THE INFLUENCE OF ROOTSTOCKS M.9 AND P 60 ON QUALITY AND STORABILITY IN 'GALA' AND 'GALA MUST' APPLES

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A B S T R A C T

The experiment was performed on two apple cultivars ('Gala' and 'Gala Must') grafted on two rootstocks (M.9 and P 60). Trees were planted in the spring 1993 in Dąbrowice Experimental Orchard of the Research Institute of Pomology and Floriculture. In the experiment, size, colour, total soluble solids, acidity and firmness were measured. In general, fruit size at harvest time was higher in 'Gala Must' than in 'Gala'. For both cultivars, fruit size was higher on M.9 rootstock. Colouring was better in 'Gala Must' than in 'Gala'. 'Gala Must' has a solid blushing pattern, and 'Gala' has a striped blushing pattern.

In 'Gala Must', fruits ripened earlier on M.9 than on P 60. In both cultivars, starch index at harvest was usually higher on M.9 than on P 60.

The effect of the rootstock on total soluble solids (TSS) at harvest varied from year to year in 'Gala'. In 'Gala Must', however, TSS was higher on M.9 than on P 60. Titratable acidity (TA) depended on the cultivar and varied from year to year.

The standard cultivar of apple and its mutant should be treated as a separate cultivars. Quality parameters and response to rootstock and seasonal conditions are different.

Key words: apples, storage, firmness, acidity, total soluble solids

INTRODUCTION

In Poland and other major apple producing countries, 'Gala' is becoming a more and more popular apple cultivar. There are many red sports and some of them have been introduced into production. The most important are 'Gala' mutants with earlier and more intense colour than the standard 'Gala'.

Surface colour alone is not a good predictor of maturity for 'Gala' type apples and cannot be used to determine the optimum harvest window (Walsh and Voltz, 1990). There are anatomical differences between 'Regal Gala' (a synonym of 'Gala Must') and other strains of 'Gala'. 'Regal Gala' has only small vacuoles, whereas other strains have both large and small vacuoles (Dickinson and White, 1986).

Fruit quality is very important in apple production. Quality depends on pre-harvest and post-harvest factors. The rootstock is one of the pre-harvest factors which can affect fruit quality in apples. The aim of this study was to examine how the rootstock influences fruit quality and storability in 'Gala' and 'Gala Must' apples.

MATERIAL AND METHODS

In the spring of 1993, one-year-old 'Gala' and 'Gala Must' apple trees grafted on M.9 and P 60 rootstock were planted at the Experimental Orchard of the Research Institute of Pomology and Floriculture in Dąbrowice, Poland. The experimental orchard was established on podsolic soil overlaying heavy clay. All trees were trained as spindles. Drip irrigation was applied. Fertilization, soil cultivation and chemical pest control were carried out as recommended for commercial orchard. The field experiment was carried out in a random block design, with four replicates of three trees per plot.

Trunk circumference 30 cm above the ground level and fruit yield were recorded each year. Trunk cross-sectional area (TCSA) and cropping efficiency index (CEI) were calculated.

From 1998 to 2001, flowering intensity was recorded on a scale from 1 to 9, where 1 equals no flowering, and 9 equals very intense flowering. Data on size and colour were based on samples of 100 fruits, that is, four replicates of 25 fruits each.

The storage experiment was carried out during 1998-2001. Fruits of both cultivars were harvested on the same day, when the starch index for 'Gala' apples was between 3 and 5. At harvest, internal ethylene concentration (IEC), fruit firmness, starch index, total soluble solids (TSS), and titratable acidity (TA) were measured. Internal ethylene concentration was measured using a HP 5890 II gas chromatograph. Fruit firmness was measured using an EPT-1R pressure tester equipped with an 11.1 mm tip. Starch index was determined using the standard iodine test and recorded on a scale from 1 to 10 (1 – black, 10 – white). Titratable acidity and total soluble solids were measured using a Mettler DL 21 titrator, and an ATAGO PR-101 refractometer, respectively.

Fruits were stored at +2°C in a normal atmosphere until February. Fruit firmness, total soluble solids and titratable acidity were measured after storage and after seven days at +20°C. Data recorded were based on samples of fifteen fruits, that is, three replicates of five fruits each.

