ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume 64 11 Number 1, 2016
http://dx.doi.org/10.11118/actaun201664010109

EVALUATION OF THE PRODUCTION TRAITS AND FRUIT QUALITY OF GERMAN PLUM CULTIVARS

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Abstract

MOLNÁR ÁGNES MÓNIKA, LADÁNYI MÁRTA, KOVÁCS SZILVIA. 2016. Evaluation of the Production Traits and Fruit Quality of German Plum Cultivars. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 64(1): 109–114.

Due to the substantial damage caused in Hungarian plum orchards by the spread of plum pox virus (PPV), high-yielding, often self-fertile German, Serbian and Romanian cultivars with better resistance to PPV have been introduced. Observations on growth characteristics, flowering and harvest time, yield potential and PPV resistance have been made in commercial plum orchards and gene bank collections since 2006, and these were supplemented with laboratory analysis on the fruit. German cultivars have spread widely in recent years, so it is particularly important to investigate the production value of these cultivars. In addition to field observations, a detailed analysis has been made over the last two years of the physical and chemical properties of the fruit of the most promising German cultivars ('Topfive', 'Toptaste', 'Tophit', 'Topend Plus' and 'Jojo') and of the control cultivars 'Cacanska rodna' and 'Stanley'.
The use of the German cultivars led to a lengthening of the harvest period, as fruit could still be harvested from 'Topend Plus' even in the middle of October. The onset of bearing was early for these cultivars, which had good yield potential, producing large numbers of buds not only on the spurs, but also on the long shoots. With the exception of 'Jojo' the cultivars exhibited greater initial vigour and the scaffold branches grew at a steeper angle, so greater care was required to form a favourable crown structure. The cultivar most resistant to PPV was 'Jojo', and 'Topend Plus' exhibited moderately severe leaf symptoms, while the other cultivars had only mild leaf symptoms. Among the cultivars included in the study, 'Topend Plus' and 'Tophit' had the largest fruit size, while 'Toptaste' had outstanding chemical properties, especially as regards the soluble solids and polyphenol contents.

Keywords: plum, production traits, fruit quality, PPV resistance, polyphenol content, titratable acid content, soluble solids content

INTRODUCTION

Plums play an outstanding role in fruit production in Hungary, where the climatic conditions favour the spread of plum cultivars belonging to the European group. Within this group, *Prunus domestica* L. cultivars can be found in the greatest proportion in Hungarian orchards, but continual changes can be observed in the cultivar structure, mainly due to the spread of *Plum Pox Virus* (PPV) and to the appearance of new, high-yielding cultivars with excellent fruit quality and good resistance to PPV and *Monolinia*. The cultivation of 'Besztercei szilva', which has been grown for centuries and has excellent commercial value, has declined considerably due to its susceptibility to PPV. The cultivar 'Stanley' was introduced into Hungary in the 1970s, while Serbian cultivars ('Cacanska lepotica', 'Cacanska rana', 'Cacanska rodna'), the US cultivar 'Bluefre' and the UK cultivar 'President' became popular from the early 1980s onwards. Cultivars originating from breeding stations in Germany (Research Station

Geisenheim; University of Hohenheim, Stuttgart) were introduced into Hungarian orchards after the millennium and their role in plum production is gradually increasing (Szabó, 2001; Kovács, 2013).

Plums are an important fruit species both for fresh consumption and as a raw material for the processing industry. The fruit have extremely valuable chemical quality, and only the stone fruits can rival their energy content. Plums are rich in carbohydrates, organic acids and fibre, and also contain large quantities of minerals, vitamins and phenolic compounds. It was reported by Gadze *et al.* (2011) that the high antioxidant activity of the phenolic compounds was much more important than the vitamin C and carotenoid contents. Among the plant antioxidants, plums contain substantial quantities of anthocyanin pigments and the flavonoids rutin and quercetin (Walkowiak-Tomczak *et al.*, 2008; Usenik *et al.*, 2009; Vangdal and Sekse, 2007).

The aim of the present work was to investigate the adaptability of new German-bred cultivars by evaluating their properties in terms of both production technology and dietary value. The results thus provide information for both growers and consumers.

