APMed

2012-2015

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Highlights

Apple and Peach in Mediterranean orchards – Integrating tree water status and irrigation management for coping with water scarcity and aphid control

- In the context of climate change, we need more research on how fruit trees adapt to water scarcity and on the effects of tree water status on pests and diseases, with an applied issue on how the grower can save water while optimizing fruit quality and orchard profitability.
- Adult apple and peach trees in contrasted environments were used to determine optimized Regulated Deficit Irrigation (RDI) for good yield and reduced impact of pests and diseases. Investigation on apple hybrids also identified promising traits for selection by breeders.
- Decision rules for irrigation must account for crop load. For apple trees, shade-nets reduce water consumption whereas for peach trees, a 25% decrease in water supply compared to crop coefficient-driven irrigation decreases pruning needs and diseases with only a slight reduction of the yield.

Apple
Peach
Water scarcity
Pests
Yield

Objectives

- To explore, on one-year-old apple trees issued from an apple progeny, the genetic range of morphological and functioning adaptations to water restriction, and to analyse how these traits simultaneously interact to determine the potential for tolerance to soil water restriction.
- To analyse on potted- and orchard- apple and peach trees the effects of tree water and nutrient status on aphid infestations and on main storage diseases.
- To investigate on orchard peach and apple trees the effects of tree water status, crop load and nitrogen supply on the decision rule for irrigation scheduling and the effects on yield quantity and quality, and to examine the effects of coloured and shading nets on tree water status and yield.
- To integrate architectural and functional aspects into quantitative models to render satisfactorily the effects of water restriction on fruit size and aphid infestations on fruit trees.

Scientific results & innovation potential

- ✓ Both genetic variability and phenotypic plasticity play a role in the response of apple trees to water stress. An applied interest for the breeder is that the reduction of leaf area and the percentage of temporary stem growth cessation are reliable and easy-to-collect proxies to phenotype the effects of water restriction on shoot growth.
- ✓ Under Mediterranean sunny conditions, shading is an effective strategy to save water in apple orchards, without negative effects on yield and quality.
- ✓ For apple and peach orchards, crop load should be considered to finely tune stem water potential (SWP) thresholds for irrigation scheduling. For a given crop load in peach, reducing irrigation water by up to 25% entails a slight decrease of yield compared to crop coefficient-driven irrigation but significantly decreases post-harvest diseases and summer pruning needs, resulting in an enhanced profitability for the grower.
- ✓ For apple and peach trees, aphid infestation is mainly related to shoot growth and only little to nitrogen concentration. Therefore, irrigation strategies should reduce severe pruning to avoid vigorous growth. Restricting water supply limits aphid development through its effect on growth, sap viscosity and leaf temperature.
- ✓ In a modelling perspective, Functional Structural Plant Models could now render satisfactorily the effects of water restriction on fruit size and aphid infestations on fruit trees.

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METHODOLOGY

Protocols to investigate genetic variability on young-potted trees and shading effects on adult trees

One-year-old apple shoots under water stress (Figure 1)
(Montpellier and Bologna)

- Two apple cultivars, Granny Smith and Starkrimson and 19 hybrids from their crossing.

Water stress management

- Single-shoots were grown in controlled environments, subjected to soil water stress (WS) or well-watered (WW, control). The relative amount of water in the pots was quantified as the Fraction of Transpirable Soil Water (FTSW). WW plants were at 100% FTSW, WS plants at 50% and then 20% FTSW (4 weeks at each WS level).

Measurements on the shoots from the 2 periods

- Shoot morphology: number of leaves, stem length, individual and total leaf area.
- Leaf functioning: photosynthesis, stomatal conductance, stem xylem % loss of conductivity, stem water potential.

Water management and light conditioning (Figure 2)
(Bologna)

Coloured nets

- 4 different light management treatments: control (no net), 50% red, 20% neutral and 50% white shading nets; each subjected to 3 different irrigation levels: 100% (control), 30% and 60% of potential evapotranspiration (ETc).

Measurements

- During the growing season: ETc, plant water status, leaf gas exchange, fruit and shoot growth. At harvest: total yield, fruit size class distribution, fruit colour class.

