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Effect of water deficit on the growth and yield of 'Topaz' apple trees planted in different former soil management

Zofia Zydlik[1], *Eugeniusz Pacholak*[1], *Czesław Przybyła*[2]

[1]Department of Pomology, Agricultural University in Poznań
[2] Department of Land Reclamation and Environmental Architecture
Agricultural University in Poznań
Dąbrowskiego 159, 60-594 Poznań, Poland
e-mail: zydlik@au.poznan.pl

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ABSTRACT

The aim of the experiment was to investigate the influence of water deficiency on the growth and yield of 'Topaz' apple trees. The study was conducted in the years 2000 – 2002 at the experimental farm of the Agricultural University, in Przybroda. The course of dynamic and water resource in soil depended on magnitude of rainfalls and their distribution in the period of vegetation. In the first years after planting, the growth and yielding of trees depended on the earlier ways of soil using. The best growth and yielding of trees was observed at a new site, and the worst – after planting in rows of old trees.

INTRODUCTION

Adequate water supply to trees is one of the basic conditions to obtain a high quality yield. The basic water source in the soil and frequently the basic water supply to plants are water resources accumulated in the soil as a result of atmospheric precipitation.

Water economy on areas intensively utilized for pomiculture depends on the water balance of the given area and also on the structure and properties of the soil and other environmental factors (Kobel 1960). The level of ground waters also plays an important part in the water balance as the possibility to supply the upper layer of soil by capillary rise. The data reported by Treder (1998) indicate that 24% of Poland`s area are characterized by a negative water balance (deficits are greater than 160 mm), therefore irrigation is regarded by many scientists as a common agrotechnical treatment (Treder 1998).

Gullino and Mezzalama (1994) stressed that in replanted orchards, a higher soil moisture favours a stronger development of diseases caused among others by *Verticilium sp.* and *Fusarium sp.* when the moisture is maintained on the level of 40% of field water capacity.

Studies on the effectiveness of apple orchard carried out under the conditions of diversified soil localities aimed at the evaluation of the effect of water deficit on the growth and yielding of apple trees 'Topaz'.

MATERIAL AND METHODS

The work presents results of 3-year studies (2000 – 2002) carried out at the Agricultural and Pomological Experimental Farm in Przybroda localized 25 km to the north of Poznań. The material consisted of 'Topaz' apple trees, on M.26 rootstock. The trees were planted in spring 2000 at the spacing of 3.5 × 1.5 m (1900 trees ha^{-1}). The trees were planted in a locality where in the years 1979 – 1999 trees of 'Cortland' were cultivated on the M.26 rootstock in 5 × 3 m spacing. The first stubbing of old trees in the orchard was carried out in autumn 1996; two rows of trees were removed, and in the successive years, agricultural plants were grown there. The next stubbing was carried out in autumn 1999 and no additional soil preparation was done. The term of the tree removal and the change of tree spacing caused the newly planted trees to grow in different localities in the following treatments:

- trees were planted in the site where old trees were stubbed,
- trees were planted in former herbicide strips,
- trees were planted in former grass alleyways,

- trees were planted in a soil after a 4-year break in apple tree cultivation,
- trees were planted at a new site (the soil was not pomiculturally utilized before).

Periodical soil moisture measurements were carried out by the dielectric method – TDR (Time Domain Reflectometry). Ground water measurements were carried out, and with the use of Penman`s formula, the potential evapotranspiration (ETp) and the real evapotraspiration (ETr) were calculated in the vegetation periods (IV-IX).

The growth of trees was evaluated on the basis of stem diameter, tree losses were counted and the unitary yield from each tree (kg per tree) was converted into $t\ ha^{-1}$.

Results were elaborated by analysis of variance, using the STATISTICA computer programme. Significance of differences between treatment means was estimated by the Duncan test at $p = 0.05$.

RESULTS AND DISCUSSION

The course of climatic conditions and particularly the amount of precipitation have a significant effect on the size and quality of the yield. In the study period in the region of Wielkopolska, in reference to rainfalls, the vegetation seasons 2000 and 2001 could be counted as moderately wet ones, while the season 2002 was a dry one. The relationship between rainfall and temperatures is shown in the climatogram indicating that in all vegetation seasons, periods of drought occurred, but the deepest one was in 2002 (Fig. 1). Deficits in rainfall calculated as climatic water balances (difference between evapotraspiration – ETp and real rainfall in Fig. 2) reflect the course of meteorological conditions in the analysed years. It was found that the differentiation of water economy in the soil was influenced by the course of rainfall in the vegetation period but also by the soil site, structure of soil profile and the localization of ground water level. The course of water reserve dynamics in the 0-60 cm layer and the level of ground water depended on the amount of rainfall and their distribution in the successive months of the vegetation period. Similar dependences were found by Pacholak and Przybyła (1994) in their studies carried out in the years 1987 – 1993.

