Water use of young apple trees related to leaf area development

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Summary: Present paper discribes an investigation concerning seasonal water use and foliage area development of apple trees. Sap flow velocity was measured in the trunks of five years old apple trees cv. 'Florina'/M.26 by a thermal dissipation (Granier) method from 20th of May to the end of September in 1998. The development of foliage area was estimated by a method including leaf area measurements, recording of leaves and shoot length. The foliage area reached to 70% of the maximum yearly value at beginning of June. The remaining 30% developed to the end of August. The leaf area specific water use was considerable higher in June and July, than in second part of summer. The trends of ET-FAO and water use curves differed mostly in the late season: the ET-FAO curve falls quite in September compared to August, whereas the value of water use was a similar as in August. This insensitivity of ET-FAO in this period may be a great disadvantage while using the Penman-Monteith equation in irrigation scheduling of apple.

Abbreviations: AWC - available water content, ETc - crop evapotranspiration, ET-FAO - crop evapotranspiration calculated by Penman-Monteith-FAO equation.

Introduction

In irrigation scheduling is widely applied the Penman-Monteith equation to estimate daily reference evapotranspiration (ET_0) and crop evapotranspiration (ET_c). The critical point in using Penman-Monteith equation is the adaptation to the climate and the features of the plant stand, like density, height of plants, etc.. It must be considered the seasonal change of water demand of plants, too. The foliage area is one of the most important seasonally changing components of the water demand of plants.

The aim of this study was to investigate the water use of trees during a growing season related to the foliage development under climatic conditions of Szabolcs-Szatmár county and compare the seasonal change of water use with ET_c.

Methods

The orchard was established by the Research and Extension Centre for Fruit Growing, Újfehértó, in NE Hungary. Trees of apple cv. 'Florina'/M.26 were planted in spring of 1994 at a spacing 5 by 2 m, into acidic (pH≈5 in KCl) sandy soil with low humus content (<1%). Trees were trained as free spindel ones, the average crop load was 15 kg/tree in 1998.

The leaf area of spurs increases until the end of May or beginning of June, during a period of 35 days after full bloom (*Barritt* et al. 1991). Our preliminary data from 1997 confirm this observation (data are not shown). The total leaf area of elongated shoots is in direct linear proportion to the length of shoots in the whole season (preliminary data).

The length of 80 elongated shoots (2-2 shoots in 40 selected trees) was measured in every week between 13th of May and 16th of September in 1998. The number of spur-leaves and shoot-leaves was counted in 20 selected trees in the first week of July. At this time the total leaf area of selected elongated shoots and five randomly choosed spurs was measured in these 20 trees with a CI-203 Laser Area Meter (CID, Inc.). The total spur-leaf and shoot-leaf area of trees was computed as a product of average leaf area and the number of leaves. The foliage area of trees was estimated using the following equation:

$$A_{t,n} = A_{sj} + f_n \cdot A_{ej},$$

where $A_{t,n}$ is the total foliage area at time n between 1st of June and 30th of September, A_{sj} is the total spur leaf area of the tree at July 1, A_{ej} is the leaf area of elongated shoots at July 1, and f_n is a growing factor of shoots, calculated as $f_n = l_n/l_j$ (l_n is the length of elongeted shoots at time n, and l_j is the length of elongated shoots at July 1). The equation is valid between June 1 and September 30, when the development of foliage area is a result of the growth of elongated shoots only, and the leaf fall is not considerable.

Sap flow velocity was determined in trunks of 5 trees by Granier method (*Granier* 1985) using 3x30 mm probes. The rate of total mass flow of water (U [l/h]) was estimated using the equation:

$$U = u \cdot S_A$$

where S_A is the cross sectional area of water conductive elements (*Granier* 1987). Data were recorded continuously with a PC at a frequency of 5 min. The measurements started at 20th of May in 1998 and ended at 30th of September. Within this interval the measuring system had some breakdown, therefore the data set was not fully continuous. Total 110 days with complete data set were used to the statistical analysis.

The water content in the upper 60 cm layer of the soil was measured near the root zone of marked trees using electronic press-push probe. The soil moisture content was calculated as a percentage of available water content (AWC, 0% = permanent wilting point ≈-1.55 MPa soil water potential value and 100% = field water-holding capacity ≈-0.03 MPa). Measurements were carried out in every week between 11th of May and 11th of September.

Within the Research Station, about 1 km to the experimental orchard worked a weather station (METOS-D, Pessl Instruments, Austria). Temperature, relative humidity, precipitation, wind speed, solar radiation and leaf wetness data were recorded at a frequency of 12 min. The daily crop evapotranspiration (ET_c) was calculated according to the modified FAO Penman-Monteith equation (*Allen* et al., 1997).

Results

The summer of 1998 was extremely rainy in Újfehértó compared to previous years. The total rainfall was 474 mm between 20th of May and 30th of September, while the average of many years is less than 270 mm. As an average, every third day was rainy, and there was only one week without rain (*Fig. 1*). The soil water content was between 70 and 100% of AWC during the whole season (*Fig. 1*), therefore irrigation was not needed within the experimental period.

