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INFLUENCE OF A ROOTSTOCK ON TRANSPIRATION RATE AND CHANGES IN DIAMETER OF AN APPLE TREE LEADER GROWING UNDER DIFFERENT SOIL WATER REGIMES

ABSTRACT. In the present study the transpiration rate and changes in the diameter of the leaders of apple trees grafted on various rootstocks (P 16, P 22 and M.9), as influenced by different soil water regimes, were examined. The results showed that both these parameters depended on the rootstock and soil water content. The most resistant to soil water deficit was M.9 and the most sensitive P 16. Despite of considerable daily changes of water status in the tissues, P 22 rootstock seems to be more suitable to soils with a low content of water than P 16.

Key words: transpiration rate, ‘Ligol’, apple rootstock

INTRODUCTION. Choice of an appropriate rootstock is one of the most crucial problems in the production of fruit trees. It affects tree vigour, blossoming, fruit yield and quality.

According to Giulivo and Bergamini (1981), a rootstock influences the productivity of a scion by affecting the tree water balance. Differences between rootstocks, especially in the physiological activity of their root system, determine their efficiency in uptaking water and mineral elements from soil (Grzyb, 1974). In the case of dwarf rootstocks, their root system is located near the ground surface, therefore they require fertile soils with adequate amounts of water.

Rootstocks M.9, P 16 and P 22 are commonly used in the production of apple trees in Poland. Available literature does not provide much data on their response to unfavourable soil mois-ture conditions. Drought that has often appeared during growing seasons in recent years may have a decisive impact on the suitability of these rootstocks for apple production in the regions of a less favourable climate.

Careful and accurate evaluation of plants' response to environmental conditions requires long-term research. However, effective and simple analysis of a plant water status is possible based on measurements of several parameters, such as stomatal conductance, water potential in tissues and transpiration rate, in controlled conditions under different soil water regimes (Dettori, 1985; Klamkowski and Treder, 2000). Another way of learning of plants' reaction to a diverse supply of water is an analysis of plant morphology, e.g. diameter of shoots, trunks and fruits and thickness of leaf blades under alterable moisture of soil. These organs change their size due to the effect of growth and as a result of changes in water content in their tissues. According to many authors (Garnier and Gerger, 1986; McBurney and Costigan, 1988; Simonneau et al., 1993; Klamkowski and Treder, 2000) changes in diameter of some organs can serve as a good indicator of plant water status.

The aim of this experiment was to evaluate the effect of a rootstock on the transpiration rate and changes in the diameter of the leaders of apple trees growing under different soil water regimes.

MATERIAL AND METHODS. The experiment was conducted in a glasshouse of the Institute of Pomology and Floriculture, Skierniewice, Poland in 2001. The objects examined were one-year-old ‘Ligol’ apple trees grown in polypropylene containers filled with sandy loam soil. Experimental design was a completely randomised block with 2 factors. First was a type of rootstock and the second the level of soil moisture. M.9, P 16 and P 22 rootstocks were used. Required soil moisture was obtained by applying different water doses using two types of emitters: with the output of 2 or 4 litres of water per hour. Soil moisture in particular combinations was:

– 80-100% of field water capacity (FWC) for plants irrigated with 4 litre emitters,
– 40-50% of FWC for stressed plants (2 litre emitters).

The experiment was done in 6 replicates. Measurements of the transpiration rate were carried out for all trees from each combination on leaves from the top part of a scion. Porometer LI-1600 (Li-Cor, USA) was used for this purpose. Changes in the diameter of the tree leaders were measured by the Pepista 3000 system (Copa-Informatique, France). Sensors used were integrated with an electronic module that collects and processes data. After processing, the results were presented as charts that displayed changes of the investigated leaders` diameter as a function of time. Soil moisture was measured by Trase meter (Soilmoisture, USA).

RESULTS AND DISCUSSION. The applied irrigation had an influence on the transpiration rate of apple trees grown on all three types of rootstocks (Tab. 1). Water deficiency constrained the intensity of this process. An average transpiration rate of stressed plants was lover by about 66% as compared to those grown at soil moisture of 80-100% FWC. A decline of transpiration rate of various tree species in conditions of insufficient water supply was also observed by other authors (Dettori, 1985; Lankes, 1985; Klamkowski and Treder, 2000).