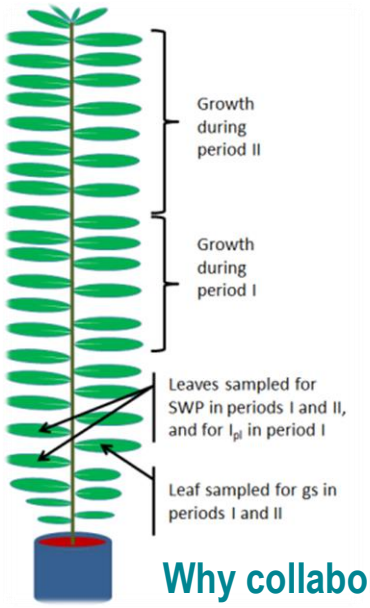


Figure 1. Scheme of a one-year-old apple shoot at the end of the experiment with the two consecutive growth periods. Adult leaves used for leaf functioning study are indicated (P.-É. Lauri, France)

Why collaborating?

- Two fruit crops with high added-values across the Mediterranean area.
- Five countries providing contrasted natural and socio-economic environments: Israel, Morocco and Spain where water saving is a major issue; France and Italy where water saving aims at reducing water irrigation leaching and pollution of the water table.
- Complementary scientific competences: France, Israel and Italy for fruit tree architecture and ecophysiology; Morocco and Spain for fruit tree growing and irrigation management; France, Israel and Morocco for entomology and pathology.
- Mixing researchers, as well as engineers and technicians from experimental stations and extension services, in strong connection with growers.
- Mixing research organizations and Universities and joining efforts towards common challenges.

Figure 2. Experimental orchard for coloured net study (L. Corelli Grappadelli & team, Italy)

Post-harvest diseases

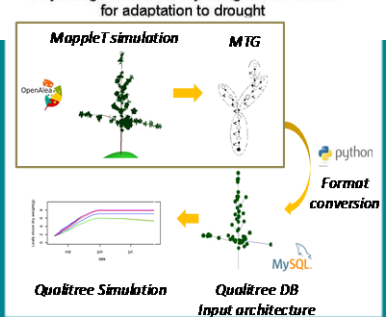
Peach-aphid interactions

Irrigation under water scarcity

Daily fruit growth

Figure 3. General scheme of the four work packages interacting in the five Mediterranean countries

Genetic variability



Plant water status

Leaf gas exchanges

ACHIEVEMENTS

Genetic variability of the young apple tree under water restriction

Both leaf functioning and whole-shoot growth were analysed under water stress (WS) and compared to the well-watered (WW) condition.

- At leaf level, a new index (IPL) was developed to measure photosynthesis on a large amount of individuals in a relatively short time which is a crucial issue for phenotyping progenies.
- At shoot level, a large variability of behaviours across genotypes was shown for stem and leaf growth positively related to stomatal conductance.
- A methodology was developed to analyse, for each genotype, the responses to water stress (WS/WW ratio).
- Results back up the hypothesis of various degrees of iso-anisohydry illustrating the ability of the apple tree to adapt to a large range of biogeographical conditions.
- Leaf area and temporary cessation of stem growth are well indicative of the ability of a genotype to adapt to water stress, which could be useful for phenotyping progenies.

Plant-aphids and plant-diseases interactions

Three plant-pest models were studied, *Aphis pomi* – apple, *Dysaphis plantaginea* – apple (Figure 4) and *Myzus persicae* – peach, on young non-fruiting trees.

- At infestation start, aphid abundance was mostly related to the tree nitrogen status. This relationship weakened over time and there was, later in the season, a positive correlation between shoot development and infestation dynamics. However, infestation remained linked to several amino acids involved in transport or osmoregulation throughout the season. Water restriction uncoupled these relationships.
- A more precise study of sap composition using stylectomy, showed that sorbitol and sucrose concentrations increased with plant growth.
- The increase in sap viscosity under WS may explain why aphids, which fed passively from the phloem, absorbed less sap under WS leading to a reduction of aphid populations on stressed plants.
- In peach orchards, decreasing water irrigation and nitrogen input by 25% compared to the crop coefficient-driven irrigation significantly reduces post-harvest diseases with only a slight yield reduction.

