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INFLUENCE OF ROOTSTOCKS ON WINTER-HARDINESS OF PLUM GENERATIVE BUDS DURING THE WINTERING PERIOD IN TWO GROWING REGIONS

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The selection of appropriate rootstock is the main precondition for obtaining a high yielding and sustainable plum orchard. In the Northern climate, plum overwintering is especially important, where winter hardiness of flower buds is one of indicators. This investigation was carried out during three wintering periods (2010–2013) at the Institute of Horticulture in Pūre (Latvia) and the Polli Horticultural Research Centre (Estonia), in orchards planted in 2001. The aim of the investigation was to evaluate the influence of different rootstocks on the viability of flower buds during winter for two plum cultivars in two growing regions. European plum 'Victoria' and hybrid plum 'Kubanskaya Kometa' grafted on eight clonal and eight seedling rootstocks were used in the investigation. Bud samples were taken two times during winter: end of January and end of March. The viability of flower buds and flowering intensity were determined in the laboratory. The viability was determined as dehydrogenase activity using triphenyl tetrazole chloride (0.5%), where in living cells the colourless substance due to enzymatic activity turns into a brightly coloured product — formasan. The optical density of colour was determined with a spectrophotometer at 485 nm. Both cultivars 'Kubanskaya Kometa' and 'Victoria' had higher flower bud viability in Polli compare to Pūre. In both growing regions, the highest activity of dehydrogenases for cultivar 'Kubanskaya Kometa' was on rootstocks 'Myrobalan', 'St. Julien INRA 2', 'Wangenheims Zwetsche' and for cultivar 'Victoria' — on rootstocks 'Ackermann', 'Brompton' seedlings, and 'St. Julien d` Orleans'. The dehydrogenase activity of in flower buds had a tendency to decrease during winter.

Key words: Prunus*, flower buds, flowering intensity, enzymatic activity, meteorological conditions, Latvia, Estonia.*

INTRODUCTION

Climatic conditions of both Latvia and Estonia are characterised by sharp air temperature fluctuations, when frosts interchange with thaws at the end of winter. The appropriate choice of cultivar/rootstock combinations that increase tree resistance to different unfavourable conditions is one of preconditions to obtaining high yield (Wertheim, 1998).

Caucasian plum (*Prunus cerasifera* Ehrh.) seedlings were the most widely used rootstocks for a long period in Latvia and Estonia, but they are not suitable for modern plum orchards because they grow too vigorously and are incompatible with several cultivars (Lepsis *et al*., 2004; Rozpara *et al*., 2010).

To increase the productivity of plum orchards, flower bud winter hardiness is very important (Tyurina *et al*., 2000). According to previous reports in the literature, flower buds are the most sensitive part of stone fruit trees (Palonen and Buszard, 1997). The winter hardiness of flower buds can vary greatly among different species, depending on the time and course of the flower bud dormancy period. Frost resistance of flower buds decreases after the beginning of vegetative growth. The end of winter is especially hazardous for flower buds, when air temperature increases and flower buds have finished the periods of endodormancy and ecodormancy (Proebsting, 1982; Tyurina *et al.*, 2000; Allona *et al.*, 2008). Therefore, the level of damage to flower buds after frost can differ between wintering periods (Szalay *et al.*, 2017). The cultivar has a high importance in flower bud winter hardiness. In a study on evaluation of rootstocks in Estonia, during spring 2004, the home plum cultivar 'Victoria' had all flower buds damaged by frosts, whereas the diploid plum cultivar 'Kubanskaya Kometa' was less damaged and produced fruits (Jänes *et al.*, 2007).

The temperature regime before and after the critical minimum is very important in the resistance of the flower buds. During winters when temperature decreases gradually and a negative low temperature is observed before critically strong frosts, plants undergo sufficient hardening. In such winters, the damage to flower buds is insignificant. Strong flower bud damage is observed in winters when there is a temperature increase followed by a very sharp decrease of temperature. Flower bud frost resistance differs among cultivars also when buds are in the same developmental stage (Enache and Baciu, 2016). The damage severity can be higher on an open field compared to in the laboratory, because the amount of hours with minimal temperature that have impact on plants differs. In laboratory conditions, the amount of hours is usually limited (Holubowicz and Bojar, 1982).

The freezing processes in fruit tree flower buds are more complicated than in wood tissue (Rodrigo, 2000). In flower buds, the formation of ice begins at the scion of the bud and in the base of the flower that is located in front of the main organs of the flower. Ice crystals may occur in selected places in the bud, and not be distributed evenly throughout the bud (Tromp *et al.*, 2005). The base of the bud and generative tissues are the most sensitive.