Table 1. Effect of a rootstock on transpiration rate of apple trees grown under different soil water regimes

Rootstock	Transpiration rate [mmol m^{-2} s^{-1}]	
	irrigation to 80-100% FWC	irrigation to 40-50% FWC
P 16	5.18 b*	1.73 a
P 22	6.35 c	2.26 a
M.9	6.52 c	2.21 a

* Means marked with the same letter do not differ significantly at P=0.05 according to Duncan's multiple range t - test

According to Flore et al. (1985), drought tolerance involves primarily two mechanisms: reduction of water loss, and maintenance of water uptake. Since plants take up water through their roots, soil moisture in their vicinity temporarily decreases, and so does the soil potential. As time passes, there is an increasing restrain of water flow from the soil to plants, and as a result of that, there is a gradual decrease of the transpiration rate. The plant restricts water loses from its tissues due to inhibition of transpiration by closing the stomata. According to Bois et al. (1985), one of the strategies used by plants to delay the occurrence of stress due to insufficient soil water is stomatal regulation of the transpiration.

Analysis of variance showed an influence of a rootstock on the transpiration rate (Tab. 1). It was lower in trees grafted on P 16 rootstock, grown both at optimum water supply (soil moisture of 80-100% FWC) and at water deficiency (40-50% FWC), but the difference was significant only in the first case. As such a dependence was not proved for water deficiency conditions, these results may show an unfavourable influence of high soil moisture on the efficiency of water uptake by trees grafted on P 16. A lower transpiration rate of those trees could be either due to a reduced water uptake by the root system or a less intensive water transport within the tree.

According to Giulivo et al. (1985) rootstock features can have an impact on a total water balance of the tree, and the processes occurring just after grafting a scion are crucial for further tree development (Czynczyk, 1998). The correct formation of vascular bundles between the rootstock and the scion is a condition for the proper supply of water for the whole plant. According to Grzyb (1984), a specific influence of a rootstock manifests itself in the ability of modifying the conductance of water and mineral elements at the graft union. Sekse (1998) also suggests that differences in water supply to plant organs can be caused by a partial xylem discontinuity in the rootstock/scion grafting point.

A characteristic feature of the plant growth is a continuous change of its organs' diameter. Shoots, fruits and roots shrink and swell during the day according to a water status of these organs, which as well reflects a water balance of the whole plant. After sunrise, the light stimulates an opening of the stomata, which were closed at night. The plant begins the transpiration process during which it is able to transpire out more water than to uptake through roots, even if the soil is moist. It is possible due to a loss of water by some tissues, causing a decrease of their volume, and in consequence a decrease of the plant organ diameter (Powell and Thorpe, 1977; Chaney, 1981; Fereres et al., 1999). After a cessation of transpiration increase, the plant restores its supplies, providing that water is available in soil; the tissues increase their volume, and so does the organ diameter. This phenomenon is presented in Figure 1, which shows exemplary changes in the diameter of leaders of apple trees grown at soil moisture of 80-100% and 40-50% FWC. When water soil content is insufficient or it is difficult to uptake, for example because of a high salinity, plants use water reserves stored in tissues. Restoration of these reserves becomes difficult and a daily increase of plant organs is less intense. This situation is shown as a thin line in Figure 1. The characteristic feature of the graph lines is the value of a maximum daily shrinkage (MDS) of a tree leader. It illustrates the difference between its maximum and minimum diameter recorded during a particular day. This parameter indicates a relative loss of water reserve in tissues of the examined plant, and it is dependent on some environmental factors influencing the plant transpiration rate, i.e. content of water in soil (Garnier and Berger, 1986; Michelakis, 1997). Average value of MDS for the plant grown at soil moisture of 80-100% FWC was 0.09 mm, whereas for the stressed plant it reached 0.23 mm. Such a large value indicates that plants grown at a low soil moisture used water reserves in tissues to a larger extent. Similar changes were also noticed by Klamkowski and Treder (2000) for apple, Garnier and Berger (1986) for peach, and by Vanniere (1992) for mandarin trees.

