

USING THE CROP WATER STRESS INDEX IN IRRIGATION SCHEDULING IN APPLE ORCHARDS ON SOUTHERN ROMANIA

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Abstract

Water is a limiting factor in many countries because of decreasing quality and supplies. The trend in climate evolution toward aridization has also been observed in Romania. The apple (*Malus domestica*) is one of the most widely cultivated temperate climate fruit-trees in Romania, particularly in hilly regions. With increasing interest in commercial production of apples, physiological responses to factors limiting growth and yield need to be studied. The soil in the experimental plots at Pitesti-Maracineni, southern Romania, is loamy-textured, with a clay (less than 0.002 mm particle diameter) content of 30 – 35 % $g\ g^{-1}$ throughout the 0 – 1 m depth profile. Soil bulk density has ranged from 1.40 to 1.49 $g\ cm^{-3}$ and total soil porosity from 44 to 48 %. The land slope is from 0 to 2 % and the water table varies between 4 and 6 m depth. The climate conditions at the experimental site are characterized by a mean annual temperature (1967 – 2007) of 9.6 °C and a mean annual precipitation of 671 mm, not uniformly distributed across the year. The experiment was carried out during two growing seasons (2006 and 2007), in an apple orchard 12 years old, with Idared cultivar grafted on M9 rootstock. There were fully-irrigated (FI), half-irrigated (HI) and control, non-irrigated treatments (NI). Trees are spaced 3.6 m between the rows and 1.5 m in the row giving 1852 trees ha^{-1} . Canopy temperature was measured using an infrared thermometer X2955L-Crop Trak Infrared Thermometer. Spectrum Technologies, Inc., with a built-in laser pointer to identify target areas, to calculate the components of the CWSI and to assess the crop response to water stress periods during the warmest months of the growing season. The lower base line of CWSI, as a correlation between the crop and air temperature difference versus the vapor pressure deficit for apple under the soil and climate conditions of Pitesti-Maracineni, Romania, has a highly significant regression equation. The CWSI mainly ranged between 0.10 and 0.80. Irrigation applications were usually carried out in this experiment at CWSI values from 0.20 to 0.50. Soil moisture content varied with time, usually between field capacity (FC) and wilting point (WP) in the research treatments during the months of maximum interest in irrigation application: July and August. There were significant differences for fruit yield between the irrigation treatments studied and the control. The FI treatments gave higher yields than the HI ones, but the difference was not significant for the conditions of experiment. This could have a major importance in the case of the global warming when water resources would be less. Significant differences in the weight of individual fruits were observed between the FI treatments and NI. So, one of the most important advantages of irrigation here is, in addition to fruit yield, greater fruit weight. Further studies are needed to find relationships between the CWSI and various soil variables, like the moisture content or matric potential.

Key words: leaf temperature, irrigation application, irrigation depth

1. Introduction

Water is a limiting factor in many countries because of decreasing quality and supplies. The trend in climate evolution toward aridization has also been observed in Romania. Some scenarios evaluating the impact of global warming in this country have suggested that aridity will increase especially during the crop growing season in southern parts of the country (Marica and Busuioc, 2004).

Irrigation is often applied to agricultural crops to obtain high and constant yields. Knowledge of water application is required for both irrigation scheme planners and farmers. In Romania, Botzan (1973), Grumeza et al. (1989) and Paltineanu et al. (2007), among others, have developed irrigation techniques and research methods. or have reported crop coefficients (K_c) based on the Thornthwaite, class A pan evaporation or Penman-Monteith (PM) formula for various crops, climate and soil conditions. Tanasescu and Paltineanu (2004) reported results on various irrigation methods for apples in the same region.

Various irrigation scheduling methods in orchards have been studied to optimize water application to fruit trees. One is use of the crop water stress index (CWSI), which is one of the best indicators for estimating yields (Idso et al., 1981). Measurements of canopy temperature and calculation of CWSI were shown to be valuable in irrigation scheduling by Jackson et al. (1981). CWSI data for ornamental plants and pecans were reported by Sammis and Jernigan (1992) and Sammis and Lugg (1988). More recently, CWSI has been used to assess water stress in wheat in China (Guofu Yuan et al., 2004) and in neck orange in Thailand (Sdoodee and Kaewkong, 2006). Ben-Asher et al. (1989) and Ben-Asher and Phene (1992) measured plant transpiration from aerodynamics and canopy resistance using infrared thermometry in arid regions such as California and Israel. Giuliani et al. (2001) reported an infrared thermal imagery method to detect plant water deficit in apple and peach orchards. However, CWSI has not been much used in apple orchards, and has not been correlated with irrigation depth.

The apple (*Malus domestica*) is one of the most widely cultivated temperate climate fruit-trees in Romania, particularly in hilly regions. With increasing interest in commercial production of apples, physiological responses to factors limiting growth and yield need to be studied.

The main purpose of this paper is to determine CWSI in apple and to study its variation under the specific irrigation conditions of Pitesti-Maracineni, southern Romania. Another purpose is to report fruit yield data under various irrigation regimes and climate conditions in the region in the context of global warming.

