



Modeling Water Requirements of Young Apple Rootstocks under Various Climates

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Abstract

Tree fruit nursery production is becoming a highly specialized horticultural sector applying a high level of technology, automation and even modeling. Providing adequate water supply to rootstocks and young plantlets is an essential requisite but often, to avoid the risk of dryness, nurseries apply excess irrigation rates, with both physiological, quality and ecological costs. The present study uses experimental data to model the fluctuation in sap flow from apple rootstocks in two different climatic areas, a rather continental climate in eastern Albania and a Mediterranean one in western coast of Albania. The study was conducted on two commercial nurseries. Sap flow sensors based on the stem heat balance (SHB) method were installed on mounded daughter rootstocks of Pajam 2 apple rootstocks. Soil water potential was measured at two different depths. A portable meteorological station measured meteorological variables enabling the calculation of VPD (vapour pressure deficit) and ET (evapotranspiration). An Apogee infrared radiometer measured the canopy temperature. Stomatal conductance was measured using a leaf porometer. Leaf area, length, diameter, SCSA (stem cross-sectional area) and root number of daughter rootstocks were measured too. The model was implemented in Mini32 software. A linear regression analysis was undertaken to study different regression models predicting the sap flow rates based on environmental variables measured. From the regression models studied, it can be concluded that sap flow was better predicted by changes in ET ($R^2 = 0.93$). Canopy temperature ($R^2 = 0.84$), global radiation ($R^2 = 78$) and even air temperature ($R^2 = 67$) are useful climatic variables for predicting SF reference values because they are easily measured.

Keywords: Apple rootstocks; Fruit nursery

Introduction

Tree fruit nursery production is becoming a highly specialized horticultural sector applying a high level of technology, automation and even modeling. An increase of apple growing in the last decade in Albania has also broadened the range of cultivars/rootstocks used [1]. Beside the typical continental region of Korca, the area of cultivation has extended towards the Western Plain with its hot, semi-arid Mediterranean climate [2,3]. Providing adequate water supply to rootstocks and young plantlets is an essential requisite but often, to avoid the risk of dryness, nurseries apply excess irrigation rates, with both physiological, quality and ecological costs. The present study uses experimental data to model the fluctuation in sap flow from apple rootstocks in two different climatic areas, a rather continental climate in eastern Albania and a Mediterranean one in western coast of Albania. Climatic variables like global radiation (GR), photosynthetically active radiation (PAR), air

temperature (T_a), canopy temperature (T_c), relative humidity (RH) and vapour pressure difference (VPD) relate to sap flow.

The results are preliminary and they serve as a basis for the modeling work.

Material and Methods

One-year old apple rootstocks of Pajam® 1 Lancep were used as replicates based on stem diameter and other biometric measurements, vigor, number of lateral shoots, leaf area, etc. Homogeneity of these trees was evaluated under another study [4]. Sap flow (SF) was measured using sap flow sensors EMS 62 (EMS Brno), based on SHB (stem heat balance) method [5,6]. Sensors were installed on the stem (12 mm thick) on rootstocks in both regions, Korca (Continental - CONTI.) and Lushnja (Mediterranean - MEDIT). The measuring interval was every minute with 1 s warm-up and storing interval every 15 minutes during July 2012. Infrared radiometers (Apogee SI 100)

continuously measured Tc. A portable meteorological station Minikin RTHi (EMS Brno, CZ) measured the Rs, Ta and RH. The closest state meteorological station measured wind speed, rainfalls and ET⁰. VPD was calculated from vapor pressure and relative humidity.

Experimental design and statistical analysis

The design of the experiment was completely randomized with four replications, each replication consisting of three adjacent rows of five rootstocks. Measurements were taken in the inner plant of the central row of each replicate, the other plants serving as borders. All the measurements were taken in the same plant in each replicate. Values for each day and replicate were averaged before the mean and the standard error were calculated [7]. To model the relationship between the series of predictor/explanatory variables (Rs, Ta, Tc, VPD and ET⁰) and the response variable (SF), regressions of various orders were computed using R statistical software (The R Foundation for Statistical Computing). Regression lines were compared using various statistical techniques from R packages.

