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Long-term evaluation of growth and yield of Stanley and Cacanska lepotica plum cultivars on selected rootstocks

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Abstract

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During 1992–2012, trunk cross-section area (TCSA), cumulative yield, yield efficiency and suckering of plum cultivars Stanley and Cacanska lepotica in combinations with vegetative rootstocks Myrobalan SE 4043, Myrobalan SE 4044, MY-KL-A, GF 655/2, GF 43, Damas C SE 4045, Pixy, St. Julien A and generative rootstock Myrobalan seedling were evaluated. The results indicated significant differencies of the characteristics between the evaluated cultivar/rootstock combinations for each cultivar. The long-term experience indicates that the evaluated characteristics of the trees on different rootstocks can significantly change during the ontogenetical developement in the orchard. This is demonstrated by the difference in the entering into the bearing stage, different abudance of the yields, the time of reaching of maximum yields and also in changes of growth intensity. For detailed description of the rootstock characteristics long-term trials are required. For cv. Stanley, Myrobalan SE 4043 is the best rootstock for long-term orchards and St. Julien A for orchards with a higher replanting rate. For cv. Cacanska lepotica, Myrobalan SE 4043 seems to be the best rootstock.

Keywords: ontogenesis; stage; productivity; TCSA; bearing; suckering

Plum is one of the traditional fruit crops grown in the Czech Republic. For good performance in the orchards, the rootstock has an important influence on the scion cultivar. The most frequently used rootstock in Czech Republic is still the myrobalan seedling. With the increased need for intensification of fruit production, several rootstock trials have already been established and evaluated in central Europe (Hrotkó et al. 1998; Kosina 1998, 2007; Sosna 2002; Sitarek et al. 2007) in order to find more productive scion-rootstock combinations. Authors in these publications presented results of the influence of new rootstocks, described by Hrotkó et al. (1998), Jakob (1992), Hartmann (1995), and Webster (1997), on selected plum cultivars, nevertheless most of them are results from young orchards, which just enter the productive stage. It is interesting to supplement this information with long-term results.

Experience from international rootstock trials shows that the performance of a rootstock in combination with the cultivar may change in different agroclimatic conditions (Hartmann et al. 2007). That is the main reason to test the same rootstocks in different regions of Europe and of the world. However, the question is, if the rootstock with the cultivar retains qualities in growth and bearing throughout the ontogeny (Hrotkó et al. 1998, 2002; Kosina 1998, 2000, 2004; Magyar, Hrotkó 2006) according to Šitt's (Šitt 1952, 1958) ontogenetical

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stages. These stages describe the life cycle of the fruit trees. First ontogenetical stage is the "growing stage" which is characterized by higher shoot and root growth. This stage continues until the trees begin to bear first fruit. Second stage is the "growing and bearing" stage. This stage lasts from the year in which the trees begin to bear fruits until they bear regularly. The growth vigour of the scaffold branches is relatively high, but they start to produce bearing shoots. The "bearing and growing" stage is characterized by weakening of the growth vigour and by higher production of bearing shoots. The yields increase during this period. During the "full bearing" stage the fruit trees reach the highest yields. Some bearing shoots in basal parts of the crown begin drying. Growth vigour of the trees is negligible and they produce mainly short bearing shoots. During the "bearing and drying" stage the trees terminate the growth of the scaffold branches. The drying of bearing shoots is progressive and the bearing potencial slowly decrease. The "drying, bearing and growing" stage is typical with continuous drying of the crown and more pronounced yield decrease. The trees begin to produce more erective shoots restoring the crown. Next stage is the "drying, growing and bearing" stage, where the trees begin bearing on branches of the restored crown. The old scaffold branches begin drying. During the next stage ("drying and growing") the trees dry through the crown. The trunks begin to rot, followed with high production of suckers. If no suckers occur, the trees die. The last stage is similar to the first stage, where new trees begin to grow from the suckers.

