable nitrates, also in excess of N supply (highest rate).

P 60.

STUDY OF DEGRADABLE MATERIALS FOR SOIL MULCHING IN GREENHOUSE-GROWN LETTUCE

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The benefits associated with use of plastic mulches include higher yields, earlier harvests, improved weed control and increased efficiency in the use of water and fertilizers. However, the plastic has a negative effect on the environment. After the crop is picked, the plastic waste must be removed from the field. In the last few years, the use of starch-based biodegradable and oxo-biodegradable films have been introduced as an alternative to conventional mulches. These materials can be incorporated into the soil at the end of the crop season and undergo biodegradation by soil microorganisms. A year study was conducted to determine the response of a lettuce crop to six mulch materials (2 low density polyethylene films (LDPE), 2 oxo-biodegradable and 2 biodegradable) in a greenhouse in south Spain. Harvest was carried out 45 days after transplanting and the following variables were determined: fresh and dry weight of the aerial part, number of leaves per plant, plant height and the longitudinal and transverse diameters of the plant. Biodegradable and oxo-biodegradable films showed an agronomic behaviour equal to LDPE and their degradation times were compatible with the protected lettuce crop cycle. The evaluation of the performance in the field showed that the biodegradable films are as suitable for crop protection as LDPE.

Key words: *Lactuca sativa* L, mulch, soil temperature, film

P 61.

EFFECT OF DIFFERENT METHODS OF VERMIWASH PREPARATION

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Global population progressive increase and accepting excessive production of livestock, disposing the wide range of animal waste matters are serious problems throughout the world and it is usually the main source of environmental pollution. These wastes can be rarely applied directly in the soil because it can cause damage to soil fertility and led to structural incompatibility, the immobility of nitrogen and phytotoxicity. Some treatments can treat these wastes to apply in soil and safe repulsion in environment. The Vermiwash is lateral product of vermicompost production process which contains nitrogen, phosphorus and many micronutrients, hormones, etc. The Purpose of this study was evaluating the different methods of vermiwash preparation. Experiments were conducted in a factorial randomize complete block design (RCBD). The treatments were: 1- mature vermicompost (V) 2- immature vermicompost (W+V) 3- composter worm (W), and either various species extractor including: 1- distilled water with pH=5 (Wt_5), pH=7 (Wt_7), pH=9 (Wt_9) 4- DTPA 5- 1/3 DTPA. The results illustrated that element concentration of calcium, magnesium, phosphorus, nitrogen and zinc in vermiwash extracted by DTPA solution extractor has significant difference than other treatment. However nitrogen concentration hadn't significant difference with vermiwash extracted by distilled water with pH=5 solution extractor. Potassium concentration of extracted vermiwash by distilled water with pH=5 solution extractor was more than other extractors. Maximum element concentration was observed in extracted vermiwash of immature vermicompost excluding potassium and nitrogen that maximum concentration was existed in extracted vermiwash of earthworms. The effect of extractor type and substrate on microbial population hadn't significant difference, but maximum respiration was observed in extracted vermiwash by DTPA solution extractor. Vermiwash sterilization had just significant difference on phosphorus concentration and pH. It is concluded that extractor type and substrate was effective on properties of produced vermiwash.

P 62.

COMPARISON OF PHYSICO-CHEMICAL PROPERTIES OF COMMON COMPOST AND VERMICOMPOST AND THE EFFECT OF THEIR APPLICATION ON TOMATO PLANT GROWTH INDICES

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Biofertilizer has been identified as an alternative to chemical fertilizer to increase soil fertility and crop production in sustainable farming. Vermicompost is considered as a biofertilizer with many beneficial physical, chemical and biological effects and it can be applied in greenhouse ecosystems. It can be utilized in production of varied products such as tomato, carrot, lettuce, cucumber, cabbage and even corn and wheat crops. The objective of this greenhouse study was to evaluate the effect of vemicompost and common compost as organic fertilizers for omitting or at least reducing the amount of chemical fertilizer consumption. In this regard, common compost and vermicompost were produced under similar conditions for 4 months in the greenhouse. Cow manure and corn plant debris at different levels of 60-40, 50-50 and 40-60 percent were applied respectively. Then the produced vermicompost and compost were utilized in different levels (1, 2 and 3 percent) for the main greenhouse experiment of growing tomato with two replicates using randomized completely block design. These vermicompost and compost treatments were mixed with soil in separate pots and tomato (*Lycopersicon sculentum*, cherry) seedling transplanted into them. The results demonstrated that plant height increased significantly in vermicompost treatments ($P<0.01$) and the biomass of plant tissues (biological yield) in vermicompost treatments showed a significant increase in comparison with common compost. To some extent the amount of available Fe, Zn and Cu for all cases indicated significant increase in vermicompost treatment ($P<0.01$). The vermicompost treatment with 60% cow manure had significant superiority in comparison with other produced vermicompost. Overall it can be concluded that vermicompost (60% cow manure) with a higher fertility was of a better quality than common compost.

P 63.

HUMIC ACID AND SEAWEED EXTRACTS IMPROVED YIELD AND QUALITY OF ORGANIC GREENHOUSE CHERRY TOMATO PRODUCTION

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Effects of humic acid (0, 1, 1.5 and 2 ml/L) and two commercial seaweed extracts including Drin and Algaren (0, 0.2, 0.6 and 1 ml/L) as foliar application on growth, yield and quality of cherry tomato in an organic greenhouse plantation were studied. Plants were sprayed four weeks after transplantation and repeated six times afterward at 14 day intervals. Humic acid increased plant vegetative growth but not seaweed extracts. Fruit quality indices including fruit firmness, vitamin C, total soluble solids and fruit weight were improved using humic acid or seaweed extracts. Fruit set percent increased with increasing humic acid and Algaren concentration. The best economic results in terms of yield and fruit quality were obtained from 1 ml/L humic acid and 0.6 ml/L seaweed extracts application.

Keywords: Organic tomato, foliar nutrition, value-added compounds

P 64.

REMOVAL OF SULFATE AND NITRATE IN RECYCLED GREENHOUSE EFFLEUNT SOLUTION USING ARTIFICIAL WETLANDS

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The majority of greenhouse crops are grown using artificial growing media and hydroponic systems. Traditionally, these soilless production systems were developed as open systems. Crops grown under these conditions generally are irrigated in 10 to 40% excess and, consequently, might represent an environmental burden such as eutrophisation if the wastewater is not recycled. Under recycled irrigation system, nutrient accumulation and ion unbalance, such as SO_4^{2-} are generally observed. Artificial wetland has been shown to be a low-cost alternative for treating agricultural wastewaters. Therefore, the objective of this study was to evaluate the effectiveness of three types of subsurface flow artificial wetlands (HSSF-AW) to reduce the content of SO_4^{2-} and NO_3^- in greenhouse effluents. To do so, AWs were filled with pozzolana and implanted with common cattail (*Typha latifolia*). Wetland units contained either a 1- simple (AWS, sucrose daily imput), 2- complex (AWC, mix of compost and sawdust) or 3- no carbon source (AW). A randomized complete block design with 4 replicates was used. After a start-up period of several months, wetland units received during 7 months a reconstituted greenhouse effluent composed of 500 ppm of SO_4^{2-} and 300 ppm of NO_3^-. Our results showed that the carbon source had a significant effect on the effectiveness of artificial wetlands. AWS had a good removal rate of SO_4^{2-} and NO_3^-, 98% and 99% respectively, by sulfate reducing bacteria and denitrificate bacteria activity. The large carbon inputs (DOC= 180 $mg.L^{-1}$) allowed a good microorganism activity and environmental condition (E(h)= -45 mV). However, we observed that AWC was carbon limited. Environmental conditions were favorable for denitrification, 99% of NO_3^- was removed and we observed release of SO_4^{2-} by autotrophic denitrification. In AW, very low denitrification (NO_3^- removal rate was 15%) and no reduction of SO_4^{2-} was observed. From our experimental results, we can conclude that AWs can be a cheap alternative to reduce the environmental footprint of a soilless hydroponic production system if an adequate source of carbon is continuously provided to maintain an adequate microorganism activity, and consequently a nutrient pollutant removal.

Keywords: marshland, pond, nutrient pollutant, SO_4, NO_3, recycling drainage solution

P 65.

DEVELOPMENT OF AN AUTOMATIC FRUIT SET REAGENT SPRAYING ROBOT FOR TOMATO PLANTS TO UNIFORM THE FRUIT RIPENESS

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In large scale tomato production, the automation is a most important matter. So we have constructing a tomato bench growing system suitable for automation with low node-order pinching and high density planting. A cluster harvesting technique is adopted because of simplifying actuating devices. In the cluster harvesting technique, it is necessary to uniform the degree of fruit ripeness on each cluster.Fruit set reagent spraying is effective to uniform the ripeness of tomato fruits on a cluster. However, the spraying needs troublesome working, especially on large scale greenhouses. The purpose of this research is to develop a robot which sprays fruit set reagent automatically to the tomato flowers.The robot consists of the 3 electric cylinders, a camera, an LED light, various sensors, a computer, a manual lift part, and a vehicle part. The robot has a function to recognize yellow petals by image processing and to spray fruit set reagent to the target flower part. It operates only at night using an LED light to stabilize the conditions of lighting. The recognition algorithm for a spraying target is as follows: firstly extracting any objects within some distance by stereo processing, detecting and labeling the petals by binarization on hue, and determining the center of the target spraying area for the cluster.The experiments of automatic reagent spraying by the robot to tomato flowers were carried out at night in a greenhouse. The percentage of recognition success for the flowered clusters was not less than 80% in the clusters having more than three flowers with opened petals, although the percentage was about 50% in the clusters having one flower with opened petals. In some plants, interruption of spray by leaves occurred. Therefore, it might be necessary to expose the flowers to the robot's side and to avoid the interruption.

