IHC2018-Symposium 10
Understanding Fruit Tree Behaviour in Dynamic Environments

KEYNOTE 1

CARBON GAIN IN RELATION TO WATER LOSS IN THE FACE OF GLOBAL CHANGE

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Availability of water is a key issue for horticultural production in many parts of the world. Uncertainty is associated with stochastic rainfall, with predictions of climate change, and also with social attitudes and priorities among competing demands for water. It is difficult to detect trends in annual rainfall, even with long records, unless the normal criteria for scientific confidence are relaxed. Producers probably make decisions with much less confidence. We can be more confident about increasing levels of atmospheric carbon dioxide, and research on understanding genetic differences in responses of growth and production to elevated [CO2] may be worthwhile. The physiological control of plant water use is only partially understood. There is some uncertainty about the role of stomata. How much do they function to limit hydraulic failure, and how much to maximise carbon gain for a given supply of water? What is meant by the distinction between efficient use of water and effective use of water? How does stomatal control differ among horticultural crops, for example in trees versus turf grass? Studies of carbon gain in relation to water loss often involve studies of leaf gas exchange. In such studies it is assumed that the atmosphere in the interior of the leaf is saturated with water vapour. This assumption affects calculations of stomatal conductance and of intercellular [CO2]. How reliable is it? We discuss the use of stable isotopes of carbon, oxygen and hydrogen in this context.

Keywords: rainfall statistics, climate change, carbon dioxide, plant growth, stomata, water vapour, stable isotopes

SESSION I: Eco-physiology

OS 1-1:
FRUIT GROWTH AND PHOTOSYNTHESIS ARE DIFFERENTIALLY AFFECTED BY LOCAL VARIATION IN SOURCE/SINK RELATIONS

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Tree crop load affects carbon acquisition as well as processes like floral induction or fruit growth. Nevertheless little is known about the impact of local variations of source/sink relationships on these processes variability within the tree. This study aims at investigating the effects of local manipulation of source/sink relationships through leaf or fruit removal on photosynthesis and fruit growth. Experiments were conducted in 2016 and 2017 on adult 'Golden' apple trees planted in the south of France. On trees in either high or low crop loads, 11 leaf or fruit removal treatments were set up early June. Treatments were performed at shoot or branch scales or one side of Y-shape trees. Photosynthesis was measured in June and August on the foliated parts of leaf-removal-treatment trees and on both the fructified and de-fructified parts of fruit-removal-treatment trees. At harvest, mean fruit weight was evaluated on the different parts of the trees. This study suggests a strong impact of the tree crop load on photosynthesis without any clear impact of the local fruit presence. Moreover, fruit weight was decreased on the defoliated parts when defoliation was performed on branches or on one side of the trees. This could suggest that trees are not able to exchange assimilates at long distances but also that defoliation caused a decrease in water transpiration with possible consequences on phloem-xylem fluxes. Conversely, our results show that long distant transport occurs between fructified and de-fructified parts of the tree. This is probably due to the very low demand of carbon in de-fructified parts which allows carbon fluxes to the fructified parts. This

study gives new knowledge on the effects of source/sink distances on carbon acquisition and transport suggesting that the distance effects could differ depending on the process. These experiments will be used to calibrate a model built to simulate carbon transport within trees.

Keywords: crop load, photosynthesis, source/sink distances, fruit growth

OS 1-2:

STOMATAL REGULATION OF TRANSPIRATION AND PHOTOSYNTHESIS IN MACADAMIAS

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Macadamia is an increasingly important crop in South Africa, with more than 25 000 ha planted, and further expansion taking place each year. Despite the importance of this crop and the vast area cropped, we still know very little about the ecophysiology and water use of this crop. This is critical to improve current management practices and for securing adequate water rights for this crop in a semi-arid country, which experiences regular droughts. It was as a result of this need that the Water Research Commission of South Africa solicited, funded and managed a project on macadamia water use. Detailed studies of transpiration and plant water relations indicate that macadamias exhibit typical isohydric behaviour, with stomata closing in response to high vapour pressure deficit (VPD) to prevent leaf water potential from dropping below critical levels. This was clearly observed in diurnal plots of stomatal conductance vs leaf water potential, where hysteresis was observed and leaf water potential was maintained at a more or less constant level close to midday in response to stomatal closure. Despite initial reports, macadamias do not appear to have higher hydraulic conductance than most other fruit tree crops, which could help explain why stomatal closure was observed once VPD exceeded 1.5 kPa. This regulation does, however, seem to be dependent on phenological stage, with stomatal adjustment occurring particularly during the oil filling stage of nut development, when sink demand is high. Analysis of the photosynthetic response to light and CO2 concentration across different phenological stages, together with sap flow determined transpiration data, demonstrated a shift in water use strategy with changing sink strength. This indicates dynamic stomatal regulation, and at times of high photosynthetic demand, stomata become less sensitive to increases in VPD and exhibit a slightly more “risky” but productive water use strategy.

Keywords: isohydric, sink strength, vapour pressure deficit, phenology, hydraulic conductance

OS 1-3:

SEASONAL AND DAİLY GROWTH PATTERN OF SWEET CHESTNUT (CASTANEA SATİVA MİLL.) HUSKS: A FİRST APPRAİSAL OF İTS PHYSİOLOGY

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The seasonal and daily growth of sweet chestnut (C. sativa Mill.) husks have been studied in a commercial orchard in Monterenzio (Bologna, Italy). The seasonal growth pattern in the maximum and minimum diameter of 20 husks were measured every 7 days from 30 days after full bloom (DAFB) - corresponding at the beginning of June - to a week before harvest (120 DAFB). The absolute and relative growth rate (AGR, RGR) have also been calculated. Growth of 6 husks was monitored from the 4th to the 11th of August 2017 through very precise fruit gauges, connected to a custom-built, Arduino-based data logger, which was monitored through a wireless network (AWSN). The 6 husks were selected on 3 trees (2 husks per tree) and their diameters were recorded every 15 minutes for the entire week. Temperature (0C) and daily precipitation (mm/day) were sourced from a close (2 km) meteorological station belonging to ARPAE (Regional agency for environmental control). The husk exhibited a seasonal diameter growth pattern resembling a double sigmoid. AGR responded positively to rainfalls, as no irrigation was provided. Interestingly, daily husk growth started mid-morning and continued till dark (from 10:00 to 21:00), followed by shrinkage during night-time. This pattern of growth appears opposite if

compared to other fruit species as Prunus persica L. or Malus domestica Bork., which exhibit growth during the last part of the day/night and shrinkage/no growth during the day. Our data show a quick increase (within the following 24 hours) in husk growth rate after a rainfall event. These preliminary data show the need for further studies on C. sativa physiology and their potential impact on improving irrigation practices for this intriguing crop.

Keywords: fruit growth, AGR, fruit gauges

SESSION-2: Tree and orchard management I

OS 2-1:

WATER USE PRODUCTIVITY OF HIGH PERFORMING APPLE ORCHARDS IN THE WINTER RAINFALL AREA OF SOUTH AFRICA

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Increasing pressure on South Africa's water resources from rising and competing user demand and climate change threatens the sustainability of the deciduous fruit industry. Apple production in South Africa is totally reliant on irrigation. Furthermore, high yielding (>100 t ha-1) apple orchards have become common, raising the need for detailed information on water use and water use productivity (WUP) by these orchards. This study, conducted from 2014-2017, investigated the dynamics of water use in four 'Golden Delicious' and four 'Cripps Pink' orchards in the winter rainfall Western Cape region. Yields ranged between 11 and 140 t ha-1 in younger to full-bearing orchards. The orchards were in two key apple producing regions with contrasting climates. The full study included detailed quantification of orchard water use using sap flow sensors, eddy covariance evapotranspiration (ET) measurements, and ET modelling. In this paper we present the analysis of WUP, together with fruit quality and gross income. We define WUP as kg of fruit produced per cubic meter of water consumed, based on both transpiration and ET. We also calculate "economic water use productivity" (EWUP) as gross income per cubic meter of water consumed. The key driver of WUP (transpiration-based) was the canopy leaf area. However, lower transpiration from smaller canopies of 'Cripps Pink' was compensated by higher evaporation from the orchard floor, resulting in comparable WUP (evapotranspiration-based) between the cultivars. WUP based on ET increased linearly with increasing yield. Differences in the length of the growing season were insignificant since the canopies continued to be highly active until autumn in both cultivars. Exceptionally high yields resulted in smaller fruit size in 'Golden Delicious' orchards which reduced the pack out of export quality fruit and lowered the EWUP. The premium prices obtained for 'Cripps Pink' compared to 'Golden Delicious' drove up the EWUP.

Keywords: Evapotranspiration, Fruit quality, Water use productivity, Yield

OS 2-2:

PHYSIOLOGICAL RESPONSES TO VIGOR IN CHERRY: WHY DWARFING ROOTSTOCKS ARE MORE EFFICIENT?

