THE EFFECT OF ROOTSTOCK ON THE PHYSIOLOGICAL STATUS AND THE STORAGE ABILITY OF 'ELISE' APPLES
POTCELMA IETEKME UZ 'ELISE' ŠĶIRNES ĀBOLU FIZIOLOĢISKAJIEM PROCESIEM UN GLABĀŠANOS

Tomala K. and Słowinska I.
Department of Pomology and Basic Natural Sciences in Horticulture, Warsaw Agricultural University – SGGW, Nowoursynowska 159, 02-776 Warszawa, Poland

Kopsavilkums

Piecpadsmit dažādu potcelmu (P 2, P 14, P 16, P 22, NR 47, P 59, P 60, B 9, B 146, B 396, PB-4, M.9 EMLA, M.26, M.27 un M.7) ietekme uz šķirnes 'Elise' glabāšanos tika pētīta četras sezonas - no 1999. līdz 2002. gadam. Ražu novācot tika noteikta vidējā augļu masa, mīkstuma blīvums, cietes indekss, šķīstošā sausna un endogēnā etilēna koncentrācija. Svara zudums, augļu blīvumsa, šķīstošā sausna un masas zudumu pakāpe bojājumu dēļ tika noteikta atkārtoti pēc 6 mēnešiem. Vērojama tendence, ka ilgāk saglabā blīvumu augļi uz sarkanlapainajiem potcelmiem (B 9, P 60, B 396, P 59). Augļi no kokiem uz P2 uzrādīja lielāku endogēnā etilēna saturu, bet uz M.27 šis rādītājs bija zemākais. B 9, P 59 un M.27 uzrādīja augstāku Streifa indeksu, kas nosaka vēlāku augļu nobriešanu. Mazākie augļi bija uz PB-4, P 22 M.27 un P 59 potcelmiem, lielākie – uz P 14, M.7 un P 2. Mīkstuma blīvums, etilēna klimaktērija fāzes sasniegšana, gatavības indeksi un augļu kvalitāte atšķīrās pa sezonām.

Abstract

The effect of fifteen rootstocks (P 2, P 14, P 16, P 22, NR 47, P 59, P 60, B 9, B 146, B 396, PB-4, M.9 EMLA, M.26, M.27 AND M.7) on the storability of 'Elise' apples was studied in the 1999-2002 seasons. Measurements during harvest included mean fruit weight, flesh firmness, starch index, soluble solids and internal ethylene concentration. After six months of cold storage, weight loss, firmness, soluble solids and incidence of storage disorders were determined. Trends showing higher firmness values for fruits from trees on red-leaved rootstocks (B 9, P 60, B 396, P 59) were noted. Fruits from trees on p 2 resulted in higher than average internal ethylene content, although values obtained for M.27 were lower than average. b 9, p 59 and m.27 resulted in higher values of the streif index that corresponded with later ripening. The smallest fruits were noted for super dwarfing rootstocks PB-4, P 22 M.27 AND P 59, while the biggest were ON P 14, M.7 and P 2. A low percentage of physiological disorders of fruits was noted for B 9, B 396, P 59 AND NR 47. A high seasonal variation was observed for firmness, climacteric ethylene production, and maturity indices and fruit quality after storage.

Key words: *Malus × domestica*, internal ethylene, firmness, soluble solids, physiological disorders, starch, Streif index, weight loss