P 66.

ASSESSMENT OF TRACEABILITY FUNCTIONS IN GREENHOUSE ORIGINATED AGRI-FOOD SUPPLY CHAIN

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Nowadays there are more similarities between manufacturing supply chains and agri-food supply chain than ever before. Functions such as traceability, quality certifications, food safety, and quick response, latest developments in the industry domain, drive the trend of a*groindustrialisation* of operations involved in agricultural production. Nevertheless, there is a lack of adequate models for operational planning for production harvest and distribution for perishable crops. In particularly, there is a need for stochastic models for the tactical planning of perishable agri-foods

providing plans which are robust to uncertainty while incorporate a number of risk reduction alternatives. On the other hand, in order to fulfil the requisite traceability principles for complete tracking and/or tracing of produce within the supply chain in a quick, reliable, and accurate way, the design of a traceability system should be driven by the appropriately selected performances criteria to reduce logistics cost. This logistics issue becomes of significant importance in the case of perishable products originated from greenhouse production systems, where the limited shelf life of the product requires an optimal planning of the logistical decisions to reduce the deterioration of the products and preserve their value. Simulation provides a suitable method to build complex stochastic networks without excessive model simplification that eventually required by analytical optimisation tools. In this paper a discrete event simulation model dedicated to agri-food supply activities is presented. The model developed in the ExtendSim® industrial simulation software and is focused on the assessment in terms of the effective tracking and tracing activities along the supply chain of greenhouse-originated perishable products.

P 67.

TRACEABLE DOCUMENTATION AND EVALUTION OF THE PRODUCTION PROCESSES IN PROTECTED CULTIVATION

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For consumers and food industry information about the quality of the production process becomes more and more important. Therefore the keyword "traceable production" plays an important role in food production. Generally the concept of the production process documentation is divided into the following three steps: data acquisition, data analysis and evaluation, and compilation of a product pass. For the producing gardener the data acquisition normally is time consuming and therefore labor cost effective. In protected cultivation nowadays computer systems for climate control are in installed and could be used in a much more comprehensive way as data source. So the climate computer could measure the consumption of the production parameters energy, water, and climatic factors. A minor amount of inputs for example the application of pesticides, beneficial organisms or fertilizers and the general production schedules have to be inputted by the gardener. With these data each production resource is analyzed per greenhouse, per square meter, per unit, and per sale proceeds by means of an automated data bank. The results are shown in a product pass.
The concept has been implemented in a computer program and by now until the end of November 2010 this program is established and tested in a salad production in a greenhouse. The results of this first testing phase will be evaluated regarding to the quality of the documentation process and the sustainability of the production process. From the beginning of March 2011 until the end of the spring period an intensive tomato production will be monitored in the same way.

P 68.

DEVELOPMENT OF A NEW DEVICE ('HORTISPEC') FOR MEASURING UV, PAR, IR, LIGHT SPECTRUM, RADIATION AND LEAF TEMPERATURE

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New equipment and technologies for measuring light, energy and leaf temperature. The purpose of this new measurement equipment is to come as well for scientific research but above all to a practical tool for glasshouse, plastic tunnel and even outdoor cropping production. The measurement equipment gives information about the PAR light spectrum, PAR light ratio's (for example B/R, R/FR) ass well total energy (Watt/cm2) as a measurement for total irradiance as a parameter for needed evaporation and/or for shading strategies as well the radiation from the plant itself. Also measurement of the plant/leave temperature will be measured at the same time. This in total of the radiation of sun and if used also artificial (SON-T, LED or IR) light sources.

Light spectrum measurement
- Measuring photon-flux (PPFD) per nm between 200 nm – 1100 nm
- Impact of light on photosynthesis
- PAR light ratio's
- Impact of light on postharvest quality

Energy measurement
- Measuring energy (Watt.cm-2) between 200 nm – 100.000 nm
- Impact of energy on evaporation
- Impact of energy on leaf temperature

Keywords: Light measurement, Spectrum measurement, UV-C, UV-B, UV-A, PAR – IR-A, IR-B, IR-C, Irradiance measurement, Photon-Flux measurement, evaporation measurement, Leaf temperature measurement.

P 69.

PERFORMANCE EVALUATION OF SEVERAL TYPES OF SENSORS APPLIED IN THE GREENHOUSE ENVIRONMENTAL CONTROL AND MANAGEMENT

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More portable sensors were adopted for the environmental control and management in the greenhouse. However, the information of performances included accuracy, precision and long-term stability was not mentioned in their spe-

cification. In this study, these sensors included chlorophyll meter, two types of ion concentration meters, frequency-domain reflectometer and time-domain reflectometer, two types of EC meters and three types of infrared thermometers were evaluated. The relative humidity measurement device developed by the measuring of dry and wet temperature meter was tested. The performance evaluation of sensors was executed by the traced with the reference materials and standard environments. The calibration equation was established using regression analysis technique. The results indicated the important of the calibration work. The accuracy of some sensors could be improved by the calibration equation. The adequate calibration equations were the high-order polynomial equations or the nonlinear equation. Precision was the key factor to ensure the applicable of these sensors. The routine calibration is the basic requirement for these sensors.

Keywords: chlorophyll meter, ion concentration meter, frequency-domain reflectometer, time-domain reflectometer, EC meter, infrared thermometer

P 70.

USE OF BIOSIGNAL ANALYSIS TO INDICATE CHRYSANTHEMUM (*CHRYSANTHEMUM MORIFOLIUM*) RESPONSE TO PAR INTENSITY

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It is well documented that higher plants respond to environmental stimuli with the production of electrical signals (biosignals) that are in practise the information carriers in intracellular and intercellular communication. In order to relate plant electric wave signals to light intensity and quality, measurements were taken in laboratory on two single stem chrysanthemum plants which had already performed flower buds. Chrysanthemum plants placed in Faraday cage, under 270, 200 and 100 μmol m^{-2} s^{-1} PAR radiation flow. The electrical signals from the plants were detected through an advanced measuring data acquisition system including Ag/AgCl electrodes, which were placed on the main shoot, in the substrate where plants were rooted and on plant leaves. The results found from acquired electrical signal spectrum analysis showed that a specific group of frequencies on the measured magnitude is related to light intensity variation.

Keywords: electrical signals, intercellular communication, spectrum analysis

P 71.

EDDY COVARIANCE MEASUREMENTS OF WATER VAPOR, HEAT AND CO_2 FLUXES IN A PEPPER SCREENHOUSE: CORRECTIONS OF RAW DATA

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Screens protect plantations from unfavorable climatic conditions, reduce insect invasion and fruit sunburn and allow savings of irrigation water. However, measurement and estimation of crop water use of covered plantations is still a challenge. In recent years we have established the use of the Eddy Covariance (EC) technique for evapotranspiration measurements of crops grown under screens. When using the EC technique several corrections are usually applied on the raw data to compensate for system and site limitations. The use of these corrections is well established in open environments, but under a porous screen the applicability of these corrections is still under study. The aim of the present study was to investigate the influence of three common corrections: Sensor Separation (SS), Path Averaging (PA) and Coordinate Rotation (CR), on EC flux measurements in a pepper insect-proof screenhouse. Screenhouse dimensions were 700m x 180m and 4m high. Evapotranspiration measurements were made in the middle of the screenhouse using an EC system consisting of a three-axis ultra-sonic anemometer and an open-path infra-red gas analyzer, positioned 2.5m high. During the measurement period, average plant height was 1.55m. Additional instruments measured net radiation, air temperature, air humidity and soil heat flux. Validation of the measured fluxes was done by energy balance closure analysis of half hourly covariances with and without the different corrections. Analysis for raw data, and raw data corrected with CR, CR+SS, CR+SS+PA, SS, SS+PA resulted in energy balance closure slopes of 1.25 (R^2 = 0.79), 0.75 (R^2 = 0.43), 0.59 (R^2 = 0.38), 0.57 (R^2 = 0.6), 0.68 (R^2 = 0.77) and 1.06 (R^2 = 0.8) respectively. All corrected slopes were approximately within the range reported for energy balance closure in open canopies, ranging from 0.55 to 0.99 (Wilson et al., 2002). Flux data was processed using the SS+PA corrections. Results show that during the measurement period, daily evapotranspiration decreased from 3.2 to 1.5 mm d^{-1} whereas net CO_2 uptake increased from 6 to 30 g m^{-2} d^{-1}. Hence, water use efficiency, defined as the ratio of net vertical fluxes of CO_2 and water vapor (both in units of g d^{-1}) increased from 0.005 to 0.028.

P 72.