2. Materials and method

2.1. Soil and climate conditions. experimental design and irrigation application

2.1.1. Soil and climate conditions

The soil in the experimental plots at Pitesti-Maracineni is loamy-textured, with a clay (less than 0.002 mm particle diameter) content of 30 – 35 % g g^{-1} throughout the 0 – 1 m depth profile. Soil bulk density has ranged from 1.40 to 1.49 g cm^{-3} and total soil porosity from 44 to 48 %. The land slope is from 0 to 2 % and the water table varies between 4 and 6 m depth.

The experiment was done during years 2006 and 2007. The climate conditions at the experimental site are characterized by a mean annual temperature (1967 – 2007) of 9.6 °C and a mean annual precipitation of 671 mm, not uniformly distributed across the year. In the months when irrigation is commonly used in Romania, July and August, the monthly precipitation (P) values in 2006 exceeded the means for these months by 128 % in July (versus 83 mm) and 149 % in August (versus 63 mm), respectively (fig. 1a).

Penman – Monteith reference evapotranspiration (PM-ET_o) was calculated for the same months using the relationships given in Allen et al. (1998), and the climatic water deficit (WD) as a difference between P values and PM-ET_o values. ET_o was calculated by the Penman-Monteith method (Monteith, 1965; Jensen et al., 1990; Allen et al., 1998). With mean annual precipitation (P), it was used to calculate WD as follows:

$$\text{WD} = \text{P} - \text{ET}_o\text{-PM} \quad (1)$$

where ET_o-PM is the Penman-Monteith reference evapotranspiration (mm), which was calculated using the combined equation (Monteith, 1965; Smith, 1992) based on monthly data of mean temperature, sunshine duration, air humidity and wind speed at 2-m height:

$$\text{ET}_o\text{-PM} = (0.408\Delta(\text{Rn}-\text{G}) + 900\gamma U(e_a - e_d) / (T + 273)) / (\Delta + \gamma(1 + 0.34U)) \quad (2)$$

where Rn is the net radiation at grass surface ($\text{MJ m}^{-2} \text{d}^{-1}$), G is the soil heat flux ($\text{MJ m}^{-2} \text{d}^{-1}$). T is average temperature (°C), U is wind speed at 2 m height (m s^{-1}), ($e_a - e_d$) is vapour pressure deficit (kPa), Δ is slope of the vapour pressure curve ($\text{kPa } ^\circ\text{C}^{-1}$), γ is psychrometric constant ($\text{kPa } ^\circ\text{C}^{-1}$). The other terms needed to calculate ET_o-PM were taken from Jensen et al. (1990) and Allen et al. (1998).

As shown in fig. 1a, PM-ET_o values of these months for 2006 and 2007 have been relatively close to its mean values. However, there was a small climatic water deficit (WD) during this period, especially in the second 10-day period of both months: about -35 mm in July and -25 mm in August.

Unlike 2006, there was severe drought in July 2007 when PM-ET_o was much greater than P values (fig. 1b). WD showed a very high value (-120 mm) in July, when P was 23 mm but PM-ET_o 143 mm. Due to high temperatures, PM-ET_o exceeded the mean by about 20 mm and this situation is expected in Romania with global warming (Marica and Busuioc, 2004). Unlike July, August was a rainy month and P and PM-ET_o values were almost equal (P = 132 mm, PM-ET_o = 129 mm); even if the monthly PM-ET_o exceeded the mean by 23 mm. P also showed high values: 132 mm versus 65 mm.