Results and Discussion

All the parameters concerning the evaporative demand where relatively constant during the measurement period with an obvious daily fluctuation trend (Figure 1a – 1d).

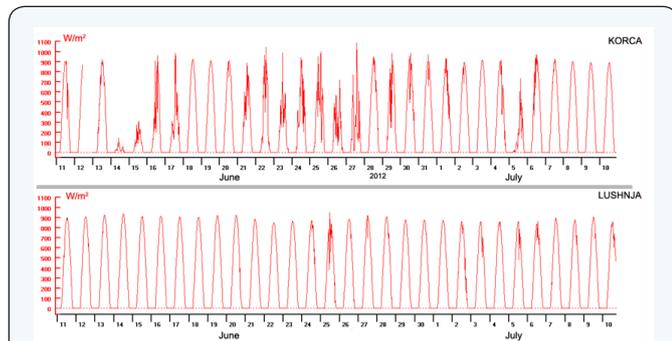


Figure 1a: Dynamics of global radiation Rs during the measurement period (June - July) in the area of Korca and Lushnja.

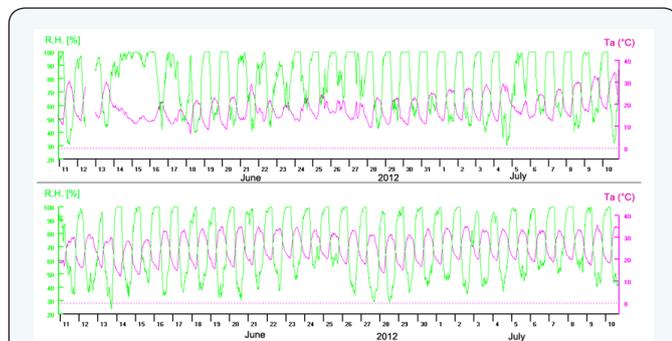


Figure 1b: Dynamics of air temperature Ta during the measurement period (June - July) in the area of Korca and Lushnja.

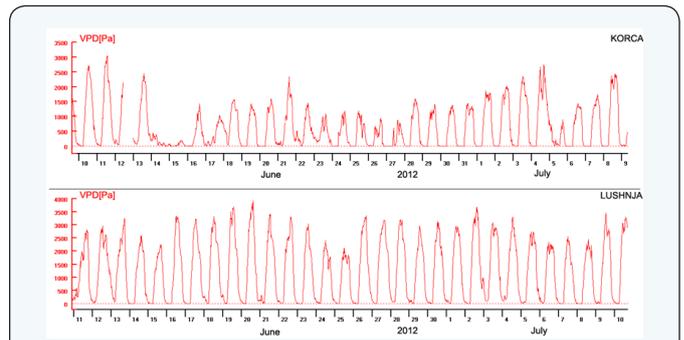


Figure 1c: Dynamics of vapor pressure deficit VPD during the measurement period (June - July) in the area of Korca and Lushnja.

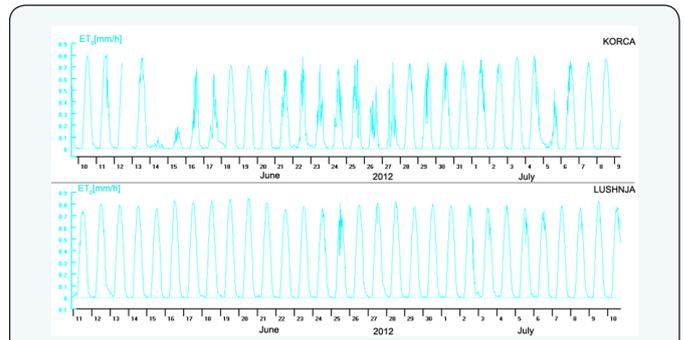


Figure 1d: Dynamics of reference evapotranspiration ET0 during the measurement period (June - July) in the area of Korca and Lushnja.

Intercorrelations shown in Figure 2 using a Correlogram indicate a stronger correlation of SFCONTI with ET⁰ and Rs (0.96 and 0.94 respectively) and less with VPD and Tc (0.89 and 0.86 respectively) whilst for SFMEDIT a higher correlation with VPD and ET⁰ (both 0.95) and less with Rs and Tc(both 0.92).

