SEED COUNT, FRUIT QUALITY AND STORAGE PROPERTIES IN FOUR APPLE CULTIVARS

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ABSTRACT

Correlations between seed count and fruit quality parameters were studied in four apple cultivars, three of which were either resistant or at least tolerant to apple scab. The following data were recorded: fruit weight, length-to-width ratio, ribbing, stem length, calyx opening, russetting, skin waxiness, base colour, blushing, flesh firmness, acidity, total sugars, soluble solids, vitamin C and calcium. Normally developed and aborted seeds were also counted. All fruit quality parameters were individually subjected to statistical analysis to evaluate the correlations between them and total seed count, normal seed count and aborted seed count. The strongest correlations found were between the normal seed count and fruit weight. In this study, better pollinated fruits contained more seeds, were larger, and generally had better external fruit quality characteristics. However, this only happens if the number of apples per tree is at an optimum level. On the other hand, high seed count seems to accelerate maturation and have a negative impact on internal fruit quality in the ripened apples. A second experiment was also carried out with the scab resistant and tolerant cultivars to see whether there were any correlations between seed count and storage diseases. Apples with a high seed count were generally less susceptible to fungal rotting.

Key words: apple, cultivar, fruit characteristics, seed number, fruit size, correlations, storage ability, storage diseases, storage disorders

INTRODUCTION

Pollination and fertilization usually have to take place for apple trees to set fruit. As a result of these processes, seeds begin to form and produce hormones necessary for fruit development. The number of seeds per fruit is a measure of successful pollination and fertilization. The higher the seed count, the better the final fruit set and, usually, the better the yield. An apple that contains only a few seeds is more likely to drop before reaching maturity, especially if water, nutrients or carbohydrates are in short supply (Blažek and Drobková, 1976; Dennis, 1986; Green, 1989; Mantinger, 1997).

Besides affecting fruit set, seed count affects several fruit quality parameters, especially fruit size and weight (Tomala and Dilley, 1989; Miller and Kaiser, 1994; Volz et al., 1995; Keulemans et al., 1996; Uemura et al., 2001). A low seed count has often been found to correlate with ribbed or malformed fruits (Brault and de Oliviera, 1995; Brookfield et al., 1996; Buccheri and Vaio, 2004). A high seed count has also been associated with increased calcium content, reduced fruit length-to-width ratio, increased firmness, and increased acidity (Broom et al., 1998; Tomala, 1999; Buccheri and Vaio, 2004).

The aim of this study was to investigate the relationships between seed numbers and fruit characteristics that directly or indirectly influence fruit quality in four apple cultivars. A storage trial was also performed to see whether there were any relationships between seed count and storage diseases and other fruit disorders.

MATERIAL AND METHODS

Correlations between seed count and fruit quality parameters were studied from 2001 to 2003 at Holovousy in the Czech Republic. Mean yearly temperature is 8.1°C, average rainfall is about 650 mm, and altitude is about 300 m. Four apple cultivars were evaluated: 'Golden Delicious', 'Nabella', 'Resista' and 'Selena'. All four cultivars were grafted on M.9 rootstock and were not irrigated.

'Golden Delicious' served as the reference. Apples of 'Golden Delicious' were obtained from a conventional commercial orchard. Trees were regularly chemically treated to control pests and diseases. Fruit thinning was performed by hand.

'Nabella', 'Resista' and 'Selena' were selected for this study because they are either resistant or at least tolerant to apple scab. Apples were picked at random from experimental orchards. No chemical pest or disease control treatments were applied, so it was expected that storage diseases would be a problem. Conditions for cross-pollination were excellent.

After harvest, apples were stored at 2 to 3°C. They were evaluated from November until February, when they were reaching the end of their marketable storage life.

At least fifty apples of each cultivar were individually evaluated every year. The following data were recorded: fruit weight, length-to-width ratio, ribbing, stem length, calyx opening, russetting, skin waxiness, base colour, blushing, flesh firmness, acidity, total sugars, soluble solids, vitamin C and calcium. The methods used for fruit quality analysis are described elsewhere (Blažek et al., 2003). Normally developed seeds and aborted seeds were counted separately.