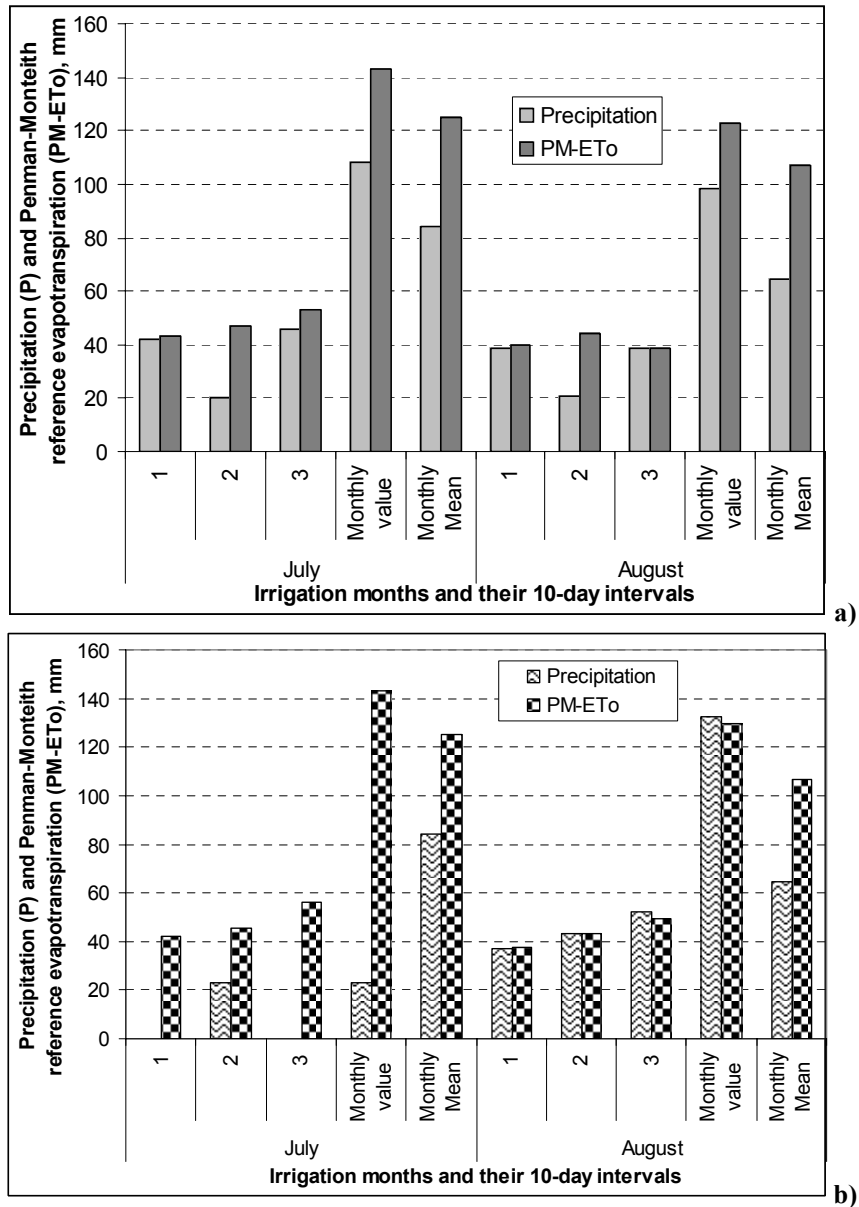


Fig. 1. 10-day values for precipitation (P) and Penman-Monteith reference evapotranspiration (PM-ETo) during July and August in a) 2006 and b) 2007, versus their mean values (1967 – 2007) at Pitesti-Maracineni, Romania

2.1.2. Experimental design and irrigation application

The experiment was carried out at Pitesti-Maracineni, southern Romania, during the two growing seasons (2006 and 2007), in an apple orchard 12 years old, with Idared cultivar grafted on M9 rootstock. Trees are spaced 3.6 m between the rows and 1.5 m in the row giving 1852 trees ha⁻¹. Tree height is about 2.5 – 3.0 m. The row direction is from north to south on horizontal fields. The groundcover management system includes mowed sod strips between the tree rows and clean cultivation in the rows.

Tree canopy shape is *oblique-branched palmette*. Leaf area index (LAI) determined with the SunScan Canopy Analysis System according to the method of Paltineanu et al. (2005) was 2.45 m² m⁻², a value typical of a mature, well developed orchard. As each tree has a truncated pyramid shape, the average tree volume was 2.28 m³.

Each irrigation treatment consisted of three adjacent rows 30 m long, each row containing 20 trees. Five consecutive trees located centrally along the row were for observations and measurements.

Irrigation was applied in both years during the two months, when it is usually used in the region, i.e. July and August. They created various soil moisture content values. Two experimental factors were investigated: irrigation application and irrigation method. The split-plot research method was used.

Irrigation applications were of three types: i) control, i.e. no irrigation treatment (NI), ii) fully-irrigated treatment (FI) up to the field capacity and according to the crop evapotranspiration obtained from Penman-Monteith reference evapotranspiration data and crop coefficients for July and August (Paltineanu and Mihailescu, 2005), and iii) irrigated under stress conditions (HI), usually with half the amount of water applied in the fully-irrigated treatment.

With regard to the irrigation method one should mention that water was applied in the FI treatment both by micro-sprinklers of 12 (FI-ms-12) and 27 l h⁻¹ (FI-ms-27), giving irrigation depths of 50 to 60 mm of water at a single application, and also as drip irrigation water along tree rows (FI-drip), giving 30 mm irrigation depths. In the HI treatments water was applied by the same methods but with half of the amounts given above (i.e. 25 – 30 mm); these were designated HI-ms-12, HI-ms-27 and HI-drip, respectively. Thus, in total they were seven treatments: NI, FI-ms-12, FI-ms-27, FI-drip, HI-ms-12, HI-ms-27 and HI-drip.

Even when P exceeded mean monthly values for relatively small periods, as in the second 10-day periods of July in 2006, 50 mm of water was applied in the last 10-day period. After that, a rainy period followed. The second application of 50 mm was done in the second 10-day period of August. Together with the P values for July and August 2006, the irrigation applied in the same months exceeded the monthly PM-ET_o values. Anyway, the crop coefficient (K_c) values for apple in the region are bigger than 1, namely between 1.15 and 1.20 (Paltineanu et al. 1999). This shows that the total crop evapotranspiration was of the same order of magnitude with irrigation, even if some runoff or leaching below the roots occurred after the heavy rainfalls.

Irrigation was applied in 2007 as follows: 1) the first application was on 9 July both as micro-sprinkler and drip irrigation, 2) then further amounts were applied by the same methods between 17 and 19 July, between 22 and 24 July, and finally between 11 and 13 August. The total irrigation water received by the soil in 2007 was 200 – 240 mm for FI-ms-12 and FI-ms-27, and 120 mm for FI-drip in the fully-irrigated treatments; for the half-irrigated ones it totalled 100 – 120 mm for FI-ms-12 and FI-ms-27, and 60 mm for FI-drip.