Introduction

There is no doubt that the rootstock may have direct or indirect influences on tree growth behaviour (Wertheim, 1998). One of the most important objectives of growers is to control fruit quality using rootstocks. The classic paper of Hatton (1935) showed that fruits from trees on the dwarf rootstock No. 9 (later named M.9) were bigger with better red blush. The rootstock effect on visual quality parameters, such as mean fruit mass, fruit shape and coloration has been shown in many trials performed at different locations (Barritt *et al.*, 1997; Callesen, 1997; Hirst *et al.*, 2001; Loreti, 2001). The internal fruit quality parameters such as firmness, soluble solids content, and acidity are also affected by the rootstock (Fallahi *et al.*, 1985; Autio *et al.*, 1991; Drake *et al.*, 1991; Ben, 1999; Slowinska and Tomala, 2001). Apple fruit mineral composition also depends on the rootstock (Drake et al., 1991; Ben, 1995) and it is well known that apple storage ability strongly depends on their mineral element content (Fallahi, 1988; Tomala, 1997). Therefore, fruit internal quality is closely related to apple storability and may influence fruit maturation (Barden, 1988; Barden and Marini, 1992; Autio *et al.,* 1996).

The objective of this study was to examine the effect of rootstocks of different vigour and origin on fruit internal quality and storability using fruits of the cultivar ‘Elise’ during the 1999-2002 periods.

Materials and Methods

‘Elise’ apple fruits from trees on fifteen rootstocks of different vigour and different origin were examined. The trees were budded on P 2, P 14, P 16, P 22, Nr 47, P 59, P 60, B 9, B 146, B 396, PB 4, M.7, M.9 EMLA, M.26, and M.27 rootstocks.

The orchard trial was set up in four replications, with 5 – 7 trees per plot and planted in the spring of 1997. The harvest date was estimated based on the induced ethylene method. At harvest time, flesh firmness was measured using the Instron penetrometer, soluble solid concentration was determined using a refractrometer, and the degree of starch breakdown (starch index, on a 1-10 scale) was assessed. The Streif maturity index was also calculated based on these values. The internal ethylene concentration was determined with a Hewlett Packard gas chromatograph Model 5890 II. All measurements were performed on the random samples of 15 fruits per plot. Mean fruit mass was assessed, based on a sample of 100 apples from each plot.

One box (ca 16 kg) of fruits from each plot was stored at 1°C for 6 months for each of three storage seasons: 1999/2000, 2000/2001, 2001/2002and 2002/2003. The flesh firmness, weight loss, soluble solids and percentage of sound fruits, storage diseases and physiological disorders were determined at the end of each storage season.

Data were subjected to an analysis of covariance, the one-factor model separately for three seasons. The two-factor model was used to compare mean values for three years and determine significance. The confounding effect of the mean fruit mass on the firmness was removed using an analysis of covariance. The data on percentage of fruits with physiological disorders, storage diseases and sound apples were transformed using the Bliss method ($\arcsin\sqrt{x}$).

Results and Discussion

The mean fruit mass was a significant covariate for the fruit firmness at harvest in all years. Adjusted means of firmness (Table 1) showed that rootstock affects this parameter; however, there was no persistent tendency for higher firmness associated with any particular rootstock.

Table 1. Rootstock effect on firmness of ´Elise´ apples at harvest and after storage

Rootstock[1]	Firmness (N; 1 kG = 9.81 N)							
	at harvest				after storage			
	1999	2000	2001	2002	1999	2000	2001	2002
PB 4	94.6	-	84.1	81.6	58.6	-	50.2	53.1
P 22	91.7	-	82.1	77.9	55.6	-	52.4	52.3
M.27	92.5	106.7	84.0	86.8	59.3	65.0	52.5	56.9
P 59	91.9	109.8	81.7	93.7	55.2	66.2	52.1	51.5
P 16	91.0	98.0	80.8	91.1	59.7	63.2	51.4	54.5
P 2	90.4	102.6	84.2	88.6	55.9	63.0	53.7	49.5
M.9 EMLA	94.7	111.6	82.8	90.6	59.0	66.6	53.0	51.2
B 9	94.2	109.3	84.6	94.7	60.9	68.1	51.2	54.1
B 396	89.3	110.0	83.7	97.9	60.5	63.5	54.7	50.1
P 60	94.4	112.1	85.5	102.4	60.7	68.1	54.2	50.9
B 146	89.8	108.4	83.5	86.1	57.8	62.2	51.6	54.1
M.7	94.3	-	85.5	93.7	58.4	-	52.4	48.0
M.26	91.1	110.6	84.8	96.1	57.6	64.6	50.3	50.4
Nr 47	94.2	108.7	82.0	94.0	57.3	65.1	52.4	48.5
P 14	90.2	105.6	83.4	86,9	57.0	65.0	53.2	49.1
p-Value[2]	*0.095*	*0.102*	*0.840*	*0.019*	*0.136*	*0.535*	*0.640*	*0.273*