Data were statistically elaborated using analysis of variance, followed by means separation using LSD at $\alpha \leq 0.05$.

RESULTS AND DISCUSSION

In both cultivars, the flowering period varied from year to year. Flowering was most intense in 1999 (9 points), and least intense in 1998 (4 to 5 points). However, in a given year, flowering time and intensity were not affected by either the cultivar or the rootstock.

On the basis of trunk cross-sectional area, 'Gala' trees were smaller than 'Gala Must' trees (data not presented). With both cultivars, the Polish rootstock P 60 had a weaker dwarfing effect than M.9. This was statistically significant for 'Gala Must', which had a TCSA of 49.4 on P 60, and 37.2 on M.9.

Cumulative yield for 1994 to 2000 was positively correlated with TCSA. Cumulative yield was the highest in 'Gala Must' on P 60 rootstock (131.6 kg per tree), and the lowest in 'Gala' grafted on M.9 rootstock (98.8 kg per tree).

Fruit size depended on the cultivar and the rootstock. Mean fruit weight was higher in 'Gala Must' than in 'Gala'. This difference was statistically significant in 1998 for both rootstocks and in 2000 for P 60. With both cultivars, the weight of 100 fruits was higher on M.9 than on P 60 (Tab. 1). This difference was not significant for 'Gala Must' in 1999 and 2000. On the other hand, in a previous study on 'Jonagold' apples, fruit weight was generally higher on the more vigorous rootstocks (Skrzyński et al., 1999).

Regardless of the rootstock used, the proportion of apples over 70 mm in diameter varied from year to year. In both cultivars, fruits size was highest in 1998 and lowest in 1999 (Tab. 1).

Rootstock had no significant effect on the proportion of fruits with blush over more than 50% of the fruit surface in either cultivar except in 2000, when 'Gala' had less blushing on P 60 than on M.9.

The proportion of fruits with blushing over more than 75% of the fruit surface was statistically higher in 'Gala Must' than in 'Gala' ones (data not shown). 'Gala Must' has a solid blushing, and 'Gala' has a striped blushing pattern.

Apples ripen earlier on dwarfing rootstocks than on vigorous rootstocks (Cummins and Aldwinckle, 1983). Internal ethylene concentration is negatively correlated with TCSA (Autio et al., 1996). Our results agreed well with these studies. On the basis of internal ethylene concentration (Tab. 2), the rootstock did not have any effect on ripening in 'Gala'. On the other hand, in 'Gala Must', fruits ripened earlier on M.9 than on P 60, particularly in 1998 and 1999, and the dwarfing effect was significantly greater on M.9 than on P 60.

The starch index was higher on M.9 than on P 60 for both cultivars in 1998, and for 'Gala' in 1999 (Tab. 2). Andziak and Tomala (2000) reported the opposite for 'Jonagold', and concluded that apples grafted on P 60 should be picked earlier than apples on M.9.

T a b l e 1 . Fruit size and blush in ‘Gala’ and ‘Gala Must’ apple trees grafted on M.9 and P 60 rootstocks at harvest

	Gala	Gala Must	| **d** |	Gala	Gala Must	| **d** |	Gala	Gala Must	| **d** |
	weight of 100 fruits [kg]			fruits with diameter >70 mm [%]			fruits with blush >50% [%]		
Season 1998									
M.9	19.2	21.8	2.6*	97.3	98.9	1.6^{NS}	88.1	96.8	8.7^{NS}
P 60	17.8	19.7	1.9*	93.9	98.5	4.6^{NS}	100.0	99.9	0.1^{NS}
| **d** |	1.4*	2.1*		3.4^{NS}	0.4^{NS}		11.9^{NS}	3.1^{NS}	
Season 1999									
M.9	14.8	15.4	0.6^{NS}	74.4	76.9	2.5^{NS}	99.4	100.0	0.6^{NS}
P 60	13.3	14.4	1.1^{NS}	46.0	64.2	18.2^{NS}	96.4	99.1	2.7^{NS}
| **d** |	1.5*	1.0^{NS}		28.4*	12.7*		3.0^{NS}	0.9^{NS}	
Season 2000									
M.9	16.5	17.5	1.0^{NS}	85.6	94.1	8.5^{NS}	97.9	95.4	2.5^{NS}
P 60	15.0	16.6	1.6*	73.3	90.5	17.2*	83.1	95.5	12.4*
| **d** |	1.5*	0.9^{NS}		12.3*	3.6^{NS}		14.8*	0.1^{NS}	
	LSD (5%) = 1.20			**LSD (5%) = 10.90**			**LSD (5%) = 12.00**		