2.1.3. Soil moisture content measurements

Soil moisture content (SMC, % cm³cm⁻³) was generally measured on a weekly basis, using Delta – T Devices ThetaProbe PR1 moisture meter. Measurements were taken at 10 cm depth intervals over a total depth of 1 m. For each treatment, SMC was measured in two access tubes, 0.5 m apart. Data were averaged over the 1 m soil depth, as apple roots in such soils in the region explore 0.8 – 1.0 m depth (Iancu, 1979; 1989). SMC data were subsequently transformed into soil moisture deficits (mm) as differences between field capacity (FC) and SMC. The deficits are equivalent to required irrigation depths (IDs).

There were 10 research orchard plots where SMC was measured in 2007: two plots for each of the fully-irrigated treatments (six plots together), one plot for NI and three plots for the half-irrigated treatments.

The orchard soil was fertilized in spring with 75 kg ha⁻¹ NPK, and with 67 kg ha⁻¹ ammonium nitrate in early summer. All phyto-sanitary treatments were applied according to the recommendations of the specialists in plant protection.

2.2. Measurement of canopy temperature (T_c) and calculation of CWSI

Canopy temperature was measured using an infrared thermometer X2955L-Crop Trak Infrared Thermometer. Spectrum Technologies, Inc., with a built-in laser pointer to identify target areas, to calculate the components of the CWSI and to assess the crop response to water stress periods during the warmest months of the growing season.

Because the trees are usually planted in north-south rows on flat lands in Romania, canopy temperature was measured on both sides of each row, i.e. the eastern side which is sunny in the morning and the western side which is sunny in the afternoon. Sdoodee and Kaewkong (2006) have reported temperature readings from all the four directions: north, south, east and west, but in well developed, dense orchards readings on the northern and southern sides are impossible as there is insufficient space between trees.

Tc measurements were obtained by pointing the infrared thermometer horizontally towards the leaves at a distance of 15-20 cm. Simultaneously, the ambient air temperature (Ta) was also determined using an Assmann psychrometer for both wet (Tw) and dry bulb (Ta) temperatures. Vapor pressure deficit (Vpd) of the ambient air was then calculated using the equations given in http://weather.nmsu.edu/Teaching_Material/soil698/CWSI.html.

Temperature readings of the canopy in July and August were taken: i) at 15-30 minute intervals from 6:30 in the morning to 14:30 in the afternoon in the case of evaluating the optimum tree row side from where readings should be taken, using 10 replicates on each side of the tree rows, and ii) from 10:00 to 14:00 to evaluate the lower base line. The readings were then averaged for each time step and Tc-Ta differences were plotted against Vpd.

2.2.1. Calculation of the lower base line (LBL) of CWSI

The two main base lines of CWSI, i.e. the lower base line (LBL) and the upper base line (UBL) should be first calculated in order to determine CWSI values (Idso et al., 1981; Jackson et al., 1981). LBL was determined in 2006 and 2007 in the two summer months: July and August, on clear-sky days when air temperature reached a maximum of 38 °C in July and 31 °C in August. To do this, in the FI-ms-27 treatment where the soil moisture content mainly ranged between the middle of the available water storage capacity of the soil and its field capacity (FC), irrigation was applied by micro-sprinklers during four days in order to wet the soil properly to 1m depth. Measurements of air temperature and canopy temperature were taken after two days needed for the excess water to drain out of the plot.

Some terms and relationships given in (http://weather.nmsu.edu/Teaching_Material/soil698/CWSI.html) were used to determine Vpd (kPa).

$$Vpd = Ew_{dry} - E_{dry} \quad (3)$$

$$Ew = 3.38639[(0.00738 T + 0.8072)^8 - 0.000019 \text{abs}(1.8 T + 48) + 0.001316] \quad (4)$$

for temperatures (T) from -51 to +54°C. with

$$Ew_{wet} = 3.38639 * [(0.00738 * Tw + 0.8072)^8 - 0.000019 * \text{ABS}(1.8 * Tw + 48) + 0.001316] \quad (5)$$

$$Ew_{dry} = 3.38639 * [(0.00738 * Ta + 0.8072)^8 - 0.000019 * \text{ABS}(1.8 * Ta + 48) + 0.001316] \quad (6)$$

$$E_{(dry\ bulb\ temp)} = Ew_{(wet\ bulb\ temp)} - 0.000661 * 100 (Ta - Tw) (1 + 0.00115 Tw) \quad (7)$$

where Ew is the saturated water content (kPa), E is the actual water content (kPa), Ta is air temperature, Tw is wet bulb temperature at saturated water content (°C).

The difference between canopy temperature (Tc) and air temperature (Ta) was then plotted against Vpd, and LBL was obtained by linear regression of Tc-Ta against Vpd (kPa), using the least square method.