EFFECT OF SALINE CONCENTRATIONS ON THE GROWTH OF MELON CULTIVATED UNDER PROTECTED ENVIRONMENT

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Adequate knowledge of the management of soilless cultivation systems, either using substrate, arouses great interest when one mentions its usage for commercial purposes. The objective of the work was evaluate the production and distribution of biomass of the melon crop (*Cucumis melo* L.) var. *Inodorus*, cultivated in rice husk, with leach recirculation, in function of three different of saline concentrations of the nutrient solution. A standard solution, of electrical conductivity initial 2,3 mS cm^{-1} (saline concentration 100%), was used how treatment reference. The concentration of the too much treatments were determined in function of standard solution, with reduction and increase of 25% in the macronutrients amount in relation at treatment reference, corresponding at electrical conductivity initial of 1,9 e 2,9 mS cm^{-1}, respectively. Sowing was done 17th February 2003. On 17 days after sowing, the plants were transferred to bags of polyethylene containing 13 L of raw rice husk, with density of 1,69 plants m^{-2}. From the data of dry and fresh matter (DM and FM), and of the leaf area accumulated at 62 days after setting, the biomass production and distribution among the different plant parts was established. The lower saline concentration in the nutrient solution (1,9 mS cm^{-1}) can be indicated for melon cultivation in raw rice husk during the autumn crop-season, because it promotes a similar plant growth to the observed in the highest concentrations.

P 73.

GROWTH, WATER CONSUMPTION AND USE EFFICIENCY OF SUMMER SQUASH CROP IN CLOSED RICE HUSK MEDIUM GROWING SYSTEM

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The determination of both crop water consumption and use efficiency provides important information for the irrigation management, especially in soilless culture in which all water must be supplied by the irrigation. In this system, the water consumption, as well as plant growth and crop yield, is affected by the ionic concentration of nutrient solution. Therefore, the aim of this work was to evaluate growth, yield and water consumption and use efficiency (WUE) of summer squash plants growing in raw rice husk medium with recirculating nutrient solution according to the ionic concentration of nutrient solution. Two experiments were conducted in spring-summer and summer-autumn crop-seasons, in Pelotas RS, south of Brazil. Four ionic concentrations of nutrient solution were evaluated: 1.3; 1.7; 2.1 and 4.2 dS m^{-1}. The water consumption was not affected by the ionic concentration in spring-summer (139,9 liters $plant^{-1}$). In summer-autumn, the increasing of ionic concentration increased the water consumption (from 41.6 to 71.6 liters $plant^{-1}$). Ionic concentrations equal or lower than 1.7 dS m^{-1} decreased growth and yield in both crop-seasons and, in spring-summer, reduced the WUE related to fresh and dry mass fruits production. In summer-autumn, ionic concentration did not affect WUE (37.8 liters of water per kg of fruit fresh weight and 0.98 g of fruit dry mass production per liter of water). According to the adjusted mathematics models, the electrical conductivity that would maximize (respectively in spring-summer and summer-autumn) the fruits dry mass (259.4 and 78.31 g $plant^{-1}$) and crop yield (7.8 and 3.7 kg m^{-2}) in both crop-seasons and WUE (21.5 liters of water kg^{-1} of fruit fresh weight and 1.94 g of fruit dry mass $liter^{-1}$ of water) in spring-summer would be approximately 3.0 dS m^{-1}. Ionic concentrations greater than 3.0 dS m^{-1} reduced fruits and shoot dry mass, yield and WUE in spring-summer.

Key words: *Cucurbita pepo* L., soilless system, recirculating nutrient solution, ionic concentration, electrical conductivity, biomass production, production physiology.

P 74.

DAILY AND SEASONAL VARIATION OF NITRATE CONTENTS IN LETTUCE CULTIVARS IN HYDROPONIC SYSTEM IN THE SOUTH OF BRAZIL

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Lettuce presents a great ability of nitrate accumulation, especially in hydroponics in which the ion availability is high. Nonetheless, nitrate accumulation depends primarily on genotype and light intensity. The aim of this work was to quantify the nitrate contents in lettuce cultivars according to the harvest time and crop-season in hydroponic system. Three experiments were conducted in three crop-seasons: spring of 2008, autumn and winter of 2009, in Pelotas RS, south of Brazil. Four cultivars were studied: Green Garden (GG), Red Garden (RG), Great Lakes iceberg (GLI) and "Vera" sunny (VS) lettuce types, at four harvest times (8:00 am, 2:00 pm, 6:00 pm and 11:00 pm). In spring, the lowest average nitrate contents were found at 6:00 pm and 11:00 pm (2058 and 2244 mg kg^{-1}) and in GLI leaves (1825 mg kg^{-1}). In autumn, the lowest average contents were observed at 8:00 am (1378 against 1620 mg kg^{-1} obtained as average of the other harvest times) and for RG and GLI cultivars (1360 and 1448 mg kg^{-1}). In winter, GG and RG presented similar nitrate contents (mean of 2182 mg kg^{-1}) and for both cultivars the lowest nitrate contents

was observed at 8:00 am (1545 against the average of 2394 mg kg^{-1} of the other harvest times). GLI presented a lower nitrate accumulation than VS (1915 and 2679 mg kg^{-1}, respectively) and the harvest at 2:00 pm lead to a lower contents than at 6:00 pm (2054 against 2454 mg kg^{-1}, respectively). The lowest nitrate accumulation average was obtained in autumn (1559 against 2526 and 2189 mg kg^{-1} obtained in spring and winter, respectively). In general, we can recommend Great Lakes iceberg cultivar and harvest in early morning in winter and autumn and late afternoon in spring crop-season in order to get a lower nitrate contents in hydroponic lettuce.
Key words: *Lactuca sativa* L., nitrate accumulation, harvesting time.

P 75.

EFFECTS OF GRAFTING AND SALINITY ON AGRONOMIC CHARACTERISTICS AND ION UPTAKE BY CUCUMBER PLANTS GROWN IN A CLOSED HYDROPONIC SYSTEM

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Recently grafting is being applied as a means of alleviating the negative effects of high salinity. In the present study we examined the effect of three salinity levels (1.9, 3.5 and 5.5 dS/m) on cucumber plants (*Cucumis sativus* L. hybrid '722 Virginia RZ.') grafted onto three commercial rootstocks ('Power F1', 'Leon F1' and 'Mammoth F1') and cultivated in recirculating nutrient solution. The results showed a significant effect of high salinity levels on plant growth parameters (shoot length, FM and DM of shoots and leaf area), which was more profound when 722 Virginia was grafted onto Power F1. Total fruit weight and fruit number per plant were reduced by high salinity, except for the 'Mammoth' x '722 Virginia RZ.' combination, where no significant effect was observed. The presence of NaCl in the nutrient solution had a significant effect on the concentration of Na^+, Cl^- and K^+ in plant tissues, whereas Ca^{+2} and Mg^{+2} were not significantly influenced. Plants grafted onto 'Mammoth' had lower Na^+ content in root tissues than Leon and Power rootstocks, whereas Na^+ content in the shoots was higher in plants grafted onto 'Mammoth' than in the other rootstock-scion combinations. Similar results were observed also in the case of K^+ content in shoots and roots, especially at the highest salinity level. The gradual increase of the NaCl concentration in the nutrient solution increased the Cl^- concentration in both shoots and roots, whereas the rootstock-scion combination had no significant impact on the tissue Cl^- levels. These results indicate that the use of 'Mammoth' as a rootstock may enhance the salt tolerance of grafted cucumber plants but this effect is not due to a restriction in Na^+ or Cl^- translocation to the photosynthetically active leaves.

P 76.

EFFECT OF PGPR APPLICATION AND NITROGEN DOSES ON BABY LEAF LETTUCE GROWN IN A FLOATING SYSTEM

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The floating system is one of the easiest and cheapest hydroponic methods used to produce baby leaf vegetables. Among these products, the baby leaf lettuce has grown in popularity in recent years as a ready-to-eat vegetable. The aim of this work was to study the effect of application of two PGPRs (*Bacillus subtilis* and *B. velezensis*) and two doses of nitrogen (4 and 12 $mmol \cdot L^{-1}$) on yield quality and nitrate content of two baby leaf lettuce cultivars grown in a floating system. Two sowings were carried out in December 2009 and February 2010 directly into styrofloat trays containing peat media. Plant density was 1700 plants m^{-2}.The duration of the crop cycles was 36 and 30 days, respectively. The experiment design was a split-split plot design. The best yield was found with *B. subtilis* application in both cycles. The use of the nutrient solution containing 12 mmol L^{-1} promoted the plant growth and the accumulation of nitrate in leaves. Finally, the application of *B. velezensis* in nutrient solution provoked a decrease of nitrate content in leaves respect to control.

P 77.

PESTICIDES APPLICATION IN GREENHOUSE CROPS USING A FOG SYSTEM, STUDY OF DEPOSITION, UNIFORMITY AND LOSSES TO THE GROUND.