The correlogram in Figure 2a,b shows intercorrelations between sap flow (SF) and environmental parameters (Rs, Tc, VPD, ET⁰). The lower triangle contains smoothed best fit lines and confidence ellipses, and the upper triangle contains scatter plots. The diagonal panel contains minimum and maximum values. Rows and columns have been reordered using principal components analysis.

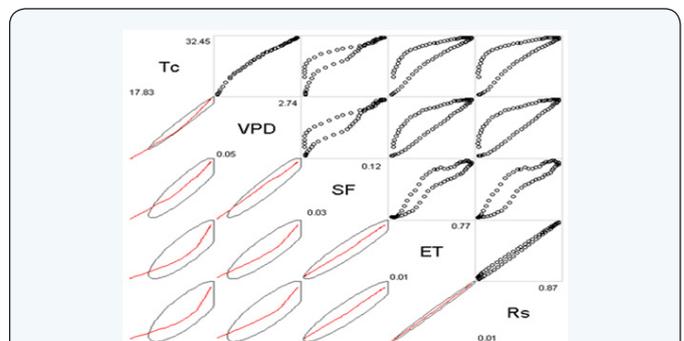


Figure 2a: Correlogram of intercorrelations for KORCA region.

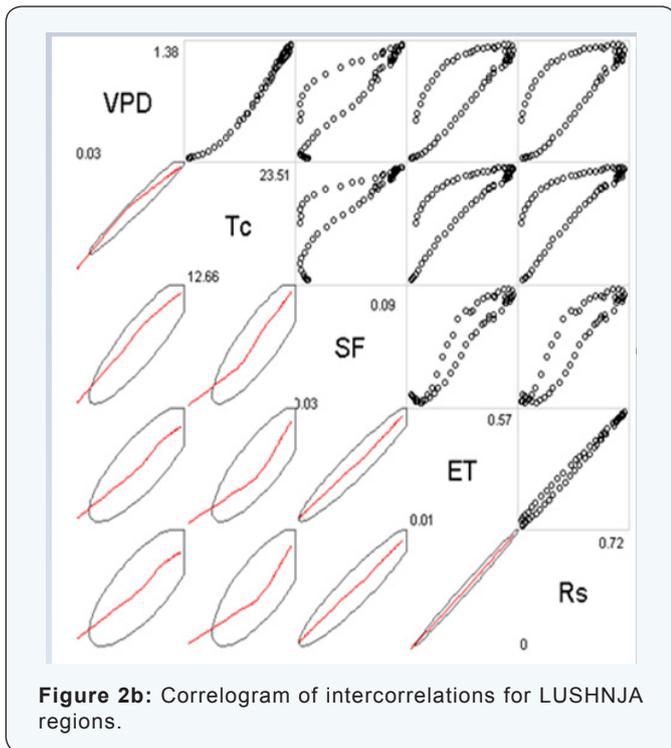


Figure 2b: Correlogram of intercorrelations for LUSHNJA regions.

In general, increases in predictor variables were associated with increases in SF. In the case of Mediterranean climate (Lushnja), climatic parameters did reach threshold values, after which SF leveled off, thus, departing from linearity (Figure 3a). Quite the reverse, in the case of Continental climate (Korca), since climatic parameters did not reach threshold values, ANCOVA between the three models did not yielded significant

differences (Figure 3b).

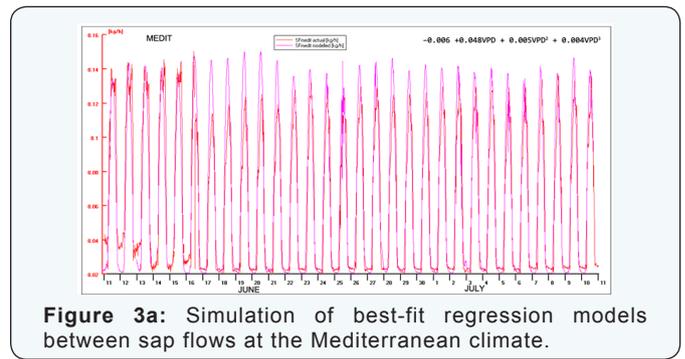


Figure 3a: Simulation of best-fit regression models between sap flows at the Mediterranean climate.