The aim of this paper is to compare the growth and productivity of two plum cultivars on selected rootstocks and also to choose the best combination for producers. The second goal was to describe the influence of different rootstocks on growth and productivity of the cultivars during the ontogeny of the trees in orchard.

MATERIAL AND METHODS

The plantation of cvs Stanley and Cacanska lepotica was established in the Research and Breeding Institute of Pomology Holovousy Ltd., Czech Republic in spring 1990. The rootstocks were obtained from Jeleč spatial isolate of the breeding station in Těchobuzice. The trees were planted in alluvial brown soils. The data were collected during years 1992–2012. The evaluated cultivars were planted on the following vegetative rootstocks: Myrobalan SE 4043, Myrobalan SE 4044, MY-KL-A, GF 655/2, GF 43, Damas C SE 4045, Pixy, St. Julien A and generative rootstock Myrobalan seedling. The experimental area was situated in conditions of East Bohemia (the Czech Republic) at altitude 300 m. The mean value of rainfall is 666.0 mm (370.6 mm during IV.–IX. month) and the average annual temperature is 8.9°C, through the last 30 years. The trees were planted in spacing of 6.0 × 3.4 m and were not irrigated. They were trained and pruned as freely growing hedgerows with a short stem height and the central leader being removed in the fifth year. The driveways were managed as mown grass. Herbicide strips placed in the tree rows were 1.5 m wide. Pest and disease control and fertilization follow local recommendations for commercial orchards. Every combination of rootstock and cultivar was planted in 4 replications with two trees per replication. The following characteristics were evaluated: trunk cross-section area (TCSA), cumulative yield, yield efficiency and suckering. The data were processed using the Mann-Whitney test in statistical program "R" (University of Auckland, Auckland, New Zealand).

RESULTS AND DISCUSSION

The yield of cultivar Stanley differed on individual rootstocks. It is evident from Table 1 that the cultivar on myrobalan rootstocks, mainly Myrobalan SE 4043, Myrobalan SE 4044 and MY-KL-A gave the highest cumulative yields. The rootstock combination with Myrobalan seedling had lower cumulative yields than combinations with vegetatively propagated myrobalan rootstocks. However, this difference was not significant. The lowest yield was achieved on Pixy and Damas C SE 4045 rootstocks. The highest TCSA of cv. Stanley was observed on rootstocks GF 43, Myrobalan SE 4044, MY-KL-A and Myrobalan seedling. The lowest growth vigour was on GF 655/2 and Pixy rootstocks. The most suckering rootstocks were GF 655/2 and Damas C SE 4045 with cv. Stanley. The occurence of suckers in other combinations with cv. Stanley was only negligible. The highest yield efficiency of cv. Stanley was on rootstocks GF 655/2 and Myrobalan SE 4043. The lowest yield efficiency with the cultivar was on GF 43, Myrobalan SE 4044, Damas C SE 4045 and Myrobalan seedling.

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Table 1. Tree growth vigour and fruit-yield of cv. Stanley in years 1992–2012

Rootstock	TCSA 2012 (cm^2)	Suckers Σ(93–12) (No./tree)	Yield Σ(92–12) (kg/tree)	Yield efficiency (kg/cm^2)
Myrobalan SE 4043	329.5^{bc}	21.0^{bc}	888.9^{a}	2.7^{ab}
Myrobalan SE 4044	395.0^{a}	19.5^{bc}	839.4^{a}	2.1^{c}
Damas C SE 4045	333.0^{bc}	177.6^{a}	591.1^{bc}	1.8^{c}
Myrobalan seedling	376.3^{ab}	13.8^{bc}	774.5^{ab}	2.1^{c}
MY-KL-A	394.2^{a}	8.2^{c}	906.5^{a}	2.3^{bc}
GF 43	397.6^{a}	15.7^{bc}	707.9^{b}	1.8^{c}
GF 655/2	236.0^{d}	284.4^{a}	695.5^{b}	3.0^{a}
St. Julien A	337.9^{bc}	8.4^{c}	742.7^{ab}	2.2^{c}
Pixy	255.8^{d}	35.8^{b}	555.2^{c}	2.2^{c}

means marked with the same letter do not differ significantly, Mann-Whitney test (α = 0.05); the results can be compared only within each column