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Rootstock vigor is well known to affect yield and productive performance in many fruit crops and the dwarfing trait is often the preferred choice for modern orchard systems thanks to its improved productivity per hectare and reduced canopy volume. This work investigates on the different physiological responses induced by rootstock vigor on cherry by comparing water relations, leaf gas exchanges, shoot and fruit growth of "Black Star" trees

grafted on semi-vigorous (CAB6P) and on semi-dwarfing (GISELA 6) rootstocks. The daily patterns of stem, leaf and fruit water potentials (WP), leaf photosynthesis, stomatal conductance and transpiration, as well as shoot and fruit growth were assessed during post-veraison, while productivity and fruit quality were determined at harvest. Trees on GISELA6 showed lower shoot growth rates and lower stem and fruit WPs compared to trees on CAB6P, while no significant differences were found on leaf WP, gas exchanges and fruit daily growth rates. As a consequence of the relative changes in WPs, trees on GISELA6 showed lower daily WP gradients between stem and leaves, which may have reduced shoot strength as a sink for water and carbohydrates and thus shoot growth, compared to CAB6P. On the contrary, a higher WP gradient between stem and fruit was recorded on GISELA6, with likely positive consequences on fruit strength as a sink. This hypothesis is confirmed by the higher productivity and fruit soluble solid content found at harvest on trees grafted on GiSELA6. These results suggest how fruit on trees grafted on dwarfing rootstocks may develop strategies to increase their resource competition towards shoots, thus leading to improved yield and fruit quality at harvest.

Keywords: Fruit growth, Leaf gas exchanges, Productive efficiency, Prunus Avium L., Water relations

OS 2-3:

SEASONAL ADAPTATION OF 'HONEYCRISP' APPLE GROWN UNDER COLORED PROTECTIVE NETTING IN A SEMI-ARID ENVIRONMENT

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Worldwide, apple production often occurs in semi-arid climates such as Washington State (WA), South Africa, Israel, Chile and Australia that are characterized by high temperatures and solar radiation. Protective netting (PN) also known as shade nets or anti-hail nets, are being increasingly used in such environments to reduce fruit sunburn development and reduce tree stress. Our goal was to study the ecophysiological response of apple trees grown under PN over the entire growing season. We wanted to determine if apple trees display any adaptions to the lower light environment under PN. Experiments were conducted in fourth leaf 'Honeycrisp' apple on B9 rootstock at Quincy, Washington, USA. Four treatments were evaluated, an uncovered control, 22% blue, 25% red and 19% pearl PN. Measurements were done at 32, 66, 100 and 132 days after full bloom (DAFB). Ecophysiological measurements included leaf gas exchange, plant water status, chlorophyll fluorescence and leaf spectral reflectance. Quantum photosynthetic yield of PSII (ΦPSII) was significantly higher in the netted treatments compared to an uncovered control at 66, 100 and 132 DAFB. There were no significant differences in maximum photochemical efficiency of PSII (Fv/Fm) between treatments at 32, 66 and 100 DAFB. At 132 DAFB, Fv/Fm was significantly lower under control (0.68) compared to netted treatments and had fallen below the threshold of a healthy leaf (0.79). Net carbon assimilation was significantly lower in uncovered control 32, 66 and 132 DAFB compared to white and blue PN. Midday stem water potential (MDSWP) was significantly more negative in the control at 32 and 66 DAFB compared to the netted treatments. In conclusion, the reduction in light stress under PN in a semi-arid environment increased light use efficiency resulting in a positive effect on net carbon assimilation and plant water status.

Keywords: light-use efficiency, photoinhibition, leaf gas exchange, apple protection, light stress, heat stress

OS 2-4:

BENEFITS OF INTENSIVE PRODUCTION SYSTEMS IN MANGO

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Mangoes are grown in over 100 countries throughout the tropical and subtropical world with a total production of over 42 x 103 tons of fruit sold in both local and export markets. In tropical regions, mangos are typically,

large, vigorous, low yielding trees with very low production and harvest efficiencies. In Queensland, Australia, a collaborative research project between the Department of Agriculture and Fisheries and the University of Queensland has been investigating high density intensive production systems in tropical and subtropical tree fruits, investigating and documenting the relationships between the key drivers of productivity. In mango the aim of this research is to radically redesign orchard systems, increasing their production efficiency and profitability. Experimental intensification using higher planting densities and single leader training of canopies has led to early gains in productivity (~25 tons / ha in year 4). This presentation will outline some of the key relationships that are underpinning these productivity gains in areas such as canopy light interception and distribution, canopy training, architectural development, progress in vigour control using rootstock and the understanding of flowering and crop load.

Keywords: high density, vigor, light interception, light distribution, architecture, crop load

OS 2-5:

ILLUMINATING THE RELATIONSHIP BETWEEN CANOPY LIGHT RELATIONS AND FRUIT YIELD AND QUALITY IN APPLE PLANAR CORDON ORCHARD SYSTEMS

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In apple orchards, total dry matter production and fruit yield are positively related to total seasonal canopy light interception and mid-season fractional light interception. High within-canopy irradiance is central to achieving optimal spur function and high fruit quality (floral and leaf properties, skin colour and dry matter content respectively). In New Zealand, current mature commercial high-density apple orchards capture about 55 to 60% of incoming light. New planar cordon systems have been designed with the objective of improving light interception and distribution, to increase yield/ha and fruit quality significantly beyond that currently achieved in the best commercial orchards. These new systems have tree densities of 1667 to 2222 trees/ha with 2 or 1.5 m row spacings. We have little knowledge of the annual light interception and light distribution characteristics during seasonal canopy growth in these cordons, and only theoretical hypotheses of the relationships planar cordon canopies may have between light interception and fruit yield, and light distribution and fruit quality. Research prototypes planted in 2013 (prototype 1) and 2014 (prototype 2) include comparison of four commercial genotypes ('Royal Gala', 'Scifresh' (JazzTM), 'Scilate' (EnvyTM), Fuji SupremeTM. In these prototypes, even in young trees (as early as their 3rd (prototype 2) and 4th (prototype 1) years), light interception (47% to 58%, and 48% to 63% respectively) reached the same seasonal maxima as current mature commercial tall spindle orchards. Fruit yield in these immature canopies ranged from 45 to 95t/ha in prototype 1 and 43 to 50t/ha in prototype 2. In their 4th and 5th leaf, the vertical fruiting shoot canopy will reach 3.2 to 3.5 metres in height and the lower half of the canopy will be in full production. This will provide the first opportunity to investigate light distribution within the strata of the canopy. Data investigating within-canopy irradiance and whole-canopy light interception will be discussed in relation to yield, fruit quality and leaf canopy properties.

Keywords: Malus, orchard training system, canopy management, light interception, irradiance, leaf area index

OS 2-6:

FRUIT SET AND QUALITY RESPONSES TO ARTIFICIAL SPUR EXTINCTION IN PLANAR CORDON SWEET CHERRY TREES

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New orchard planting systems using planar cordon sweet cherry trees in closely planted rows (1.5 m or 2 m apart) have been designed with the aim of increasing orchard light interception and to at least double productivity, whilst maintaining high fruit quality. These simplified planar planting arrays should make precision management easier to achieve and should enable growers to "dial up" exact yields per hectare by late spring.
Artificial spur extinction (ASE) uses hand-thinning of whole buds in late dormancy and alters the distribution of floral buds on individual limbs in whole trees. ASE removes floral and vegetative sinks and potential leaf area,

which reduces competition and improves the light environment of the remaining buds. In apples this has resulted in improved fruit set and larger fruit of better quality without the need for chemical flower thinning, and has enabled accurate prediction of yield soon after bud break. A trial was established using planar cordon cherry trees of 'Sweetheart', 'Lapins' and 'Staccato', to determine whether ASE may be a potential tool for controlling fruit yield, size and quality in this new system. ASE may also improve spur longevity because of improved light regimes, and reduce the need for frequent upright shoot replacement. ASE was carried out shortly after harvest in the previous season because of the risk of bacterial canker (Pseudomonas syringae) infection from wounding trees in spring. This timing may also improve flower bud development. In mid-February 2017, every second bud on two- and three-year-old sections of wood was removed from replicate whole trees of ASE treatments. Non-ASE treatment trees were used as controls. Flower numbers were estimated from floral bud counts on two sub-plots per tree in spring (September 2017). Initial and final fruit sets were calculated from fruit counts made in November 2017 and at harvest in January 2018. A subsample of fruit was used to evaluate fruit size (weight, diameter), and soluble solids concentration.
Keywords: Precision management, fruit quality, yield, Prunus avium, floral bud density

SESSION-2: Tree and orchard management II

OS 3-1:
RESEARCH TO PREVENT DOUBLE FRUIT FORMATION DEPENDING ON CLIMATE CHANGE ON CHERRIES

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This study was carried out at the experimental areas of Pozantı Agricultural Research and Application Center both in Adana (subtropical) and Pozantı (highlands) during 2012 and 2016. Prima Giant, Brooks and Early Burlat (pollinator) were used. In Pozantı location, 0900 Ziraat cherry cultivar was also experimented besides the other cherry cultivars. The aim of the project was to prevent double fruit formation by using cover system, fogging, caolin application and the combinations of these techniques. The chilling requirements of the cultivars were found to be sufficient by the calculations and phenological observations in both regions. Double fruit formation found to be higher in Adana than in Pozantı depending on the temperature and cultivars. The most effective method to decrease double pistile formation was found to be cover+fogging combination with 84 %. It was followed by cover+caolin, cover and caolin applications. The best values for the photosynthetic parameters were measured on the plants under cover+fogging application. According to the results, photosynthesis speed was measured to be 14.45 µmol CO2 m-2 s-1, stoma conductance was 177.75mmol m-2 s-1, PSII (Fv'/Fm') was 0.74 and SPAD value was 42.60µmol m-2.