Notice: * – significant difference at 5% level of significance; ^{NS} – not significant difference;
| **d** | – difference
LSD – least significance difference

T a b l e 2 . Internal ethylene concentration (IEC) [µl/l] and starch index in ‘Gala’ and ‘Gala Must’ apple trees grafted on M.9 and P 60 rootstocks at harvest

	Gala	Gala Must	| **d** |	Gala	Gala Must	| **d** |
	IEC [µl/l]			starch index		
Season 1998						
M.9	1.60	2.11	0.51^{NS}	4.9	4.3	0.6^{NS}
P 60	2.11	1.41	0.70*	4.1	3.5	0.6^{NS}
| **d** |	0.51^{NS}	0.70 *		0.8*	0.8*	
Season 1999						
M.9	2.28	1.96	0.32^{NS}	4.5	4.9	0.4^{NS}
P 60	1.86	1.40	0.46^{NS}	3.5	4.4	0.9*
| **d** |	0.42^{NS}	0.56*		1.0*	0.5^{NS}	
Season 2000						
M.9	1.06	1.19	0.13^{NS}	3.1	3.8	0.7*
P 60	0.79	0.78	0.01^{NS}	3.3	3.7	0.4^{NS}
| **d** |	0.27^{NS}	0.41^{NS}		0.2^{NS}	0.1^{NS}	
	LSD (5%) = 0.549			**LSD (5%) = 0.66**		

Notice: see Table 1

T a b l e 3 . Total soluble solids [%] in ‘Gala’ and ‘Gala Must’ apple trees grafted on M.9 and P 60 rootstocks at harvest, after storage, and after shelf life

	Gala	Gala Must	| **d** |	Gala	Gala Must	| **d** |	Gala	Gala Must	| **d** |
	at harvest			after storage			after shelf life		
Season 1998/1999									
M.9	12.1	13.0	0.9*	13.0	14.9	1.9*	12.4	14.6	2.2*
P 60	13.1	12.2	0.9*	12.8	14.1	1.3*	12.9	14.2	1.3*
| **d** |	1.0*	0.8*		0.2 ^{NS}	0.8*		0.5*	0.4 ^{NS}	
Season 1999/2000									
M.9	13.0	13.7	0.7*	12.8	13.6	0.8*	12.3	13.3	1.0*
P 60	13.2	13.4	0.2 ^{NS}	13.0	13.0	0.0 ^{NS}	12.6	13.1	0.5*
| **d** |	0.2 ^{NS}	0.3 ^{NS}		0.2 ^{NS}	0.6 *		0.3 ^{NS}	0.2 ^{NS}	
Season 2000/2001									
M.9	12.6	13.0	0.4*	12.8	13.5	0.7*	13.3	13.9	0.6*
P 60	12.0	12.7	0.7*	12.9	13.4	0.5*	12.8	12.6	0.2 ^{NS}
| **d** |	0.6*	0.3 ^{NS}		0.1 ^{NS}	0.1 ^{NS}		0.5*	1.3*	
	LSD (5%) = 0.37			**LSD (5%) = 0.37**			**LSD (5%) = 0.48**		

Notice: see Table 1

T a b l e 4 . Flesh firmness [kG] in ‘Gala’ and ‘Gala Must’ apple trees grafted on M.9 and P 60 rootstocks at harvest, after storage, and after shelf life