The results of the rootstock combination with cv. Cacanska lepotica are presented in Table 2. It shows that the highest cumulative yield was observed on rootstocks MY-KL-A, Myrobalan SE 4043 and Myrobalan seedling. The lowest yield was observed on Pixy rootstock. Cv. Cacanska lepotica had the highest TCSA on rootstocks MY-KL-A, GF 43, Damas C SE 4045 and Myrobalan SE 4044. The lowest growth vigour was on Pixy and GF 655/2. The most suckering rootstocks with cv. Cacanska lepotica were GF 655/2 and Damas C SE 4045. Similar results on GF 655/2 were obtained with cv. Cacanska rana (Sosna 2002). The suckering on rootstocks Pixy and Myrobalan seedling was also abundant. The best yield efficiency was observed on rootstocks Myrobalan SE 4043, Myrobalan seedling and GF 655/2. The lowest yield efficiency was in the combination of the cultivar on GF 43, Pixy, Damas C SE 4045 and Myrobalan SE 4044. These results are partially in contrast to the previous results of this trial (Kosina 1998, 2000, 2004), where some cultivar/rootstock combinations had higher cumulative yields in the first years of the trial and later their productivity was only low or moderate as compared with other combinations, which shows more gradual increase of cumulative yields, but mostly with higher cumulative yields in later period of the trial. The changes in ranking of cultivar/rootstock combinations in growth vigour and yield efficiency during the trial were also

Table 2. Tree growth vigour and fruit-yield of cv. Cacanska lepotica in years 1992–2012

Rootstock	TCSA 2012 (cm^2)	Suckers Σ(93–12) (No./tree)	Yield Σ(92–12) (kg/tree)	Yield efficiency (kg/cm^2)
Myrobalan SE 4043	280.7^{bc}	44.6^{cd}	$1{,}000.0^{a}$	3.6^{a}
Myrobalan SE 4044	300.4^{abc}	22.8^{de}	847.8^{bc}	2.9^{b}
Damas C SE 4045	300.9^{ab}	245.0^{ab}	793.8^{bc}	2.7^{b}
Myrobalan seedling	251.8^{cd}	91.3^{bc}	888.4^{ab}	3.6^{a}
MY-KL-A	343.2^{a}	6.3^{f}	$1{,}079.0^{a}$	3.1^{ab}
GF 43	320.1^{ab}	20.3^{e}	754.2^{bc}	2.4^{b}
GF 655/2	215.4^{d}	374.7^{a}	747.6^{c}	3.5^{a}
Pixy	204.7^{d}	108.2^{bc}	546.1^{d}	2.7^{b}

means marked with the same letter do not differ significantly, Mann-Whitney test (α = 0.05); the results can be compared only within each column

