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EVALUATION RESULTS OF FINNISH APPLE ROOTSTOCKS IN LATVIA

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A trial was established in 2011 with five rootstocks — MTT1, MTT4 and control B.9 (1.5 × 4 m, five replications with two trees), MTT5 and control MM.106 (2.5 × 5 m, six replications with two trees), and two cultivars — 'Auksis' and 'Gita'. The evaluated parameters were: tree general condition, flowering, and yielding intensity (points), number of root suckers, average yield (kg·tree^{-1}), yield per trunk cross section area (g·cm^{-2}), average fruit mass (g), and amount of non-standard fruits (%). A randomised fruit sample from each cultivar-rootstock combination was put into storage, and a panel taste was performed once each season. A snowless winter occurred in 2013/2014, when soil froze to 1.5 m depth, which was critical for MM.106. Other rootstocks did not show injury. The best results were obtained for MTT4, which was similar to that of M.26 in Finland. Its vigour was similar to MM.106, and start of bearing to B.9. Rootstock MTT5 was initially grouped with medium vigour MM.106, as having 60–80 % of vigour of 'Antonovka' seedlings in Finland. Yet in our trial, it had vigour and start of bearing was similar to that of B.9 or slightly larger, depending on cultivar; it has a tendency to form root suckers. MTT1, ranged with B.9 in Finland, had too weak vigour. The most promising cultivar-rootstock combination was 'Gita' on MTT4.

Key words: Malus × domestica*, cultivars, vigour, productivity, winter-hardiness.*

INTRODUCTION

Rootstock winter-hardiness is a critical factor for success of fruit growing in northern areas, especially in snowless winters, when soil temperatures may be below zero for a longer time. Long-term experience shows that the worldwide popular rootstock M.9 is too risky in Latvia (Lepsis, 1999), and MM.106 also has shown injury in critical winters, especially when cold starts early. The roots of clonal rootstocks are shallower than those of seedlings, which make them more susceptible.

Breeding of rootstocks for winter-hardiness has been done in Russia, obtaining the B-series (Budagovsky, 1976), Canada (Khanizadeh *et al*., 2000), Estonia (Kivistik, 2014), and recently also at MTT Agrifood Research Finland (now: Natural Resources Institute Finland (Luke)), where the first hardy rootstock YP was a seedling of *Malus baccata* that had vigorous growth (Hiirsalmi and Säkö, 1991); the next generation crosses were with vigour-reducing rootstocks (Hovi *et al*., 2002; Karhu *et al*., 2016): MTT1, MTT2 — YP (*M. baccata* o.p.) × M.26 (released 1997); MTT3 — YP (*M. baccata* o.p.) × M.27 (released 1997); MTT4 — YP (*M. baccata* o.p.) × M27 (2006); MTT5 – YP (*M. baccata* o.p.) × M.26 (2006).

Dwarfing Russian rootstocks B.9 and B.396 are most widely used in Latvia, but medium vigour plantings have become increasingly popular (Skrivele *et al*., 2011). These usually are established on MM.106, which presents a certain risk, as demonstrated by the recent winter of 2013/2014 (Rubauskis and Skrivele, 2015). Search for new rootstocks hardy in Latvian climate is an important task.

The aim of this study was to evaluate the potential of new hardy Finnish rootstocks MTT1, MTT4, and MTT5 in Latvian conditions.

MATERIALS AND METHODS

The trial was established in 2011 with five rootstocks and two cultivars. Cultivar 'Auksis' ('McIntosh' × 'Gravensteiner'; Lithuania) is medium vigour, tendency to bienniality, medium to large fruits; it is the most commercially important cultivar in Latvia. The new Latvian cultivar 'Gita' ('Liberty' × 'Melba') is vigorous, has annual yields, large fruits; it is a promising scab resistant cultivar. Both cultivars are harvested in midseason (first half of September), approximately at the same time.