The aim of the investigation was to evaluate the influence of different rootstocks on the viability of flower buds during winter for two widespread plum cultivars in two growing regions of Latvia and Estonia.

MATERIALS AND METHODS

Plant material. The plum cultivars 'Kubanskaya Kometa' (*Prunus rossica*. Erem.) and 'Victoria' (*Prunus domestica* L.) were grafted on eight seedling rootstocks (St. Julien INRA 2, St. Julien d'Orleans, St. Julien Noir, Brompton, Wangenheims Zwetsche, St. Julien Wädenswil, and Myrobalanand *Prunus cerasifera* var. *divaricate*), and eight clonal rootstocks ('St. Julien A', 'Brompton', 'Ackermann', 'Pixy', 'GF8/1', 'G5/22', 'GF655/2', and 'Hamyra'). The study was performed at the Institute of Horticulture in Pūre, Latvia, and at the Polli Horticultural Research Centre, Estonia. The experimental orchards were established in spring 2001. Plants were planted at a space of 3 × 5 m, in four replications, with three trees per plot. The soil type was clay loam in Pūre, and sandy clay loam in Polli. Bud samples were taken two times during the wintering period: in the end of January and end of March. The viability of flower buds and flowering intensity were determined at the laboratory of Plant Physiology of University of Life Sciences and Technologies. The viability was determined as activity of dehydrogenases using triphenyltetrazole chloride (0.5%), where in living cells the colourless substance due to enzymatic activity turns into a brightly coloured product — formasan (TTCF) (Anonymous, 2012). The optical density of colour was determined with a spectrophotometer at wavelength 485 nm. Data were analysed using descriptive statistics and ANOVA. Differences between means were tested by the least significant difference (LSD) and Duncan's criteria at a 5% significance level.

Meteorological conditions. Meteorological data were collected at the local meteorological stations in both trial places. Minimal, maximal, and average air temperatures during winters in 2010/2011, 2011/2012, and 2012/2013 are presented in Table 1. Significant differences in meteorological parameters were observed among years whereas they did not differ significantly between growing regions. The air temperature fluctuation trend during winter was similar between the growing regions. The lowest air temperature

Table 1

MINIMAL, MAXIMAL AND AVERAGE AIR TEMPERATURES DURING THE WINTERS OF 2010/2011, 2011/2012 AND 2012/2013

Month	Region	2010/2011			2011/2012			2012/2013		
		min	max	average	min	max	average	min	max	average
October	Polli	–4.3	12.9	4.1	–0.8	15.5	7.3	–5.1	17.1	5.7
	Pūre	–3.2	15.3	4.8	–2.0	18.1	7.9	–5.7	18.8	6.5
November	Polli	–21.9	11.3	0.2	–6.6	9.9	3.9	–7.7	8.2	2.7
	Pūre	–15.2	13.3	2.4	–6.2	11.0	5.0	–1.1	10.0	4.4
December	Polli	–14.4	0.2	–7.9	–3.1	8.5	1.6	19.1	3.0	–6.7
	Pūre	–18.0	0.7	–6.2	–4.9	9.5	2.0	–17.1	5.5	–5.8
January	Polli	–22.1	3.0	4.2	–21.7	4.2	–5.1	–27.2	4.0	–6.6
	Pūre	–16.9	3.7	–2.4	–22.5	6.4	–2.8	–21.1	5.7	–7.7
February	Polli	–33.5	2.3	–11	–32.1	3.1	–10.2	–19.8	5.3	–2.9
	Pūre	–28.5	4.5	–8.9	–29.7	8.2	–7.7	–20.9	8.2	–6.4
March	Polli	–15.3	8.7	–1.1	–19.0	9.9	–0.1	–24.8	5.1	–7.4
	Pūre	–16.9	8.7	0.1	–13.0	15.0	1.8	–19.3	8.4	–5.4

was observed in February 2010/2011, when temperature dropped to –33.5 °C in Polli and to –28.5 °C in Pūre. In Polli in February 2011/2012, the air temperature also dropped below –30.0 °C. The winter of 2010/2011 was especially cold, because frosts below –10.0 °C were observed from November to March in both trial locations, and the temperature in Pūre was –16.9 °C even in March.

RESULTS

In Pūre, the lowest activity of dehydrogenases for cultivar ‘Kubanskaya Kometa’ was observed in flower bud samples collected in January and March of 2011. In the three-year period of study, the biggest differences among rootstocks in winter were observed in March (Table 2). During all three winters, this cultivar had the most stable results on rootstocks ‘St. Julien d` Orleans’, ‘Wangenheims Zwetsche’, ‘Myrobalan’ ‘Ackermann’ and ‘Brompton’ seedlings.

