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Soil exhaustion and rootstock effect on the growth of apple planting material

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Abstract. Apple rootstocks P 59, P 22, P 2, P 60, M.9, M.26, MM.106, B.118 (54–118), B.396 (62–396) and 'Antonowka' seedlings were tested at the Lithuanian Institute of Horticulture in fresh soil and in soil previously used for an apple nursery. Replanting had a negative effect on the development of apple tree propagation material in the nursery. Bud survival of cv. 'Sampion' decreased by 24% compared to those in fresh soil. Other tree growth parameters were suppressed as well: tree height by 29%, trunk diameter by 24%, average leaf area by 28%, and absolutely dry leaf weight by 33%. Combining all parameters it could be concluded that apple trees of cv. 'Sampion' on P 59 and P 60 rootstocks are the most sensitive to soil exhaustion, whereas trees on P 2 and B.396 rootstocks show tolerance to replanting.

Key words: *Malus* sp., nursery, replanting, rootstock, vegetative growth

INTRODUCTION

Soil exhaustion or apple replant disease is a serious problem which suppresses growth and decreases yield of apple trees in all major fruit-growing areas of the world (Hoestra, 1968; Szczygieł, Zepp, 1993; Švirinas & Lanauskas; 2000 Pacholak et al., 2004). Apple replant disease is even more pronounced in the nursery, causing poor growth and development of apple planting material. Common practice for the nurseries is to start every propagation cycle on fresh soil in order to avoid replant problems (Wertheim, 1998). The reasons for disease occurrence and possible agents are still not clear enough. In some theories various organisms are associated with apple replant disease (Mazzola, 1998; Rumberger et al., 2007); others theorize that nutrition level is the main reason for poorer apple tree performance. The most common practice to prevent replant problems was soil fumigation with methyl bromide. Due to the resulting pollution, different strategies of replant problem control were investigated and suggested to replace fumigation. Use of organic matter in the planting hole (Nielsen, 1994) or fertilizers with high available phosphorous levels have been reported to improve apple tree growth in replant soils (Wilson et al., 2004). Replant problems in the orchard can be counteracted also by trickle irrigation and fertigation leaching toxic substances from the rhizosphere (Robinsson & Stiles, 1993; Paoli, 1997). The applications of acetic acid and *B. subtilis* as preplanting drench applications could also provide a solution (Utkhede et al., 2001).

Due to varying success of the mentioned practice to control apple replant disease new rootstock breeding programs were initiated, targeting rootstock resistance or tolerance to apple replant disease (Laurens et al., 2004). Differing origins and genetic backgrounds of rootstocks suggest that their adaptiveness to replanted soil will vary. Clear differences of rootstock effect on the quality of apple planting material in fresh soil were established (Kviklys, 2004), but rootstock performance in replanted soil conditions has not been widely tested. Information on replant tolerance of the most popular rootstocks is poor and controversial (Otto & Winkler, 1981). Recently, only a few rootstocks from the Cornel–Geneva rootstock breeding program showed some tolerance to replant problems (Robinson et al., 2004; Rumberger et al., 2004).

The aim of the trial was to evaluate the effect of soil exhaustion on rootstock performance and quality of apple planting material.

MATERIALS AND METHODS

The nursery trial was performed at the Lithuanian Institute of Horticulture (Central Lithuania 55˚ 60’ N, 23˚ 48’ E) in 2005–2007. Apple rootstocks P 59, P 22, P 2, P 60, M.9, M.26, MM.106, B.118 (54–118), B.396 (62–396) and ‘Antonowka‘ seedlings were tested in fresh soil and in soil previously used for an apple nursery that was left fallow for one year. Sixty rootstocks of every clone were planted at 90x30 cm distances and budded in summer with apple cv. ‘Sampion’. The trial was performed in 5 replications. The trial was managed according to nursery technology. No fertilization was applied in order to avoid possible interaction between fertilizers and soil exhaustion. Meteorological conditions during the years of investigation had no negative influence on trial results.

The following characteristics were measured: number of surviving buds (%); one year old tree height (cm); trunk diameter (mm, 30 cm above ground level); average leaf area (cm^2, counted as a mean of 10 fully developed leaves from the upper part of the tree by area measure WinDIAS, Delta–T Devices); absolutely dry leaf weight (g, of the sample of 10 fully developed leaves dried at 105°C temperature until permanent weight).