MATERIALS AND METHODS

Field observations on the growth characteristics, flowering and harvesting dates, yield potential and PPV resistance of the PPV-resistant German cultivars 'Topfive', 'Toptaste', 'Tophit', 'Topend Plus' and 'Jojo' have been underway in the plum gene bank of the Department of Pomology, Corvinus University of Budapest collection since 2006.

The orchard is located in Soroksár (47°40' N, 19°15' E) in the north-west part of the Great Hungarian Plain, on the flood plain of the River Danube, so most of the soils were formed on calcareous sandy alluvial deposits. The total sunshine per year is 2014 hours, and the mean temperature is 11.9 °C. The 500–560 mm mean annual rainfall quantity is insufficient, therefore drip irrigation is used, especially during the period of fruit growing.

Trees were planted in 2004–2008 ('Cacanska rodna' and 'Stanley' in 2004; 'Jojo' and 'Tophit' in 2005; 'Topfive', 'Toptaste' and 'Topend Plus' in 2008). Row orientation is N-S, in the alleyway the natural vegetation (grass and weed species) is mown. The trees grown on Myrabolan rootstock were spaced at 5×3 m. Most of the trees had been trained as spindle but 'Topend Plus', 'Toptaste' and 'Topfive' have vase canopy. In every year fertilization is planned on the basis of soil and leaf analysis, and integrated plant protection is applied in the orchard.

Over the last two years detailed studies have been made on the physical (height, width, thickness, weight, flesh firmness) and chemical (soluble solids, acid and polyphenol contents) of the fruit. The control cultivars were 'Cacanska rodna' and 'Stanley'. Fruit in the approx. 90% ripe stage were used for the evaluation of fruit characteristics. The soluble solids content was analysed according to the Codex Alimentarius 3-1-558/93 standard (Determination of the soluble solids content of foodstuffs) and the titratable acid content according to the Hungarian standard MSZ EN 12147:1998 (Fruit and vegetable juice. Determination of titratable acidity.) The soluble solids contents were given as Brix% and the titratable acid contents as acid %. The total phenol content was determined in terms of gallic acid (GA) using the spectrophotometric method reported by Singleton and Rossi (1965).

The statistical analysis of the results was performed with the SPSS 20 program package. The six cultivars tested were compared using the multivariable, two-factor ANOVA model (MANOVA). On the figures different letters, in alphabetical order, indicate significant differences.

RESULTS AND DISCUSSION

Production Traits

The German cultivars mainly expanded the choice of late-maturing cultivars; fruit could still be harvested from 'Topend Plus' in mid-October. In the case of 'Topfive' and 'Jojo' it may be difficult to pinpoint the correct harvesting date, as both colour a lot earlier than they reach picking maturity. Special care should be taken with 'Topfive', as the flesh is also relatively soft during this period. It is thus advisable to analyse the soluble solids content of the fruit before determining the picking date.

Observations showed that the cultivars tested had a medium flowering date: 'Topend Plus' was mid-early, 'Jojo' and 'Topfive' were mid-season and 'Tophit' and 'Toptaste" mid-late. Among the control cultivars, 'Cacanska rodna' was mid-early to early and 'Stanley' mid-late to late. Spring frosts causing substantial yield losses were only observed in 2012 for 'Jojo' and the control cultivar 'Cacanska rodna'.

The experiments confirmed the early onset of bearing and good yield potential of the German cultivars. The early onset of bearing could be attributed primarily to the fact that not only the spurs but also the long shoots were laden with flower buds. Some of the cultivars tend to overset fruit, leading to alternate bearing (e.g. 'Tophit', 'Topfive'), so it may be necessary to regulate fruit setting. In some years 'Jojo' had a great tendency to produce twin fruit.

Based on the observations it can be said that the German cultivars exhibited intensive initial growth and that the main branches grew at a steep angle, so special care should be taken when developing the crown structure. The exception was 'Jojo', which had a spreading crown.