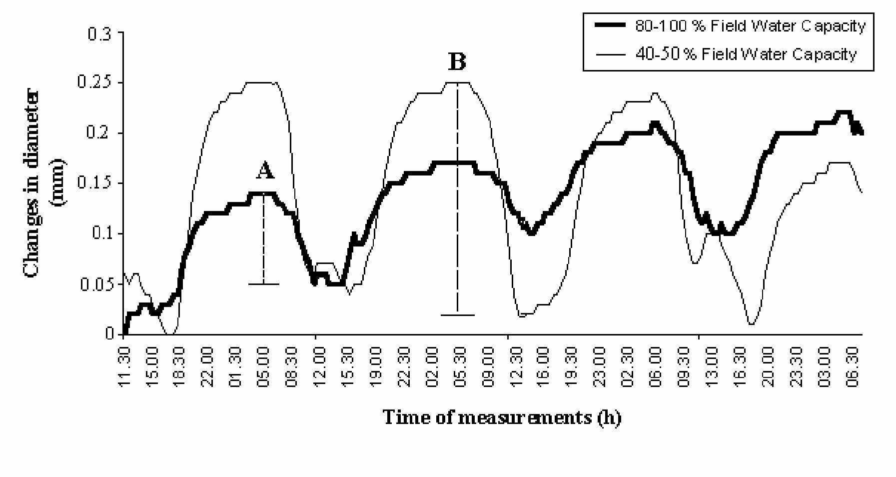

Figure 1. Changes in diameter of apple tree leader as affected by different soil water content. **A, B** – Maximum Daily Shrinkage (MDS) of apple tree leaders, grown under conditions of soil moisture maintained at 80-100 and 40-50% of Field Water Capacity, respectively

Table 2 shows a comparison of maximum daily shrinkage of tree leaders grafted on the three rootstocks, grown at two irrigation levels examined. In the case of P 16 and P 22, these values considerably differed from each other. For M.9 no essential difference occurred in MDS for trees grown at both soil moistures; both the values obtained were significantly lower as compared to the other examined root-stocks. It could be due to a relatively higher resistance of M.9 to water stress. Examination of a vigour of trees grown at water deficiency (data not presented) seems to confirm this fact.

T a b l e 2. Maximum daily shrinkage (MDS) of apple tree leaders as influenced by rootstock and different soil moisture

Rootstock	MDS [mm]	
	irrigation to 80-100% FWC	irrigation to 40-50% FWC
P 16	0.12 c*	0.16 d
P 22	0.09 b	0.23 e
M.9	0.05 a	0.06 a

* Explanation – see Table 1

P 16 rootstock most severely responded to a drought. Changes in the diameter of tree leaders during 7 days are presented in Table 3. Over this time, the diameter of trees grafted on P 16 and grown at 40-50% FWC decreased by 0.11 mm, while for P 22 it declined by 0.08 mm. However, the latter rootstock showed a higher daily fluctuation of the leader diameter (expressed as MDS) (Tab. 2) indicating a considerable loss of water. It may be due to a higher water status of P 22 rootstock tissues, and as a result they become more susceptible to changes in water supply, altering their diameter to a large extent. However, despite of an essential loss of water during the day, trees grafted on P 22 could regenerate their supplies to a greater degree after a cease of transpiration at night, as compared to those on P 16.

T a b l e 3. Changes in diameter of apple tree leader during 7 days

Rootstock	Changes in diameter [mm]	
	irrigation to 80-100% FWC	irrigation to 40-50% FWC
P 16	0.07 a*	-0.11 c**
P 22	0.08 a	-0.08 b
M.9	0.12 b	-0.02 a

* Explanation – see Table 1

** Negative value indicates a decrease in diameter

CONCLUSIONS. The presented results lead to a conclusion about an essential influence of a rootstock on water relations of the whole tree. Both the rate of transpiration and changes in the diameter of apple tree leaders were dependent not only on a degree of water supply (soil moisture), but also on the type of rootstock.

Further study on this subject is being continued in order to analyse the root systems and growth of apple trees on the same three rootstock at various water regimes.

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