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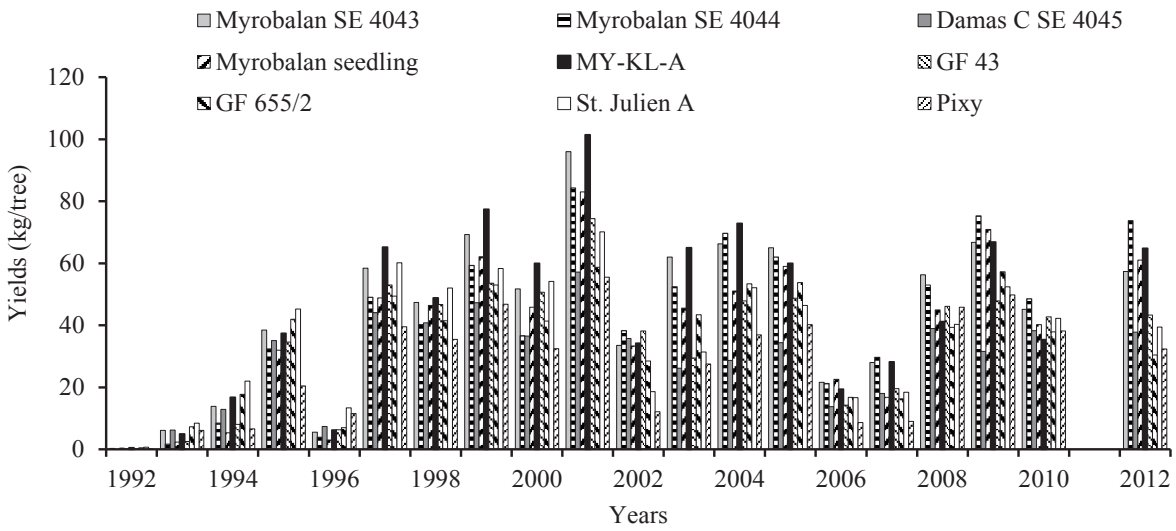

Fig. 1. Mean values of yield in years 1992–2012 of cv. Stanley

observed. Similar changes were observed also in other rootstock trials (Hrotkó et al. 1998, 2002; Magyar, Hrotkó 2006). A possible explanation of those differencies is the change in the evaluated characteristics during ontogeny of the cultivars on different rootstock. Due to 21 years of observation, this study allows to describe these changes.

The long-term yield developement of individual rootstock combinations with both cvs Stanley and Cacanska lepotica during ontogeny stages are showed in Figs 1 and 2. With cv. Stanley, several fluctuations in bearing were observed in years 1996, 2002, 2006 and 2007. Similar fluctuations were observed with cv. Cacanska lepotica in years 1998 and 2010. The reason was low flower set or unsuitable environmental conditions during bloom. The highest yields with cv. Stanley were in the year 2001. In 2011, the flower set on both cultivars was fully destroyed by late frost, independently of the rootstock combination. Except in the above-mentioned years, the bearing of both cultivars was regular.

In years 1993–1997 the yield had progresively increased at cv. Stanley. Especially through the first two years of this period ("bearing and growing" stage) the combinations with Myrobalan SE 4043, Damas C SE 4045, GF 655/2 and St. Julien A showed a precocious bearing. In contrast, combinations of cv. Stanley with Myrobalan SE 4044, GF 43, Myrobalan seedling and Pixy had lower yields in the first years of bearing. In years 1997–2001 the rootstock combinations with cv. Stanley reached the "full bearing" stage; the differences between the rootstock combinations in the yield have increased then. Higher absolute yield was observed on my-