Results were statistically elaborated by two–factorial analysis of variance (rootstock was factor A, planting site was factor B). To evaluate the significance of the differences between means, LSD test with 5% significance level was used.

RESULTS AND DISCUSSION

Soil conditions and rootstock growth during the first year in the nursery had significant influence on bud survival during the winter. On average of all rootstocks 83% of buds survived in the fresh soil during the budding year and following winter, while only 63% of buds survived in the replanted field (Table 1). Soil conditions could have influenced the physiological state of the rootstock that determined poor bud survival, although rootstock growth was not suppressed during the planting year. The most sensitive to replantation are newly germinated apple tree seedlings. They are often used in biotests for prediction of replant diseases (Hudska, 1988; Szczygiel & Zepp, 1993; Lanauskas, 2001; Manici et al., 2003). Absence of biometrical differences in the first year of our investigations could be explained by rootstock development before planting that was sufficient for rootstock establishment and growth during the planting year in both soil conditions.

Table 1. Rootstock and planting site effect on ‘Sampion’ apple tree bud survival in the nursery, by %.

Rootstock	New field	Replanted field	Decrement of survived buds
Factor A	Factor B		
Seedling	80	42	47
B.118	83	70	15
MM.106	85	84	1
M.26	92	80	13
P 60	77	37	52
B.396	90	70	23
P 2	84	83	1
M.9	90	65	28
P 22	75	45	40
P 59	76	56	26
LSD_{05AB}	12.3		
Average	83	63	24
LSD_{05B}	9.6		

The biggest loss of buds was determined on rootstocks of Polish origin: P 22, P 60 and P 59. In both soil conditions these rootstocks had a lower percentage of surviving buds. On the other hand, another rootstock, P 2, from the same breeding programme had good bud survival. P 2 and MM.106 did not show negative effects of replanting. The highest bud loss (40–52%) in the replanted field compared with fresh soil was observed on P 60, ‘Antonowka‘ seedlings and P 22 rootstocks. These three rootstocks showed poor results in a similar trial performed at the Lithuanian Institute of Horticulture with apple cv. ‘Auksis’ (Kviklys et al., 2007).

Rootstock affects the quality of planting material. Our earlier performed trial determined significant influence of rootstock genotype on biometrical parameters of maiden trees (Kviklys, 2004). However rootstock performance in replanted field conditions was different than in the fresh soil. Significantly, the highest one year old trees in fresh soil were on B.118 and seedling rootstocks (Table 2). Nursery tree height on these rootstocks in the replanted field was also the biggest, but there was no significant difference with trees on P 2 rootstock, though in the fresh soil trees on P 2 were the smallest. The shortest trees in the replanted field were on P 60 and P 59 rootstocks.

The tree height of all rootstocks was significantly reduced in the replanted field: average height decrease was 29.4%. The greatest reduction (around 40%) of tree height was observed on P 60 and P 59 rootstocks, which confirmed the previous investigation with cv. ‘Auksis’ (Kviklys et al., 2007). ‘Sampion’ trees on P 2 and B.396 rootstocks were the least sensitive to replant problems, though height decrease was rather high - 13 and 20% respectively.

Decrement of tree trunk diameter due to replanting was slightly lower than the decrement of tree height. On the average of all rootstocks, trunk diameter decreased in the replanted field by 23.6%. The smallest changes of trunk diameter were recorded for trees on P 2 rootstock (9%); the largest, on P 59 and M.26 rootstocks (30% and more). Susceptibility of M.26 rootstock to replanting is mentioned in other investigations, also (Rumberger et al., 2004; Rumberger et al., 2007).

Table 2. Rootstock and planting site effect on 'Sampion' apple tree height and trunk diameter in the nursery.

Rootstock	Tree height, cm			Tree trunk diameter, mm		
	New field	Replanted field	Height decrement, %	New field	Replanted field	Diameter decrement, %
Factor A	Factor B			Factor B		
Seedling	113.4	80.0	29.4	10.3	7.9	23.2
B.118	117.9	82.4	30.1	11.8	8.6	27.1
MM.106	101.6	67.0	34.1	9.3	7.4	20.5
M.26	99.0	66.0	33.3	9.1	6.2	32.4
P 60	94.1	57.5	38.9	8.8	6.3	29.0
B.396	92.7	74.1	20.0	8.5	7.0	18.5
P 2	91.5	79.5	13.1	8.2	7.5	9.0
M.9	98.2	70.0	28.7	9.4	7.8	16.8
P 22	94.9	68.8	27.5	9.7	6.8	29.4
P 59	99.7	61.3	38.5	9.6	6.7	30.0
LSD_{05AB}	5.67			0.56		
Average	100.3	70.7	29.4	9.5	7.3	23.6
LSD_{05B}	1.3			0.13		