Figure 4. Apple shoot infested by the Rosy apple aphid (*Dysaphis plantaginea*). Infestation is related to individual shoot growth and not to the whole-tree growth (MO Jordan & MH Sauge, France)

Water and nitrogen management techniques to optimize fruit quality

- In peach and apple orchards, reducing by ca. 25% water and nitrogen inputs did not reduce significantly the yield compared to the usual crop coefficient-driven irrigation but reduces the need for pruning. Mediterranean fruit growers can thus cut down their input costs, while preserving the water resource and reducing pollution caused by over-fertilisation.
- From an applied point of view, the question on how to better adjust irrigation to the tree water status was specifically investigated. As already known, stem water potential (SWP) gives relevant thresholds for irrigation scheduling. However, we showed that there were strong interactions with crop load: the demand for assimilates affects leaf functioning, and for the same SWP, low crop load decreases stomatal conductance compared to high crop load (Figure 5).
- In apple, coloured nets reduce the need for irrigation and can therefore mitigate the effects of water stress.

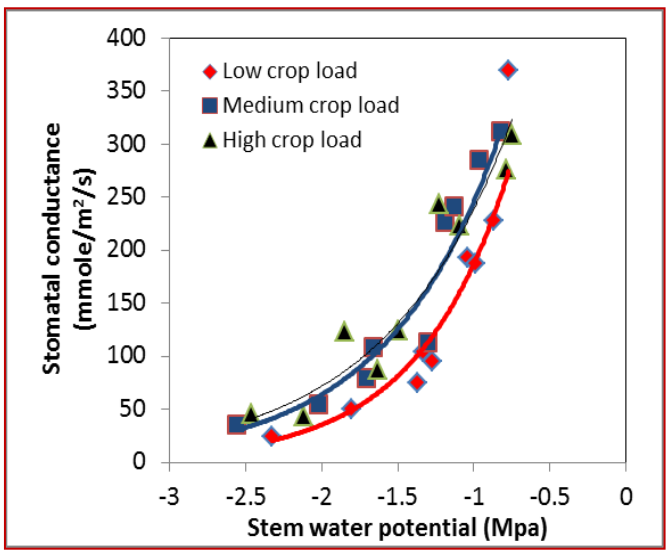


Figure 5. Peach-Nectarine - Crop load affects the relationship between SWP and stomatal conductance (A. Naor, Israel)

Modelling water and nitrogen management techniques

- The modelling objective was to integrate architectural and functional aspects into quantitative models to render satisfactorily the effects of water restriction on fruit size, and of aphid infestations on fruit trees.
- Modelling was based on the existing complementarity between three models already developed by the partners, MAppleT (architecture-based), QualiTree (function-based) and CropSyst (cropping system model).
- One of the output was the development of a multi-year aphid infestation module which showed that the effects of aphid infestation on fruit production was evident only 2-3 years after the first infestation, confirming ongoing field studies.

ACHIEVEMENTS

Stakeholder engagement

In APMed, relationships with stakeholders were developed at various levels:

- France – An experimental station and an extension service were included as subcontractors in the consortium. They focused on irrigation management and effects on labour costs, post-harvest diseases and overall orchard profitability.
- Israel and Spain – Growers networks were interested in irrigation scheduling through a better use of soil and plant sensors.
- Italy – Growers' networks were specifically interested in the use of coloured nets to decrease water use by trees and to improve fruit quality.
- Morocco – Experiments were developed in orchards belonging to some main "aggregators" (large farms). Results were disseminated through regular meetings to small farmers with the practical interest that growers are entitled to cultivate more land if they are able to save water.
- The End-of-Project conference held in Montpellier, France, on 15-16 June 2015, hosted some 70 researchers, engineers and technicians. The main outputs of the APMed project were then presented by all partners. A half-day was also dedicated to more general talks on societal aspects of water in the society such as "water saving policy in Morocco" or "strategical approaches of water management involving all the actors" (Figure 6).

Figure 6. End-of-Project conference of the APMed programme – Montpellier Agropolis, France, 15-16 June 2015

Next steps

- Phenotyping genetic variability for water stress tolerance in the apple tree - Submitted publications and exchanges with breeders in connection with the Fruit Breedomics European Programme (2011-2015).
- Apple response to water stress at two main levels, plant architecture and ecophysiology modelling, and genetic determinism – Ongoing research works at INRA, France, in connection with other French and non-French teams.
- Dissemination towards fruit growers of the emerging techniques and know-how on irrigation scheduling in relation to plant resistance to aphids – Continuous work in the various countries through informal or formal initiatives, e.g. French programme RegPuc (2016-2018).

Do you want to know more?

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http://arimnet2.net/index.php/researchprojects/apmed1#presentation

For more information on the ARIMNet2 Network

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