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EFFECT EXERTED REPLANTATION ON THE GROWTH AND YIELDING OF THE APPLE TREES

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Abstract. The problem of soil fatigue occur in polish orchards more and more often. This problem can cause to lower profitability of the production. Studies were carried out in an experimental orchard in the years 2008–2010. The objective of the presented studies was the determination of the earlier applied method of soil utilization on the growth and yield of `Topaz` apple-tree cultivar. Apple-trees were planted in fivesoil localities: 1 – directly in grubbed up rows of an apple-tree orchard, 2 – in herbicide fallow belts of grubbed up apple-tree orchard, 3 – in turf belts of grabbed up apple-tree orchard, 4 – in a locality after a four-year break in apple-tree cultivation, without any preparatory treatments and 5 – in a soil after previous agricultural use – virgin soil. During the realization of our studies, an estimation was carried out of the trunk cross-section, of leaf blade area and of the yield, size and fruits quality. Our studies have shown an influence of the soil locality on the yielding of trees which ten years after replantation was very low amounting on the average to about 4 $t \cdot ha^{-1}$ in case of apple trees planted directly in the place of the grubbed up trees, while in the virgin soil, the yield reached up to 40 $t \cdot ha^{-1}$. The growth of trees planted in the locality after replantation was also significantly poorer, in comparison with the apple trees planted in the soil which was agriculturally utilized before.

Key words: soil fatigue, replantation disease, yield, leaf blade area, fruit mass, fruit firmness

INTRODUCTION

The problem of soil fatigue has been known since long ago and the first mentions referring to the cultivation of the same plant species on the same area had been already recorded in Mesopotamia ages ago. However, the greatest revival in the studies on soil fatigue occurred at the turn of the 20th century and the studies have taken a completely new course because of a significant shortening of the period of an orchard utilization. In

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the subjective literature, there appeared reports about a poor taking root by trees after a grubbed up orchard [Bingye and Shengrui 1998] and about a poor tree growth [Constante et al. 1991], and non-uniform tree growth [Sewell et al. 1992]. Soil fatigue also contributes to the shortening of internodes, it decrease leaf blade area [Traquair 1984, Pacholak and Zydlik 2004], it decreases yielding even 5–10 years after replantation [Otto and Winkler 1993], most frequently it is associated with the decrease of the number of root hairs and the creation of the so called `bird`s ne sts`on the roots [Mai and Abawi 1981; Trottin-Caudal 1985]. Replantation disease is closely associated with the soil and it is limited to the places, where the affected removed tree roots were growing earlier.

The results of soil fatigue are most visible in the first years of tree growth [Sewell et al. 1992]. In spite of the fact that after 2–3 years, the disease starts partially to retreat, it always causes delays and decreases the yielding which can lead to the necessity of orchard liquidation [Trottin-Caudal 1985, Zucconi 1993, Hoestra 1994]. It must be stressed that trees grafted on dwarf or semi-dwarf clonal rootstocks are more sensitive to soil fatigue than trees growing on healthy clonal rootstocks.

However, in the world literature, no reports are available dealing with the direct effect of replantation disease on the quality features and on the storing quality of fruits. One can only find some general statements that such effect must have taken place [Schoor et al. 2009].

The objective of our studies carried out in the years 2008–2010 was to determine the effect of the replantation on the growth and yielding of `Topaz` cultivar apple trees.

MATERIAL AND METHODS

Studies carried out in the years 2008–2010 in the Experimental Station of the Department of Pomology University of Life Sciences in Poznań, on the area of the Agricultural and Fruit-Growing Farm in Przybroda. The experiment was established on a grey-brown podzolic soil created of boulder clay sandy loam. The arable soil layer consisted of boulder clay sandy loam strongly sandyfied, containing 17–20% of floatable parts. The groundwater level was at the depth of 120–180 cm.