All fruit quality parameters were individually subjected to statistical analysis to evaluate the correlations between them and total seed count, normal seed count and aborted seed count. With 'Golden Delicious', data from an earlier experiment were used for comparison. The experiment had

been conducted at Holovousy thirty years ago in an orchard with poor pollination (Blažek, 1996).

Only 'Nabella', 'Resista' and 'Selena' were included in the storage experiment. For each cultivar, three replicates consisting of one plastic box each containing 100 apples were kept in cold storage until the end of their storage life. They were then evaluated in terms of storage diseases and disorders. Seed counts were recorded for each individual fruit. With 'Resista', fruit weight was recorded for each healthy fruit.

Data were elaborated by analysis of variance, followed by means separation with Turkey's Least Significant Difference tests.

RESULTS AND DISCUSSION

The strongest correlations found were between the normal seed count and fruit weight (Tab. 1). The correlation varied from year to year in each cultivar, but was strongest in 'Resista' and weakest in 'Nabella'. This agrees well with many other studies which have been previously reported in the literature. Conversely, aborted seed count was negatively correlated with fruit weight. This agrees well with a study by Miller and Kaiser (1994), but conflicts with the findings reported by Keulemans et al. (1996).

The high variability in individual values is well illustrated by the correlation between seed count and fruit weight for 2002 for 'Golden Delicious' (Fig. 1). In the orchard from which the 'Golden Delicious' apples were obtained, fruit set was regulated by hand thinning. In 2002, there was a relatively strong correlation between seed count and fruit weight. However, when 'Golden Delicious' fruits were picked from trees which had not been hand thinned, there was generally a negative correlation between seed count and fruit weight (Fig. 2 and 3). There was more competition among fruits on trees with a heavy fruit set based more on the original flower set than on the quality of pollination.

Fruit size is primarily determined by the number of fruits per tree (Naschitz and Naor, 2005). If the influence of this factor is minimised, and the number of evaluated fruits is high enough, there was an unambiguous positive correlation between seed count and fruit weight (Fig. 4). The higher the seed count, the higher the sink strength in the fruit, which is reflected by an increase in fruit weight. Therefore, seeds are important for fruit set and differences in fruit size (Keulemans et al., 1996).

Nothing can be said about how seed count affects russetting in 'Selena' because in the three years of the study, hardly any russet apples were found in this cultivar. In 'Nabella' and 'Resista', apples with a higher seed count were less susceptible to russetting. Curiously, russetting was negatively correlated not only with normal seed count, but also with aborted seed count. This is probably because seeds, whether normal or aborted, affect the production of gibberellins, which are known to play a role in russetting (Looney et al., 1992).

