APMEd

In the context of climate change likely related to an increased frequency of drought episodes, our aims were to gain knowledge on how the fruit tree adapts to water scarcity, to investigate the effects of tree water status on pests and diseases, and eventually to examine how the grower can improve tree water status through irrigation scheduling and/or through a reduction of tree water consumption and transpiration. The programme encompasses four research topics: what is the genetic variability of Apple tolerance to soil water restriction (WP1)?, how Peach and Apple tree water status interacts with pests and diseases, especially aphid infestation (WP2)?, what are the efficient means to improve fruit production under water restriction minimizing phytosanitary issues (WP3)?, and can we model efficiently the effects of water restriction on both yield, and pests and diseases attacks (WP4)?

WP1 - The analysis of the **genetic variability** of the responses of shoot growth and ecophysiology was carried out in several Apple genotypes issued from a progeny. Complementary approaches were developed in France (Montpellier) and Italy (Bologna) on the same genotypes as one-year-old and adult-fruiting trees, with the objective to compare their behaviour under two water status, water restriction and well-watered. At leaf level, we developed a methodology to estimate net photosynthesis (P_n) using easy- and quick-to-measure variables. The new index, I_{PL}, permitted to measure a large amount of individuals in a relatively short time which is a crucial issue for phenotyping progenies. We showed that genotypes covered a high range of P_n values under the two water status and could be ranked according to their relative responses for P_n, ie, strong to weak decrease under water restriction compared to the well-watered status. However, the absence of significant relationships for P_n between one-year-old trees and adult-fruiting trees raised methodological issues (shoot type, absence/presence of fruit…) that could not be handled satisfactorily in this programme. At shoot level, we showed a large variability of behaviours across genotypes for stem and leaf growth positively related to stomatal conductance (g_s) under well-watered and both a moderate and a severe water restrictions. From a methodological point of view, our study showed that the percentage of growth cessation over a population of shoots from a given genotype is a reliable and easy-to-collect proxy to quantify the effects of water restriction on shoot growth. More fundamentally, our study agreed with the idea of various degrees of iso-anisohydry illustrating the ability of the apple tree to adapt to a large range of biogeographical conditions. As a whole, our study assessed some methodological issues and already brought preliminary results on phenotyping young Apple trees for growth and functioning under water restriction. These first results should be confirmed on larger Apple progenies in connection with geneticists and breeders.

WP2 - Analyses of **plant-aphid interactions** were carried out at the physiological level in complementary experiments conducted in France (Avignon) and Israel on the two plant-pest models, *Aphis pomi*–Apple and *Myzus persicae*–Peach, in both cases as young non-fruiting trees. At infestation start (early May), the aphid abundance was mostly related to the tree nitrogen status. This relationship decreased over time and there was, later in the season, a positive correlation between shoot development and infestation dynamics. Water restriction uncoupled these relationships. The more precise study of sap composition, using stylectomy, showed that sorbitol and sucrose concentrations increased with plant growth. Water restriction entailed an increase in sorbitol concentration whereas sucrose concentration was only slightly affected. Amino acids also varied along the season but were not related to water restriction. The exuded volume from the stylet was negatively correlated with sugar concentration which tended to increase during the season, especially under water restriction, most likely through the variation of the phloem sap viscosity. This may explain why aphids, which are fed passively from the phloem, absorbed lower sap under drought conditions which led to a decrease in the aphid populations on stressed plants. Experiments carried out in Morocco in Apple and Peach commercial orchards substantiated that if, as expected, aphids were generally more abundant on well-watered and well-fed orchards, complex interactions with both natural enemies (e.g., about 3-fold more abundant in the water-restricted Peach orchard than in the well-watered one) and cardinal direction (e.g., in relation

to the source of aphids infestation) led to more complex schemes than the ones developed from the potted trees.

WP3 – The **management of water and nitrogen in orchards** was carried out through complementary experiments among the different partners. Working in commercial Apple and Peach orchards (France, subcontractants; Morocco) we showed that water and nitrogen could be significantly reduced (ca. 25% of Potential Evapotranspiration (PET) on average) affecting only slightly yield and fruit quality. This is particularly important for Morocco as growers are entitled to cultivate more land if they are able to save water. We also showed that, at this level of water and nitrogen restriction, there was a significant decrease of post-harvest diseases and pruning needs ending up with the same revenue for all treatments. A dynamic irrigation scheduling was also experimented in Apple (France, subcontractants) showing that a higher water restriction, i.e., 50% of PET, could be managed in one month over the summer permitting to save water without negative effects on total yield, while prolonged water restriction (during 3 summer months) at the same level had negative effects on orchard profitability. The determination of thresholds for water restriction was investigated more precisely in Israel, for Apple and Peach, showing that crop load has to be taken into account to finely tune stem water potential (SWP) thresholds for irrigation. Especially, we confirmed the usefulness of midday SWP to trigger irrigation scheduling. These results open to practical outputs to be delivered to growers. We also showed consistent differences between Apple and Peach, this latter species responding to irrigation even at very low crop levels, indicating a direct effect of tree water status on fruit expansion rate. The possibility to mitigate water scarcity with colored nets was explored in Italy. Growing Apple under shading nets entailed higher marketable yields with less irrigation needed during the season. These results indicated how, in Mediterranean sunny conditions, shading represents an effective strategy to save water in Apple, without negative effects on yield and quality, thus allowing the application of protocols for deficit irrigation scheduling.

WP4 – A main objective of this WP was 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. Developments were made based on the complementarity existing between models already developed by the three partners, *MAppleT* (architecture based) and *QualiTree* (function based) at INRA Montpellier and INRA Avignon, France, respectively, and *CropSyst* (cropping system model) at IRTA Lerida, Spain. Two modules were implemented to build an integrated simplified model. For the water module, a radiative balance model linked with plant hydraulic constraints (stomata and axes hydraulic resistance) was developed. It was coupled with a reduction function describing the sensitivity of the leafy shoot growth to the plant water status through the leafy shoot water potential. A multi-year aphid infestation module was developed which showed that consequences of aphid infestation, in terms of fruit production, become evident only 2-3 years after first infestation confirming ongoing field studies. At the orchard scale, field work validated the *CropSyst* model for calculating crop coefficient (Kc) used for the Apple cultivar ‘Golden Reinders’ considering differential tree responses between early and late irrigation reductions. A well-fit application of *CropSyst* for Apple will be later to analyse different irrigation strategies under Mediterranean environments.

A final and public meeting is organized on June 15 and 16, 2015, in Montpellier, France, in tight collaboration with an association of technicians and engineers in South-Eastern France. This meeting will be open to scientists, technicians and other stakeholders along the fruit chain from France, Italy and Spain. It will present the main results of each WP and will also give a large place for discussions on technical and societal aspects related to water and irrigation.