Keywords: Sweet cherry, double fruits, cover-fogging-caolin

OS 3-2:
AGRONOMICAL AND PHYSIOLOGICAL RESPONSES OF SWEET CHERRY (*Prunus avium* L.) UNDER HIGH TUNNELS

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The use of high tunnels in sweet cherry orchards is increasing since these help avoiding fruit cracking, prevent frost and promote earlier harvest, among others. However, physiological and agronomical information about sweet cherry trees grown under tunnels is scarce. Consequently, the aim of this study was to measure the effect of high tunnel on the physiology, yield and fruit quality of the highly-productive and cracking-susceptible combination "Royal Dawn®"/"MaxMa 14". The experiment was conducted in the spring of 2017 in Palquibudi,

Chile. Eight year-old trees trained as Y-trellis (4.5 x 2.0 m) and drip irrigated with four emitters (4 l h-1) per tree were evaluated under two treatments (TR): TR1= trees with high tunnels and TR2= trees without high tunnel. Environmental parameters (i.e., temperature relative and relative humidity), midday stem water potential (Ys, MPa) and stomatal conductance (gs, mmol m-2 s-1) were measured inside and outside tunnels. Vegetative (e.g., extension shoot and spur number and leaf area), reproductive parameters (e.g. fruit number per spur and fruit size) were measured at 0.75, 1.5 and 2.0 m height, weekly. Fruit quality and cracking susceptibility were evaluated at commercial harvest for each TR. There were significant differences in the date of harvest, fruit yield, fruit quality and cracking susceptibility between TR. Trees under tunnels were harvested 8 d earlier and showed higher yields (>30%) than uncovered trees. Trees under tunnels showed a similar Ys and higher gs mean values (-0,56 MPa, 220.85 mmol m-2 s-1). In addition, tunnels promoted higher, softer, less sweet and less cracking susceptible fruit (11.1 g, 71.6 Durofel units, 16.3°Brix, 4.8 Cracking Index) than uncovered trees (8.9 g, 76.5 Durofel units, 20.3°Brix, 5.9 Cracking Index). Implication of these results will be discussed.

Keywords: harvest, fruit quality, cracking, firmness, Royal Dawn.

OS 3-3:

INVESTIGATING THE EFFECTS OF PLANTING DENSITY AND TREE SIZE ON YIELD THROUGH FUNCTIONAL-STRUCTURAL MODELING

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Reducing planting distances is one of the strategies to increase yield in fruit orchards. Increments in orchard yield with tree density occur especially when trees are small. However, orchard yield can decrease with big trees planted at high densities. In trees growing in optimal conditions, that is, without water or nutrient stress, this yield reduction is likely to be the result of competition for light as well as an imbalance between vegetative and fruit growth. Separating these factors and their interactions in the field is not straightforward. Models of carbon acquisition and distribution between organs have been used to simulate and understand some factors affecting yield per tree or within the tree. Modelling might help to understand better the effects of tree density and size on orchard yield. We employed a functional-structural tree model to simulate individual organ growth within the canopy as well as tree and orchard yield with different planting distances and tree size. The model combined models of light interception, photosynthesis, potential relative growth rates of individual organs and inter-organ competition for carbon. Tree canopy architecture measured in the field was used to create several virtual orchard canopies with a range of tree sizes and planting distances. The model simulated growth and yield of individual trees and orchards during one growing season. Our virtual experiments showed how different tree densities and sizes affected yield. It increased our understanding and probe concepts about the effects of planting distances and tree size on orchard yields, which can be useful for designing future field experiments and orchards.

Keywords:carbon availability, fruit growth, light interception, orchard, tree architecture, virtual plants

OS 3-4:

ANALYZING SYNERGIES AND CONFLICTS BETWEEN MULTIPLE ECOSYSTEM SERVICES IN APPLE ORCHARDS THROUGH MODELLING

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The investigation of sustainable fruit tree production systems might benefit greatly from the rising concept of ecosystem service. The understanding of how management changes relationships between multiple ecosystem services in orchards is a key milestone. In this study, we developed a modelling approach of this understanding. We considered five ecosystem services: fruit production, soil nitrogen availability, climate regulation, pest and disease control and water regulation. Together with these five services, we considered environmental disturbance due to pesticides. We simulated ecosystem functions and derived services using modelling tools parameterized

on apple orchards: the STICS soil crop model and the IPSIM modelling framework. Simulations were performed for 150 virtual apple orchard cropping systems designed by varying the modalities of nitrogen fertilization, irrigation, and the control of the main apple pests, codling moth, rosy apple aphid and apple scab. The results were analyzed using two-table multivariate analyses, hierarchical clustering and radar plots. We found conflicts and synergies among the studied ecosystems services. They were explained by underlying functions driven by agriculture practices. For example, N denitrification prevention appeared to be in conflict with yield, carbon sequestration and mean fruit mass, mostly due to nitrogen absorption. This function decreases when organic fertilizers are exclusively used and when irrigation inputs are reduced. The synergy between yield and carbon sequestration was mostly due to carbon allocation to fruit, which is clearly a specificity of orchards compared to other ecosystems. We identified five cropping systems optimizing both marketed and non-marketed services. They were characterized by organic or mineral fertilization not exceeding 70 kg N/ha/year, comfort irrigation, codling moth protection nets, apple scab resistant cultivar and the use of pesticides for rosy apple aphid control. This approach could be useful to guide the design of innovative apple orchard cropping systems aiming at finding acceptable tradeoffs among ecosystem services.

Keywords: fruit production, soil nitrogen availability, climate regulation, water regulation, pest and disease control, cropping system, modelling, STICS, IPSIM, PCAIV

SESSION 3: Environmental effects; drought

OS 4-1:

ASSESSING THE EFFECTS OF WATER STRESS ON PEACH FRUIT QUALITY AND SIZE USING THE QUALITREE MODEL

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According to climate change projections, increasing temperature and reduced water availability are expected in the near future. Therefore, growers must adapt their production systems, minimizing the negative effects of water scarcity, such as lower yields, and maximizing those positive, such as fruit-quality improvements. In this sense, process-based models could be useful tools for assessing fruit-tree responses to different irrigation strategies and support decision-making at the orchard level. In this study, an existing fruit-tree model (QualiTree) was adapted for describing the water stress effects on peach (Prunus persica L. Batsch) vegetative growth, fruit size and composition. New modules for calculating energy balance and water transfer at each fruit-bearing shoot, the growth of water sprouts and a vegetative growth reduction function dependent on tree water status, were implemented in QualiTree. Then, QualiTree was parameterized and calibrated for a late-maturing peach cultivar (‘Elberta’) using data collected under semi-arid conditions in Iran, under 3 different water irrigation treatment, corresponding to low, moderate and severe water stress.These different irrigation practices were simulated and outputs were confronted with experimental data. Fruit and vegetative growth variability over time was consistent with observed data on trees submitted to different irrigation levels. Fruit size class distribution shifted toward smaller sizes as water deficit intensified. Sugar concentrations in fruit flesh were well simulated. In general, the relative mean square errors were low. According to simulations, severe water deficit decreased fruit, leafy shoot and water sprout dry masses by 31%, 44% and 91%, respectively, but increased fruit sugar concentrations by 30%, when compared to the low stress treatment. The new implementations allowed Qualitree to represent the within-tree variability of water status and its effects on vegetative and fruit growth, as well as on fruit composition, proving the usefulness of QualiTree for designing innovative horticultural practices under a climate change scenario.