Three rootstocks of the MTT series were chosen for the trial as reducing tree vigour rootstocks. Propagation material of MTT rootstocks obtained from *in vitro* plants was received from Finland, while B.9 and MM. 106 were obtained from the nursery of our Institute. Characteristics of rootstocks by originator data are:

- **MTT1:** vigour like B.9 (40% of 'Antonovka' seedling rootstocks), stronger roots and less suckers than B.9, trees need support, very winter and cold-hardy, easily propagated.
- **MTT4**: vigour like M.26 (50–60% of 'Antonovka' seedling rootstocks), support is recommended for the first years after planting and for early cropping, very winter and cold-hardy, easily propagated, tolerant to specific apple replant disease (SARD).
- **MTT5**: vigour 60–80% of 'Antonovka' seedling rootstocks, support is recommended for the first years after planting and for early cropping, very winter and cold-hardy, easily propagated.
- **B.9** (control): weak vigour, but larger than M.9 (30–40 % of 'Antonovka' seedling rootstocks), trees need support, often root suckers, root cold tolerance — 12 to –14 °C, early and good yields, propagation in stool bed poorer than M.9, negative influence on fruit colour possible.
- **MM.106** (control): medium vigour (60–75% of seedling rootstocks), in young age vigorous, does not need support, very few root suckers, root cold tolerance –12 °C or poorer, susceptible to early cold, medium early production, good yields, drought susceptible, good fruit colour.

Rootstocks were grouped at planting by vigour using data from MTT Finland:

- Weak to medium vigour — MTT1, MTT4, control — B.9 (1.5 × 4 m). Five replications with two trees each cultivar-rootstock combination, total — ten trees per combination.

- Medium vigour — MTT5, control — MM.106 (2.5 × 5 m). Six replications with two trees each cultivar-rootstock combination, total — 12 trees per combination.

Soil in the trial was sod carbonate gleyic, pH 6.5, organic matter 2.1%. Growing techniques used was standard integrated growing. Trees were planted as one-year old whips. All trees were individually staked.

Evaluated parameters in points were (10-point scale): tree general condition in spring; flowering intensity and yielding intensity; and tree diseases (if any) — scab, mildew, canker, etc.

Measured and counted parameters were: number of root suckers; and trunk diameter (cm) at 20 cm height, used for calculation of trunk cross section area (TCSA, cm^2). Trunk diameter and TCSA were used to characterise tree vigour, here understood as growth intensity and resulting tree size.

Yield evaluation included: fruit count (pcs.) and mass (kg) from each tree; average yield ($kg \cdot tree^{-1}$) and yield per TCSA ($kg \cdot cm^{-2}$), and average fruit mass (g); and amount of non-standard fruits (%) and their type (too small, scab, fruit rot, etc.). For storage a randomised fruit sample from each cultivar-rootstock combination was collected, 15–30 kg (depending on fruit size). A taste panel was organized in 2013–2015, once per season for fully ripe fruits, with ten untrained members.

During the trial, it became evident that not all the rootstocks had the expected tree vigour by which they were grouped initially. For this reason, in statistical analysis all rootstocks in the trial were compared between themselves. The effect of different planting distances was considered not yet significant for young trees, as their roots and crowns had not filled the entire growth space. To compensate unequal sample size, adjustment of missing data was used.

Data were statistically processed using variance and Pearson correlation analysis, Student criterion and Tukey criterion (HSD and LSD).

RESULTS

Effect of weather conditions was observed after the winter of 2013/2014, which was snowless, and very unfavourable for rootstock over-wintering. The cold started in January and lasted till March, and the soil already in January froze to 1...1.5 m depth. The soil temperature at 20 cm depth till February gradually fell below 0 °C. This resulted in significant injury of 1–3-year-old trees on rootstock MM.106 with root zone not covered with mulch. The roots were not extracted for analysis, to avoid further tree damage, but visual observations of trees showed that part of trees on MM.106 had lower yield and smaller fruits, as well as poorer tree general condition (tree health), seen as chlorosis and reduced new growth. The injuries depended on the tree place in field, more exposed trees (e.g. row ends) showed more injury. The effect was observed also in 2015 by chlorosis and poorer growth of some trees. Other rootstocks did not have visible injuries.

There was strong positive correlation of tree health with yield per trunk cross section area TCSA ($r = 0.669$), significant correlation with flowering intensity ($r = 0.232$) and TCSA ($r = 0.352$), and negative correlation with amount of non-standard fruits ($r = -0.214$). All correlations were significant at $p < 0.01$.