Numerous studies indicate that the intensity of tree growth depends to a high degree on soil moisture (Blaase et al. 1993, Pacholak and Przybyła 1996). Studies carried out in the years 2000 – 2002 showed an essential effect of water content and locality on the tree growth and tree losses. Trees planted at the site where old trees had been stubbed showed an impediment of growth measured by the area of stem cross-section and increased number of lost trees amounting to 38% (Table 1).

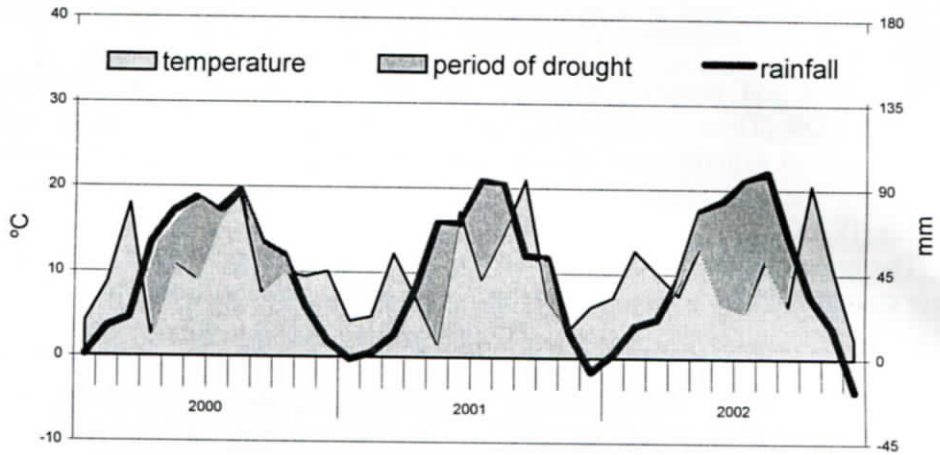

Figure1. Diagram for the climatic conditions in Przybroda (2000 – 2002)

Table 1. The influence of cultivation localities on the growth and yielding of 'Topaz' apple trees (mean 2000 – 2002)

Cultivation locality	Tree losses [%]	Stem cross-sectional area [cm^2]	Yield [kg per tree]	Yield [t ha^{-1}]	Yield efficiency [kg cm^{-2}]	Fruit weight [g]
Old tree sites	38	1.80 a*	1.0 a	1.9	0.56 a	139 a
Former herbicide strips	30	2.94 c	2.2 a	4.2	0.75 a	173 b
Former grass alleyways	28	2.45 b	2.4 a	4.6	0.98 a	160 b
Four-year break in tree cultivation	13	3.21 c	2.9 a	5.5	0.90 a	170 b
New site	3	3.67 d	8.5 b	16.2	2.32 b	198 c

* Means marked with the same letters did not significantly differ at level p = 0.05

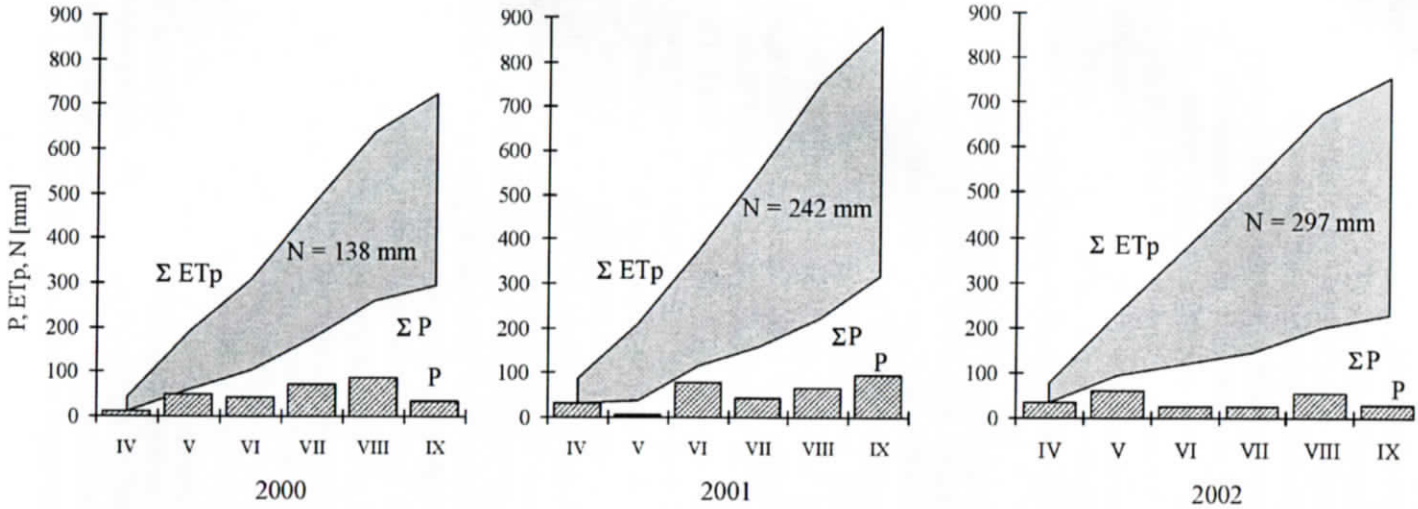

Figure. 2. Mean monthly sums of precipitation P from the mean of 2000 – 2002 and cumulative curves of precipitation ΣP, potential evapotranspiration ΣETp and water deficiency N =Σ(ETp– P)