Keywords: water deficit; Modeling; growth;photosynthesis; fruit; composition

OS 4-2:

EFFECTS OF SOIL WATER DEPRIVATION DURING SUMMER ON TREE ARCHITECTURE OF THREE APPLE CULTIVARS GROWN UNDER MEDITERRANEAN CLIMATE

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Fruit trees grown under Mediterranean climate must face high temperatures and dry conditions during summer. Despite irrigation supply in most orchards of the area, water resource is likely to be reduced in the next future. In this study we aimed at analyzing the impact of soil water deficit during summer on tree development over two consecutive years, thus mimicking repetitive summer stresses. Twenty trees per cultivar, 'Braeburn", 'Fuji' or 'Ariane', were planted in 2015 in an experimental station near Montpellier (south of France). Different irrigation systems were applied per block and the orchard was equipped with tensiometric sensors to monitor soil water potential (SWP). During the first year of growth, no water deprivation was applied to allow trees to establish their initial structure. Water deprivation was then applied from July until early September in 2016 and 2017 on half of the trees, letting the SWP decreased from -50 kPa to -250 kPa. During winter, the architecture i.e. the number of leaves per shoot, the number of shoots per tree, their length category (short, medium, long) and organ final dimensions, was observed on all trees in 2016 and on a sample in 2017. The effect of water stress was analyzed at different scales of plant organization (leaves, shoots and a whole tree) for the three cultivars. A global decrease in vegetative growth was observed under water stress treatment, which is associated to changes in the trunks and lateral axes growth. Water stress had a strong effect on shoot neoformation process in 2016-2017 and on the number of shoots in 2017 whereas the effect on organ size, either leaves or internodes, was more limited. Despite these effects were observed whatever the cultivar, the three cultivars responded to water stress in quite different ways. Fuji exhibited limited modifications of tree architecture whereas Ariane and Braeburn appeared to be more sensitive.

Keywords: growth, branching, neoformation, organ size, water stress, apple tree

OS 4-3:

MEASUREMENT AND COMPARISON OF WATER USE IN AN INTERMEDIATE AND A MATURE AVOCADO ORCHARD

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The scarce water resources in South Africa are vulnerable to the increasing pressure of a changing climate. Current water problems have greatly affected the fruit industry, hence the need to optimise water use efficiency (WUE) as well as accurately estimate water use. With avocado production in South Africa being export-oriented and dependant on irrigation, proper water management is vital to minimising water use, while maintaining fruit yield and quality. Data were collected in two commercial 'Hass' on 'Dusa' orchards, one a 4-year-old intermediate bearing orchard and the other, a 10-year-old full bearing orchard. Actual orchard evapotranspiration (ETa) was measured continually using eddy covariance systems and the surface renewal method and a monthly crop factor was estimated. Measurements began in May and September 2017 for the intermediate and mature bearing orchard respectively. Transpiration was measured using the heat pulse velocity (HPV) sap flow method. Additional measurements included soil water content, predawn and midday stem water potential and orchard microclimate. Preliminary ETa results for the intermediate avocado orchard range between 0.1 and 2.8 mm day-1.

Keywords: sap flow, evapotranspiration, heat pulse velocity, eddy covariance, crop factor

OS 4-4:

FROM FIELD PHENOTYPING TO GWAS: A MULTI-SCALE, MULTI-ENVIRONMENT STUDY TO DECIPHER THE PHYSIOLOGICAL AND GENETIC DETERMINANTS OF APPLE TREE RESPONSES TO DROUGHT

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To cope with increasing water scarcity, breeding programs targeting for more efficient crop water use are crucial. This requires comprehensive knowledge of plant responses to drought, including the regulation of water status (by stomatal closure) and water-use efficiency (the ratio of carbon gain to water use). These questions have been scarcely studied in fruit trees, yet are of major economic importance. A main limitation results from the lack of high throughput techniques to characterize the physiological responses of hundreds of trees in the field as required to perform genetic analyses. We screened the diversity of European apple tree responses to drought, by unique combination of high-throughput and in planta measurements applied on two core-collections in Montpellier (France) and Bologna (Italy), respectively. A progressive soil water deficit was ensured and continuously monitored in both orchards, through summer irrigation withholding. In the whole collections (>250 varieties), a semi-empirical index (IPL index), computed from chlorophyll fluorescence measurements, was used as an indicator of leaf photosynthesis, whereas the variability of stomatal regulation and canopy structure was characterized by airborne imagery. The validity of high-throughput indices was assessed through fine measurements of water potential, stomatal conductance and photosynthesis on 6 varieties common to both collections. A large variability of IPL index was observed, with highly significant effects of the genotype and watering scenario (well-watered vs water stress). A genome wide association study (GWAS) was undertaken to identify the genomic regions controlling the variations detected. In parallel, the effect of interaction between Genotype and Environment (GxE) was dissected to highlight contrasted strategies of water use under drought across the varieties studied.

Keywords: Malus × domestica, core-collection, water deficit, photosynthesis, fluorimetry, water-use efficiency, GWAS

SESSION 4: Environmental effects; temperatures

OS 5-1:

DOES LACK OF WINTER CHILL CAUSE VARIABILITY IN FRUIT MATURITY AND QUALITY?

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Apple buds are dependent on sufficient winter chill for optimum budbreak and flowering in spring. Apples grown in Mediterranean-like climates (such as the Western Cape in South Africa) do not receive adequate chill during winter. Endodormancy is only partially released resulting in decreased, uneven and delayed bud break that leads to formation of “bare necks” (unbranched shoots), decreased vigour and an extended flowering period. To prevent this phenomenon, the use of chemical rest breaking agents has become the norm in these areas and profitable, sustainable annual yields would not be possible without it. To test the effect of inadequate winter chill on fruit quality, 14 ‘Golden Delicious’ orchards were harvested in two climatically contrasting production areas and fruit quality and maturity parameters (starch breakdown, firmness, weight, diameter, height, colour, total soluble sugars (TSS)) were measured. Results showed that fruit from the warm winter area have significantly higher variability in fruit maturity and lower fruit quality at harvest. Dormancy progression curves constructed for the two areas, using the shoot assay (measuring the time to budbreak under favourable conditions), showed that trees grown in the warm winter area reached a lower maximum endodormancy level later during winter compared to trees from the cold winter area. To link these two findings and determine the origin of the variability, we followed the development of the fruit in relation to its position on the tree/shoot, its time of flowering and its ultimate quality in the climatically contrasting areas. Results showed that the warm winter area had fruit of widely variable maturity at harvest originating from a protracted bloom period and its position on the

tree/branch. As these are symptoms of low chill accumulation associated with incomplete endodormancy release, it is likely that the lack of winter chill can cause high variability in fruit maturity and quality at harvest.

Keywords: apple, bud dormancy, fruit maturity, fruit quality, dormancy progression, chill accumulation

OS 5-2:

ARE YOUR ROOTS SUPPORTIVE? (SPRING CONDITIONS FOR WHOLE TREE ENERGETIC SUPPORT OF REPRODUCTION IN DECIDUOUS TREE CROPS)

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Demands for sugars peak when deciduous trees flower. At this time storages, that supported trees through winter, are the only carbon source for the renewed growth. Yet there is not enough sugar by the emerging buds (in fact, flowers and early fruits often weigh more than branches) and trees need to reallocate resources from stem and roots. This whole-tree sugar transport is activated by abiotic cues and we study what are the necessary environmental conditions for it to support vital spring growth. We found that temperature is a critical driver for late-winter carbohydrate transport, concurrence to the chill requirements concept. Yet we deducted that it's the low soil temperatures (still overlooked by the chill models) that determine if roots hydrolyze starch in spring, while the warmer canopy is already hauling sugars for bud-break. If soil is too warm, the canopy won't have access to the roots reservoirs, and will be forced to early bloom. These trees would probably not be pollinated, for orchards are unsynchronized and insects may not be active yet, and yields will be minimal. While this may be an effective survival strategy to minimize reproduction in dry and hot years, it's hindrance for farmers and we seek applied approaches to mitigate it in light of climate shifts.

Keywords: carbohydrate, climate, winter

OS 5-3:

IDENTIFICATION OF QTLS FOR CHILLING AND HEAT REQUIREMENTS FOR BUD DORMANCY RELEASE IN PRUNUS MUME AND THEIR CO-LOCALIZATION WITH THE DAM6 EQTL

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Bud dormancy is an important developmental stage that affects the blooming date (BD) and leafing date (LD) in fruit trees. Recent global climate change may affect the progress of dormancy, and the BD and LD. However, the genetic factors controlling the chilling requirement (CR) and heat requirement (HR) for dormancy release are yet to be elucidated. In this study, we conducted a quantitative trait locus (QTL) analysis using two F1 segregating populations derived from the cross between high-chill and low-chill lines of Japanese apricot (Prunus mume) to identify loci affecting these traits. We first constructed a high-density genetic map using the Genotyping-By-Sequencing technique. We observed four traits (CR and HR for dormancy release, BD, and LD) for several years. We also measured the transcript levels of DORMANCY-ASSOCIATED MADS-box6 (DAM6) in P. mume leaf buds in the dormancy release period as a dormancy-related phenotype. All five dormancy-associated traits were segregated in both populations in all analyzed seasons. For flower buds, BD was correlated with HR but not CR, suggesting that HR rather than CR contributed to BD. For leaf bud dormancy, CR, HR, LD, and DAM6 expression were highly correlated. The co-localization of significant QTLs controlling CR, HR, LD in leaf buds at the terminal region of linkage group 4 (LG4) suggested that this locus controls dormancy release and bud break. In addition, the DAM6 eQTL overlapped with this QTL, suggesting that this locus also contributes to the regulation of DAM6 transcription in leaf buds. Considering that chromatin modifications are known to be

involved in chilling-mediated down-regulation of DAMs in other Prunus species, the genes related to epigenetic regulation located in the LG4 QTL interval are good candidates for the genes controlling CR and HR in P. mume.