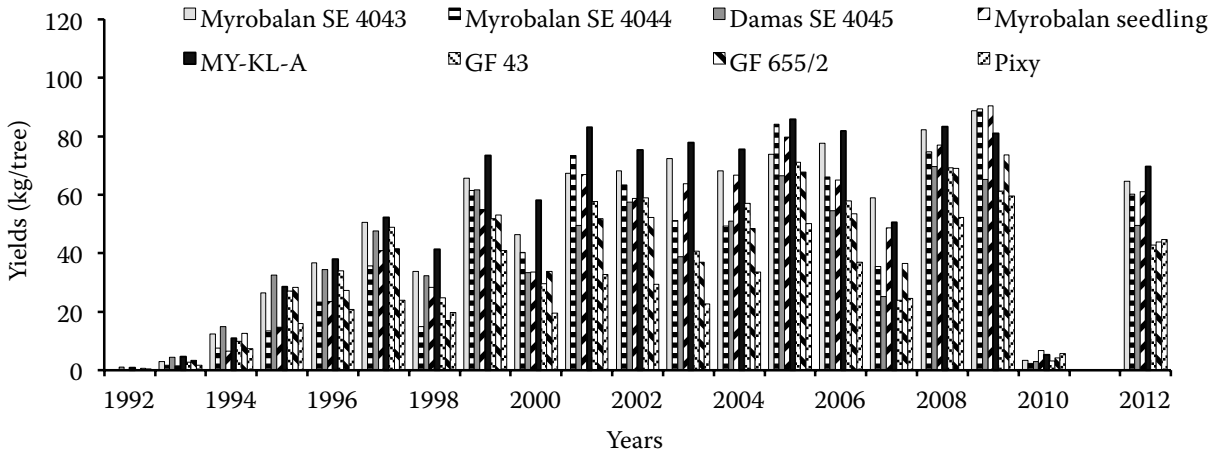

Fig. 2. Mean values of yield in years 1992–2012 of cv. Cacanska lepotica

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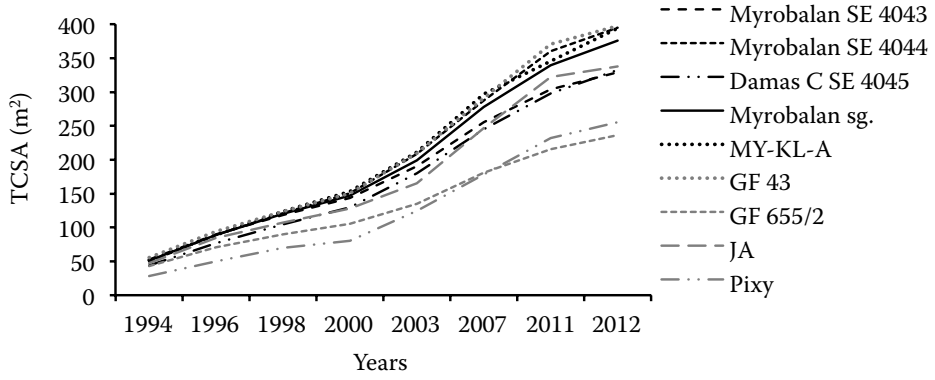

Fig. 3. Mean values of TCSA (1992–2012) of cv. Stanley

TCSA – trunk cross-section area; sg. – seedling$_g$

robalan (Myrobalan SE 4043, Myrobalan SE 4044, MY-KL-A and Myrobalan seedling); nevertheless, on the rootstocks GF 43, St. Julien A and Pixy, cv. Stanley had only an average increase in yield. On GF 655/2, Damas C SE 4045, the cultivar showed almost no increase. After 2001, a slow decrease in the yield was observed in all combinations. The most intensive decrease of the yield was with cv. Stanley mainly on Damas C SE 4045, St. Julien A, GF 43 and Pixy; the trees reached the "bearing and drying up" stage. On all the evaluated combinations, several diebacks of the bearing laterals were detected. In following years (2006–2007) a considerable decrease of both, flower set (data not showed) and the yield occured. The trees became more withering through the crown, they produced more erective shoots regenerating crown and reached the "drying, bearing and growing" stage. After 2008, the trees started bearing on the secondary shoots restoring the crown. The senescence symptoms were not significantly dependent on different rootstock, but the yield potencial on different rootstocks was changing significantly.

The increase of TCSA of cv. Stanley was stable on the evaluated rootstocks (Fig. 3), except for rootstocks Pixy and St. Julien A. In those combinations with cv. Stanley the growth of TCSA increased after years 2000 (Pixy) and 2003 (St. Julien A) in comparison to other rootstock combination.

The yield efficiency of cv. Stanley increased on all rootstock combinations until 11–14 years after planting (Fig. 4). During this period, cv. Stanley had the highest yield efficiency on Pixy, GF 655/2 and St. Julien A. In years 2000–2003 a decrease of yield efficiency on the rootstocks Pixy, Damas C SE 4045 and St. Julien A was detected. In the "bearing and drying up" stage, cv. Stanley had the highest yield efficiency on GF 655/2 and later also on Myrobalan SE 4043.