The investigated material was represented by apple-trees of `Topaz` cultivar inoculated on M.26 rootstock, planted in spring 2000 in a space distribution of 3.5 × 1.5 m (1900 trees/ha) on three quarters:

Quarter I – from the year 1949 until the termination of our studies (2010), apple-trees were cultivated. In that period, three replantations of trees were carried out. In 1979, the first replantation was performed without any additional preparation of soil. Apple-trees of `Cortland` cultivar, on M.26 rootstock were planted in the spacing of 5 × 3 m (667 trees/ha) in a one-row system. Width of the belt of herbicide fallow was 2.3 m. In spring 2000, the second replantation was carried out with the application of `Topaz` cultivar. The introduced decrease of the spacing permitted to obtain the following combinations of soil localities:

– combination 1 – directly in the rows of the grubbed up trees,

– combination 2 – in the belts of the herbicide fallow of the grubbed up trees,

– combination 3 – in the belts of turf between the grubbed up trees.

Quarter II – similarly as in quarter I, apple-trees cultivation had been carried out since 1949. The first replantation was done in 1979 using `Cortland` cultivar apple-trees (as described above), which were grubbed up in autumn 1996. In that quarter, no other plants were cultivated and no additional treatments were carried out to prepare it under the orchard. The second replantation was performed in spring 2000, which permitted to separate a locality with a 4-year break in apple-tree cultivation and this locality constituted combination 4.

Quarter III – it was locality, where no orchard plants had been grown before (it was used for agricultural purposes). The first orchard was established here in spring 2000 as – combination 5.

Content of the mineral components and biochemical properties of the soil was described in the earlier papers [Zydlik et al. 2011 a, b].

All combinations of soil localities were established in two blocks and in each block, 40 trees were planted. In each block, 20 trees were selected for observation purposes (every second tree) . All agricultural treatments were carried out according to the recommendations for this species.

Assessment of the tree growth was carried out on the basis:

– of tree trunk circumference at the height of 30 cm above earth level and from this measurement, the trunk cross-section area (TCSA) was calculated.

– estimation of the long-shoots number in the tree crown. It was made in the 1/4 of the tree crown.

– surface of the leafs – 100 leafs was collected from each plots. After scanning, the surface of the leafs was measured (in cm^2) using a digiShape program.

The term of fruit harvest was determined on the basis of starch decomposition degree and on the fruit firmness. In the estimation of yielding, the unitary yield from one tree (tree$\cdot$ kg^{-1}) was taken into consideration and it was converted into the yield efficacy from one ha ($t \cdot ha^{-1}$).

Fruit quality assessment was performed directly after harvest, taking into consideration the following features:

– Fruit mass – from each replication, 20 fruits were taken and they weight exact to one gram

– Measurement of fruit firmness was done on 10 fruits from each replication using fruit pressure tester mod. 327 of Facchini Co., fixed on a tripod. The measurement value is expressed in kG.

– Extract content was measured on the same fruits which were tested Extract content was estimated using Abbe`s refractometer. The measurement value was expressed in Brix degrees.

For the purpose of results interpretation, a two-factorial statistical analysis was carried out, where the factors were represented by soil localities combinations and by the years of studies, at the significance level of $\alpha = 0.05$. All results have been discussed basing on the mean values for combinations from the year 2008–2010. Statistical analysis has been carried out using the STATISTICA 7.1 program.

RESULTS AND DISCUSSION

Tree growth measured by the trunk cross-section area, by the number of longshoots and the leaf blades area was significantly differentiated, depending on the locality, where the trees were planted (tab. 1; photo 1)). Trees planted intothe dug up tree rows and into the rows of herbicide fallow after 11 years of cultivation, were characterized by a poor increment of the trunk cross-section area which showed 8.2 cm^2 and 13.3 cm^2, respectively. After the application of a 4-year break in the apple tree cultivation, the increment of the trunk cross-section area was 42.3 cm^2 and it was by one half smaller than in trees planted on virgin soil (tab. 1). The poorer growth under the influence of the use of replantation was shown also by Laurent et al. [2008], Reginato et al. [2008] and Zydlik [2010]. The use of replantation contributed into places of dug up trees was, on the average, 6.5 pices, while in apple trees planted in the belt of herbicide fallow, it was 9.9 pices (tab. 1). The highest number of longshoots was found in the trees planted on virgin soil and in belts of turf after a dug up orchard, did not differ significantly in the number of longshoots in the crown (tab. 1).Apple trees planted directly into the place of dug up trees were also characterized by a smaller surface of the leaf blade area it was shown by trees planted in a locality where a 4-year break in the cultivation of apple trees was applied, or in a virgin soil (tab. 1). Similar effecta of the applied replantation were obtained by many authors, among others, by Leinfelder and Merwin [2006] showed that sweet cherry trees grown in a sick soil were characterized by a 40% poorer growth tham trees grown in a chemically disinfected soil. On the other hand, Brown and Koutoulis [2008] found that apple trees growing in a soil with replantation disease showed a poorer vigor, the smallest leaf area, the smallest leaf area , the smallest increments of long shoots and a poor increment of stem cross-section surface area.