Keywords: bud dormancy, DAM, global climate change, low-chill, QTL, Prunus

OS 5-4:
RELATIVE STABILITY OF PEACH PLANTS TO ACID STRESS

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Oxides of sulphur and nitrogen cause the air contamination and have strong oxidation effect. There is possibility to oppose this effect on the plant. It connects with the activity of antioxidant system. It is ability to inhibit the process of free radical oxidation. Ascorbic acid and glutathione are important components of this system in the plant organism as they are able to redox reactions. But the role of these substances and degree of their changes in fruit plants tissues in condition of air contamination wasn't studied enough. We studied the growth of plant and changes in contents of ascorbic acid (AA), glutathione (GT) and total reduce activity (TRA) in peach plants leaves in condition of simulation acid stress. Acid stress was modeled with the use of simulated acid rain (SAR) sulfate and nitrate composition with different pH values with its periodic short-term acute effects during 4 vegetation periods in the field experiment. It was established that this concentration of H2SO4 is toxic to resistance cultivars of peach tree. It is displayed in damages of leaves, depression of growth up to 50% in comparison with control (pH≈6). The investigation was included 11 cultivars of peach (Prunus persica (L.) Batsch) on the almond stock (Prunus dulcis Mill.). The cultivars were selected on the content of ascorbic acid in fruits and the different reply to acid stress on outward symptoms. It was established the strong changes in elements of antioxidant system by the influence of acid stress. The different reaction of cultivars in these conditions was discovered. More early ripening cultivars were more sensitive to acid stress. The relative indexes of plant antioxidant system conditions were calculated. The relative evaluation the sensitivity of studied cultivars to the acid stress was done by that index. We propose to use index of red-ox activity of tissue as a test index for the estimation of different peach cultivars stability to acid stress.

Keywords: acid stress, peach plants, antioxidants, ascorbic acid, glutathione

COLLOQUIA-2

KEYNOTE 2

MODELLING TREES IN THE CONTEXT OF THEIR ENVIRONMENT

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In my presentation, I will survey modelling techniques and selected models designed to explain the interplay between genetic, physiological, and environmental processes that underlie tree development. The presentation

will emphasize the essence of two classes of architectural models, which approach tree modelling using recursive or self-organizing techniques; the modelling of endogenous signals that coordinate tree development, the creation of tree models responding to environmental input; and the modelling of the feedback loop of interactions between a tree and its environment. I will also show how small modifications of the models and their parameters yield diverse tree forms observed in nature. These general concepts will be illustrated using case studies of simulating carbon allocation and partitioning, plant-light interaction, and the effects of management practices. The talk will be concluded by highlighting open problems concerning functional-structural tree modeling in the context of environmental interactions.

SESSION 6: Modelling within-tree processes

OS 6-1:

ASSESMENT OF THE ROLE OF AGE AND LIGHT AVAILABILITY IN LEAF MORTALITY IN MANGO TREE

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The branch autonomy principle states that the branch carbohydrate economy can be largely independent of the other branches of a tree. This may influence fruit growth and affect global crop yield. While this concept has already been tested on different fruit tree species, branch autonomy has not been characterized with respect to fruit growth in the mango tree. The mango tree, a major fruit production in tropical and subtropical regions, exhibits phenological asynchronisms indicating decorrelated development of branches within a tree and thus a possible autonomy among them. To assess this autonomy, we used a quantitative model of the vegetative and reproductive development of mango tree architecture and fruit quality. This functional-structural plant model combines complementary architectural, phenological and ecophysiological knowledges and relies on two sub-models parameterized for the cultivar Cogshall in Réunion Island. The first sub-model simulates stochastically the development of mango tree architecture, growth units and inflorescences, based on empirical rules. A recent improvement was to take into account leaf mortality to achieve more realistic foliage distribution. Fruit growth and quality development are simulated by a second sub-model that simulates carbon- and water-related processes occurring at the fruiting branch scale during the fruit-growing season. This model assumes the independence of the fruiting branches in terms of carbohydrates synthesis and allocation. We conducted a sensitivity analysis on the size of the fruiting branches and compared the simulated and measured fruit fresh masses at maturity in order to assess the level of autonomy of the branches regarding carbohydrates supply for fruit production. Our results show that the leaf to fruit ratio and the simulated fruit fresh mass increase proportionally with the size of the branches. The comparison with measured fruit masses indicates that a branch size of 2 to 3 GUs are sufficient with respect to fruit growth.

Keywords:Mangifera indica, tree architecture, functional-structural plant model, carbon allocation, 3D digitizing

OS 6-2:

ARCHITECTURAL FACTORS AFFECT FRUIT SET IN MANGO: EVIDENCE AND MODELLING

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Fruit set, the transition from the flower to the growing fruit, is an essential step for fruit production. This process can be affected by environmental factors and by endogenous factors at the tree scale. The identification of these factors is important to improve cultivation practices and increase fruit set and fruit production. In this study, we focused on the identification of architectural factors affecting fruit set, with the mango tree, cv Cogshall, as a case study. The hypothesis is that topological, phenological and morphological characteristics of the flowering terminal growth unit affect its probability of fruit set. Two datasets describing exhaustively the vegetative and reproductive development of mango trees during two and three years, respectively, were analyzed. Generalized linear models were used to test the effects of the characteristics of the terminal growth units on their probability of fruit set. The effects of factors at a scale larger than the growth unit, such as the tree or the year were also tested. The date of burst of the terminal growth unit, i.e. its age at the time of flowering, its topological position, apical or lateral, and the number of inflorescences on the growth unit affected significantly its probability of fruit set during most of the years. The probability of fruit set was also affected by the year, by the tree and by the previous year tree yield, suggesting that factors at the tree scale and environmental factors were involved in fruit set. These results are useful to design cultivation practices aiming to improve mango tree fruit set. They will also be integrated in a model of mango fruit yield and quality at the tree scale to simulate more accurately fruit set and fruit production.

Keywords: flowering, growth unit, inflorescence, Mangifera indica, tree architecture, yield

OS 6-3:

FRUIT WATER CONTENT: A BENEFIT IN THE FRUIT CARBOHYDRATE ACCUMULATION SIMULATION

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The carbohydrate is one major assimilate determining the fruit growth and quality, with its roles as raw materials for growth and as carbon reserves for quality. Fruit water content, an indicator of water status in fruit, is closely related to the fruit carbohydrate metabolism. A semi-mechanism model developed by Génard et al. (2003) is modified with the consideration of fruit water content to simulate the carbohydrate accumulation during the fruit growth with different cultivation practices. The fruit water content is applied to regulate the processes controlling the conversions from soluble sugars to starch as well as to synthesis compounds other than carbohydrates. The data collected from three experimentations on tomato, a model plant for fleshy fruit, grown under different conditions (the first experiment with standard condition; the second with high and low fruit loads treatments; the third with full irrigation and water deficit treatments) is used to evaluate the model's performance. Taking fruit water content into consideration, the model well simulates the soluble sugars and starch accumulation during the fruit growth under different conditions. A sensitivity analysis indicates that both soluble sugar and starch simulations are sensitive to the parameters related to the conversion of soluble sugars to synthesis compounds other than carbohydrates, while only starch simulation is sensitive to the parameters related to the interconversion between soluble sugars and starch. Fruit water content with its potential influence on carbohydrate metabolism could bring benefit to the simulation of fruit carbohydrate accumulation.

Keywords: fruit water content, sugar metabolism, modelling, sensitivity analysis

OS 6-4:

USING T-LIDAR SCANNING FOR HIGH-THROUGHPUT PHENOTYPING OF APPLE TREE ARCHITECTURE

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Genotypic variation in apple tree was reported but phenotyping architecture on large population remains challenging. In this study, we investigated the possibility to extent methodologies based on T-Lidar scanning for quickly evaluate architectural traits on an apple core collection. Experiments were performed on 2- and 3-year-old trees in winter and summer 2016 and 2017. In 2016, 12 trees were precisely scanned to assess our ability to extract architectural traits from T-Lidar scans. In 2017, the whole population was scanned with a distance of 10 meters between each scan position. Winter data were used for assessing topological traits, whereas variables related to the vegetative development were computed from summer data. Point clouds were analyzed using two software solutions: Computree for segmenting trees and Plantscan3D for extracting architectural traits. A sensitivity analysis on the parameters of the noise filtering and reconstruction algorithms was first conducted. The quality of the method was evaluated by comparing T-Lidar reconstructions with digitizing data. In 2016, tree reconstruction gave promising results with R^2 values equal to 0.91 and 0.98 for the total number of axes and their length when T-Lidar or digitizing data were compared. RMSE of both variables remain low for shoots longer than 5 cm. However, a significant number of short shoots were not detected by the T-Lidar. Some first analyses on 2017 summer data showed a high heritability (> 0.8) for global traits such as the tree volume, height, width, or foliage density. A clustering method was then used to define architectural morpho-types based on these variables. Forthcoming works are undergoing for extracting topological traits on the whole population and to extract new variables related to vegetative development. Nevertheless this first step suggests that this method could be adapted for phenotypic architectural traits on which genetic analyses could be performed.