Table 1. Seed counts versus fruit quality parameters

	Cultivar	Normal seeds		Aborted seeds		Total seeds	
		min.	max	min.	max	min.	max
Fruit weight	Golden Del.	0.09	0.25*	0.01	-0.11	0.06	0.23*
	Nabella	0	0.21*	-0.01	-0.26*	0.02	0.19
	Resista	0.23*	0.32**	0.01	-0.16	0.19	0.28**
	Selena	0.12	0.35**	-0.15	-0.25*	0.13	0.24**
Russeting	Golden Del.	0.05	-0.17	-0.01	-0.08	-0.05	-0.18
	Nabella	-0.15	-0.25*	-0.17	-0.24*	-0.16	-0.35**
	Resista	-0.05	-0.30**	0.02	0.18	0.07	-0.28**
	Selena	ND[a])	ND	ND	ND	ND	ND
Stem length	Golden Del.	0.03	0.15	0.04	-0.10	0.05	0.16
	Nabella	0.04	0.25*	-0.05	-0.19	0.07	0.15
	Resista	-0.02	0.12	-0.02	0.13	-0.03	0.17
	Selena	0.03	0.13	0.04	-0.07	0.0	0.14
Base colour	Golden Del.	0.01	0.16	-0.04	0.14	0.02	0.23
	Nabella	0.06	-0.17	0.03	-0.24*	0,07	-0.28**
	Resista	-0.12	0.13	-0.02	-0.15	-0.06	0.13
	Selena	0.14	-0.26*	0.11	-0,20	0.15	-0.18
Calyx opening	Golden Del.	0.07	-0.14	-0.01	-0.06	0.02	-0.14
	Nabella	\ 0.24*	0.36**	0.10	0.24*	0.15	0.33**
	Resista	-0.03	0.07	-0.01	0.04	-0.06	0.10
	Selena	0.02	0.16	-0.09	-0.25*	0.01	0.06
Length-to-width ratio	Golden Del.	0.10	-0.24*	0.08	0.21	-0.04	-0.15
	Nabella	0.09	0.20	0.03	-0.11	0.10	0.16
	Resista	0.12	-0.26*	0.01	0.16	0.01	-0.29**
	Selena	0.16	-0.23*	-0.06	0.15	0.06	-0.15
Flesh firmness	Golden Del.	0.03	-0.19	0.05	0.18	0.11	-0.21
	Nabella	0.01	0.20	-0.08	0.17	0.07	0.19
	Resista	-0.07	0.12	0.03	0.13	0.04	0.16
	Selena	0.04	-0.24*	-0.02	0.16	-0.03	-0.21
Acidity	Golden Del.	-0.05	-0.28**	0.01	0.12	-0.05	-0.17
	Nabella	-0.21	-0.25*	-0.02	0.16	-0.14	-0.21
	Resista	0.02	-0.13	0.07	0.20	-0,08	0.12
	Selena	-0.05	0.14	0.01	-0.06	-0.02	0.11
Sugars	Golden Del.	0.04	-0.15	-0,02	0.09	0.01	-0.16
	Nabella	0.03	-0.07	-0.09	-0.14	0.07	-0.12
	Resista	-0.04	-0.22	0.01	-0.10	-0.11	-0.30**
	Selena	-0. 09	0.12	0.04	0.13	-0.10	0.13
Soluble solids	Golden Del.	0.04	-0.10	-0.01	0.09	0.12	-0.20
	Nabella	-0.12	-0.19	-0.08	0.18	-0.04	-0.16
	Resista	0.02	-0.18	-0.01	0.06	0.09	-0.24*
	Selena	-0.04	-0.13	0.08	-0.09	0.02	-0.11
Vitamin C	Golden Del.	0.14	-0.16	0.02	0.11	0.05	-0.14
	Nabella	0.06	0.25*	0.17	0.30*	0.09	0.29**
	Resista	0.03	0.11	0.05	0.15	0.10	0.21
	Selena	-0.11	0.15	-0.01	0.17	-0.13	0.14
Calcium	Golden Del.	0.04	0.21	-0.05	0.09	0.04	0.24*
	Nabella	0.08	-0.17	0.04	-0.12	0.02	-0.19
	Resista	0.13	-0.23*	0.01	0.10	0.10	-0.20
	Selena	0.05	0.19	0.06	-0.17	0.05	0.18

Note: *significance at P≥0.05; **significance at P≥0.01 [a]) ND = not determined

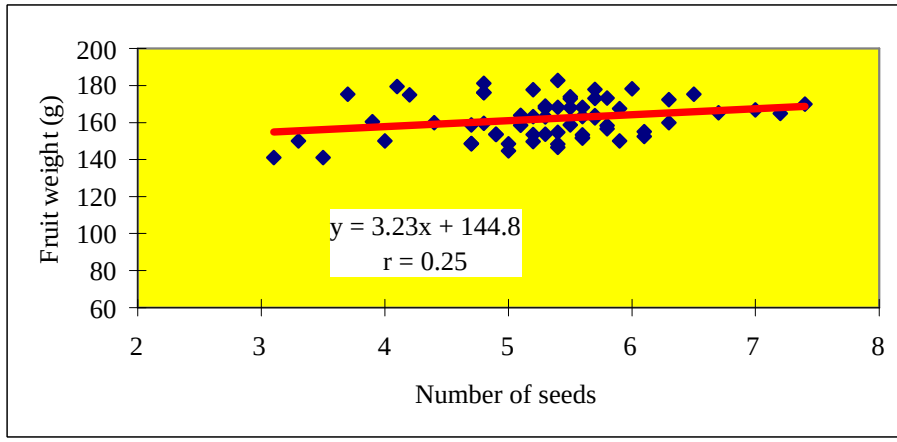

Figure 1. Seed count versus fruit weight in 'Golden Delicious' from a hand thinned orchard in 2002