The present results confirmed those of other authors (Balmer, 2012; Hartmann, 1998; Jacob, 2007), who found that 'Jojo' had the best resistance to PPV. Mild leaf symptoms were observed in

the cultivars 'Tophit', 'Topfive' and 'Toptaste' and moderately strong symptoms in 'Topend Plus'.

Evaluation of Fruit Quality

The largest fruit were picked in both years from the trees of 'Tophit' and 'Topend Plus', which had a mean fruit weight of over 56 g in 2012 and over 44 g in 2013. The measurements showed that 'Toptaste', 'Topfive' and the control cultivars had medium fruit size, while the smallest fruit were produced by 'Jojo' (20.7 g). The fruit of the latter were considerably smaller than the 30–47 g size reported in the literature (Blazek and Pisteková, 2009; Gadze *et al*., 2011; Usenik *et al*., 2008). On the other hand, these authors reported a fruit weight of 27–28 g for 'Topfive', which produced much larger fruit in the present experiments, especially in 2012, while the data reported for 'Toptaste' were similar to those found in the present work. In the case of 'Tophit' the data in the literature are contradictory, with fruit weights ranging from 51–53 g (Gadze *et al*., 2008; Blazek and Pisteková, 2009) to 65 g (Jacob, 1998). There were also substantial differences in the present data, with a mean weight of 62 g in 2012 and 50 g in 2013. The cultivar 'Topend Plus' is listed in the literature in the large (50 g <) fruit category (Jacob, 2007; Szabó *et al*., 2012), which is in agreement with the results obtained in 2012 (Tab. I, Fig. 1).

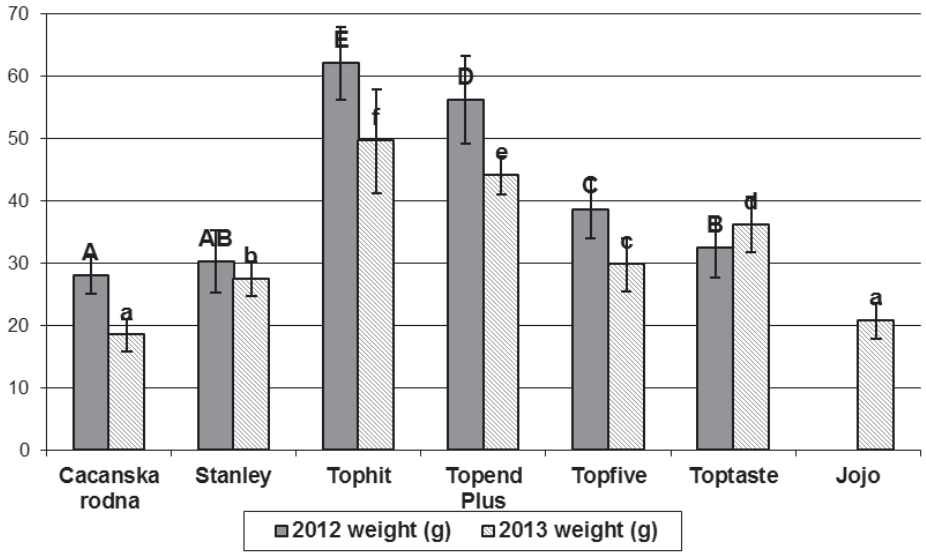
Comparing the data of the two years, the fruit were found to be larger in 2012 than in 2013, with the exception of 'Toptaste', which produced heavier fruit in 2013. With the exception of 'Jojo' the quantity of fruit produced on the trees did not differ in the two years. As efforts were made to take representative samples, the differences in fruit size can be attributed primarily to the exceptional weather conditions in 2013.

All the plum cultivars examined had the elongated fruit shape typical of Hungarian plums (Surányi, 2006; Szabó *et al*., 2012). With the exception of 'Topfive', all the cultivars were characterised by Jacob (2007) as having elongated fruit shape. The present work showed that 'Topfive', 'Toptaste' and 'Tophit' had the least elongated fruit, while 'Jojo', like the control cultivars, had very elongated fruit (Tab. II).