Keywords: apple tree, topology, geometry, T-Lidar, genotypic variability

POSTER PRESENTATIONS

P 1:

INTERNAL FRUIT QUALITY DEPENDS ON THE REGULATION OF APPLE-TREE VEGETATIVE GROWTH

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The effect of tree growth control methods on the accumulation of bioactive compounds in apple fruit was investigated with apple cultivar ‘Rubin’ on rootstock P 60 at the Institute of Horticulture Lithuanian Research Centre for Agriculture and Forestry in 2016-2017. Tree growth was regulated by prohexadione-calcium at different rates and time, tree trunk incision by chain saw and summer pruning. Beside basic internal quality parameters (soluble solids, sugar content, acidity, dry matter) accumulation of phenolic and triterpene compounds was investigated. Trunk incision significantly reduced triterpene concentration to 10,853 mg g-1 DW, while summer pruning had the opposite effect – apples accumulated significantly higher content of triterpenes (13,727 mg g-1 DW). Growth regulator Regalis™ did not had impact on triterpene concentration in apples. Trunk incision didn’t had impact on the change of phenolics. Summer pruning significantly increased phenolics in apples (1,905 mg g-1 DW), whereas the use of Regalis™ had a drastic decrease of phenols to 1,307 mg g-1 DW.

Keywords: Malus x domestica, phenolics, triterpenes, trunk incision, Regalis

P 2:

THE ROLE OF LIGHT IN RED SKIN COLOUR OF PREMP009/PIQA®BOO® INTERSPECIFIC PEAR

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'PremP009' (piqa®boo®) interspecific pears have a bright red skin colour that differentiates them in the market. It is important to have an understanding of how this colour develops in order to have a consistent product. Observations of 'Prem 009' (Piqa® Boo) fruit in the orchard suggested that there was a lower red colour intensity in areas of the skin that were covered by a leaf. This suggests that light plays an essential role in skin colour development. A trial was designed to examine the role of light in the development of red colour in 'Prem009' pears. Treatments were applied to exclude light exposure to developing fruit for a period of 1 month, or for the remainder of the season, by bagging fruit at either early, mid, or late stages of fruit development, approximately 30, 60, and 90 days after full bloom, respectively. All treatments were sampled at normal harvest time and assessed for anthocyanin content and colour. All bagging treatments resulted in loss of red colouration and fruit skin appeared white on removal of the bags. Colour was visually observed to have recovered after approximately 30 days of normal light exposure from the early and mid-season one-month treatments. Skin anthocyanin data will be presented to illustrate recovery of colouration after bagging.

Keywords: PremP009, piqa®boo®, anthocyanin, light

P 3:

INFLUENCE OF CLIMATIC ELEMENTS ON THE QUALITY OF FUJI APPLES IN KOREA

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The correlation between the climatic elements for 10 years in Korea and the quality of Fuji apple was investigated. The correlation coefficient between fruit weight and number of raining days was 0.41, and the correlation coefficient between fruit weight and other climatic elements was lower than this. The L(length)/D(diameter) ratio, which indicates the shape of fruits, was low in correlation coefficient with maximum temperature, inimum temperature, average temperature. L/D ratio was higher with number of raining days and rainfall, and with more sunshine hours. Soluble solid content was negatively correlated with the rainfall and number of raining days, and positive correlation with average temperature and sunshine hours. Correlation coefficient between acidity and climatic factors were very low. The value of Hunter a, red color indicator of fruits, tended to low as the maximum temperature, minimum temperature and average temperature increased. The correlation coefficient between Hunter a value and number of raining days and rainfall were low. But, Of the monthly climate factors, number of raining days and rainfall in September~October tended to have a large effect on fruit color.

Keywords: Climatic element, apple, colour, quality

P 4:

ASSESSMENT OF MANGO TREE - BLOSSOM GALL MIDGE MANAGEMENT SOLUTIONS FROM IN-SILICO EXPERIMENTS: OVERVIEW OF AN ON-GOING MODELLING APPROACH

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Mango (*Mangifera indica*), a major fruit production in tropical and subtropical regions, is facing many production constraints. Mango yield is irregular across years, fruit quality is heterogeneous at harvest, and mango tree exhibits phenological asynchronisms within and between trees that result in long periods with phenological stages susceptible to pests and diseases. Among them, the mango blossom gall midge (MBGM, Procontarinia mangiferae) is a major pest of mango tree which can cause significant yield losses by damaging mango inflorescences. Management solutions to improve fruit yield and quality while reducing the use of pesticides are required. A crop-pest model applied to the mango-MBGM system is currently being developed for the assessment of different MBGM management levers from in silico experiments. These management levers include soil cover with woven plastic mulching during flowering, used as a physical barrier to break the MBGM development cycle, and manipulation of mango phenology to synchronize flowering at the orchard scale, combined with pesticides applications. To develop the crop-pest model, we relied on a functional-structural plant model (FSPM) that describes mango tree vegetative and reproductive architectural development and phenology, and fruit growth and quality development. The FSPM was scaled-up at the orchard level and coupled with a model currently developed for MBGM. The MBGM model aimed to describe i) orchard colonisation by exogenous females and their displacement to mango resources (mainly inflorescences) according to their spatio-temporal distribution within the orchard, ii) female egg-laying and larval and pupal development, iii) MBGM damages on inflorescences, and iv) adult and larval mortality induced by soil cover and pesticide applications. Virtual experiments will be performed with the crop-pest model to assess the effects of the management levers on fruit yield and quality according to exogenous pest pressure. The on-going modelling approach and preliminary results are presented and discussed.

P 5:

ESTIMATING FRUIT ORCHARD STOMATAL CONDUCTANCE AND TRANSPIRATION UNDER DYNAMIC ENVIRONMENTS

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Fruit tree growers perceive the need for decision making tools for their water management as they realize how such climate change and, more specifically, water scarcity is affecting the performance of their orchards. Furthermore, fruit trees, including olives, citrus and nuts have different hydraulic conductance, turgor loss point or fruit growing mechanisms which largely determine their response to environmental changes. Despite the multitude of models, estimating stomatal conductance and transpiration at orchard level remains a challenge. In this study, we applied a direct parameterization of the Penman–Monteith equation developed to compute diurnal courses of orchard canopy conductance (gc) from sap flow in sub-hour resolution for both day and night conditions. We found that the model was sufficiently sensitive for detecting diurnal variation in gc and for predicting sap flow from environmental variables under various atmospheric evapotranspirative demands and differing levels of soil water availability. We used an extensive experimental dataset of apple tree transpiration from 2011 in various sites ranging from very warm to temperate. The daily pattern of canopy conductance for water vapour at canopy level provided by the model offers an unprecedented insight into rapid response to humidity of different cultivars as well as their light saturation levels. The model can be used to better understand the physiological (and productive) behaviour of fruit tree crops in different environments, particularly in response to drought stress.

Keywords: apple, trunk heat balance, Penman–Monteith

P 6:

ANATOMICAL CHANGES IN THE PEEL OF SUN DAMAGED POMEGRANATES

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Pomegranate sunburn is a physiological disorder that is caused by environmental factors such as high temperature, light and radiation, and leads to productivity losses and deterioration in pomegranate cultivation. The pomegranate peel exposed to high temperature and solar radiation undergoes a brown or black discoloration. To characterize the bronzing phenomenon and its development in pomegranate fruit tissues, we conducted an anatomical examination of bronzed fruit. At the end of the study, it was determined that sunburns on the peel of pomegranates first appeared in the cuticle layer, so that the cutaneous layer and epidermis layer under the cuticle began to disperse and disintegrate, and the parenchyma cells were progressively damaged. Also, light microscope images showed that before the visible change of color on the peel of fruit, a number of cellular activities such as accumulation of phenolic compounds, cell wall thickening and lignin-up take place especially among cells close to the epidermis, which is regarded as a symptom of sunburn. At the end of this study, the anatomical changes were found to have begun before the visible signs of sunburn occurred in fruits, so the most suitable period was determined for the applications that will be performed to prevent sunburn.