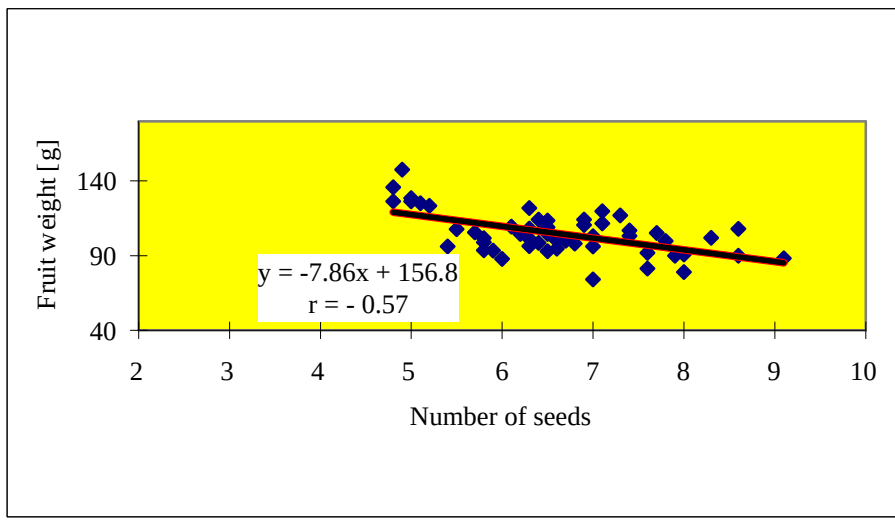

Figure 2. Seed count versus fruit weight in 'Golden Delicious' from an unthinned orchard in 1972

High seed count was often associated with low fruit length-to-width ratio in all cultivars except 'Nabella'. Fruits with a higher seed count had a bigger diameter in relation to length.

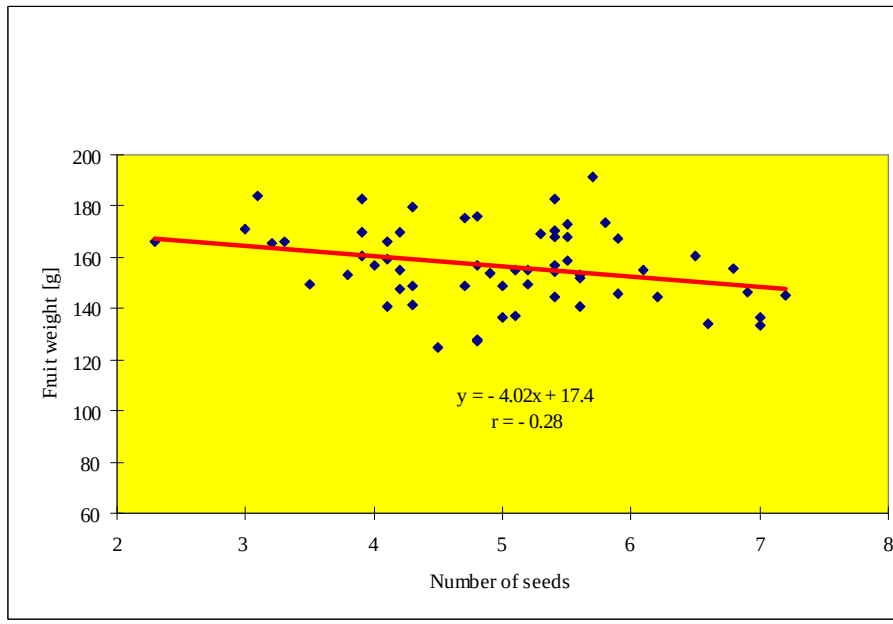

Figure 3. Seed count versus fruit weight in 'Golden Delicious' from an unthinned orchard in 1973