2.2.2. Calculation of the upper base line (UBL) of CWSI

UBL was determined by cutting down an apple tree at the base of trunk, located in the same plot, then wiring the plant back in place, waiting one day until the plant had ceased transpiring and then measuring the temperature which was considered the upper base line of the tree leaves at solar noon. As will be seen further, Tc-Ta difference is inversely positioned versus live leaves and the y = 0 axis. In Pitesti – Maracineni this UBL measured by infrared thermometer achieved 4.5 °C in summer time at noon.

2.2.3. Calculation of CWSI during the period of irrigation application

The space between LBL and UBL is the range of CWSI. It was calculated for each temperature measurement as a ratio between: a = the vertical distance between the point location of the (Tc-Ta) difference plotted against Vpd in the graph and LBL, and b = the vertical distance between LBL and UBL, i.e. CWSI = a/b (Idso et al., 1981). CWSI was determined in all treatments.

2.3. Fruit yield and fruit weight

Fruit yield ($t\ ha^{-1}$) and fruit weight ($g\ fruit^{-1}$) were also determined for all the treatments and were then included and processed by the analysis of variance.

3. Results and discussions

3.1. Canopy temperature and calculation of CWSI

The temperature difference between the sunny and shady sides of the tree row was highly significantly correlated with time over the summer day (fig. 2).

The regression can be expressed by a grade-2 polynomial equation. The difference was nil at sunrise and increased strongly to a maximum at hour 10:00 a.m. After that, the difference decreased to hour 14:00 when the temperature difference again reached zero. Between 8:30 and 12:30 hours, the difference was about 4 to 5 °C. The consequence of this big difference as a function of time and solar radiation angle indicates the proper position and moment when temperatures should be taken. Thus, it is recommended that measurements should be made when the sun is in the south (hours 13:00 to 14:00). In order to have negligible temperature differences between the leaves, temperature measurements should be taken on the western side of rows which are shaded at the time from above. This finding is different from the recommendations reported by Ben-Asher and Phene (1992) who suggested that infrared thermometers should face south when measuring the shady crop side. This provides additional information when working in orchards in which trees are planted in rows, and one should not take infrared measurements facing south.

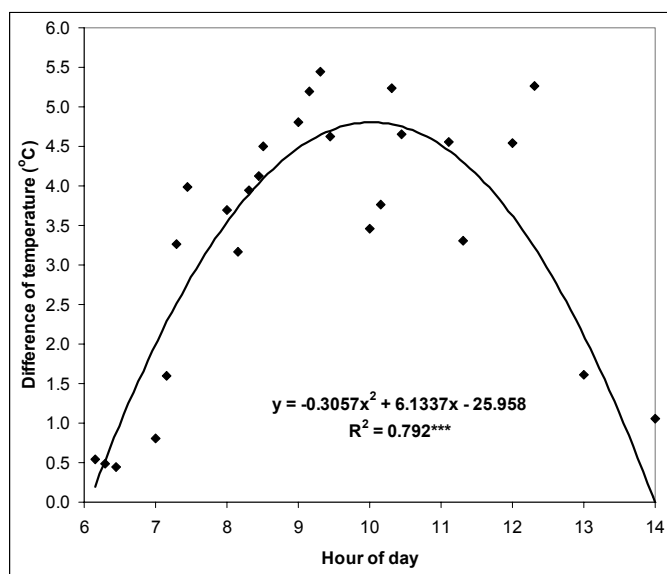


Fig. 2. Correlation of the temperature difference in summer between the eastern and western sides of tree row in an apple orchard 12 years old, Idared cultivar grafted on M9 rootstock, at Pitesti-Maracineni, Romania

3.2. CWSI

To determine CWSI, we first determined the two base lines: LBL and UBL (Idso et al., 1981; Jackson et al., 1981).

3.2.1. LBL

From data taken in the two summer months: July and August of the two years, a graph with V_{pd} for the horizontal axis and $T_c - T_a$ for the vertical axis was drawn (fig. 3). The linear relationship for LBL is highly significantly ($R^2=0.701^{***}$).

Compared with LBL values reported by Sammis and Jernigan (1992) for other crop species (*Medicago sativa*, L., *Fraxinus velutina glabra*, *Prunus cerasifera*) and environmental conditions (fig. 3), the LBL for

apple has a slightly lower slope and y-intercept value. However, the range of CWSI for apple is somewhat similar with the other crops mentioned.

3.2.2. CWSI in irrigation scheduling

Theoretically, CWSI depends on the ratio between the measured transpiration (T) divided by the potential transpiration (Tp), (Idso et al., 1981):

$$CWSI = 1 - T/T_p \quad (8)$$

CWSI was determined for all treatments based on the space between LBL and UBL. Values of CWSI for the year 2007, when there were more irrigation events than in the previous year, were plotted against time to show its changes during the irrigation season (fig. 4).

CWSI values mainly ranged between 0.10 and 0.80, though with a few exceptions which exceeded these figures. Irrigation was usually applied at CWSI values from 0.20 to 0.50. Fully-irrigated treatments had values within this interval, but the half-irrigated and control treatments showed higher values.

CWSI also showed a similar pattern in 2006, when the irrigation events were less frequent; for this reason the 2006 results are not presented.