Tree health was affected only by winter damage. No significant fungal disease injuries were observed.

Start of production. The trees started flowering in 2012, part of the flowers were removed to improve tree growth. On average, significantly higher number of flowers was observed on B.9. Cultivar 'Gita' had earlier start of bearing than 'Auksis'. The earliest start of bearing was observed for 'Gita' on MTT4, and the latest for 'Auksis' on MM.106. The highest yield (kg per tree) in 2012–2013 was observed

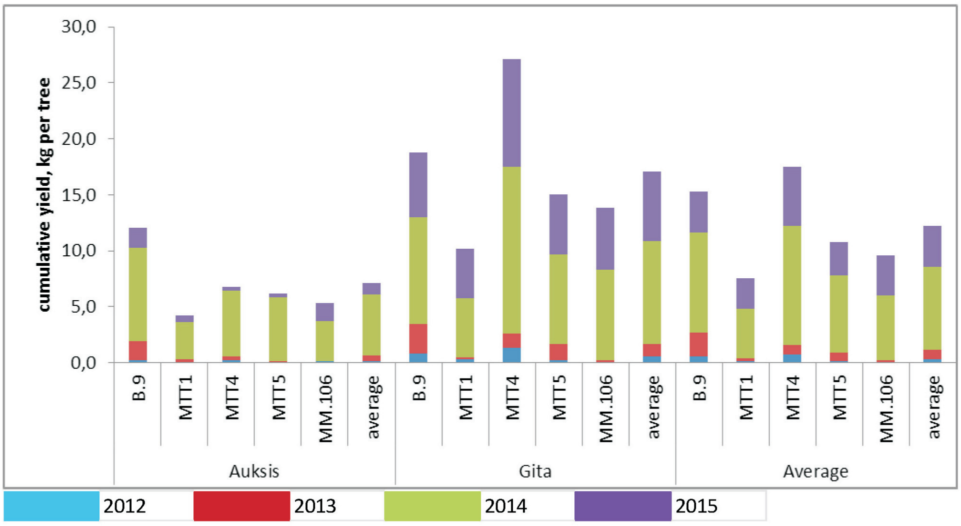

Fig. 1. Cumulative yield of cultivars 'Auksis'and 'Gita' on 5 rootstocks in 2012-2015, kg·tree^{-1}

for 'Gita' on B.9. 'Gita' on MTT4 had the highest yield only in 2014–2015, closely followed by 'Gita' on B.9 (Fig. 1).

Productivity. Both rootstock and cultivar effect on yield were highly significant ($p = 0$).

The highest yield in average was obtained on MTT4 and B.9, and the lowest on MTT1. On average for all years, the highest yield per tree for 'Gita' was on MTT 4, and for 'Auksis' on B.9 (Fig. 1). Cultivar 'Gita' was more productive than 'Auksis'. The poorest yield was observed for 'Auksis' on MTT1, and thus this rootstock evidently is not suitable for this cultivar.

The yield per TCSA differed from that in kg per tree (Tables 1, 2). Yield per TCSA for 'Gita' on MTT1 was similar