In the interests of easy transportation, long shelf life and storability, breeders aim to develop cultivars with firm flesh (2.5–3 kg/cm²) (Butac *et al*., 2011). The fruit of 'Topfive' was the firmest, with a value

I: *Height and width parameters of the fruit of tested cultivars (Soroksár, 2012–2013)*

Name of cultivar	Height (mm)		Width (mm)		Thickness (mm)	
	2012	2013	2012	2013	2012	2013
Topfive	44.04 ± 1.75 *b*	39.73 ± 1.71 *a*	38.95 ± 1.90 *b*	35.49 ± 1.59 *c*	35.03 ± 2.01 *b*	35.96 ± 1.72 *d*
Tophit	54.12 ± 2.14 *c*	51.12 ± 2.82 *d*	46.62 ± 1.98 *d*	42.91 ± 2.59 *e*	43.27 ± 1.86 *d*	39.40 ± 2.26 *e*
Topend Plus	53.91 ± 2.75 *c*	50.37 ± 1.62 *d*	42.7 ± 1.74 *c*	39.08 ± 1.72 *c*	41.01 ± 2.16 *c*	35.20 ± 1.12 *c*
Jojo	-	41.96 ± 2.18	-	29.32 ± 1.56	-	28.39 ± 1.57
Toptaste	39.31 ± 1.90 *a*	42.73 ± 2.03 *b*	35.45 ± 2.25 *a*	36.01 ± 1.88 *c*	35.75 ± 2.37 *b*	35.30 ± 1.50 *c*
Stanley	44.87 ± 2.23 *b*	47.62 ± 2.49 *c*	34.85 ± 2.04 *a*	32.51 ± 1.35 *b*	32.36 ± 2.17 *a*	30.95 ± 0.92 *b*
Cacanska rodna	44.20 ± 2.14 *b*	41.45 ± 2.49 *a*	34.63 ± 1.25 *a*	30.46 ± 1.92 *a*	31.75 ± 1.65 *a*	26.96 ± 1.22 *a*



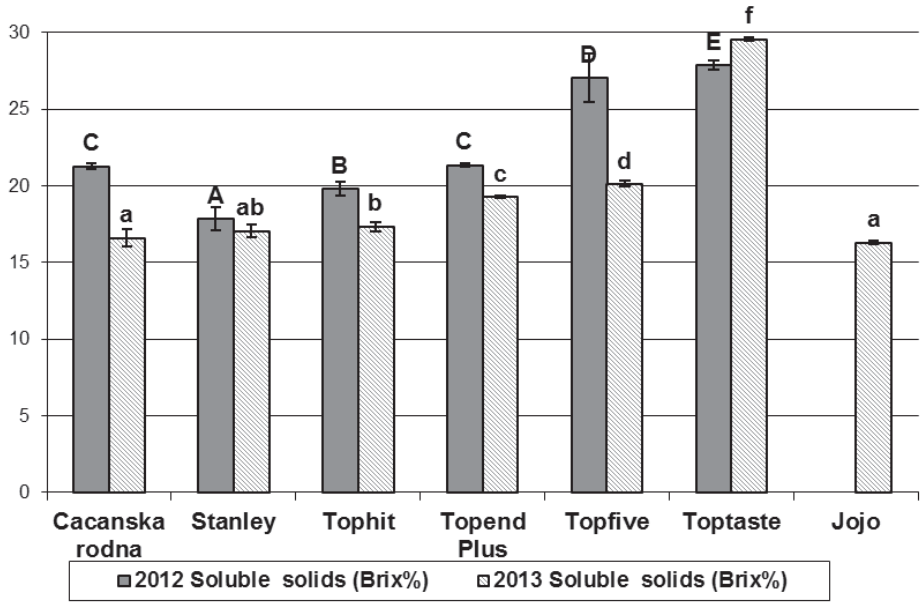
1: *Fruit weight of the cultivars tested (Soroksár, 2012–2013)*

II: *Flesh firmness and shape parameters of the cultivars tested (Soroksár, 2012–2013)*