[1] Rootstocks are listed in increasing TCSA value [2] p-Value is equal to F probability

High variation was observed between seasons, as was also found in research by Fallahi *et al.* (1985) and Autio *et al.* (1996). Trends for higher firmness values for fruits from trees on red-leaved rootstocks (B 9, P 60, B 396, P 59) were noted. This fact could be related to higher Ca content in fruits from trees on these rootstocks (Tomala *et al*., 1999; Slowinska and Tomala, 2001; Chun *et al.*, 2002). The firmness after storage was significantly related (data not shown) to firmness at harvest but it was not possible to detect any strong rootstock effect on this. There was no evidence of a relationship between fruit firmness and rootstock vigour as found in a previous paper by Autio *et al.* (1996).

The percentage of soluble solids content (Table 2) was affected by rootstock. In this case, a high seasonal variation was also observed. There were no higher values of these indices recorded for more dwarfing rootstocks, as reported by Autio *et al.* (1991). It is worth mentioning that in certain specific years the percentage of soluble solids after storage was higher for some red leaved rootstocks, as was also pointed out for the case of fruit firmness.

Table 2. Rootstock effect on soluble solids of ´Elise´ apples at harvest and after storage

Rootstock[1]	Soluble solids, %							
	at harvest				after storage			
	1999	2000	2001	2002	1999	2000	2001	2002
PB 4	14.8	-	12.6	14,6	16.1	-	12.1	14.2
P 22	15.0	-	12.6	14,4	15.5	-	11.6	14.3
M.27	14.6	16.4	11.8	14,5	16.1	16.7	11.7	14.4
P 59	14.6	16.3	11.9	13,6	15.5	17.3	10.9	13.9
P 16	14.7	15.9	12.4	14,4	15.4	16.2	11.2	13.9
P 2	15.0	16.6	12.5	14,4	15.7	16.7	12.3	13.9
M.9 EMLA	14.6	16.7	12.2	13,3	15.3	16.8	11.8	13.9
B 9	15.2	16.0	12.2	12,9	15.3	17.8	11.1	14.1
B 396	14.9	16.9	12.7	13,7	15.6	16.4	12.7	13.7
P 60	15.0	16.5	12.9	13,8	15.8	17.1	12.4	13.6
B 146	14.6	16.6	12.1	13,3	15.4	17.1	11.9	14.0
M.7	14.0	-	12.8	14,2	14.8	-	11.6	13.1
M.26	14.6	15.3	11.8	14,6	15.0	16.7	12.0	13.7
Nr 47	14.9	16.7	12.9	13,8	15.6	17.1	12.2	13.5
P 14	14.0	15.5	11.9	13,2	14.3	16.5	11.8	13.4
p-Value[2]	*0.1774*	*0.0402*	*0.4244*	*0.0941*	*0.0020*	*0.1937*	*0.0022*	*0.0470*

[1,2] See table 1

The Streif index (Table 3) associates all maturity indices, and could be used as a more secure indicator of the fruit ripening process. Rootstock effect varied from year to year, but some rootstocks were consistent in their effect. Specifically, B 9, P 59 and M.27 resulted in higher values of this index and this corresponds with later ripening. Delay of maturity on trees on M.27 was also found by Barden (1988).

Mean fruit mass was affected by rootstock (Table 3), and a trend towards bigger fruits on more vigorous rootstocks was observed. The smallest fruits were noted for super dwarfing rootstocks PB-4, P 22 M.27 and P 59, while the biggest were on P 14, M.7 and P 2.