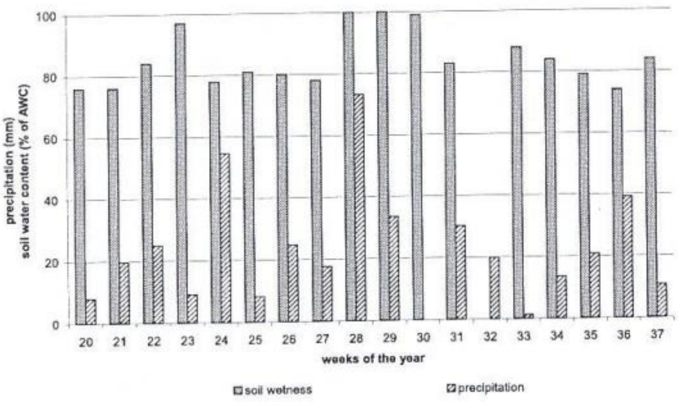

Figure 1 Weekly values of precipitation and the soil water content in 1998.

The average foliage area per tree was 4.6 m² at 1st of June and 6.6 m² at 30th September. The foliage area from bud burst (the middle of April) to the completion of spur leaf area development reached to 70% of the value calculated at the end of the season. The remaining 30% developed during three months, till the end of August. During the period from completion of spurs'leaves area (first days of June) to the end of the season, the rate in increase of total leaf area was not constant due to the periodicity of shoot growth (*Fig. 2*).

Furthermore, the average ratio of spur leaf area to the total foliage area decreased permanently during the second phase of season. The value of this index was at beginning of June near 50%, while at the end of August 35% only.

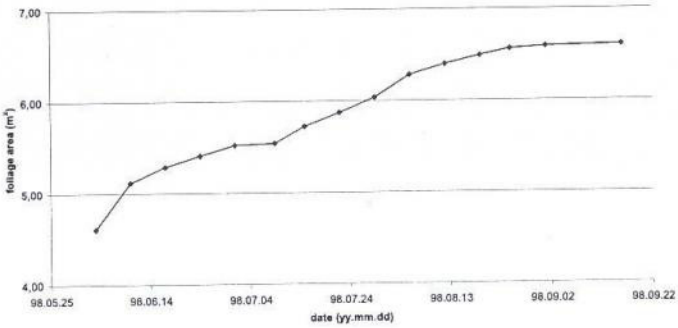

Figure 2 The growth of total foliage area of 'Florina'/M.26 apple trees in 1998.

There was not a local minimum at noon in daily water use curves in the period of investigation (data are not shown), while that is typical under drought conditions (*Lakatos* et al. 1999). The water use related to the leaf area was considerable higher in June and July, than in second part of summer. (*Table 1*). The seasonal trend of ET-FAO differed from the water use of trees a certain degree (*Fig. 3*): the maximum

Table 1 Average daily water use of Florina/M.26 apple trees in 1998.

	l · tree⁻¹ · day⁻¹	l · m⁻² · day⁻¹
May	0.8432	–
June	1.2527	0.2581
July	1.4695	0.2586
August	1.2732	0.1931
September	1.1916	0.1585

value was in both cases at July, but the minimum of ET-FAO during the 5 months investigated was at September, while the minimum of water use per tree was at May.

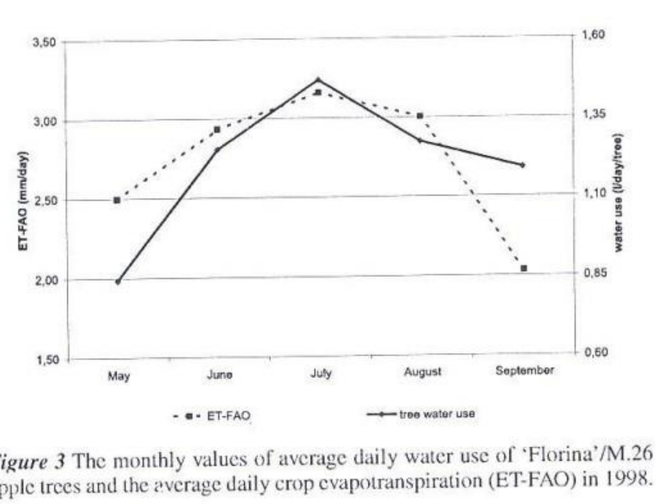

Figure 3 The monthly values of average daily water use of 'Florina'/M.26 apple trees and the average daily crop evapotranspiration (ET-FAO) in 1998.

Discussion

Present paper discribes an investigation concerning seasonal water use and foliage area development of apple trees. In the year of the study there there was no drought period (*Fig. 1*), therefore seasonal water use curve (*Fig. 3*) reflected the specific water demand of apple tree well.

During the first one and a half month of the growing season evolved the two-thirds of the total foliage area. This very dynamic development was mainly a result of very high growth rate of spur leaf area. The transpiration of spur leaves is less, than that of generally higher exposed shoot leaves (*Rom* 1991) and the ratio of spur leaf area to the shoot leaf area became even smaller during the season. Nevertheless, the area specific water use decreased during summer. This may suggest, on the one hand, the great importance of processes leading to the leaf senescence, and other hand the selfshading of the foliage should play a role in water demand of trees.

In spite of decrease in water use related to the leaf area remained the average daily water use of trees relatively high in September. It was a result of the increased foliage area, and – probably – the increased water uptake of fruits. The transpiration of the apple fruit decreases during maturity, but the actual water uptake of fruits is highest before the harvest (*Blanke & Lenz* 1988). The apple cv. 'Florina' investigated is a late ripening variety, therefore September is a critical month from the point of view of fruit water balance. The trends of ET-FAO and water use curves differed mostly in the late season: the ET-FAO curve falls considerable in September compared to August, whereas the value of water use remained similar as it was in August. This insensitivity of ET-FAO in this period may be a great disadvantage using the Penman-Monteith equation in irrigation scheduling of apple.

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