Name of cultivar	Flesh firmness (kg/cm²)		Height/Width ratio		Height/Thickness ratio	
Topfive	3.00 ± 0.97 *b*	3.00 ± 0.42 *a*	1.13 ± 0.04	1.12 ± 0.03	1.26 ± 0.06	1.11 ± 0.04
Tophit	2.97 ± 0.67 *b*	2.97 ± 0.50 *b*	1.16 ± 0.05	1.19 ± 0.04	1.25 ± 0.05	1.30 ± 0.05
Topend Plus	1.16 ± 0.67 *a*	-	1.26 ± 0.05	1.29 ± 0.05	1.32 ± 0.05	1.43 ± 0.05
Jojo	-	1.47 ± 0.31	-	1.43 ± 0.15	-	1.48 ± 0.18
Toptaste	2.86 ± 0.68 *b*	-	1.11 ± 0.04	1.19 ± 0.04	1.1 ± 0.05	1.21 ± 0.05
Stanley	2.99 ± 0.77 *b*	1.65 ± 0.53 *a*	1.29 ± 0.06	1.47 ± 0.07	1.39 ± 0.07	1.54 ± 0.09
Cacanska rodna	2.96 ± 1.68 *b*	2.55 ± 0.70 *b*	1.28 ± 0.05	1.36 ± 0.07	1.39 ± 0.07	1.54 ± 0.06

III: *Titratable acidity, sugar:acid ratio and polyphenol content of the cultivars tested (Soroksár, 2012–2013)*

Name of cultivar	Titratable acidity (%)	Soluble solids:titratable acidity ratio		Polyphenol content (mg/l)	
	2012	2013	2012	2013	2013
Topfive	0.52 ± 0.03 *b*	0.97 ± 0.05 *e*	51.90 ± 4.49 *e*	20.69 ± 1.06 *b*	2003.3 ± 110.5
Tophit	0.73 ± 0.04 *c*	0.76 ± 0.06 *d*	27.19 ± 1.18 *a*	22.86 ± 0.53 *c*	1351.3 ± 18.7
Topend Plus	0.47 ± 0.02 *a*	0.36 ± 0.01 *a*	45.18 ± 2.016 *d*	53.72 ± 1.39 *e*	2122.1 ± 93.8
Jojo	-	0.7 ± 0.02	-	18.65 ± 0.40	882.5 ± 34.80
Toptaste	0.87 ± 0.05 *e*	0.48 ± 0.02 *b*	31.95 ± 1.88 *b*	61.47 ± 1.75 *f*	1711.7 ± 139.0
Stanley	0.48 ± 0.04 a	0.62 ± 0.02 *c*	37.26 ± 2.66 *c*	27.46 ± 1.54 *d*	1484.5 ± 58.1
Cacanska rodna	0.79 ± 0.08 *d*	1.01 ± 0.03 *e*	26.79 ± 2.65 *a*	16.42 ± 0.50 *a*	807.5 ± 6.30



2: *Soluble solids content of the cultivars tested (Soroksár, 2012–2013)*

of 3.0 kg/cm² in both years, while 'Topend Plus' had the softest fruit (Tab. II). The flesh firmness values recorded in the present work most closely resembled those reported by Blazek and Pisteková (2009).

According to Surányi (2006) late-maturing cultivars are generally characterised by higher dry matter content and lower acid content. This was confirmed in the present work for the mid-late to late cultivars tested, as the water-soluble dry matter content of the fruit of most of the cultivars ('Cacanska rodna', 'Tophit', 'Stanley', 'Topend Plus') ranged from 18–21 Brix%, while the titratable acid content was generally around 0.5–0.6% (Tab. III, Fig. 2).

Based on the 2-year data for soluble solids content, 'Toptaste' far surpassed the other cultivars (27.8–29.6 Brix%). These findings are confirmed by those of Jacob (2007), but Blazek and Pisteková (2009) reported somewhat lower values. In 2012 the

dry matter content of 'Topfive' was similar to that of 'Toptaste', but lower values were obtained for this cultivar in 2013. Better results were recorded for 'Topfive' than those reported by Blazek and Pisteková (2009) (19.7 Brix%), Jacob (2007) (18 Brix%) and Gadze *et al*. (2011) (19.4 Brix%). The lowest soluble solids content was found for 'Jojo' (16.3 Brix%), which was less than that obtained by Blazek and Pisteková (2009) and Gadze *et al*. (2011), but more than that detected by Usenik (2008). In the case of 'Tophit' the present results were similar to those published by Gadze *et al*. (2011) and Jacob (1998). The dry matter content of 'Topend Plus' was 21.3 Brix% in 2012 and 19.27 Brix% in 2013. These results were in agreement with those of Jacob (2007). Similar values were obtained in both years for the cultivar 'Stanley', while for most of the other cultivars higher values were obtained in 2012. The only exception was 'Toptaste', where the 2013 values were greater.