Table 1. Tree growth in replanted orchard
Tabela 1. Wzrost drzew w sadzie po replantacji

Locality Stanowisko	Trunk cross-sectional area Pole przekroju poprzecznego pnia (cm^2)			Number of longshoots Liczba długopędów (szt)	Leaf area powierzchnia liścia (cm^2)
	in planted year w roku sadzenia drzew	in year w roku 2010	increase przyrost		
Old row of trees Stary rząd drzew	1.4 a*	9.6 a	8.2 a	6.5 a	19.7 a
Old herbicide fallow Stary ugór herbicydowy	1.4 a	14.6 ab	13.2 ab	9.9 a	22.8 a
Old turf Belt Stary pas murawy	1.4 a	18.1 b	16.7 b	69.1 b	23.6 a
4-year break 4-letnia przerwa	1.4 a	43.7 c	42.3 c	91.8 c	26.8 ab
Virgin soil Nowina	1.4 a	82.1 d	80.7 d	67.0 b	32.7 b

*mean values marked with the same letter do not differ significantly at $\alpha = 0.05$
*średnie oznaczone tymi samymi literami nie różnią się istotnie na poziomie $\alpha = 0,05$

Phot. 1. Trees growth and yalding in replant orchard in the 11 year after plantation (Phot. Z. Zydlik)

Fot 1. Wzrost i plonowanie drzew odmiany Topaz w 11 roku uprawy w zależności od stanowiska glebowego. (fot. Z. Zydlik)

Table 2. Yielding of apple trees in replanted orchard
Tabela 2. Plonowanie jabłoni w sadzie po replantacji

Locality Stanowisko	yield in kg·tree^{-1} – plon w kg·drzewo^{-1}				Yield in t·ha^{-1} Plon w t·ha^{-1}
	2008	2009	2010	mean średnio	
Old row of trees Stary rząd drzew	1.9 a*	2.3 ab	2.8ab	2.3 a	4.4 a
Old herbicide fallow Stary ugór herbicydowy	3.0 ab	4.4 a-c	4.2 a-c	3.9 b	7.4 b
Old turf belt Stary pas murawy	10.6 f	7.2 c-e	15.7 g	11.2 d	21.3 d
4-year break 4-letnia przerwa	10.8 f	5.8 b-d	9.8 ef	8.8 c	16.7 c
Virgin soil Nowina	26.6 h	16.8 g	16.1 g	19.8 e	37.6 e

*mean values marked with the same letter do not differ significantly at $\alpha = 0.05$
*średnie oznaczone tymi samymi literami nie różnią się istotnie na poziomie $\alpha = 0{,}05$

Differentiated growth of trees strictly correlated and exerted a significant influence on apple tree yielding. In the years 2008–2010, the lowest yields were obtained from apple trees planted directly in the place of grubbed up trees and in herbicide fallow belts, while the highest yields were harvested on the virgin soil (tab. 2). It is noteworthy that higher yields were harvested from trees planted in the turf belts of the grubbed up orchard than from trees planted in localities which had a 4-year break in apple-tree cultivation. However, the yields were almost by one half lower, in comparison with the yield obtained from trees planted in virgin soil (tab. 2). These studies have been confirmed by the results obtained by many authors who argue that replantation brings decreased yields caused by replantation disease developing when a new orchard is established on the area where a previous orchard was liquidated [Campanha et al. 2004; Tustin et al. 2008; Brown and Koutoulis 2008].