	Gala	Gala Must	| **d** |	Gala	Gala Must	| **d** |	Gala	Gala Must	| **d** |
	at harvest			after storage			after shelf life		
Season 1998/1999									
M.9	8.1	8.1	0.0 ^{NS}	6.7	7.8	0.9*	6.9	6.9	0.0 ^{NS}
P 60	8.6	8.7	0.1 ^{NS}	7.2	7.6	0.4*	7.5	7.6	0.1 ^{NS}
| **d** |	0.5*	0.6*		0.5*	0.2 ^{NS}		0.6*	0.7*	
Season 1999/2000									
M.9	8.1	8.4	0.3 ^{NS}	6.9	7.4	0.5*	6.5	7.2	0.7*
P 60	9.1	8.3	0.8*	7.2	7.2	0.0 ^{NS}	6.2	7.0	0.8*
| **d** |	1.0*	0.1 ^{NS}		0.3 ^{NS}	0.2 ^{NS}		0.3 ^{NS}	0.2 ^{NS}	
Season 2000/2001									
M.9	7.9	8.0	0.1 ^{NS}	6.6	7.0	0.4*	6.7	6.9	0.2 ^{NS}
P 60	8.0	7.8	0.2 ^{NS}	7.2	6.8	0.4*	6.8	6.6	0.2 ^{NS}
| **d** |	0.1 ^{NS}	0.2 ^{NS}		0.6*	0.2 ^{NS}		0.1 ^{NS}	0.3 ^{NS}	
	LSD (5%) = 0.39			**LSD (5%) = 0.39**			**LSD (5%) = 0.43**		

Notice: see Table 1

Table 5. Titratable acidity [%] in 'Gala' and 'Gala Must' apple trees grafted on M.9 and P 60 rootstocks at harvest, after storage, and after shelf life

	Gala	Gala Must	| **d** |	Gala	Gala Must	| **d** |	Gala	Gala Must	| **d** |
	at harvest			after storage			after shelf life		
Season 1998 / 1999									
M.9	-	-	-	0.25	0.27	0.02*	0.23	0.23	0.00^{NS}
P 60	-	-	-	0.26	0.27	0.01^{NS}	0.25	0.25	0.00^{NS}
| **d** |	-	-		0.01^{NS}	0.00^{NS}		0.02^{NS}	0.02^{NS}	
Season 1999 / 2000									
M.9	0.40	0.38	0.02^{NS}	0.30	0.32	0.02*	0.25	0.28	0.03*
P 60	0.48	0.38	0.10^{NS}	0.30	0.31	0.01^{NS}	0.24	0.31	0.07*
| **d** |	0.08*	0.00^{NS}		0.00^{NS}	0.01^{NS}		0.01^{NS}	0.03*	
Season 2000 / 2001									
M.9	0.45	0.41	0.04*	0.24	0.26	0.02*	0.22	0.23	0.01^{NS}
P 60	0.37	0.37	0.00^{NS}	0.26	0.24	0.02*	0.23	0.22	0.01^{NS}
| **d** |	0.08*	0.04*		0.02*	0.02*		0.01^{NS}	0.01^{NS}	
	LSD (5%) = 0.021			**LSD (5%) = 0.019**			**LSD (5%) = 0.022**		

Notice: see Table 1

The effect of the rootstock on TSS depended on the cultivar and varied from year to year. With 'Gala Must', TSS at harvest, after storage and after shelf life was always higher on M.9 than on P 60, although the differences were usually statistically insignificant (Tab. 3). With 'Gala', the effect of rootstock on TSS varied from year to year. TSS was generally higher in 'Gala Must' than in 'Gala'. This agrees well with previous reports (Kruczynska et al., 2001).

The effect of the rootstock on fruit firmness was not clear. However, in some cases, apples were significantly firmer on P 60 than on M.9 (Tab. 4). This agrees well with a previous study on 'Jonagold' (Skrzyński, 1997).

After storage, apples were firmer in 'Gala Must' than in 'Gala', except in 1999/2000 and 2000/2001 for trees grafted on P 60. After shelf life, apples were firmer in 'Gala Must' than in 'Gala' only in 1999/2000 (Tab. 4).