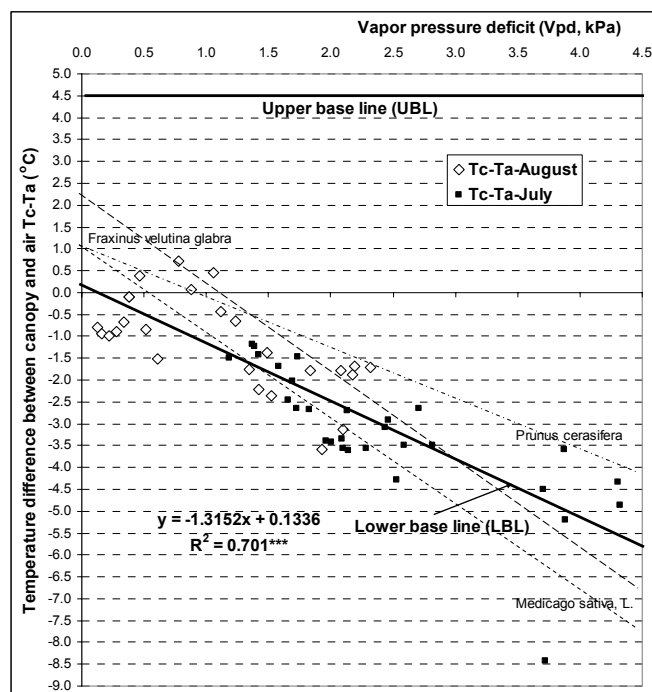


Fig. 3. Lower base line (LBL) and upper base line (UBL) for determining CWSI in apple during summer. Pitesti – Maracineni, Romania; dotted lines represent LBLs for other crops according to Sammis and Jernigan (1992)

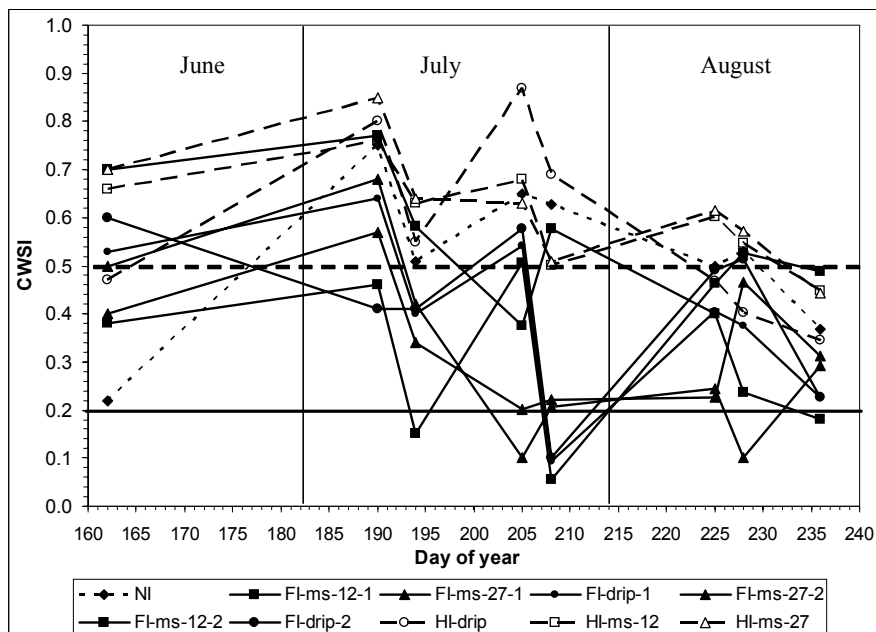


Fig. 4. Changes in CWSI in the 10 plots during the June to August period, 2007, at Pitesti-Maracineni, Romania; the fully-irrigated treatments are based on two replicates and the half-irrigated ones and no-irrigation (control) treatment are based on one plot each

3.3. Dynamics of soil moisture content

SMC averaged over the 0 – 100 cm depth varied with time, usually between FC and wilting point (WP) in the various treatments during the months of maximum interest in irrigation application, i.e. July and August (day of year (DOY) 182 and 237) as shown in fig. 5. However, there were changes even from the second 10-day period of June (DOY = 162).