The planting of trees in former herbicide strips or former grass alleyways caused the greater tree growth measured by the area of stem cross-section, but the number of tree losses was high, reaching up to 30%. On the other hand, the application of a 4-year break in apple tree cultivation resulted in a high improvement of tree growth as compared to the locality with replantation, and the number of lost newly planted trees amounted to 13%. Definitely the best conditions for growth were found in the soil which was not pomiculturally used before. There, the growth force of trees measured by the area of stem cross-section was the greatest and the number of lost trees did not exceed 3%. Poorer growth of trees and an increased number of lost trees in conditions of replantation, i.e. plantation of apple trees after stubbed old apple trees of the same species were reported by Geldard (1994) and Hoestra (1994).

The tree growth in the experimental conditions was closely correlated with the yielding of apple trees 'Topaz'. Regardless of the cultivation locality, the trees entered into the fruiting period in the second year after planting, but the yields from trees after replantation were very low and they oscillated in the range 0.0-0.6 kg per tree. On the other hand, definitely higher yields were obtained from trees in a new soil (1.7 kg per tree). In the second year of fruiting and the third year after planting, the yields were higher and significantly diversified depending on the cultivation locality. Similarly as in the first year, the lowest yields were noted in trees planted in the old tree rows (mean yield 1.0 kg per tree). The plantation of trees in the previously applied herbicide fallow belts or former grass alleyways, as well as application of a 4-year break in apple tree cultivation did not statistically improve the yield which was higher and ranged between 2.2 and 2.9 kg per tree. On the other hand, the plantation of trees in a new soil gave the highest yield reaching up to 8.5 kg per tree. The yield obtained from an area unit was definitely the highest in the case of an orchard in a new soil amounting to 16.2 t ha^{-1}. The cultivation of trees in a locality after replantation gave a yield depending on the treatment from 1.9 t ha^{-1} (when trees were planted in rows where apple trees were cultivated earlier) to 5.5 t ha^{-1} in treatment with a 4-year break in apple tree cultivation (Table 1). The intensity of yielding is frequently expressed by yield efficiency index, which defines the dependence between the vegetative growth and the yield. It was found that the productivity of trees depended essentially on the cultivation locality. The most productive trees were those growing in virgin soil (2.32 kg cm^{-2}) while trees growing in the replanted orchard were characterized by a lower yield coefficient ranging between 0.56 and 0.98 kg cm^{-2} (Table 1). These results have confirmed the results obtained by Geldard (1994) and Pacholak et al. (1996) who found that trees in replantation conditions (in monoculture) can be characterized by a decrease or complete absence of yield in the first five years of cultivation involving serious negative economic results.

The quality of fruits evaluated on the basis of apple weight also depended on the locality (Table 1). The plantation of apple trees in rows of stubbed old trees significantly decreased the fruit weight (138 g). The plantation of trees in former herbicide strips and former sward, or after a 4-year break significantly increased the fruit weight. Trees planted in a new soil had fruits with the greatest weight of 198 g.

CONCLUSIONS

1. The course of the dynamics of water and its resources in the soil depended on the amount of precipitation and its distribution in the vegetation period.
2. The growth of trees measured by the area of stem cross-section and the number of lost trees depended on soil moisture and cultivation locality. The best growth was shown by trees in new soil, and the poorest one was observed in trees planted in former herbicide strips.
3. The yielding of trees, similarly as their growth, depended on water content in the soil and the plantation locality. The highest yield of good quality fruit was obtained from trees planted in a new soil. Plantation of trees in replanted soil decreased the yield and deteriorated the fruit quality.

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WPŁYW DEFICYTÓW WODY NA WZROST I PLONOWANIE JABŁONI ODMIANY TOPAZ W RÓŻNYCH STANOWISKACH UPRAWY

Streszczenie: Badania nad wpływem deficytu wody i stanowiska wzrost i plonowanie jabłoni odmiany 'Topaz' przeprowadzono w latach 2000 – 2002 w sadzie doświadczalnym Katedry Sadownictwa Akademii Rolniczej w Poznaniu mieszczącego się na terenie Rolniczo-Sadowniczego Gospodarstwa Doświadczalnego w Przybrodzie. Przebieg dynamiki i zasobów wody w glebie uzależniony był od wielkości opadów i ich rozkładu w okresie wegetacji. W pierwszych latach po posadzeniu wzrost drzew i plonowanie były uzależnione od wilgotności gleby i stanowiska uprawy. Najlepiej rosły i plonowały drzewa na nowinie, a najsłabiej te, które wysadzono w rzędach starych drzew.

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