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In recent years, fog systems have become more prevalent, with the primary function of air conditioning the greenhouse by changing the relative humidity, but these systems are also being used to apply pesticides. This enables a faster amortization of equipment and improvement in pesticide application, because the process is automated and avoids the presence of operators inside the greenhouse. This study evaluates this new use of fog systems from the technical standpoint, analysing the deposition and uniformity of the treatment in the plant mass, comparing results with those from spray-gun applications. For this purpose, both methods were used to spray a solution containing a colour tracer (Tartrazine) on a tomato crop with a volume of 2000 l/ha, and deposition was measured using filter paper strips placed in 12 areas of the plant mass (three heights and four depths). To evaluate the fog distribution within the greenhouse, filter papers were placed on the floor, 1 and 2 meters of height in all the corridors between plant rows. Ground losses were quantified with the target placed on the floor. With the resulting data, the normalized deposition was calculated as a function of amount of tracer per unit area. On the one hand the results indicate that the height deposition with fog system is homogeneous, a bit higher in the bottom zone of the crop. Using the spray gun bigger deposition is achieved in top zones. On the other hand, the depth deposition with fog system is similar when comparing inner and outer zones of the crop, while using the spray gun, lower deposition is obtained in inner zones. Yet the total deposition per unit area doesn't achieve the threshold of controlling the pest or disease, so that is not advisable to use fog system for applying plant protection products.

P 78.

COMMUNITY LEVEL PHYSIOLOGICAL PROFILING AS A METHOD TO MONITOR HEALTH STATUS OF TOMATO PLANTS IN CLOSED HYDROPONIC GROWING SYSTEMS

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A closed hydroponic growing system is a good solution to minimize release of nutrient enriched water to the environment. This type of growing system does not only spare the environment but it also saves money for the growers in terms of water and fertilizer use. Due to the risk of dissemination of root borne pathogens, there is reluctance amongst growers towards closed growing systems. Especially zoospore forming pathogens such as *Pythium* can easily spread in these water based systems and cause serious damages. In an experiment with 14 week-old, hydroponically grown, tomato plants the microflora of the roots of *Pythium ultimum* infected plants and non-infected plants were analysed by community level physiological profiling; PM1-3, Omnilog. The analysis showed clear differences in carbon utilization between infected and non-infected plants. During the spring, complementary analyses will be made on seedlings and plants prior to flowering to see if the pattern is repeated. TRFLP will also be used on the samples for profiling of the microbial communities. The results from these analyses will be presented on the poster.

P 79.

EFFECT OF APPLICATION OF *PSEUDOMONAS FLUORESCENCE* ON YIELD AND YIELD COMPONENTS OF WHEAT UNDER DROUGHT TOLERANCE

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Plant growth promoting rhizobacteria enhance plant growth and yield directly and or indirectly. A factorial experiment was conducted in greenhouse to determine the efficiency of three strains of *Pseudomonas Fluorescence* on wheat growth parameters under drought conditions. The treatments were: 1. four resistance level of bacteria strains to drought (including: control, resistant, semi resistant and sensitive isolates of Pseudomonas Fluorescence) and 2. three levels of irrigation (%80, %50 and %20 available water). After harvest, biologic , grain and straw yield and 1000 grain weight plant height, spike length and number of tillers and shoot dry weight of seeds were measured. The results showed that by increasing drought level spike length, leaf number, tiller number and plant biological yield were significantly reduced. It is concluded that effect of inoculation on yield and yield components of wheat was significant at all levels of drought.

P 80.

MICROCEPHALOTHRIPS ABDOMINALIS (THYSANOPTERA: THRIPIDAE) DISCOVERED IN SOUTHERN FRANCE

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Microcephalothrips abdominalis (Crawford) (Thysanoptera: Thripidae), a species of neotropical origin, has been found for the first time in France (Alpes - Maritimes, Sophia - Antipolis) in 2008. Information is provided on its identification, geographical distribution and on the damage that it can cause. The plant health risk for France is discussed.

P 81.

SURVEY OF THRIPS SPECIES IN HORTICULTURAL GREENHOUSES IN SOUTHERN FRANCE

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Thrips are important pests in ornamental greenhouses in France. Survey of thrips populations in greenhouses (roses and gerbera crops) on two sites in southern France (INRA research center based in Sophia Antipolis and GREAT experimental station based in Nice, Alpes Maritimes) have been performed from 2006 to 2009 (on a weekly basis). More than 6000 thrips were collected using a rose shaking method. Nine genus and nineteen different species have been identified and two species were the most abundant: *Frankliniella occidentalis* Pergande and *Thrips tabaci* Lindeman [Thysanoptera: Thripidae] (81.5% and 16.5% respectively). Among other species identified, two species are new records, one in France *Scirtothrips inermis* Priesner and one in Europe *Thrips hawaiiensis* Morgan. Two different predatory species belonging to *Aeolothrips* genus were also present: *Aeolothrips tenuicornis* Bagnall and *A. ericae* Bagnall [Thysanoptera: Aeolothripidae].

P 82.

MECHANICAL DISTRIBUTION OF *PHYTOSEIULUS PERSIMILIS* ON CHRYSANTHEMUM

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A new version prototype of a device for centrifugal distribution of arthropods was built in order to obtain better performances. This version allows to carry out the natural enemies distribution both in open field and in greenhouses, installing three or more prototypes on a horizontal bar carried by a tractor or a wheel frame.
Preliminary trials were conducted under laboratory conditions to evaluate the vitality and the damages possibly caused to the predators and to determine the range of action of the machine. No physical damage to the arthro-

pods limiting their mobility and vitality was observed. The field test was carried out in a cultivation of chrysanthemum, using the predatory mite *Phytoseiulus persimilis* Athias Henriot produced and sold by Bioplanet S.c.a r.l. (Martorano di Cesena-FC Italy) to control the two-spotted spider mite *Tetranychus urticae* Koch. The trial was conducted with natural enemies in an area of seven ridges: on three ridges the distribution was mechanised using three prototypes installed on a wheel frame, in other three was manual and the central ridge was not treated. The two planned releases have been carried out in September 2010. In order to assess the biological effect of the distribution, each ridge was divided into four plots (A, B, C, D) and sampling was carried out separately by collecting 18 leaves per plot. The survey was conducted before the first release and then 7 and 14 days after it. The results show that after 7 days in most of the mechanised plots *P. persimilis* was regularly recovered, therefore reducing the percentage of leaves infested with the two-spotted spider mite and its density at 14th day. The mechanised distribution allowed to control the pest sooner than the manual one, where *T. urticae* persisted in a considerable number of plots after an additional 7-days interval.

P 83.

S-ABA EFFECTS ON EVAPOTRANSPIRATION AND LEAF BURN IN *SALVIA FARINACEA*

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In a series of experiments with *Salvia farinacea* 'Rhea Deep Violet' under high air temperatures and light levels, s-abscisic acid (S-ABA) was evaluated for reducing evapotranspiration rates (ET) and for the potential of injury due to high leaf temperatures. Plants were sprayed with S-ABA at a range of 125 to 1000 mg·L^{-1}, moved to a simulated retail environment under full sun (811 to 941 W·m^{-2}), 30% shade, or 57% shade, and observed for 24 hours. On 15 June 2010, maximum air temperature was 37 °C. In full sun, ET for plants sprayed at 1000 mg·L^{-1} and 125 was 35% and 80% of ET in control plants. For plants sprayed at 1,000 mg·L^{-1}, 125 mg·L^{-1}, and 0 mg·L^{-1} midday leaf temperatures were 37.7, 31.0 and 26.3 °C and injury ratings (1=none; 5=most injury) were 5.0, 2.8, and 1.0, respectively. On 12 May with maximum air temperature of 30 °C, ET in full sun for plants treated at 1000 mg·L^{-1} and 125 mg·L^{-1} was 20% and 66% of control plants. For plants in 1000 mg·L^{-1}, 125 mg·L^{-1}, and 0 mg·L^{-1} treatments, leaf temperatures were 31.8, 27.5, and 24.1 °C and injury ratings were 3.5, 1.0, and 1.0, respectively. On 2 June, air temperature reached 33 °C. Plants treated with 1000 mg·L^{-1} and held in either full sun, 30% shade, or 57% shade had leaf temperatures of 36.9, 34.0, and 32.0 °C and received injury ratings of 3.8, 1.2, and 1.0, respectively. There was a significant multiple variant correlation for amount of injury with leaf temperature, S-ABA concentration, light level and air temperature. These results with *S. farinacea* indicate that to reduce the risk of injury from high tissue temperatures under hot conditions users should either apply lower concentrations of S-ABA or the plants should not be displayed in full sun.

P 84.