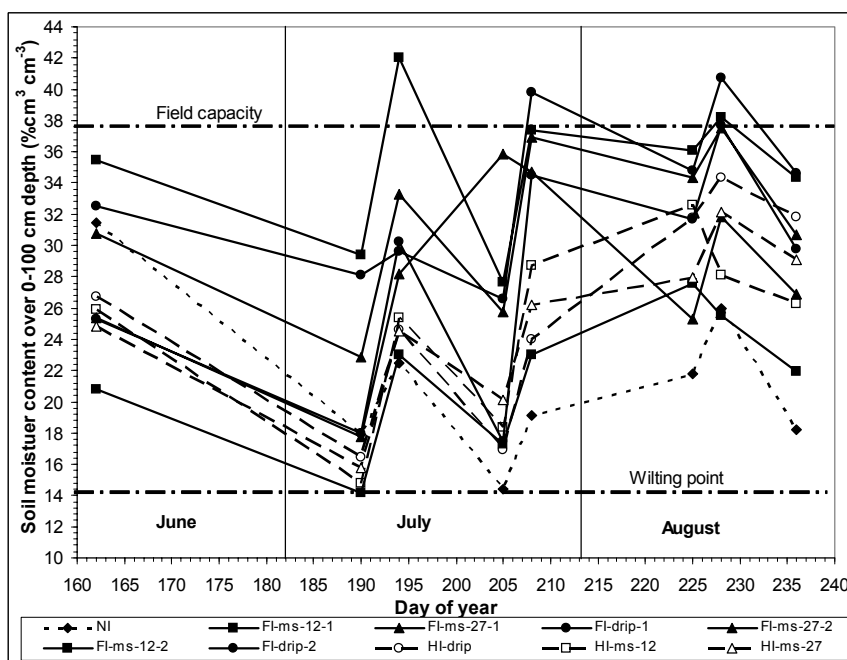


Fig. 5. Dynamics of the soil moisture content as averaged values over the 0-100 cm depth in the researched treatments during the June through August period, 2007, at Pitesti-Maracineni, Romania; the fully-irrigated treatments are based on two plot replicates and the half-irrigated ones and no-irrigation (control) treatment are based on one plot each

Due to the high soil variability in the field plots, SMC averaged over the 0 – 100 cm depth showed considerable variability, even between replicates of the same treatment. SMC was generally least in the NI treatment followed by the HI treatments during July and August. SMC increased rapidly after irrigation application or periods of rainfall.

The SMC values occasionally exceeded FC with the fully-irrigated treatments and probably induced waterlogging in the soil profile for 1-2 days. This could be explained by the uneven process of water distribution on the soil surface which depends on a lot of agronomic or natural factors. However, on no occasions did SMC decrease below WP.

SMC showed a similar pattern in 2006, when there were fewer irrigation events; these results are not presented. The pattern of CWSI and SMC variation suggests a correlation between these two terms.

3.4. Crop parameters: fruit yield and weight

3.4.1. Fruit yield

Fruit yield ($t\ ha^{-1}$) is the main indicator of production in orchards. The yield of all five trees within each irrigation treatment showed the following in fig. 6.

In both years (2006 and 2007), there were significant differences only between the irrigation treatments and the control treatment. However, there were small differences between the same treatments in the two years. Unlike the annual field crops, fruit yield in orchards depends on the conditions occurred in the previous year (Paltineanu and Chitu, 2004).

The fully-irrigated treatments gave higher yields than the half-irrigated ones, but they were not significantly different with each other in spite of more irrigation water received within the first. This seemed to be attributed to the fact that the most important thing for this combination of Idared apple cultivar grafted on M9 rootstock was not the fully-irrigation application which moistened the soil over the whole profile (0 – 100 cm depth), but the fact that the irrigation application was performed in all sensitive phases, even with smaller depths. This could have a major importance in the case of the global warming when water resources would be less.

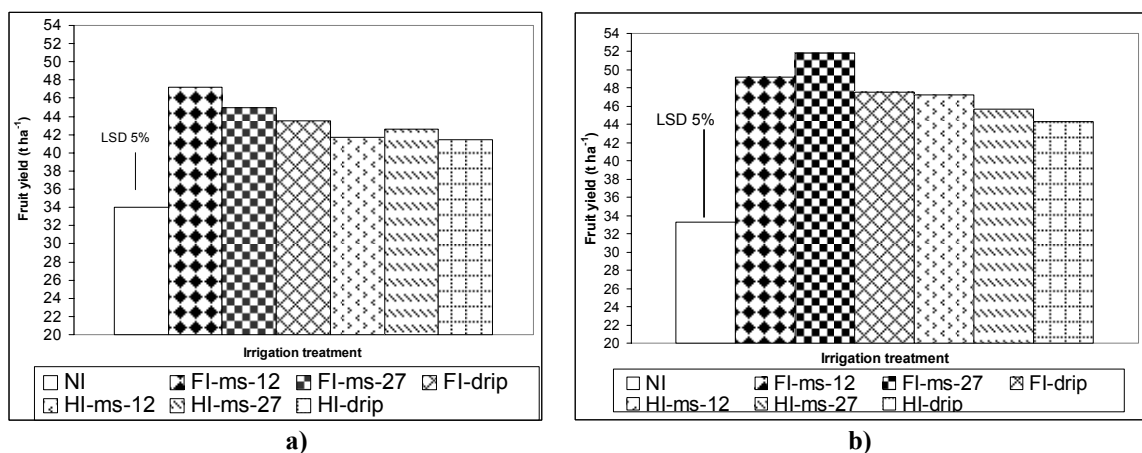


Fig. 6. Fruit yields of the irrigation treatments at Pitesti – Maracineni, Romania: a) in 2006 and b) in 2007; vertical bars indicate the least significant differences (LSD) for 5% probability

3.6.2. Fruit weight

In the year 2006 individual fruit weight ranged from 173 g for the NI treatment to 197 g for the FI-ms-27 treatment. In 2007 it ranged from 164 to 195 g/fruit for the same two treatments (fig. 7a and b). Significant differences were observed only between the fully-irrigated treatments and NI. So, one of the major advantages irrigation brought was greater individual fruit weight. Even though it was greater for the FI treatment than the HI, the difference was not significant.