Keywords: Pomegranate, sunburn, peel, anatomy, cuticle, epidermis, high temperature

P 7:

TOPO CLIMATE EFFECTS ON THE PERFORMANCE AND WINE QUALITY OF THIRTY GRAPEVINE CULTIVARS UNDER DESERT CONDITIONS

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Desert conditions are considered beyond the climate frame of the traditional wine producing belts. Nevertheless, irrigation practices have enabled the reassessment of wine production under desert environments. The broad genetic diversity encompassed by Vitis vinifera bears capacity to provide varieties with ability to produce high quality wines. The Negev desert offers diverse topo climate conditions, with altitudes ranging from 250 to 900 m asl. The objectives of the present study are two: identify cultivars obtaining a suitable vine performance and high-quality wine under desert environments; and, analyze the environmental effects on the metabolic profile of the ripening berry. Experiments take place in two vineyards: Ramat Negev R&D Center, and Ramon, at 300 and 850m asl, respectively. Both vineyards share a similar experimental setup, comprising 10 white, and 20 red cultivars. In the first two harvest years (2015 and 2016), Chennin Blanc and French Colombard among the white cultivars, and Petit Verdot and Malbec among the red ones, exhibited promising wine qualities, with some advantages to the relatively cooler region, Ramon. In 2017, a consistent two-week difference between the two vineyards was preserved from emergence to véraison, while the differences among cultivars at each site were small. The delay in Ramon vineyard brought bloom to coincide with a severe heatwave on mid-May, negatively affecting fruit yield of some cultivars. Nevertheless, the ripening period from véraison to harvest (July-August) is the most critical one. This period was averagely 50% longer in the significantly warmer Ramat Negev vineyard, where Brix often failed reaching the harvest thresholds. Also, considerable numbers of clusters shrank in many cultivars in Ramat Negev before harvest, and hence, reduced the harvestable yields. Metabolic analyses of berry skin and pulp are currently carried out in order to elucidate environmental and varietal effects on primary and secondary metabolism.

Keywords: Arid, daily-degree-days, above-optimum temperature, secondary metabolites, Vitis vinifera

P 8:

POMO-TECHNOLOGICAL PROPERTIES OF INTRODUCED SWEET CHERRY CULTIVARS IN ECOLOGICAL CONDITIONS OF PODGORICA (MONTENEGRO)

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Montenegro's production of sweet cherry (Prunus avium L.) doesn't fulfill its capacities nor the necessary market needs for this fruit. In order to increase and improve the production of sweet cherries an introduction of new and more productive cultivars in terms of higher fruit weight is needed, as well as the excellent pomo-technological characteristics, good transportability characteristics and late season ripening. Cultivation of different ripening season cultivars is necessary in order to meet the demands of consistent and extended season offer. This study aims to examine the characteristics of the recently introduced sweet cherry cultivars in the agro-ecological conditions of Podgorica on rootstocks Gisela 6 and Prunus mahaleb in order to select the most promising ones for intensive production. The research has been conducted in a collection orchard situated within 10 km distance from Podgorica, and it covered period from 2015- 2017. The study included eight sweet cherry cultivars: 'Burlat', 'Sunburst', 'Giorgia', 'Van', 'Ferrovia', 'Lapins', 'Starking Hardy Giant' and 'Stella'. Pomo-technological parameters related to fruit weight and stone weight, fruit flesh firmness, colour, fruit stalk length and randman, dry matter content and acid content were determined. Phenological observations including ripening time, harvest duration and yield per cultivar were examined. The fruit weight in most of the examined cultivars was in the category of medium big to big (7 -12g) while the shape of fruit was within the range of 92,5-96,2%. The highest fruit weight (9,7 g) and randman (95,77 %) was measured in cultivar Sunburst while the lowest fruit weight (6,57 g) and randman (94,15 %) were noted in cultivars Van and Burlat, respectively. Measurements of pedicel length showed that the longest pedicel was noted in cultivar Sunburst (4,7cm) and the shortest with cultivar Van (3,28 cm). Results showed that dry matter content ranged from 14,39 – 17,90 % with cultivar Bing having the highest value (17, 90 %) and Starking Hardy Giant having the lowest value (14,39 %) of dry matter content. Total acid content had the lowest value in the fruits of cultivar Sunburst (0,42 %) and the highest in fruits of cultivar Starking Hardy Giant (0,55 %). The time leaps between the earliest and latest ripening cultivar was 17 days. The time of ripening was between the period of 24.05. (Starking Hardy Giant) to 10.06. (Ferrovia). Highest yielding cultivar was Van (22,32 kg per tree) while the lowest yielding cultivar per tree was Ferrovia (19,11 kg). The average yield for the studied cultivars was 21,61 kg.

Keywords: sweet cherry, cultivar, time of ripening, yield

P 9:

EFFECTS OF SEMI ARID CONDITIONS ON FLOWERING, FRUIT SET, YIELD AND OIL QUALITY OF OLIVES "*Olea europaea* L."

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Olive trees are well adapted to hot and dry conditions and have been designated as drought tolerant. Such type of climate and conditions led to irregular and uneconomical yields. In the present study, olive cultivars grown in southern Egypt were monitored during the growth seasons to observe the flowering, fruit set, fruit growth and the quality of the oil in response to different environmental factors. The results indicated that high temperature, high irradiance and inadequate rainfall, during growth season, restrict flowering and fruit set of two oil cultivars such as 'Picual' 'Manznillo' compared to 'Koroneiki', 'Dolci', 'coratina' and 'Maraki' that gave a regular production. There were reasonable effects on fruit development of the producing cultivars. The fruit weight, size and flesh/stone ratio were slightly lower than the typical for the cultivars, while the oil and moisture contents were within the range. 'Maraki' had the highest percentage of oil followed by 'coratina' cultivar. The oil characteristics were found to be affected as the fatty acids profile was slightly changed. The physiochemical and antioxidant properties of the oil were within the limits of the extra version oil of the cultivars. Our results indicated that some of the studied oil olive cultivars can adapt the condition in southern Egypt region and have morphological characteristics, economical yield and fruits that can be used for extra version oil production.

Keywords: Temperature, rainfall, flowering, , oil quality, fatty acids

P 10:
AN APPROACH FOR ESTIMATION OF PISTACHIO ROOT DEPTH IN SALINE CONDITION

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Root depth is one of the important crop parameters in irrigation management and planning. This parameter is influenced by various factors such as physicochemical properties of soil, geographical region, root type and management practices. In the case of horticulture (e.g. perennial trees), determination of accurate root depth always has been a challenge, compared with the annual crops. Numerous studies have been conducted to document tree rooting depths based upon field studies and observations. They reported that whilst genetic characteristics of the trees play some part in the rooting depth, soil condition and water management are of overriding importance in estimating root depth of the under-irrigated trees. Pistachio (Pistacia vera L.) is a sub-tropical tree, which its high tolerance to the soil water and salinity along with its promising economic gains are the major reasons for development of this crop to many parts of the world e.g. Iran, Middle Eastern, some European and American countries. Main objective of this research was to introduce an approach for estimation of pistachio root zone depth (Drz) in saline condition. This study was carried out in Yazd province, Central Iran, which is identified as an arid and severe water scarce region in addition to high levels of soil and water salinities. This approach is based on the well-known root water uptake pattern of 40-30-20-10 for successive quarters of the root zone. This Approach incorporates a trial/error procedure and includes soil water salinity (ECsw), Leaching Fraction (LF), depth of irrigation water (Diw) and pistachio evapotranspiration (ET) parameters. Moreover, based on the concept of Leaching Fraction (LF) in saline condition, a control point was designed for evaluation of the final output (Drz) by considering and comparing the predicted and measured LF and ECsw values. This approach starts with preliminary assumption of Drz and ET parameters and stops by equilibrium of predicted and measured LF and ECsw values in a specified point of the root zone profile (e.g. in 120 cm, that known as a hypothetical control point). In a field experiment, measured ECsw of the 120 cm soil profile was to about 23 dS/m, which yielded an average LF of 0.53 for the specified control point. Also, total depth of applied water was measured to about 1655 mm. Successive changes of Drz and ET parameters gained final Drz of pistachio tree to about 340 cm. Considering the final output (Drz=340 cm), good agreements were observed between measured and predicted ECsw and LF parameters for the above mentioned control point, which show the approach capabilities in estimation of pistachio rooting depth in saline condition. However, more researches suggest to be carried out in other climates, soil types, salinity levels and etc.

Keywords: Applied Water, Pistachio, Salinity, Leaching Fraction, WFD device.

P 11:
ASSESSMENT OF PLANT GROWTH IN GUAVA CULTIVARS UNDER WATER STRESS

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Different potted guava cultivars were evaluated for potential tolerance under water stress conditions maintained for sixteen weeks in a greenhouse during summer season. Plant growth was significantly arrested by water stress in both cultivars maintained at 75% (T1) and 50% (T2) field capacity compared with plants maintained at 100% field capacity (To). Net plant height and number of leaves were higher in ‘Pyriform’ (Surahi) compared with ‘Round’ (Gola) after water stress and recovery. No genotypic differences were observed for net leaf length however, expansion in leaf width was higher in ‘Pyriform’ compared with ‘Round’. Ratio LL:LW was higher in ‘Round’. Net chlorophyll contents were more in ‘Pyriform’ after recovery. Genotypic differences were non-significant for net fresh weight and dry weight of leaves. Overall, cultivar ‘Pyriform’ performed better compared with ‘Round’ under water stress conditions indicating its higher potential to pass through the stress conditions

compared with 'Round'. Further studies on evaluation of field grown mature plants under water stress is in progress. Such studies shall be promising towards selection of better cultivar against water stress.