Cv. Cacanska lepotica had more precocious bearing on rootstocks Myrobalan SE 4043, MY-KL-A, Damas C SE 4045 and GF 655/2 in years 1993–2000 ("bearing and growing" stage) than on Myrobalan SE 4044, Myrobalan seedling and Pixy rootstocks. The mean yield increased until the years 2001 to 2008 ("full bearing" stage). In this stage, the differences in yield between the rootstock combinations increased. Yield decrease was the most remarkable in combinations with Damas C SE 4045, GF 43 and Pixy rootstocks. The most stable yield with cv. Cacanska lepotica was observed on MY-KL-A and

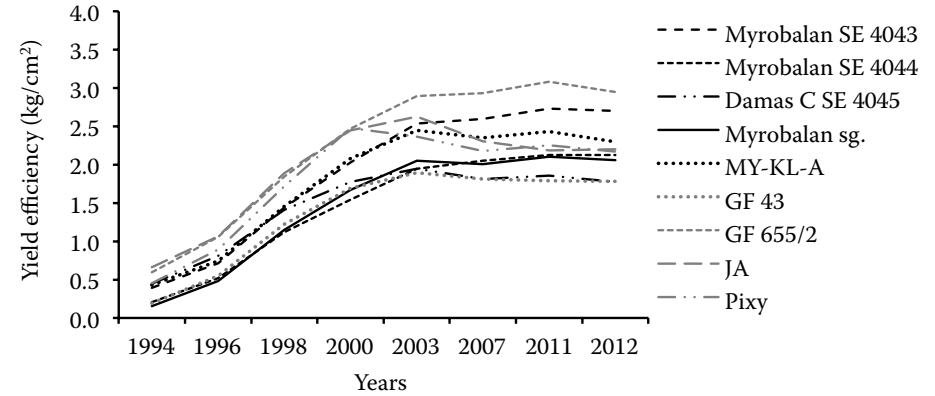

Fig. 4. Mean values of yield efficiency (1992–2012) of cv. Stanley

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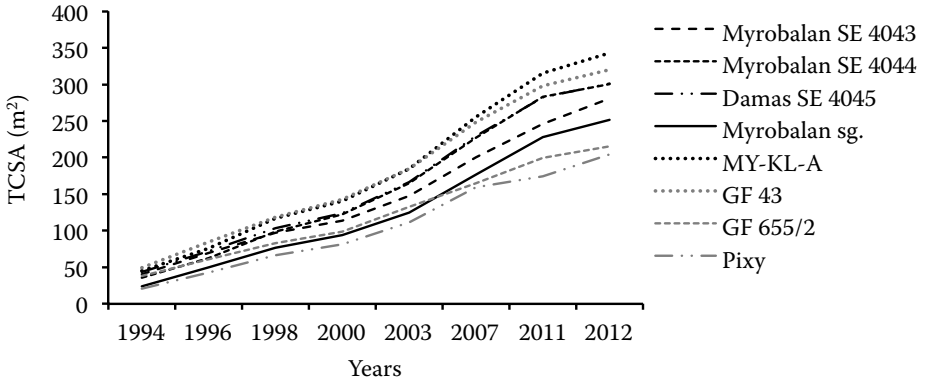

Fig. 5. Mean values of TCSA (1992–2012) of cv. Cacanska lepotica

TCSA – trunk cross-section area; sg. – seedling

Myrobalan SE 4043. On the other two Myrobalan rootstocks (Myrobalan SE 4044 and Myrobalan seedling) a slower increase of yield during this stage was observed. The yield of cv. Cacanska lepotica began to decrease after 2009, as showed in Fig. 2. The differences in symptoms of senescence on different rootstocks were not observed with cv. Cacanska lepotica.

The increment of TCSA was different among combinations but the trend was stable, except for the combination with GF 655/2 rootstock (Fig. 5).