Apple trees on seedling rootstocks and B.118 had significantly bigger trunk diameter in the new field. In the replanted field significant differences remained only when compared with B.118 rootstock. Significant differences were not established among seedling rootstock, M.9, P 2 and MM.106 rootstocks. Trees on B.396 and P 2 rootstocks had the smallest trunk diameter in the new field, while in replanted conditions their diameter was significantly thicker than on M.26 and P 60 rootstocks.

In some countries more vigorous rootstocks are suggested for use when replanting in old apple land, although it has been shown that vigorous rootstocks are as sensitive to replant as dwarfing ones (Waechter-Kristensen, 1991). Some data reported that dwarfing rootstocks CG.5935 (G.935) and CG.4202 (G.202) showed some tolerance of replant disease (Robinson et al., 2004; Robinson et al., 2006). Our trial confirmed that rootstock response to replanting did not depend on their growth vigour, therefore specific rootstock behaviour should be taken into account when orchards are replanted.

Leaf area usually correlates with the intensity of photosynthesis and is an important factor for maiden trees that need to use sun radiation effectively. The tallest and thickest trees on B.118 rootstock had the biggest average leaf area and dry leaf weight in the fresh soil (Table 3). The lowest and thinner trees on P 2 had smaller leaf area and dry leaf weight.

On average, leaf area and leaf dry weight decreased in replanted soil by 27.8 and 32.8% respectively. Our earlier performed investigations with cv. 'Auksis' resulted in smaller reduction of average leaf area and dry leaf weight (Kviklys et al., 2007). Such differences could be attributed to specific rootstock cultivar combinations. The average leaf area of cv. 'Sampion' on B.118 rootstock decreased in replanted soil more than 46%. Trees on M.26 and P 59 were also more sensitive among tested rootstocks. Their absolutely dry leaf weight decreased around 40%. The lowest decrement of average leaf area was recorded for trees on MM.106, seedling, P 60 and B.396 rootstocks, while the lowest decrement of dry leaf weight was found on seedling and P 60 rootstocks.

Table 3. Rootstock and planting site effect on apple tree 'Sampion' leaf area and leaf weight in the nursery.

Rootstock	Leaf area, cm^2			Absolutely dry leaf weight, g		
	New field	Replanted field	Decrement, %	New field	Replanted field	Decrement, %
Factor A	Factor B			Factor B		
Seedling	34.8	27.2	21.9	0.49	0.37	24.5
B.118	51.3	27.5	46.4	0.76	0.36	52.4
MM.106	37.0	29.2	21.0	0.53	0.39	26.4
M.26	37.3	26.0	30.5	0.55	0.33	39.7
P 60	37.7	29.2	22.4	0.54	0.40	24.8
B.396	37.4	29.0	22.6	0.52	0.38	26.2
P 2	35.6	26.7	25.1	0.50	0.37	25.9
M.9	38.4	29.5	23.3	0.56	0.38	32.0
P 22	44.1	29.2	33.8	0.62	0.40	35.2
P 59	39.7	27.2	31.6	0.60	0.35	40.9
LSD_{05AB}	1.61			0.038		
Average	39.3	28.1	27.8	0.57	0.37	32.8
LSD_{05B}	0.37			0.026		

CONCLUSIONS

Replanting has a negative effect on the development of apple tree propagation material. Bud survival of cv. 'Sampion' decreased by 24% compared to the fresh soil. Other tree growth parameters are suppressed as well: tree height by 29%, trunk diameter by 24%, average leaf area by 28%, and absolutely dry leaf weight by 33%.

Tested rootstocks exhibit different reactions to soil exhaustion. The largest decrement of the number of surviving buds was recorded for trees on P 60, seedling and P 22 rootstocks. The biggest reduction of tree height was observed on P 60 and P 59 rootstocks, the biggest reduction of trunk diameter - on P 59 and M.26 rootstocks. Average leaf area decreased mostly on B.118, M.26 and P 59 rootstocks.

Combining all parameters it could be concluded that apple trees of cv. 'Sampion' on P 59 and P 60 rootstocks are the most sensitive to soil exhaustion, whereas trees on P 2 and B.396 rootstocks show tolerance to replanting.

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