Table 1

TRUNK CROSS SECTION AREA AND YIELD PER TCSA OF 2 CULTIVARS ON 5 ROOTSTOCKS, 2012–2015

Cultivar	Rootstock	Year	TCSA, cm²	Yield per TCSA, kg·cm^{-2}	Cultivar	Rootstock	Year	TCSA, cm²	Yield per TCSA, kg·cm^{-2}
Auksis	B 9	2012	1.7	0.40	Gita	B 9	2012	1.6	0.68
		2013	2.2	0.85			2013	2.2	1.16
		2014	2.6	3.17			2014	2.6	3.73
		2015	3.2	0.81			2015	2.9	1.89
		Mean	2.5^{bc}	1.62^{a}			Mean	2.3^{c}	1.96^{a}
	MTT 1	2012	1.1	0.00		MTT 1	2012	1.3	0.59
		2013	1.5	0.52			2013	1.8	0.27
		2014	2.0	1.65			2014	2.1	2.28
		2015	2.4	1.47			2015	2.6	1.65
		Mean	*1.7*^{d}	1.38^{ab}			Mean	*1.9*^{d}	1.50^{b}
	MTT 4	2012	1.7	0.27		MTT 4	2012	2.2	0.64
		2013	2.4	0.29			2013	3.0	0.43
		2014	2.9	1.96			2014	3.6	4.01
		2015	3.6	0.15			2015	4.1	2.36
		Mean	2.6^{ab}	0.85^{bc}			Mean	3.2^{a}	1.89^{ab}
	MTT 5	2012	1.5	0.00		MTT 5	2012	1.7	0.35
		2013	2.1	0.32			2013	2.3	0.82
		2014	2.5	2.35			2014	2.8	2.80
		2015	3.3	0.69			2015	3.6	1.47
		Mean	2.3^{c}	1.86^{a}			Mean	2.6^{b}	1.60^{ab}
	MM 106	2012	1.8	0.19		MM 106	2012	2.0	0.00
		2013	2.5	0.12			2013	2.8	0.14
		2014	2.9	1.17			2014	3.4	2.40
		2015	3.6	0.58			2015	4.0	1.37
		Mean	2.7^{a}	0.75^{c}			Mean	3.0^{a}	1.54^{b}

Different letters show significantly different variants at $p < 0.01$ level and $p < 0.05$ level 'Gita' yield per TCSA –at $p < 0.05$ level

Table 2

DIFFERENCES BY TRUNK CROSS SECTION AREA (TCSA) CM², AND YIELD PER TCSA KG CM⁻² ON 5 ROOTSTOCKS, AVERAGE OF 2 CULTIVARS IN 2012-2015

Rootstock	TCSA, cm²	Yield per TCSA, kg·cm⁻²
MTT1	1.83 [c]	1.16 [b]
B.9	2.40 [b]	1.46 [ab]
MTT5	2.47 [b]	1.49 [ab]
MM.106	2.86 [a]	1.66 [a]
MTT4	2.95 [a]	1.80 [a]

Tukey HSD[a,b,c] was used to evaluate differences. Different letters show significantly different variants at $p < 0.01$ level

to that of MM.106 and significantly differed only from B.9, while in kg/tree the yield on MTT1 was the lowest for this cultivar. On average of all years, the yield per TCSA was the highest for 'Gita' on B.9 and for 'Auksis' on B.9 and MTT5. The highest yield intensity (kg per TCSA) in the first years was observed on B.9.

No bienniality was observed till 2015, when the yield of 'Auksis' was lower than in 2014.

Tree vigour. Both rootstocks and cultivars had highly significant differences in vigour ($p = 0$). Cultivar 'Gita' had more vigorous growth, earlier start of bearing and less bienniality than 'Auksis'. This affected also rootstock performance (Table 1).

The most vigorous rootstocks were MM.106 and MTT 4; the weakest was MTT 1. On average for both cultivars, MTT5 and B.9 had similar vigour (Table 2), but 'Gita' on B.9 was significantly less vigorous than on MTT5 (Table 1). MTT 1 is not suitable for cultivar 'Auksis', as about half of the trees in the nursery did not reach standard plant size, one third of the trees in the 3rd year of growth had not yet developed good laterals. 'Gita' may be grown on MTT1, as it is more vigorous.

Number of root suckers was significantly affected by rootstock ($p = 0$) and cultivar ($p = 0.019$). MTT5 developed significantly higher number of root suckers. In contrast, the number of suckers for B.9 was similar to that of other rootstocks.

Fruit quality. Fruit size variation between rootstocks was observed in some years, and was linked with yield amount. Differences in fruit size were significant (p = 0). The smallest fruits on average were on MM.106, which may be a result of winter injury. The largest fruits were on MTT4 and MTT5. Number of non-standard fruits did not differ significantly. Observations of improved fruit colour were not consistent. The taste panel showed higher quality for MTT1, but this may be the result of low yield (large, well ripened fruits). Evaluation of fruit quality needs further observation on mature trees.

DISCUSSION

The best results were obtained for rootstock MTT4, which were similar to that of M.26 in Finland. In our trial, according to trunk diameter data it had medium vigour, similar to that of MM.106, while the start of bearing was very early, as for B.9. The root winter hardiness of MTT4 was better than that of MM.106.