Comparing both growing regions, the difference in dehydrogenase activity between January and March was larger in Pūre, which can be explained by greater fluctuation between minimal and maximal air temperatures. In both study locations, for cultivar ‘Kubanskaya Kometa’ the most stable combinations with higher dehydrogenase activity were with rootstocks ‘Myrobalan’, ‘St. Julien INRA 2’, ‘Wangenheims Zwetsche’, *P. cerasifera* var. *divaricata* and ‘St. Julien d` Orleans’ (Fig. 1).

During three winters, cultivar ‘Victoria’ had lower dehydrogenase activity than for ‘Kubanskaya Kometa’. In general,

Table 2

DEHYDROGENASES ACTIVITY IN FLOWER BUDS OF CULTIVAR ‘KUBANSKAYA KOMETA’ DURING WINTERS OF THE YEARS 2010/2011, 2011/2012, 2012/ 2013, μg TTCF g^{-1}

Rootstocks	Pūre			Polli		
	January	March	Average	January	March	Average
Ackermann	2.35 ab*	3.83 abcd	3.09	5.10**	1.96 a	3.53
St. Julien INRA2	1.74 a	2.28 abc	2.01	5.49	3.57 ab	4.53
Brompton seedlings	2.00 ab	3.60 abcd	2.80	3.96	5.25 b	4.60
Myrobalan	2.57 ab	6.02 d	4.29	5.17	3.76 ab	4.47
GF 8/1	2.53 ab	3.18 abcd	2.85	5.00	3.14 ab	4.07
G 5/22	2.71 ab	2.92 abcd	2.81	3.27	3.00 ab	3.13
St.Julien d` Orleans	3.38 ab	5.34 cd	4.36	4.81	4.17 ab	4.49
Brompton clonal	2.79 ab	1.96 abcd	2.38	3.04	3.68 ab	3.36
St. Julien Noir	2.66 ab	1.92 ab	2.29	3.08	3.24 ab	3.16
St. JulienWädenswill	2.78 ab	3.38 abcd	3.08	3.02	3.19 ab	3.11
WangenheimsZwetsche	3.42 ab	4.58 abcd	4.00	3.86	2.19 a	3.02
St Julien A	2.44 ab	1.73 a	2.08	2.52	2.06 a	2.29
Pixy	3.36 ab	2.34 abcd	2.85	2.95	2.15 a	2.55
Hamyra	2.73 ab	3.48 abcd	3.11	3.55	2.59 ab	3.07
P. cerasifera var. *divaricata*	4.32 a	5.25 bcd	4.78	3.43	2.60 ab	3.02
GF 655/2	2.29 ab	2.73 abc	2.51	5.00	2.61 ab	3.81
Average	2.75	3.41	3.08	3.95	3.07	

* values within columns marked by different letters have significant difference (Duncan’s criteria, $p = 0.05$)

** no statistically significant difference between values within column

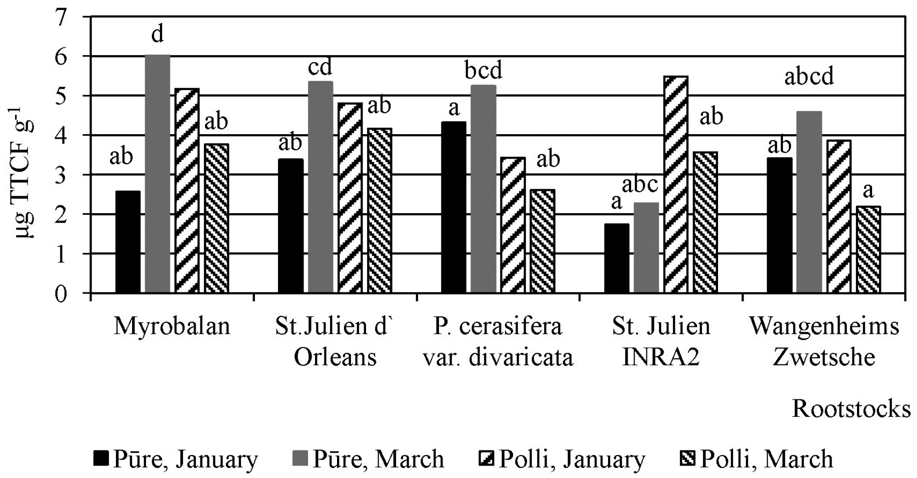

Fig. 1. Rootstocks with the highest dehydrogenase activity in flower buds for the cultivar ‘Kubanskaya Kometa’ (values within columns marked by different letters over the months have significant difference, Duncan’s criteria, $p = 0.05$).

for both trial locations and winters evaluated, the dehydrogenase activity was higher for trees grafted on rootstocks 'Ackermann', 'Brompton' seedlings, 'St. Julien d` Orleans', 'GF8/1', 'Pixy' and *P. cerasifera* var. *divaricata* (Table 3).