The effect of the rootstock on titratable acidity (Tab. 5) varied from year to year. In 'Gala Must', there was no significant difference in acidity at harvest time between the rootstocks in 1999. In 2000, however, acidity was higher on M.9. In 'Gala', acidity was higher on P 60 than on M.9 in 1999, and lower on P 60 than on M.9 in 2000. In both cultivars, the effect of the rootstock influence on acidity after storage and after shelf life was not significant. After storage, acidity tended to be slightly higher in 'Gala Must' than in 'Gala'.

Our results for firmness and TSS agree well with previous reports that

both firmness and TSS vary from year to year and from orchard to orchard (Autio et al., 1996).

CONCLUSION

The standard cultivar of apple and its mutant should be treated as a separate cultivars. Quality parameters and response to rootstock and seasonal conditions are different.

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JAKOŚĆ I ZDOLNOŚĆ PRZECHOWALNICZA OWOCÓW JABŁONI ODMIAN ‘GALA’ I ‘GALA MUST’ ROSNĄCYCH NA PODKŁADKACH M.9 I P 60

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S T R E S Z C Z E N I E

Celem doświadczenia było zbadanie wpływu podkładek M.9 i P 60 na jakość i zdolność przechowalniczą jabłek odmian ‘Gala’ i ‘Gala Must’. Badania prowadzono w latach 1998-2001. Owoce pochodziły z drzew posadzonych wiosną 1993 roku w Sadzie Doświadczalnym w Dąbrowicach. W doświadczeniu oceniano wygląd owoców (wielkość, powierzchnia rumieńca) i ich wewnętrzne cechy jakościowe (zawartość ekstraktu, kwasowość i jędrność). W każdym sezonie jabłka obu odmian zbierano tego samego dnia, gdy wartość indeksu skrobiowego dla odmiany ‘Gala’ była między 3 a 5. Niezależnie od sezonu badań jabłka odmiany ‘Gala Must’ charakteryzowały się większą masą niż owoce odmiany ‘Gala’. We wszystkich latach badań stwierdzono także, że dla obu badanych odmian owoce pochodzące z drzew rosnących na podkładce M.9 były większe. Ocena powierzchni i jakości rumieńca wskazuje, że jabłka odmiany ‘Gala Must’ charakteryzują się intensywnym rozmytym rumieńcem obejmującym większą powierzchnię owocu w porównaniu do odmiany ‘Gala’, której rumieniec jest paskowany. Na wykształcenie się rumieńca duży wpływ miały warunki pogodowe w sezonie wegetacyjnym.

Po zbiorze oznaczano stężenie etylenu w komorach nasiennych, indeks skrobiowy, zawartość ekstraktu, kwasowość i jędrność owoców. Nie stwierdzono istotnego wpływu podkładki na stężenie etylenu w komorach nasiennych owoców odmiany ‘Gala’. W przypadku odmiany ‘Gala Must’ stężenie etylenu w komorach nasiennych owoców pochodzących z drzew na podkładce M.9 było wyższe niż w tych na podkładce P 60. Dla obu badanych odmian wartości indeksu skrobiowego były wyższe dla owoców z drzew na M.9 (z wyjątkiem odmiany ‘Gala’ w sezonie 2000). Różnice te nie zawsze były statystycznie istotne.

Po 4 miesiącach przechowywania w temperaturze $+2^{o}C$, w warunkach normalnej atmosfery, oznaczano zawartość ekstraktu, kwasowość i jędrność owoców. Wpływ podkładki na te cechy zmieniał się w zależności od sezonu badań. Stwierdzono jednak, że owoce odmiany ‘Gala Must’ z drzew rosnących na M.9 posiadały wyższy ekstrakt niż te na P 60.

Po przechowywaniu jabłka odmiany ‘Gala Must’ mają nieznacznie wyższą kwasowość w porównaniu do owoców odmiany ‘Gala’.

Owoce odmiany standardowej i jej mutantów powinny być traktowane jako niezależne odmiany, ponieważ różnią się one jakością oraz reakcją na podkładkę i na warunki pogodowe podczas sezonu wegetacyjnego.

Słowa kluczowe: jabłka, przechowywanie, jędrność, kwasowość, zawartość ekstraktu