Keywords: Drought, plant growth, Gola, Surahi

P 12:

IDENTIFICATION OF THE MAJOR FACTORS AFFECTING PISTACHIO PRODUCTION IN SALINE CONDITION (CASE STUDY: YAZD PROVINCE, CENTRAL IRAN)

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Iran is known as the biggest Pistachio (Pistacia Vera L.) producer in the world. In 2014, for instance, Iran and the United States were the major producers of pistachios, together accounting for 76% of the total world production. However, while less than 1.4 tons pistachio is produced from each hectare of Iranian orchards that of US is more than 2.6 tons per hectare. At the same time, high yielding pistachio orchards with more than 12 tons per hectare are reported in Iran. This can be related to several different factors such as climate, geography, water shortage or quality, soil physicochemical properties as well as plant properties. The present study was aimed to evaluate the most important factors affecting the variations of pistachio production in salt affected commercial pistachio orchards of the central part of Iran as well as to identify the most limiting factors. For this purpose, twenty four representative commercial pistachio orchards, located in Yazd province, were selected and evaluated for the major yield-related parameters. Correlation matrix and Factor Analysis (FA) approaches were used to identify the most effective factors on pistachio production. Several different factors including climate (e.g. temperature, humidity, wind speed and etc.), geography (latitude, longitude and altitude), quality and quantity of water and soil resources (e.g. salinities of irrigation water and soil, leaching fraction, depth of applied water and etc.), soil physical properties (sand, silt and clay contents, bulk density, field capacity and PWP) as well as pistachio tree features (age, daily and seasonal evapotranspiration) were correlated with the pistachio yield. Results of this investigation showed that latitude (r=0.49), air humidity (r=-0.43), evapotranspiration (r=0.60), soil moisture at the PWP point (r=-0.30) and leaching fraction (r=0.33) parameters had crucial role on pistachio yield. Whilst, other parameters like sunshine hours, longitude and irrigation water pH had lower and insignificant effects on yield of the representative commercial pistachio orchards. Overall, irrigation system optimization, pistachio tree rejuvenation as well as increasing soil water holding capacity are recommended for improvement of pistachio production in the studied region.

Keywords: Factor Analysis, Correlation Matrix, Pistachio, Salinity, Yield.

P 13:

TRANSCRIPTOME PROFILING OF COLD HARDINESS RELATED GENES IN PEACH TREE (*Prunus persica*) SHOOTS

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Cold hardiness of peach (Prunus persica) trees varies with cultivar. To search the genes responsible for the cultivar difference, we compared the transcriptomes from two peach cultivars showing different cold hardiness by using next generation sequencing. 'Soomee' and 'Kiraranokiwami' peach trees are known to be relatively cold-tolerant and -susceptible, respectively. RNAs from shoots were prepared for the transcriptome analysis. The shoots were collected in October and January from the field-grown 5-year-old trees of the two cultivars. Following the transcriptome sequencing, total bases of 4.8-7.1 Gb were obtained and 94-97 % of total reads were mapped to the reference peach genome. Totally, 190 and 262 differentially expressed genes (DEGs) were found in October and January, respectively, from the two cultivars. Gene set enrichment analysis revealed that most of the DEGs belonged to cell wall macromolecule catabolic process, signal transduction, ADP binding, trehalose biosynthetic process, and integral component of plasma membrane along with several uncharacterized proteins and long noncoding RNAs. The in silico results were validated by performing reverse transcript quantitative

polymerase chain reaction against ten DEGs showing the highest fold change both in October and January. The present results demonstrate the cultivar difference in cold hardiness at transcriptome level.

Keywords: Cold acclimation, Cold hardiness, Transcriptome analysis.

P 14:

WATER RELATIONS IN DIFFERENT SWEET CHERRY (PRUNUS AVIUM L.) CULTIVARS IN CHILE

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Water availability is of paramount importance in plant production, particularly in Mediterranean climates with dry summer seasons, because of the impact on plant carbon gain and hydraulic failure events upon water scarcity conditions. Besides, the so far recognized global warming is negatively affecting the availability of irrigation water leading to an effort for breeding fruit species more resilient to water stress. In Chile, cherry production is of great economical importance, with productive areas under water shortages and high evaporative demands, compromising the crop yield and sustainability. The aim of the present study was to assess the stomatal sensitivity, photosynthesis, hydraulic capacity and vulnerability, of different sweet cherry cultivars (Prunus avium L): Regina, Lapins, Sweet Heart and Santina, in central Chile. All the varieties were exposed to irrigation withhold previous to harvest. Also, pressure vs volume curves were carried out in leaves. According to our results, Lapins is highly sensitive to water stress compared to the other varieties in the mid-term, reaching stem water potential values of nearly -2.3 MPa, much more negative than their counterparts, likely because of its less sensitive stomatal regulation. So far, the osmoregulation capacity and the elasticity module are similar between varieties. All these results will be discussed in the context of the hydraulic vulnerability of the cherry varieties.

Keywords: stomatal sensitivity, photosynthesis, hydraulic capacity, hydraulic vulnerability, Regina, Lapins, Sweet Heart, Santina

P 15:

CHILLING ACCUMULATION BEFORE AND AFTER A REST-BREAKING TREATMENT AND ITS RELATION TO HEAT REQUIREMENT FOR BUDBURST IN SWEET CHERRY TREES

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Climate change is evident in the central zone of Chile, where fruit production has experienced problems due to the lack of cold accumulation in the winter or low temperatures during the budbreak, especially in sweet cherry trees that have shown late and irregular flowering and erratic fruit setting. This situation has been more evident in the last decade. To avoid or minimize these negative consequences, hydrogen cyanamide (HC) is applied. In some cases, although cooling requirements are met in winter, HC is used to advance and / or concentrate budburst and blossom. The spray recommendation according to the days before the estimated budbreak or the historical date is no longer sustainable, since the cold and heat of winter in early spring vary from season to season. Much is known about the positive effect of chilling accumulation before HC treatment, and it is assumed that not chilling is effective once HC us sprayed. The aim of this study was to determine the effect of chilling accumulation before HC treatment and the low temperatures effect after application. One trial was performed in sweet cherry trees cv. Bing, consisting of applications of HC at 1,5% a.i., according to chilling accumulation 1100, 1200 y 1300 Richardson Chilling Units (CU), plus an un-sprayed control; additionally a treatment of 1% HC sprayed after 1300 CU, was included. Afterwards, one and two-year-old branches were stored in a cold room at 5°C, to reach 100 and 200 CU, after that branches were exposed to a growing conditions in chamber with light and temperature controlled. Chilling accumulation before HC application did not concentrate budburst, showing a similar pattern with 1100, 1200 and 1300 CU. However, HC applied after 1200 CU advance budburst in c.a. 7 days compared to the control, reducing heat requirement to 50% budburst. On the other hand, late application (1300 CU) of 1,5% HC had no effect on budburst advance, but when HC was sprayed at 1% heat requirements were also reduced being similar to 1,5% CH at 1200 CU. It was possible to determine that cold-air conditions

(5°C) after HC treatments have a positive effect on reducing heat requirements for burd-burst, but is ineffective when HC is applied after 1300 CU.

Keywords: budburst patern, cv. Bing.

P 16:

MECHANICAL THINNING OF APPLES REDUCES FRUIT DROP

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The effect of the intensity of mechanical thinning with the device Darwin 250 on fruit drop and final fruit set was investigated in the years 2011 and 2014 on apple trees with varying flower set considering the cultivars 'Elstar', 'Gala' and 'Pinova' grafted on M9. Thinning was carried out at balloon stage (BBCH 59) at constant vehicle speed of 8 km h-1 with rotational frequencies of 200 rpm, 240 rpm, 280 rpm, and 280 rpm. By calculating kinetical energy at the end of the rope, thinning treatments equal 0.68 J, 1.01 J, 1.42 J and 1.89 J. Removal of flowers increased with enhanced rotational frequency. Additionally removal of flowers was affected by flower set and increased at higher abundance of flowers. Thinning showed no effect on fruit drop in 'Elstar' and 'Pinova' in 2011. In 2014, thinning treatment of 1.42 J and higher reduced fruit drop on 'Elstar' and 'Gala' due to a reduced number of sinks competing for available carbohydrates. Consistently, fruit drop was enhanced on trees with high flower set in comparison to trees with low flower set in every trial. Final fruit set underrun yield capacity of the trees when trees had flower set of 1-200, and on trees with higher flower set when thinned above 1.01 J. Therefore thinning above 1.01 J caused over thinning in all trials.

Keywords: precision horticulture, crop load, Malus x domestica, flower thinning,'Elstar', 'Gala', 'Pinova'