The rootstock effect on physiological disorders (Table 4) and percentage of sound fruits was significant. The presence of physiological disorders was very high in the first year of the experiment.

The low percentage of physiological disorders of fruits noted for B 9, B 396, P 59 and Nr 47 rootstocks was associated with a high Ca and low K:Ca ratio, as presented in a previous paper for these rootstocks (Slowinska and Tomala, 2001). This is in line with data reported by many authors (Fallahi *et al.*, 1988; Tomala, 1997). There was no evidence of any rootstock effect on weight loss caused by respiration and transpiration.

Table 3. Rootstock effect on Streif index and mean fruit mass of ´Elise´ apples at harvest

Rootstock[1]	Streif index				Mean fruit mass, g			
	1999	2000	2001	2002	1999	2000	2001	2002
PB 4	0.11	-	0.11	0,227	161	-	173	200
P 22	0.09	-	0.13	0,244	160	-	189	220
M.27	0.12	0.16	0.17	0,212	175	144	181	205
P 59	0.10	0.19	0.12	0,189	177	148	172	206
P 16	0.10	0.11	0.10	0,298	173	160	192	207
P 2	0.09	0.12	0.14	0,332	188	169	205	219
M.9 EMLA	0.11	0.15	0.14	0,189	170	147	207	221
B 9	0.11	0.20	0.14	0,201	162	138	210	217
B 396	0.09	0.17	0.11	0,274	195	150	206	211
P 60	0.11	0.13	0.12	0,256	170	152	215	217
B 146	0.09	0.14	0.11	0,295	182	160	201	222
M.7	0.13	-	0.14	0,272	163	-	228	231
M.26	0.10	0.17	0.12	0,260	180	153	212	223
Nr 47	0.10	0.16	0.11	0,216	196	160	199	217
P 14	0.10	0.11	0.11	0,242	185	168	232	252
p-Value[2]	*0.0310*	*0.0054*	*0.0023*	*0.0043*	*0.0885*	*0.1106*	*0.0010*	*0.0667*

[1,2] See table 1

Table 4. Rootstock effect on the percentage of physiological disorders and weight loss of ´Elise´ apples after storage

Rootstock[1]	Physiological disorders, %				Weight loss, %			
	1999	2000	2001	2002	1999	2000	2001	2002
PB 4	17.3	-	1.5	15.1	3.2	-	3.3	3,9
P 22	18.7	-	0.9	6.4	3.1	-	3.2	3,5
M.27	9.8	6.8	0.3	11.6	3.2	4.9	3.1	3,5
P 59	7.3	6.8	2.7	4.5	3.1	4.4	3.4	3,7
P 16	10.2	13.1	2.0	7.5	3.2	3.8	3.2	3,5
P 2	34.4	19.9	1.4	12.6	3.2	4.4	3.0	4,3
M.9 EMLA	9.0	5.7	1.2	4.2	3.3	4.8	3.7	4,2
B 9	8.6	4.7	0.7	3.0	3.0	4.8	3.1	3,8
B 396	18.3	9.0	1.6	5.2	2.9	4.4	2.5	3,7
P 60	14.5	4.4	0.7	4.1	3.3	4.4	3.3	3,6
B 146	16.7	6.8	0.4	9.8	3.2	5.1	3.2	4,0
M.7	14.1	-	10.5	7.1	3.6	-	3.3	4,0
M.26	19.3	6.6	6.8	4.5	3.7	4.6	3.1	3,8
Nr 47	16.3	5.0	3.4	5.4	3.4	4.6	3.3	3,9
P 14	11.1	11.2	5.0	9.1	3.3	4.1	3.6	4,1
p-Value[2]	*0.011*	*0.160*	*0.064*	*0.041*	*0.051*	*0.305*	*0.497*	*0.283*

[1,2] See table 1

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