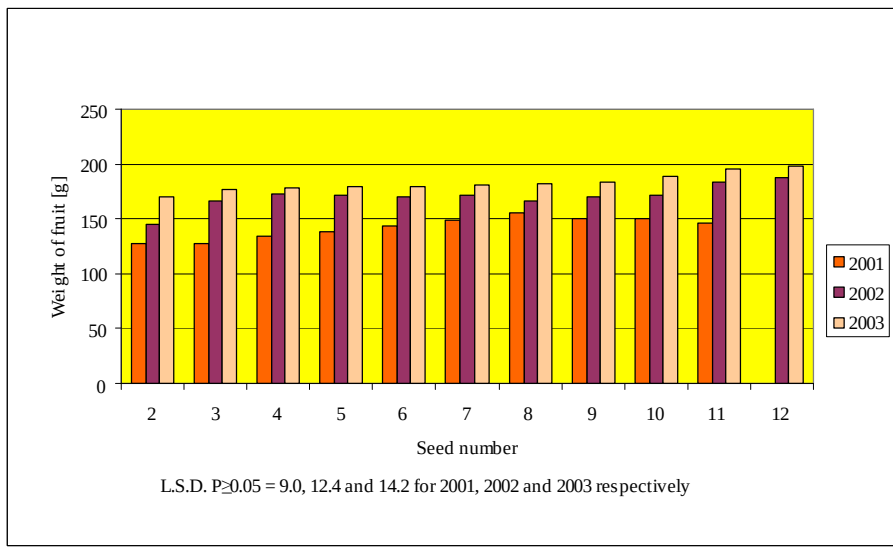

Figure 4. Seed count and fruit weight in 'Resista' from 2001 to 2003

No correlation was found between seed count and ribbin33g or malformation, probably because the apples in this study were generally well pollinated and seed count was probably above the critical level connected with these problems.

Seed count was also not correlated with skin waxiness and blushing (data not presented).

There was a correlation between seed count and calyx opening only in 'Nabella'. Fruits with higher seed counts more often had closed calyces.

In 'Nabella', fruits with a higher seed count had higher vitamin C content. Except for this, though, high seed count was generally negatively correlated with almost all fruit quality parameters. These conflicts with some studies in the literature which report that seed count is positively correlated with acidity and firmness. The discrepancy may be due to the fact that the apples were evaluated at different stages of maturity.

Seed count was correlated with calcium content in only one single case in this study. This conflicts with other studies in the literature. In fact, one year, there was a markedly negative correlation between seed count and calcium content in 'Resista'. However, it should be kept in mind that calcium content in apples is also negatively correlated with fruit size (Broom et al., 1998; Tomala, 1999). Calcium concentration has also been reported to be negatively correlated with ethylene concentration (Tomala and Dilley, 1989). 'Resista' is one of the apple cultivars with an extremely high concentration of ethylene (Goliáš, 2005). There is probably a complex interrelationship between all of these factors.

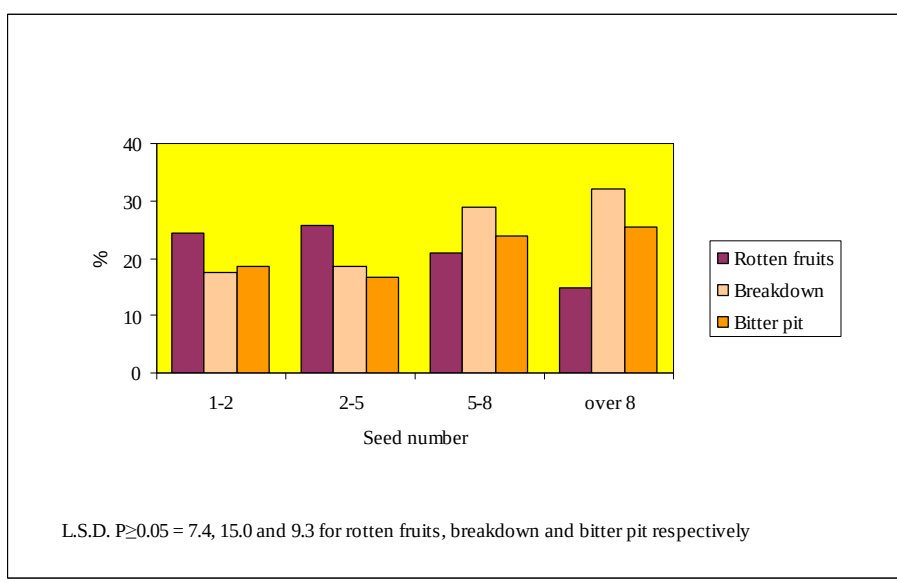

Figure 5. Seed count versus fruit rotting, internal breakdown and bitter pit in 'Nabella'