In 2013 the lowest titratable acidity (0.36%) was found for 'Topend Plus' and the highest for 'Cacanska rodna' (1.01%). Most of the cultivars had higher values in 2013, with the exception of 'Topend Plus' and 'Toptaste'. Great differences could be observed between the two years for 'Toptaste' (0.87%; 0.48%) and 'Topfive' (0.52%; 0.97%), while the fruit of 'Tophit' had similar titratable acidity in the two years (0.73%; 0.76%) (Tab. III). Compared with data from the literature the Hungarian measurements revealed much lower acid contents for 'Topfive', 'Toptaste' and 'Topend Plus'. Jacob (2007) reported acid contents of 1.7% for the first two cultivars and 0.95% for 'Topend Plus'. A similar situation was found for the acid content of 'Tophit' when compared with the data of Jacob (1998). However, the titratable acidity recorded for 'Topfive', 'Tophit' and 'Jojo' were similar to those reported by Gadze *et al*. (2011) and Stefanova *et al*. (2010).

In terms of the soluble solids : titratable acidity ratio, the highest values were found for 'Topfive' and 'Topend Plus' in 2012 and for 'Toptaste' and 'Topend Plus' in 2013. In both years this parameter was lowest for 'Cacanska rodna', due to the relatively high titratable acidity (Tab. III). This ratio is one of the best indicators of fruit flavour. It was stated by Vangdal and Flatland (2007) that a dry matter content in excess of 12.5% and a soluble solids : titratable acidity ratio of over 10 is required if the fruit is to be suitable for eating. Kader (1999) concluded that the titratable acidity should be below 0.8% and the soluble solids content above 12%, which means that the lowest acceptable sugar/acid ratio is over 15. All the cultivars investigated in the present work had a soluble solids : titratable acidity ratio of over 15 and a soluble solids content exceeding 12.5%.

Diverse data can be found in the literature for the polyphenol content of individual plum cultivars and hybrids. Kim *et al*. (2003) measured total polyphenol contents of 174–375 mg GAE/100 g, while the figures given by Chun and Kim (2004) ranged from 138.1–833.6 mg GAE/100 g. Vasantha Rupasinghe *et al*. (2006) determined polyphenol contents of 86–413 mg GAE/100 g in plum hybrids, while in the present work the values ranged from 807.5 mg/l for 'Cacanska rodna' to 2122.1 mg/l for 'Topend Plus'. Among the German cultivars the highest polyphenol contents were recorded in the fruit of 'Topend Plus' and 'Topfive' and the lowest in 'Jojo' (Tab. III). The values reported by Gadze *et al*. (2011) were lower than those found in the present work for 'Jojo' (531.53 mg/l), 'Topfive' (734.53 mg/l) and 'Tophit' (831.53 mg/l).

CONCLUSION

In terms of both production traits and fruit quality, German cultivars can make a great contribution to modernising plum production. Their high commercial value could make Hungarian farmers more competitive even on foreign markets, thanks to the fact that fruit can still be harvested in October. The extremely attractive, large, late-maturing fruit of the cultivars 'Topend Plus' and 'Tophit' give them an advantage on the market, while 'Toptaste' is particularly outstanding for its good chemical quality. Only the fruit of the 'Jojo' cultivar failed to come up to expectations, but the data in the literature suggest it could have prospects in wetter growing areas, as it has no rival with respect to its PPV resistance.

Acknowledgement

This research was supported by TÁMOP 4.2.1./B-09/1/KMR-2010-0005.

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