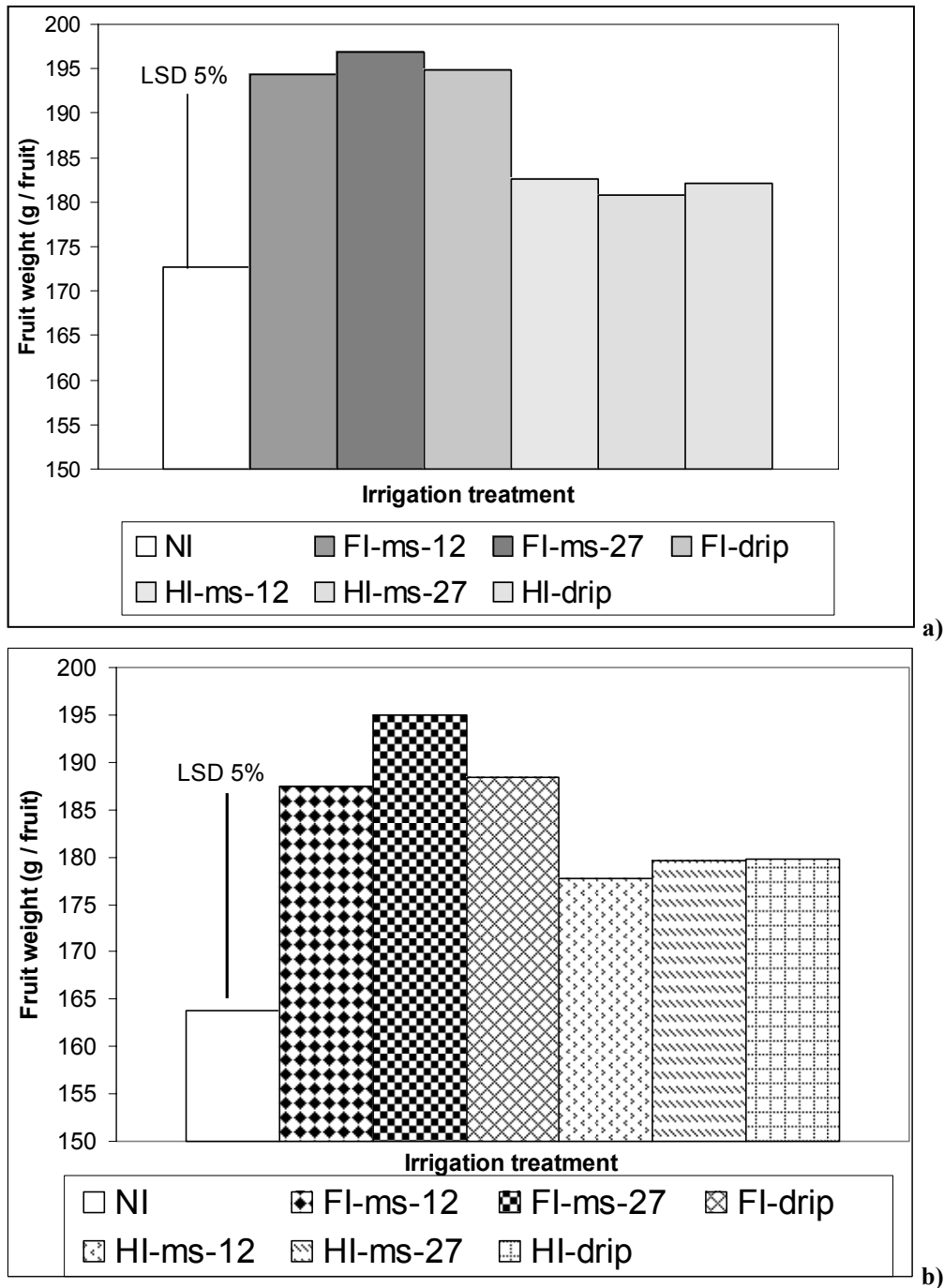


Fig. 7. Fruit weights of the irrigation treatments at Pitesti – Maracineni, a) in 2006 and b) in 2007; vertical bars indicate the least significant differences (LSD) for 5% probability

Individual fruit weight showed a similar variation in all the irrigation treatments during the two years. but in the control treatment fruits were heavier in 2006 when the precipitation was greater in the summer 2006 than in 2007.

4. Conclusions

There was a highly significant correlation ($R^2=0.701^{***}$) for the lower base line for apple under the soil and climate conditions of Pitesti-Maracineni, Romania.

The crop water stress index (CWSI) for apple here mainly ranged between 0.10 and 0.80. Irrigation was usually applied at CWSI values from 0.20 to 0.50.

Soil moisture content (SMC) averaged over the 0 – 100 cm depth varied widely with time, even between field capacity (FC) and wilting point (WP) in the various treatments during the months of maximum interest in irrigation application: July and August.

There were significant differences for fruit yield between only the irrigation treatments studied and the control. The fully-irrigated treatments gave higher yields than the half-irrigated ones, but the difference was not significant for the conditions of experiment. This could have a major importance in the case of the global warming when water resources would be less.

Significant differences in the weight of individual fruits were observed between the fully-irrigated (FI) treatments and the control. So, one of the most important advantages of irrigation here is, in addition to fruit yield, greater fruit weight.

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