Table 3. Same parameters of fruits quality (mean of 2008–2010 years)
Tabela 3. Wybrane parametry jakości owoców (średnia z lat 2008–2010)

Locality Stanowisko	Weight of fruit Masa owocu (g)	Extracts content Zawartość ekstraktu (% ^{o}Brixa)	Firmness Jędrność (kG)
Old row of trees Stary rząd drzew	157.6 a*	14.5 a	6.7 a
Old herbicide fallow Stary ugór herbicydowy	183.0 b	14.9 a	6.5 a
Old turf Belt Stary pas murawy	193.9 b	14.3 a	6.6 a
4-year break 4-letnia przerwa	192.3 b	14.5 a	6.8 a
Virgin soil Nowina	180.0 b	14.0 a	6.7 a

*mean values marked with the same letter do not differ significantly at $\alpha = 0.05$
*średnie oznaczone tymi samymi literami nie różnią się istotnie na poziomie $\alpha = 0{,}05$

Obtained results also indicate that the application of replantation exerts an influence on the quality of the produced fruits (tab. 3). During the research period, it has been found that only the fruit weight depended on the locality where the apple trees were planted. The smallest fruits with a weight of 157.6 g were obtained from apple trees planted directly in the place of grubbed up previous trees (tab. 3). On the other hand, the remaining localities used in our experiment did not exert any significant effect on the fruits mass (tab. 3). It must be stressed that the soil locality did not exert any essential effect on the internal characteristics of fruits measured by extract content and by fruit firmness (tab. 3). Brown and Koutoulis [2009], in their 7-year studies carried out in a replanted orchard, where they applied different chemical treatments which limited the results of replantation disease, also did not find any significant effect of these chemical treatments on any changes in the firmness and in sugar content in the fruits.

CONCLUSIONS

1. Replantation exerted a significant effect on the limitation of apple growth by decreasing the trunk cross-section area, the number of longshoots and the leaf blade area.

2. The yield of apple trees cultivated after replantation was significantly lower, in comparison with the yield obtained from trees planted in a locality after previous agricultural use. Plantation of trees in turf belts of grubbed up orchard and the application of a 4-year break in apple tree cultivation improved fruit yield, but it was significantly lower that given by trees planted in a virgin soil.

3. The application of replantation contributed to the decrease of fruit weight, however, it did not exert any effect on the internal fruit quality expressed by fruit firmness and by the content of extract.

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WPŁYW STOSOWANIA REPLANTACJI NA WZROST I PLONOWANIE JABŁONI

Streszczenie. Zmęczenie gleby jest zjawiskiem coraz częściej występującym w polskich sadach przyczyniającym się do obniżenia opłacalności produkcji. Badania przeprowadzono w sadzie doświadczalnym na terenie RSGD w Przybrodzie w latach 2008–2010. Jabłonie odmiany Topaz posadzono na pięciu stanowiskach glebowych: 1 – bezpośrednio w rzędach wykarczowanego sadu jabłoniowego, 2 – w pasach ugoru herbicydowego wykarczowanego sadu jabłoniowego, 3 – w pasach murawy wykarczowanego sadu jabłoniowego, 4 – na stanowisku z czteroletnią przerwą w uprawie jabłoni, bez zabiegów przygotowawczych i 5 – glebie po uprawach rolniczych – nowina. W trakcie realizacji badań dokonano oceny wzrostu na podstawie powierzchni pola poprzecznego przekroju pnia i powierzchni blaszek liściowych oraz wysokości i jakości plonu. Badania wykazały istotny wpływ stanowiska glebowego na plonowanie drzew, które po dziesięciu latach uprawy

po replantacji było bardzo niskie i wynosiło średnio 4 t·ha^{-1} w przypadku jabłoni sadzonych bezpośrednio w miejscu wykarczowanych drzew, podczas gdy na nowinie dochodziło do 40 t·ha^{-1}. Wzrost drzew sadzonych na stanowisku po replantacji również był istotnie słabszy w porównaniu z jabłoniami wysadzonymi na glebie wcześniej użytkowanej rolniczo.

Słowa kluczowe: zmęczenie gleby, choroba replantacji, plon, powierzchnia liści, masa owoców, jędrność

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