In Polli, the highest dehydrogenase activity for all rootstocks in general was observed during winter of 2010/2011, while the lowest was in March of 2013, when for some cultivar/rootstock combinations there was an insufficient amount of living buds for analysis of dehydrogenase activity.

Significant differences among sampling times for cultivar 'Victoria' were observed for all three winters ($p = 0$), where lower dehydrogenase activity was observed in March compared to January. The highest dehydrogenase activity was observed in Polli for trees on rootstock 'Ackermann' in January (5.73 µg TTCF·g^{-1}) (Fig. 2).

In both trial locations, rootstocks 'Ackermann', 'Brompton' seedlings, 'St. Julien d` Orleans', 'St. Julien Noir', 'GF 8/1' were selected as the most favourable for cultivar 'Victoria', as they had the highest dehydrogenase activity.

DISCUSSION

To increase plum orchard productivity in northern European countries, flower bud winter hardiness is very important. Significant differences among sampling times were found for dehydrogenases activity, and among cultivar/rootstock combinations and growing regions.

In Polli, during three winters, cultivar 'Kubanskaya Kometa' had more stable results regarding dehydrogenase activity in flower buds compared to that in Pūre. In January, significant differences among rootstocks were not found

Table 3

DEHYDROGENASES ACTIVITY IN FLOWER BUDS OF CULTIVAR 'VICTORIA' DURING WINTERS OF YEARS 2010/2011, 2011/2012, 2012/2013, µg TTCF g^{-1}

Rootstocks	Pūre			Polli		
	January	March	Average	January	March	Average
Ackermann	4.15 c*	3.51 ab	3.83	5.73 b	3.34 b	4.54
St. Julien INRA2	2.19 ab	1.57 a	1.88	2.54 a	0.92 a	1.73
Brompton seedlings	2.12 ab	4.45 b	3.29	3.74 ab	2.14 ab	2.94
Myrobalan	2.30 ab	2.66 ab	2.48	2.73 a	2.48 ab	2.60
GF 8/1	3.36 bc	2.44 ab	2.90	3.66 ab	1.85 ab	2.75
G 5/22	2.79 abc	1.35 a	2.07	2.59 a	0.88 a	1.73
St.Julien d` Orleans	2.53 abc	2.88 ab	2.71	3.58 ab	2.99 ab	3.28
Brompton clonal	1.25 a	2.72 ab	1.98	4.14 ab	1.99 ab	3.07
St. Julien Noir	2.05 ab	2.80 ab	2.42	3.26 ab	2.27 ab	2.77
St. JulienWädenswill	2.47 abc	2.57 ab	2.52	3.42 ab	1.85 ab	2.63
WangenheimsZwetsche	2.41 abc	1.43 a	1.92	2.06 a	1.32 ab	1.69
St Julien A	2.69 abc	2.09 ab	2.39	2.68 a	1.89 ab	2.29
Pixy	3.09 abc	2.26 ab	2.68	3.19 ab	1.82 ab	2.50
Hamyra	2.53 abc	2.12 ab	2.32	2.90 a	1.23 ab	2.06
P. cerasifera var. *divaricata*	2.38 abc	2.80 ab	2.59	2.45 a	1.15 a	1.80
GF 655/2	1.52 ab	1.79 a	1.66	3.22 ab	2.03 ab	2.62
Average	2.49	2.46	2.48	3.24	1.88	

*values within columns marked by different letters have significant difference (Duncan's criteria, $p = 0.05$).