EFFECT OF CROWN SIZE AND CULTIVAR ON STRAWBERRIES FRESH BARE ROOT PLANTS YIELD AND QUALITY IN SICILY

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In the southern regions of Mediterranean areas the plantation with fresh plants (winter planting system) have almost completely replaced those with cold stored plants (summer planting system). Particularly, fresh bare-root plants produced in high elevation nurseries located in Spain and Poland and in experimental phase, in the southern of Italy (in the mountains of Sicily, Calabria, Basilicata), are the most used. Such type of plant usually has a crown diameter from 6 to 14 mm, but the smallest plants should be (<8 mm) discarded in phase of selection and packing. Objective of this study was to investigate the influence of the different crown diameter on the earliness, productivity and quality of two new varieties of strawberry.
The research was carried out in 2007/08 in the experimental fields located in Palermo. Three typologies of fresh bare-root plants (small plants: crown diameter 6-8 mm; medium plants: 8.1-11 mm and large plants 11.1- 14 mm) and two cultivars (Candonga and Nora) were compared. The experimental design was a split-plot with 3 replication and individual experimental plot of 4,6 m^2. The plantation was established the 22nd of October in a plastic greenhouse of 600 m^2, on two-row beds and at a plants density of 9,1 plant/m^2.
The production started in January and finished in May. The medium plants (crown diameter 8.1-11 mm) were earlier than the others types. The marketable production during the whole harvesting period was influenced by crown diameter. Large and medium plants (crown diameter 8.1-14 mm) (590 g/plant) produced more than small plants (crown diameter 6-8 mm) (551 g/plant). Candonga (586.8 g/plant) produced more than Nora (567.9 g/plant).
The average strawberry weight wasn't statistically influenced by the typology of plant but by the cultivar; Candonga produced the biggest fruits.
The crown diameter of fresh plants influenced earliness and productivity of strawberries. To ensure high production it should be use medium and large fresh plant with a crown diameter from 8.1 to 14 mm.

P 85.

INFLUENCE OF DIFFERENT DOSES OF NITROGEN ON PRODUCTION AND QUALITY OF STRAWBERRY FROM FRESH PLUG PLANTS

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In Italy, fruit crops differing from one another in a wide variety of soil and climate conditions determine specific issues related to the use of fertilizers. Nitrogen is an essential element, not only for its influence on the vegetative-

productive activity of the plants but also on fruit quality (color, shelf life, etc.). To achieve high production and quality standards, reducing environment impact, the DAAT, Horticulture and Floriculture Section of Palermo carried out some research to identify the most suitable fertilizer to maximize the productive potential of fresh plug plants of two cultivars of strawberry spread in the Sicilian area, Candonga®Sabrosa and Nora, reducing inputs. The experimental design adopted was a splitplot, in which the main thesis was the different doses of nitrogen, 120, 170, 220, 270, 320 kg/ha and the secondary thesis was the cultivar. This research showed a rather wide variability of results, dependent on levels available for plants and doses distrubuted between the cultures. The seasonal pattern of production has shown how the thesis fertilized with 270 kg/ha has always achieved the highest harvest, but without significant statistical differences, in the early productive period (January-March) with the thesis treated from lower doses (120 and 170 kg/ha). The lowest doses (120 and 170 kg/ha) provided the firmest fruits, 735 g, with a good content of total solids soluble content, 7.3°Brix, with the highest vitamin C content, 53 mg/100g of f.s. and a very bright orange-red color. It has been noted that the two cultivars cultivated with medium and low doses produced larger fruits, with high solids soluble content and vitamin C. In conclusion, in cultivation in a protected environment, the application of low doses of nitrogen achieves the same production, as higher doses, and high quality of fruits, reducing environmental and production costs.

P 86.

CULTURE PRACTICES FOR SELECTING AND GROWING WILD BELLFLOWER (*CAMPANULA RAPUNCULOIDES* L.) COMMERCIALLY

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Few European native plants have been the focus of rigorous improvement programs. Basically these species are still wild plants, grown from seed and their cultivation requirements are largely unknown. *C. rapunculoides* L. is a perennial plant with attractive blue bell-shape flowers, growing on stony and wooded areas of Europe, except for the arctic regions and islands. So that a large volume of the same product can be introduced and offered to the flower market, the assessment of its propagation and cultivation techniques is required to obtain plants in large numbers and with vigorous growth. A suitable species should also have a long flowering season or have several cultivars available which have different but slightly overlapping flowering seasons. Campanulas mostly flower in spring and have a relatively short flowering season. Little is known about what triggers flowering. Its manipulation, so that they can flower on demand, would be of benefit. The present research investigated rooting capacity and propagation attitude by cutting of *C. rapunculoides* wild specimens. Plants were then grown in greenhouse and distributed to several nurseries in which they were cultivated in different conditions (pot/soil, greenhouse/open air). Plant growth, health, vigor and shape, and bloom characteristics were observed. Effects of substrate amendments and pruning techniques on flower characteristics and production were also evaluated in two different populations. Differences were detected according both the culture conditions/practices and the populations considered. Growers can adapt this information to suit their situation and market needs.

P 87.

USE OF SHADING NETS TO IMPROVE QUALITY CHARACTERISTICS OF COMPACT GARDENIA (*GARDENIA JASMINOIDES* ELLIS) POTTED PLANT

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The quality of compact gardenia potted plants is characterized by plants' shape, number of flowers and leaves' color. These characteristics are related mainly to photoperiod and light intensity. The effect of shading, by means of shading nets, on quality characteristics of compact gardenia potted plants was investigated during summer in a polyethylene covered greenhouse located near Volos, on the coastal area of Central Greece. Shading nets with 70% (30% shading) and 40% (60% shading) light transmission coefficient were used inside the greenhouse that was already shaded by white paint and had a total light transmission coefficient of 30%. Gardenia plants were grown under the above shading nets and under ambient greenhouse conditions from April to July 2010. Measurements of plant growth and development characteristics were carried out along with microclimate measurements. The results showed that plants placed under 30% and 60% shading nets were 10% and 13% shorter than the plants grown under ambient greenhouse conditions, respectively. Furthermore, shaded plants grown under the 30% and 60% shading nets had 23% and 45% lower leaf area and fresh and dry weight than the plants grown under ambient greenhouse conditions, respectively. Finally, it was found that plants grown under the 60% shading net had more vivid green color compared to the rest of the plants.

Keywords: light intensity, biomass production, potted plant quality, foliage color

P 88.

PRODUCTION OF HIGH-QUALITY ALOE PLANTLETS THROUGH TISSUE CULTURE

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The growing demand by the pharmaceutical industry and cosmetics of medicinal plants represents to one part a seri-

ous risk for the maintenance of biodiversity and the survival of many species of the genus Aloe and for the other provides a valuable input to the nursery production of this succulent plant. The micropropagation of aloe could allow the production in a short time of a large number of plants satisfying the commercial demand of plants and contributing to its preservation by promoting the conservation and reintroduction in natural habitats. Several studies have shown the possibility to propagate the *Aloe barbadensis* Miller through tissue culture with coefficients of multiplication and subculture time variables. The objective of the research activity was to evaluate the possibility to improve the growth and quality of micropropagated shoots of *Aloe barbadensis* Miller through the addition of charcoal to the rooting substrate. Single shoots were multiplied in 45 days using a substrate containing agar, MS salts, sucrose 3%, BA 1 mg L^{-1}, and IAA 0.2 mg L^{-1}; shoots were then transferred for 20 and 40 days in a solid substrate containing half-strength MS salts, and sucrose 3% with or without the addition of charcoal at the concentration of 1%. After this period, shoots were transferred in greenhouse for acclimatization using a substrate containing peat:perlite (1:1 v/v). Growth parameters of shoots and their content of total chlorophyll and carotenoids were analyzed at the end of 20 and 40 days of in vitro culture and after 50 days of acclimatization. Mineral composition of shoots was also analyzed after 40 days of in vitro culture. The height, fresh weight and root number of shoots were highest in the substrate containing charcoal after 40 days of in vitro culture. The content of total chlorophyll and carotenoids in shoots were highest without the addition of charcoal to the substrate and after 40 days of in vitro culture. Nitrogen content of leaves increased with the addition of charcoal into the substrate while the other macro e micronutrients decreased. The positive effects of charcoal on growth parameters of shoots remained even in the next phase of acclimatization while the content of total chlorophyll and carotenoids in shoots decreased.

Keywords: micropropagation, Aloe barbadensis Miller, growth

P 89.

IMPLEMENTATION OF MANAGEMENT PRINCIPLES ON GREENHOUSE VEGETABLES NEAR THE CITY OF THESSALONIKI

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The aim of the thesis was to implement the management principles on greenhouse vegetables in Thessaloniki and to estimate the effectiveness on greenhouse crops. For this purpose a questionnaire was composed and filled in by the greenhouse growers (with formal, integrated and biological production) with visits to greenhouse farms in the area near Thessaloniki. Before visiting the growers, a visit to the Directorate of Rural Development in Thessaloniki took place in order to provide with the necessary information about the greenhouse growers and their reliability. Simultaneously with the questionnaires were filled tables for observation accounting which helps to be extracted the finance results. Results testified for greenhouse grower's separation and theirs explanation based on growers profile and theirs ability to management. Finally, Data Envelopment Analysis (DEA) took place as a method for approximation of estimation of technical efficiency (TE), for greenhouse farms. Data Envelopment Analysis method is based on influx and efflux of farms and contributed to range greenhouse farms according their efficiency to higher and lower efficient. The results showed that the strategy sets objectives, provides changes, make choices according to: i). the choice of the production method, ii). the determination of the production plan, iii). the definition of other investments iv). the desire of the farmer - trader to have some control over the growing procedures. However, these results can not be generalized, mainly because of the climate differences between cultivation periods and simultaneously the differences in influx and efflux values. In order to be achieved results efficiency a series of experiments with a lot of repetitions been proposed.

Key words: Data Envelopment Analysis, greenhouse, management, vegetables, crop production.

P 90.