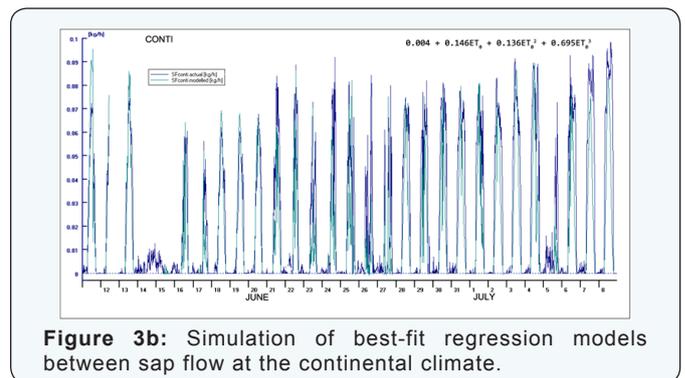


Figure 3b: Simulation of best-fit regression models between sap flow at the continental climate.

Residuals versus Fitted graph indicated evidence of curved relationship. Thus, best-fit curve using polynomial regression, a second-order (quadratic) and third-order (cubic) yielded equations with a higher determination coefficient. The study confirmed that Ta [8,9] and Tc are not accurate indicators of the evaporative demand of the atmosphere (Figure 4a,b).

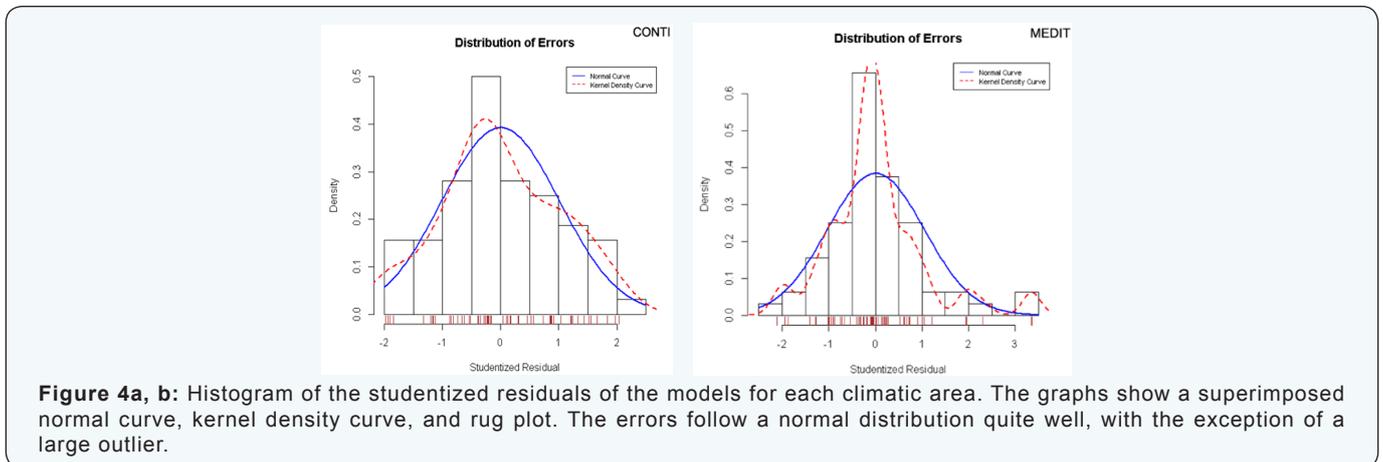


Figure 4a, b: Histogram of the studentized residuals of the models for each climatic area. The graphs show a superimposed normal curve, kernel density curve, and rug plot. The errors follow a normal distribution quite well, with the exception of a large outlier.

Conclusion

Results indicate that modeling of sap flow by using best-fit regression approach can be used as a proxy of daily rates of sap flow, even though there was a certain scattering in the relations between the plant-based measurements and the environmental variables. The regression analysis indicated that the highest coefficients of determination were obtained for the regressions of SFCONTI against ET⁰ and SFMEDIT against VPD. These estimates can be used in automatic irrigation scheduling

in apple rootstocks for different climates.

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