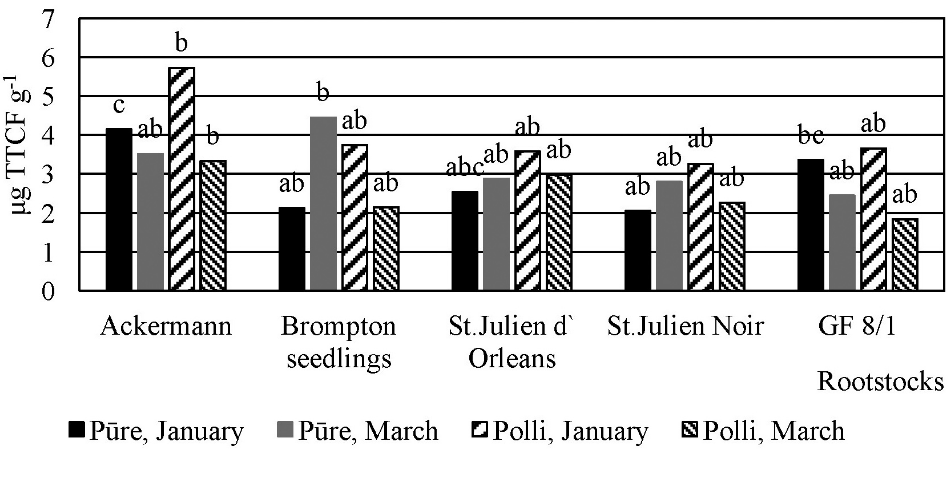

Fig. 2. Rootstocks with the highest dehydrogenase activity in flower buds for the cultivar 'Victoria' (values within columns marked by different letters over the months have significant difference, Duncan's criteria, $p = 0.05$).

(Duncan's criteria). This can be explained by greater fluctuations between the minimum and maximum air temperatures during winter. According to Yeryomin and Safarov (2013), cultivar 'Kubanskaya Kometa' is characterised by high winter hardiness in Southern regions of Russia, whereas in Latvia and Estonia tree and flower bud damage is observed during winter (Jänes and Kahu, 2008; Lepsis *et al.*, 2008). The winter hardiness of this cultivar can be also influenced by thaws during winter, as it belongs to the *P. cerasifera* plum group that has a short dormancy period. During the dormancy period it can withstand even drops in temperature to –30 ^{o}C, whereas after the dormancy period, the resistance to low temperatures sharply decreases and then it can withstand temperature –10 to –15 ^{o}C only for a short period (Yeryomin, 1993).

CONCLUSIONS

Both cultivars 'Kubanskaya Kometa' and 'Victoria' had higher flower bud viability at Polli compared to Pūre. In both growing regions, the highest dehydrogenase activity for cultivar 'Kubanskaya Kometa' was on rootstocks 'Myrobalan', 'St. Julien INRA 2', and 'Wangenheims Zwetsche', and for cultivar 'Victoria' on rootstocks 'Ackermann', 'Brompton' seedlings, and 'St. Julien d` Orleans'. The dehydrogenase activity in flower buds has a tendency to decrease during winter.

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POTCELMU IETEKME UZ PLŪMJU ĢENERATĪVO PUMPURU ZIEMCIETĪBU ZIEMOŠANAS PERIODA LAIKĀ DIVOS AUDZĒŠANAS REĢIONOS

Piemērotu potcelmu izvēle ir galvenais priekšnoteikums ilgtspējīgu plūmju dārzu ierīkošanā. Ziemeļu klimatā ziedpumpuru ziemcietība ir viens no galvenajiem rādītājiem. Pētījums veikts 2001. gadā ierīkotā izmēģinājumā, Dārzkopības institūtā Pūrē (Latvija) un Polli Dārzkopības pētījumu centrā, no 2010. līdz 2013. gadam. Pētījuma mērķis bija izvērtēt dažādu plūmju potcelmu ietekmi uz ziedpumpuru ziemcietību divām šķirnēm divos audzēšanas reģionos. Pētījumā izmantota Eiropas plūmju šķirne 'Viktorija' un hibrīdplūme 'Kubanskaja Kometa', kas potētas uz astoņiem ģeneratīvi vairotiem un astoņiem veģetatīvi vairotiem potcelmiem. Ziedpumpuru paraugi ievākti divas reizes ziemošanas periodā — janvārī un martā. Ziedpumpuru dzīvotspēja noteikta kā dehidrogenāzes aktivitāte, izmantojot 0,5% trifeniltetrazola hlorīdu. Salīdzinot abas izmēģinājuma vietas, augstāka ziedpumpuru dzīvotspēja abām šķirnēm bija Polli. Abās izmēģinājumu vietās augstākā ziedpumpuru dehidrogenāzes aktivitāte šķirnei 'Kubanskaja Kometa' bija uz potcelmiem 'Myrobalan', St. Julien d' Orleans', 'Wangenheims Zwetcshe' un šķirnei 'Viktorija' — uz potcelmiem 'Ackermann' 'Brompton' ģeneratīvi vairotiem, 'St. Julien d' Orleans'. Ziedpumpuru dehidrogenāzes aktivitātei ir tendence ziemošanas perioda laikā samazināties.