EFFECT OF LIGHT REGIME ON GROWTH AND FLOWERING OF *PHALAENOPSIS* ORCHID

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We investigated the effects of supplemental lighting on flowering of the white hybrid of *Phalaenopsis* Premium. The experiment was carried out in Naples (San Sebastiano al Vesuvio, 40° 51' N, 14° 22' E), in a heated glasshouse. Plants of the hybrid 'Premium' were grown in pot under two lighting regimes, natural light and supplemental light. Supplemental lighting was performed by extending the natural day length to 12 hours using High Pressure Sodium lamps. The effects of treatments were studied in terms of plant growth, flowering time and flower stem production and characteristics.

Key words: potted plant, flower induction,

P 91.

THE EFFECTS OF ARBUSCULAR MYCORRHIZAL FUNGI ON OSMOTIC ADJUSTMENT SYSTEM OF TOMATO UNDER SALINE STRESS

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This study investigated several aspects related to salt tolerance in arbuscular mycorrhizal (AM) tomato. Non-AM

and AM tomato plants were grown in pots with organic soil and watered with different level of NaCl solution (0, 0.5 and 1%). Concentration of Na^+ and Cl^- in shoots or roots, solute accumulation, cell membrane damage and other parameters were determined for both treatments under continuous salt stress. A significantly positive impact of AM fungi on plant growth was observed. Leaves and roots accumulated more soluble sugar and showed higher leaf water potential(ψ), soluble protein in AM symbiosis. Proline was also higher in AM roots, while the opposite was observed in leaves. MDA content, O_{2^-} generation rate increased in both AM and non-AM seedlings under salt stress, especially in non-AM seeding. In addition, AM colonization significantly decreased Na^+ concentration in roots and shoots, but reduction of Cl^- concentration was indistinctive. As a consequence, we suggested that the improved salt tolerance of AM tomato is related to lower Na^+ toxicity in shoots and roots, greater osmotic adjustment which resulted from the higher accumulation of soluble sugar, protein and proline in salinity.

P 92.

GRAFTING EFFECTS ON EARLINESS, YIELD AND FRUIT QUALITY OF TWO TOMATO CULTIVARS

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Although the primary reason for grafting vegetables was the reduction of the infections caused by certain soilborne diseases, many additional direct as well as indirect responses have been induced regarding earliness, yield and quality. Therefore, there is a need for comparative studies of new rootstocks used in tomato grafting. The aim of this study was to investigate the effect of two tomato rootstocks (Primavera and Nova) that are commercially used, on earliness, yield, quality (color, dry matter, soluble solids, nitrate, ascorbic acid, lycopene and soluble phenol content, as well as pH and titratable acidity) and mineral composition (N, P, K, Ca, Fe, Mg, Mn, Zn and Cu) of fruit of two tomato cultivars (Sacos F1 and Saidan F1). The results showed that grafting had significant effects on earliness, yield and fruit quality, which were dependent on cultivar and rootstock used. Sacos F1 benefited considerably by grafting plants on Primavera rootstock, due to the higher total yield per plant by 36%, resulting from a greater number of flower and fruits produced per plant, as well as due to the higher yield per plant of the normal period by 62%, without significantly affecting nutritional and mineral composition of fruit, in comparison to the ungrafted plants, since only pH, Mg and N were slightly affected by grafting. Grafting Sacos F1 on Nova did not increase yield per plant and although mineral composition of harvested fruit was increased, nutritional quality was deteriorated. On the other hand, Saidan F1, although was not benefited by grafting, in terms of yield per plant, grafted on Primavera, had a higher yield by 23%, higher fruit set and greater number of fruit produced per plant and higher nutritional quality than grafted on Nova. However, grafting Saidan F1 on Nova resulted in a higher fruit mineral composition.

P 93.

THE EFFECT OF SUPLEMENTARY LED LIGHTING ON THE ANTIOXIDANT AND NUTRITIONAL PROPERTIES OF LETTUCE

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We report on the application of supplementary solid-state lighting within an industrial greenhouse for the cultivation of various lettuces (*Lactuca sativa* L.) varieties grown under natural solar illumination and high pressure sodium lamps. Red leaf 'Multired 4', green leaf 'Multigreen 3' and light green leaf 'Multiblond 2' lettuce were grown to harvest time within a greenhouse in a peat substrate (pH 5-6) under daylight with supplementary lighting provided by standard high-pressure sodium lamps (HPS) (16-h). Supplementary lighting from blue 455 nm and 470 nm and green 505 nm and 530 nm light-emitting diodes (LEDs) was applied within a 16-h photoperiod. The generated photosynthetic photon flux density of each type of solid-state lamps was 15 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and the photosynthetic photon flux density of HPS lamps was 90 $\mu mol \cdot m^{-2} \cdot s^{-1}$. The day/night temperature was 17-22/14-17°C and relative air humidity was 50-60 %. Such supplementary LED treatment was found to enhance antioxidant and nutritional properties of lettuce due to the increased activity of the metabolic system for the protection from a mild photooxidative stress. The reduction of nitrates was accompanied by an increased concentration of nutritionally valuable carbohydrates, what is also in line with stimulation of expression of nitrate reductase by photosynthetic metabolites. Another indicator of nutritional quality, the content of vitamin C, exhibited some variation that was not directly correlated with the nitrate reduction rate. However, the effect of supplementary blue and green light was found to be variety dependent. The sensitivity to the light conditions was determined by the natural level of total anthocyanin concentration in red, green or light green lettuce. Supplemental lighting evoked a metabolic disbalance in lettuce thus resulting the accumulation of higher amounts of antioxidative compounds, such as anthocyanins, tocopherols, total phenolic compounds and lead to the alteration of higher DPPH free-radical scavenging capacity.

P 94.

EFFECT OF *Ocimum basilicum* L. BIOLOGICAL PREPARATION ON TOMATO FRUIT QUALITY GROWN IN GREENHOUSE

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The objective of our investigation was to evaluate the impact of *Ocimum basilicum* L. biological preparation on tomato fruits quality. Two Lithuanian tomatoes cultivars were investigated: 'Balčiai' and 'Vytėnų didieji'. In the first decade of June tomatoes transplants were planted into the not heated greenhouse. Four different concentrations

(dilution level: D6, C30, C200 and 1M) of biological preparation were used six times during tomatoes' vegetation in every ten days. The following parameters determining the quality of tomato fruits were analyzed: fruit size, firmness, soluble dry matter, titratable acidity, β-carotene and lycopene. Our experiment revealed that quality indices of tomatoes depended on the concentrations of used biological preparation. The highest concentration (1M) of *Ocimum basilicum* L. preparation had no positive effect on tomato fruit quality. The watering with C30 and C200 concentrations increased the contents of β-carotene and lycopene. Soluble dry matter, titratable acidity content and firmness showed no significant differences between treatments.

P 95.

GREENHOUSE BABY LEAF PRODUCTION IN SEMI-ARID CLIMATE: SEASONAL EFFECTS ON YIELD AND QUALITY

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Greenhouse production of baby salad leaves is a means to provide a clean, safe product for consumers. However, productivity and nutritional quality is not well known especially under semi-arid greenhouse conditions. As a part of a diet intervention study, three varieties of leafy greens, *Lactuca sativa* 'Red Salad Bowl', *L. sativa* 'Cimmaron' and *Brassica rapa* var. 'Komatsuna' were grown during two years (2008-2009) in a pad-and-fan cooled acrylic greenhouse using ebb-and-flood irrigation with perlite-based substrate contained in 72-cell plug trays. Nutrient solution was half-strength general purpose hydroponic formulation. Seeds were germinated in a temperature-controlled room for four days then moved to greenhouse for three weeks after which it was harvested. Leaves were harvested and the fresh weight recorded on a weekly basis. Carotenoids, ascorbic acid, phenolics and anthocyanins were phytonutrients measured. Yield and quality were significantly affected by seasonal environment. Fresh weight ranged from 0.21 to 1.88 kg m^{-2} per 3-week production cycle and was greatest during spring/summer season. Percent dry mass was greatest during autumn/winter. Anthocyanin, strongly affected by season, ranged from 1 to 148 mg kg^{-1} FW for lettuces. Phenolics showed seasonal variation, concentration ranging from 310 to 2177 and 357 to 1690 mg kg^{-1} FW GAE for lettuces and Komatsuna respectively. Anthocyanin and phenolics concentrations were greatest during winter season on fresh weight basis but for phenolics only on dry weight basis. Other phytonutrient concentrations were not clearly affected by season. Total carotenoids and ascorbic acid of lettuce grown in our greenhouse were comparable to, but anthocyanins were lower than, levels reported by USDA National Nutrient Database for Standard Reference. Overall color was less intense, texture was tenderer than those grown in open field. Yield and quality of leafy greens could be improved by further optimizing the greenhouse environmental conditions.

P 96.