Rootstock MTT5 was initially grouped with the medium vigour MM.106, following its ranging by vigour in Finland. Yet in our trial it had vigour similar to B.9 on average for both cultivars, and at a level between that of B.9 and MM.106 for the more vigorous cultivar 'Gita'. The first flowering of trees on MTT5 was more abundant than on MM.106 and was slightly lower than on B.9, with lower first yield. The rootstock had a tendency to form root suckers in the first years.

Rootstock MTT1 has been ranked as similar to B.9 in Finland, with stronger root support. In our trial it had very weak vigour, which resulted in low yields, in kg per tree, although in 2015 good yield per TCSA was obtained for the vigorous cv. 'Gita'. This rootstock can be recommended only for vigorous cultivars, and the planting distances should be reduced, maybe to 1 m between trees.

The observed differences between tree growth in Finland (Hovi *et al.*, 2002; Karhu *et al.*, 2016) and Latvia possibly were caused by differences in climate (day length, temperatures). Another reason may be *in vitro* propagation of Finnish rootstock material. It is possible that in subsequent years the effect of crop load will change the vigour of rootstocks and cultivars.

The critical winter of 2013/2014 helped to evaluate tree performance after cold injury. As shown by correlation analysis, the effect was significant not only for growth, flowering and yield (especially per TCSA), but also the amount of low quality fruits. This demonstrated the importance of rootstock winter-hardiness for effective fruit production.

CONCLUSIONS

1. Rootstock MTT 4 is the most promising in Latvia. Its vigour is similar to that of MM.106, and start of bearing to that of B.9. It has better root winter-hardiness than MM.106.

2. Rootstock MTT5 has vigour similar to B.9 or larger, depending on cultivar, with similar start of bearing but lower first yields; it has a tendency to form root suckers.

3. Rootstock MTT1 is not promising in Latvia, as it has too weak vigour; it may be used only for vigorous cultivars.

4. A promising cultivar-rootstock combination is 'Gita' on MTT4.

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SOMIJAS POTCELMU VĒRTĒŠANAS REZULTĀTI LATVIJĀ

2011. gadā ierīkots izmēģinājums ar pieciem ābeļu potcelmiem — MTT1, MTT4 un B.9 (kontrole) (1,5 x 4 m, 5 atkārtojumi pa 2 kokiem), MTT5 un MM.106 kā kontroli (2,5 x 5 m, 6 atkārtojumi pa 2 kokiem), un 2 šķirnēm — 'Auksis' un 'Gita'. Vērtēja parametrus — koku vispārīgais stāvoklis, ziedēšanas un ražošanas intensitāte (ballēs), sakņu atvašu skaits, vidējā raža (kg no koka) un raža uz stumbra šķērsgriezuma laukumu ($g \cdot cm^{-2}$), vidējā augļu masa (g), nestandarta augļu daudzums (%). No katras šķirnes-potcelma kombinācijas randomizētu augļu paraugu ielika glabāties, un 1 reizi sezonā veica to degustāciju. 2013./2014. gada bezsniega ziema, kad augsne sasala līdz 1,5 m dziļumam, bija kritiska potcelmam MM.106. Citiem potcelmiem nebija sala bojājumu pazīmju. Labākie rezultāti tika iegūti potcelmam MTT4, kas Somijā vērtēts kā augumā līdzīgs M.26. Tā augums bija līdzīgs MM.106, bet ražošanas sākums — B.9. Potcelma sakņu ziemcietība bija labāka nekā MM.106. Potcelms MTT5 sākotnēji tika grupēts kopā ar vidēja auguma potcelmu MM.106, jo Somijā tas bijis 60–80 % no 'Antonovkas' sējeņu auguma. Taču mūsu pētījumā tā augums bija līdzīgs B9 vai lielāks, atkarībā no šķirnes, ar līdzīgu ražošanas sākumu, bet mazākām pirmajām ražām; potcelmam ir tieksme veidot sakņu atvases. MTT1, kas Somijā vērtēts kā līdzīgs B.9, Latvijā bija pārāk vājš augums; to var ieteikt tikai spēcīga auguma šķirnēm. Perspektīvākā šķirnes-potcelma kombinācija bija 'Gita' uz MTT4.