The yield efficiency of all combinations increased through the first 14 years after planting. In the first years ("bearing and growing" stage) the best results in yield efficiency in cv. Cacanska lepotica were on Myrobalan SE 4043, Damas C SE 4045, GF 655/2 and MY-KL-A rootstocks. The yield efficiency of the combinations cv. Cacanska lepotica with Damas C SE 4045 and Pixy slowed down after 2000 (Fig. 6).

The results of long-term evaluation of plum cvs Stanley and Cacanska lepotica showed significant differences in tree growth vigour and yield depending on cultivar and rootstock combination. Furthermore, the results also show that the rootstocks have a significant influence on some characteristics changing throughout the ontogeny of the grafted cultivar. This is demonstrated by the difference in the entering into the bearing stage in the first years of the economically relevant yields, different abudance of the yields, difference in the time of reaching of max. yields and last but not least also in changes of growth intensity. Consequently, the results of bearing indicate that despite of the similar rate of ontogeny development of the trees of one cultivar on different rootstock, the progress in the bearing during separate ontogeny stages can be different. The significant decrease of the yields and simultaneous increase in growth vigor leads to a significant decrease in yield efficiency on Damas C SE 4045, Pixy and St. Julien A rootstocks during the experiment. These results correspond with previous publications (Kosina 1998, 2000, 2004). It is also important to present that the evaluated cvs Stanley and Cacanska lepotica were not in the same ontogeny stage at the end of the trial. Cv. Stanley was in the stage of "drying, growing and bearing", while the trees of cv. Cacanska lepotica were in the "bearing and drying" stage, according to Šitt's ontogenetical stages (Šitt 1952, 1958). It

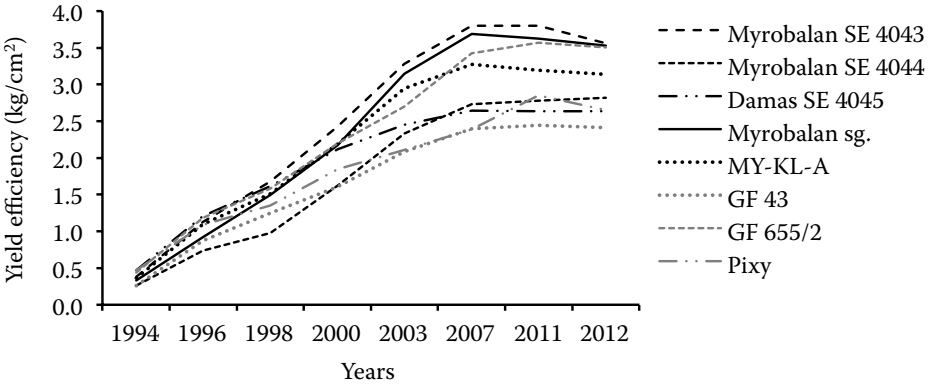

Fig. 6. Mean values of yield efficiency (1992–2012) of cv. Cacanska lepotica

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means that the cultivars have a greater influence on longevity of fruit trees than the rootstock. On the basis of 21 years results it is possible to state, that the average length of a rootstock trial should be until the end of the "full bearing stage", i.e. till the beginning of "bearing and drying" stage. Some experience (Hartmann et al. 2007) shows that the length of the trial is an important factor and that 7 years of observations can be insufficient. According to the observation of changes during the ontogeny and depending on the cultivar it requires at least 12–15 years. Evaluated cultivars on some Myrobalan (e.g. Myrobalan SE 4043) and GF 655/2 rootstocks seems to be more stable and in the long-term scale more productive. An interesting result is also the yield efficiency of cv. Cacanska lepotica on Myrobalan seedling. The use of Damas C SE 4045, GF 655/2 for both cultivars and Pixy and Myrobalan seedling for cv. Cacanska lepotica is considerably limited because of relatively high suckering rate. Myrobalan SE 4043 is the best rootstock for long-live orchards and St. Julien A for orchards with a higher replanting rate for cv. Stanley. For cv. Cacanska lepotica, Myrobalan SE 4043 seems to be the best rootstock.

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