ANTIOXIDANT COMPOUNDS AND NITRATES IN BABY LETTUCE AS AFFECTED BY NITROGEN AND CALCIUM FERTILIZATION AND HARVESTING TIME DURING THE COURSE OF THE DAY

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Lettuce, a high-value popular vegetable, is rich in health promoting antioxidant compounds as well as in nitrates that are considered to be a risk to the health of consumer. For this reason, a European Commission Regulation setting maximum levels for nitrate in lettuce has been applied since 1997. The accumulation of both antioxidant compounds and nitrates in lettuce depends on genetic and environmental factors. Although the effect of these factors has been extensively studied in nitrate accumulation, information on antioxidant compounds is relatively scarce. In the present study, some antioxidant compounds (ascorbic acid, total soluble phenols and total flavonoids), total antioxidant activity (DPPH radical scavenging activity and FRAP assay) and nitrates of two lettuce cultivars (Sanguine, leaf type and Paris Island, cos type) grown for 43 days in floating system with three concentrations of nitrogen and calcium (N+Ca: 135+120, 270+290 and 405+460 mg/l) were investigated during the course of the day by harvesting at 06:30 (morning), 13:30 (afternoon) and 20:30 (night). Analysis of variance was performed for each one cultivar separately. Results showed that the higher concentration of nitrogen and calcium (N+Ca: 405+460 mg/l) reduced nitrates by 12.5% and the reduction was highest (36.5%) by harvesting at afternoon as well as increased total antioxidant activity (DPPH radical scavenging activity) by 34.7%. Moreover, harvesting at afternoon and night or at night resulted in the highest DPPH radical scavenging activity or FRAP assay, respectively. However, the above effects were observed only in Paris Island. It is important to mention that the highest measured concentration for nitrates in all treatments was lower that the one fifth of the specified limits for lettuce by the Commission Regulation. In addition, our results suggest that other compounds beyond ascorbic acid, total soluble phenols and total flavonoids contribute also to the total antioxidant activity in baby lettuce.

P 97.

EFFECTS OF DIFFERENT ROOTSTOCKS ON YIELD, QUALITY AND PLANT VIGOUR OF WATERMELON GROWN IN GREENHOUSE

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This study was carried out in a PE-unheated greenhouse at the Faculty of Agriculture, Ege University during the spring season of 2009 to determine the effects of different rootstocks on yield, quality and plant vigor of watermelon. In this experiment watermelon cultivar Crimson Type was grafted on five rootstocks, namely RS841 (*C. maximaxC. moschata*), Nunhems 9075 (*C. maximaxC. moschata*), Maximus (AG 1355) (*C. maximaxC. moschata*), Macis (*Lageneria siceraria*) and Argentario (*L. siceraria*). As the control non-grafted and also self-grafted plants due to the grafted union effect were tested in the experiment. Plants were grown in perlite as open system. The seedlings were

transferred into the greenhouse on 13.03.2009 and they were planted as one plant per container with a plant density of 1.16 plant m-2. The experimental design was randomized parcels with 3 replicates and plant number was 4 in each replicate. Water and nutrient requirements of plants were supplied with complete nutrient solution via drip irrigation. At the end of growing season parameters related to yield (fruit weight), fruit characteristics (width, length, rind thickness, number of seeds, dry matter percentage of pulp, rind and seeds), quality (firmness, total soluble solids, EC, pH, titrable acidity and fruit color) and plant growth (rootstock and stem diameter, main stem length, root and shoot fresh and dry weight) were measured. The highest yield was obtained from Maximus (8.32 kg m-2) which was %89.9 and %66.3 higher than non-grafted and self-grafted treatments respectively. Plant height, fruit size, number of seeds, total soluble solids, EC, pH and pulp red color also increased with the use of rootstock. The increase of root and shoot fresh and dry weight was depended on rootstocks. It was concluded that grafting improved plant growth, yield and some quality properties depending on rootstock genotype.

P 98.

ROOTING AND GROWTH OF CUTTINGS FROM ETHYLENE-LOW OR ETHYLENE-HIGH SENSITIVE MINIATURE ROSE GENOTYPES

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Using cuttings is a main approach in the clonal propagation of herbaceous or woody ornamental greenhouse crops. Rose plants are commercially propagated by hardwood and softwood cuttings. Ethylene is a gaseous plant hormone that plays important role in adventitious root initiation of plant species and it was suggested that an ethylene-mediated signal transduction pathway is mediated in root initiation. This study conducted to evaluate rooting ability and bud growth in miniature rose genotypes showed high-sensitivity or low-sensitivity to exogenous ethylene treatment, under mist environmental conditions. Data showed that 98.3% of cuttings were rooted whether treated or untreated with IBA and rooting ability did not depend on ethylene sensitivity of investigated genotypes. Although axillary bud growth was delayed in one of the low sensitive genotypes, time to axillary bud growth did not significantly affected by cutting size and IBA treatment. In that ethylene low-sensitive genotype, less than 20% of cuttings showed bud growth after 16 days, while it was about 90% in other genotypes. Plant height, fresh and dry weight of roots and shoots showed significantly differences within genotypes, regardless cutting size or IBA treatment. The mean rooting time was shorter than 10.3 days for all genotypes, except for one genotype with required 20 days for rooting. Results revealed that all genotypes showed optimum shoot growth and the highest rate of rooting under mist and fog conditions, regardless of their ethylene sensitivity or IBA application.

P 99.

EFFECT OF SILICATE APPLIED DURING CUTTING PROPAGATION ON ROOTING AND GROWTH OF TWO ROSE CULTIVARS

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This study was conducted to investigate the effect of silicate applied during cutting propagation on rooting and early growth of young rose (*Rosa hybrid* Hort.) cultivars (a standard 'Red Carpet' and a spray 'Yellow King') in an effort to promote rooting of cuttings. Cuttings, prepared as single node cuttings, each with a five-leaflet leaf, were stuck in rockwool cubes (5 cm x 5 cm x 5cm, Grodan, Denmark) on May 18, 2010. The cultivars were hand watered with either one of 0, 50, or 100 mg·L^{-1} potassium silicate (K_2SiO_3) or sodium silicate (Na_2SiO_3) solutions. Silicate applications shortened days to rooting. Treatment of 50 mg·L^{-1} potassium silicate (K_2SiO_3) solution resulted in the least number of days to rooting in both 'Red Carpet' and 'Yellow King'. In 'Red Carpet', chlorophyll content was also the greatest in the 50 mg·L^{-1} potassium silicate (K_2SiO_3) treatment. Sodium silicate (Na_2SiO_3) applications promoted shoot growth in 'Red Carpet', but not in 'Yellow King'. The results suggested that the silicate applications had a positive effect on rooting. Additional results are anticipated on the reproductive growth of the crop after transplanting.

P 100.

GROWTH OF BLUEBERRY CULTIVARS IN NFT HYDROPONIC SYSTEM

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The expansion of blueberry culture is affected by the difficulty of propagation and slow development. Hydroponics system is an alternative technique that offers several advantages for many crops. The aim of this study was to evaluate the growth of different blueberry cultivars plants, Bluebelle, Bluegem, Georgiagem and Delite, in hydroponic system. The experiment was conducted at "Departamento de Fitotecnia/ Universidade Federal de Pelotas", Pelotas, RS, from May to August of 2010. Plants originated from tissue culture were transplanted to cultivation benches, using phenolic foam as the substrate. The NFT system consisted of two cultivation benches made of cement tile. The spacing was 10cm between plants in the growing channels and 18cm between rows (channels). The irrigation frequency was once a day for 5 min. Randomized blocks experimental design was used with four treatments (cultivars) and four replications composed of ten seedlings each. Plant height, shoot number and length evaluations were performed at 30, 60 and 90 days after setting. The data were submitted to analysis of variance and comparisons of means by Tukey test at 5% probability. At 60 and 90 days after setting all variables showed significant differences. At 90 days after setting, Georgiagem cultivar showed greater plant height (20.25 cm) and higher average shoot length (10.64 cm) followed by Delite cultivar (10.27 cm). The highest number of shoots was obtained

at 90 days after setting by cultivar Bluegem (7.05). In general, all cultivars showed a gradual increase of growth according to the time of cultivation, however Georgiagem and Bluegem cultivars showed better results.

Key words: blueberry, soilless system, nutrient solution.

P 101.

SOILLESS CULTIVATION SYSTEMS: A NEW APPROACH IN FRUIT PLANTS PROPAGATION IN THE SOUTH OF BRAZIL

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The search for new propagation techniques that can enhance the quality and quantity of propagation material is essential in the fruit production. The vegetative or asexual propagation of fruit plants is highly recommended because it enables the maintenance of plant characteristics. The multiplication of fruit trees by vegetative propagation can be done of several ways, each species suiting best one of them. Among the important propagation techniques can be found cuttings and micropropagation. Although in many species these techniques would provide the multiplication and rooting of plant material to be cloned, growth and survival may be low. Technologies that benefit the growth and survival of plants produced asexually can increase the yield of fruit plants production. The production of fruit plants in soilless systems is a new process with great potential in its use. The advantages of soilless culture in plant propagation are earliness on producing it, more adequate mineral nutrients supply, better conditions for plant development and better control of diseases and pests. The use of soilless culture systems combined with more efficient forms of vegetative propagation such as cuttings and micropropagation has been tested in southern Brazil to obtain more quantity and greater quality of limitation propagation temperate fruit species plants. Different soilless culture systems (hydroponics and inert substrate growing systems) and nutrient solutions are being developed at "Universidade Federal de Pelotas" for blueberry crops, rootstock and scion cultivars of stone fruit trees and others such as quince, pear, olive trees and native fruits.

Key words: blueberry, soilless system, nutrient solution, stone fruits, quince, pear, olive.

P 102.

CULTIVATION OF VEGETABLE TRANSPLANTS USING SOLID-STATE LAMPS FOR THE SHORT-WAVELENGTH SUPLEMENTARY LIGHTING IN GREENHOUSES

G. Samuolienė, A. Brazaitytė, P. Duchovskis, A. Viršilė, J. Jankauskienė, R. Sirtautas, A. Novičkovas, S. Sakalauskienė, J. Sakalauskaitė
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The objective of our studies was to compare cultivation of greenhouse vegetable transplants under short-wavelength single-monochromatic solid-state lamps developed for supplementation of high-pressure sodium (HPS) lamps used in greenhouses. Four types of lamps with peak emissions at 455 nm, 470 nm, 505 nm, and 530 nm were made. Lamps were installed in a phytotron greenhouse. The generated photosynthetic photon flux density of each type of solid-state lamps was 15 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and the photosynthetic photon flux density of HPS lamps was 90 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Transplants of cucumber hybrid 'Mirabelle' F_1 , tomato hybrid 'Magnus' F_1 and sweet pepper variety 'Reda' were grown in phytotron greenhouse under illumination of HPS lamps and with supplementation by emission of solid-state lamps. The reference transplants were grown under illumination of HPS lamps. During transplants cultivation photoperiod was maintained at 18 h, the day/night temperature was 20-23/15-18°C and relative air humidity was 50-60 %. Measurements of growth parameters and photosynthetic pigments were performed at the end of the experiment. Our investigations revealed that the effect of supplementary blue and green light was found to be species dependent. Supplemental 455, 470 and 505 nm LED illumination with high pressure sodium lamps increased leaf area, fresh and dry weight and photosynthetic pigments content of all transplants. Meanwhile, supplemental 530 nm LED illumination had positive effect on growth, development and photosynthetic pigments accumulation of only cucumber transplants. Such illumination caused slower growth and development of tomato and sweet pepper transplants.

P 103.

ENHANCING NITROGEN USE EFFICIENCY IN *CUCURBITACEAE* CROPS BY GRAFTING

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Nitrogen plays a major role in the yield and quality of melon and watermelon plants. This work explored the Nitrogen Use Efficiency (NUE) traits and how it can be affected by grafting. Four experiments were designed. In the first two experiments, melon (*Cucumis melo* L. cv. 'Proteo') and mini-watermelon (*Citrullus lanatus* (Thumb.) Matsum. and Nakai cv. 'Minirossa') plants either ungrafted or grafted onto two rootstocks: 'P360', and 'PS1313' (*Cucurbita maxima* Duchesne x *Cucurbita moschata* Duchesne) for melon, and 'Macis', and 'Vita' (*Lagenaria siceraria* (Mol.) Standl.) for mini-watermelon grown in hydroponics were compared in terms of shoot dry biomass in response to nitrate availability (0.5, 2.5, 5, 10 or 15 mM of NO_3^- for melon and 0.5, 2.5, 5, 10, 15 or 20 mM of NO_3^- for mini-watermelon). The other two experiments were aimed to confirm whether the use of a selected rootstock with high NUE ('P360' for melon and 'Vita' for mini-watermelon) could improve crop performance and NUE of grafted plants under field conditions. In the first two experiments, carried out under greenhouse conditions, melon plants grafted onto 'P360' rootstock needed 6.1 mM of NO_3, to reach half maximum shoot dry weight, whereas plants grafted onto 'PS1313'

rootstock and the control treatment (ungrafted plants) needed 9.1, and 13.1 mM of NO_3, respectively. Moreover, mini-watermelon plants grafted onto Vita' rootstock needed the lowest nitrate concentration (1.31 mM of NO_3) to reach half maximum shoot dry weight. In the other two experiments, carried out under open field conditions increasing the nitrogen fertilization rates from 0 to 120 kg·ha^{-1} for melon and from 0 to 100 kg ha^{-1} increased the total and marketable yields of melon and mini-watermelon plants. When averaged over nitrogen levels, the marketable yield, NUE, and N uptake efficiency were higher by 9%, 11.9%, and 16.4%, respectively in 'Proteo' grafted onto 'P360' than in ungrafted 'Proteo' plants and by 39%, 38%, and 21%, respectively in 'Minirossa' grafted onto 'Vita' than in ungrafted 'Minirossa' plants. Hence grafting melon and mini-watermelon plants onto selected rootstocks can be used as a quick and effective method to improve productivity, NUE, and to reduce environmental pollution.

Keywords: *Citrullus lanatus* (Thumb.) Matsum. and Nakai, *Cucumis melo* L., NUE, rootstocks.

P 104.

GREENHOUSE MIST SYSTEM CAN IMPROVE ROOTING AND PROVIDE GREATER FLEXIBILITY IN ROOTING CUTTINGS OF GRAPEVINE IN ALBANIA

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Propagation of fruit trees in Albania has been facilities range from simple greenhouse fog to elaborate temperature, humidity, CO2 , light and nutrient controlled. Adding an intermittent mist system can improve rooting and provide greater flexibility in rooting cuttings.
The study aims to propagate the green macro implants of five vine cultivars, cropped over the radical substrate and stimulated by synthetic hormones. Implants have been prepared in sections by two nodes, treated on the tail end with synthetic hormone AIB, AIA, in concentration 1000 ppm and control (hydroalcolic solution) .
Humidity is controlled by a solar cellular, a leaf electronics that measures the percentage of evaporacionit, a solar integrator that controls the automatic so an autoclave, a pump, a magnetic elektrovalvul that together create water vapor (2 MICR) in every 200 K. kal.cm ^{2}. Calculated light through a 70% synthetic hideous network. while the temperature regulated by a 20,000 k.kal. a boiler system control device.The more droplets that are produced, the better also the critical under-leaf coverage. Experience has shown that the ratio of coverage on the surface of the leaf compared with the under-leaf coverage is approximately 1 to 8. By increasing the number of droplets by applying more water, the absolute number of droplets covering the bottom side of the leaves is also increased. Control of humidity, temperature and light in thegreenhouse of fog in relation to plant material has great interest.
Rizzoggeneza with 1 g/lt IBA and AIA have been 21.6 % and 17.7 % respectively, better then in the case of control of all the cultivars. The material have been acclimatization and preserve for reproduction purposes.
Fogging has created a liquid curtain and prevent evaporation and maintain tissue of turgor.

Key words: grapevine, fog system of greenhouse, propagation, indol butyric acid, indol acetic acid

P 105.

IMPACT OF SALINITY DUE TO A HIGH CONCENTRATION OF NACL OR TO A HIGH CONCENTRATION OF NUTRIENTS ON TOMATO PLANTS

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Keywords: osmotic pressure, photosynthesis, hydroponics, water use efficiency, LAI.

Abstract
Salinity is a constantly aggravating agricultural problem due to the increasing demand for irrigation water and the concomitant overexploitation of water resources. Large amounts of saline waters worldwide are rich in Ca; however, in coastal regions the problem is arises mainly from too high concentrations of NaCl in the available water resources. In order to test to what extent the salt speciation affect plant growth, photosynthesis and production of tomato, a greenhouse experiment was conducted. Plants were supplied with three different nutrient solutions: (1) a standard nutrient solution (SNS) with an electrical conductivity (EC) of 2.5 dS m^{-1}, (2) a saline nutrient solution (12.5 dS m^{-1}), which was obtained by adding 100mM NaCl to the SNS and (3) a highly concentrated nutrient solution (12.5 dS m^{-1}). The results confirmed the negative impact of salinity on growth characteristics and production. Moreover tomato plants that were grown under the higher EC (12 mS cm^{-1}) caused by excess amounts of macronunutrients showed a 20% less decrease in yield than those grown under NaCl-salinity. Although stomatal conductance, transpiration rate and intercellular CO_2 decreased significantly during the exposure of plants to salinity, the rate of photosynthesis was maintained at the same levels as in the control. Moreover the chlorophyll content of leaves per unit of leaf area increased, due to the reduction of the leaf area. In conclusion, it seems that the growth and production of tomato are influenced by salinity, but at high EC levels, salt speciation is also important. The lower susceptibility of tomato to nutrient-induced salinity in comparison with equally high EC levels caused by NaCl is ascribed to differences in osmotic pressure in combination with the occurrence of specific ion toxicity in the case of NaCl-salinity.

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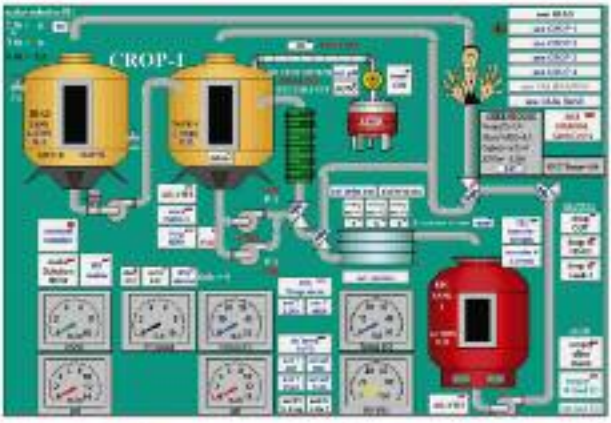

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