Furthermore, seed count in 'Nabella' is also positively correlated with bitter pit. Affected fruits are susceptible to internal breakdown (Fig. 5). Bitter pit seems to be strongly correlated with calcium content (Brookfield et al., 1996).

In 'Resista', apples with a high seed count were less susceptible to superficial scalding (Fig. 6).

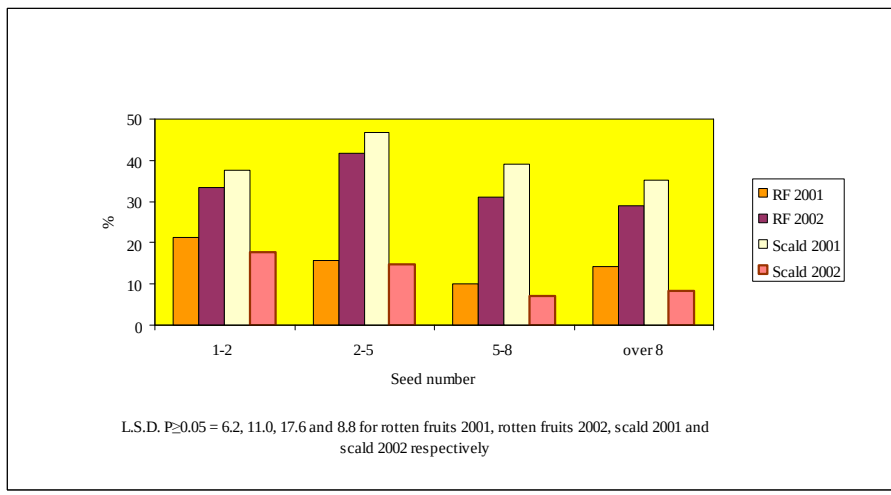

Figure 6. Seed count versus fruit rotting and scald in 'Resista' in 2001 and 2002

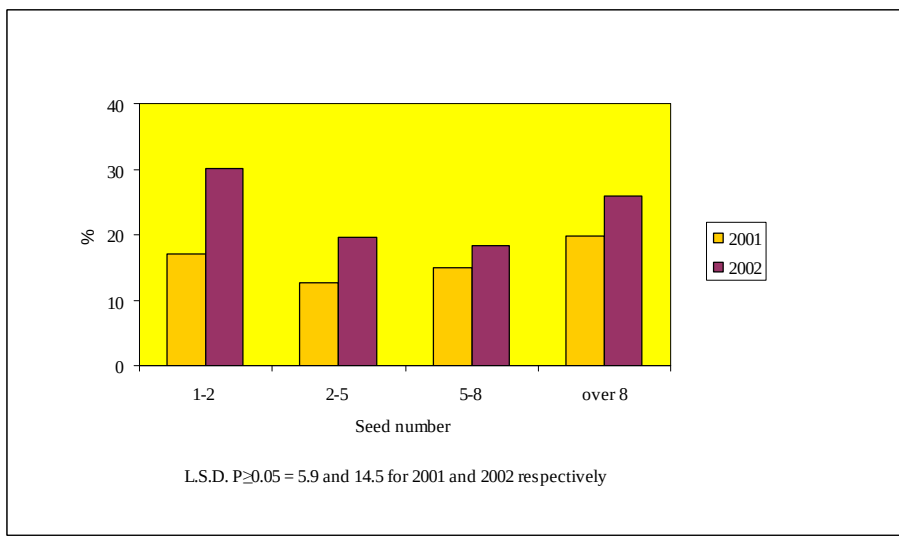

Figure 7. Seed count versus fruit rotting in 'Selena' in 2001 and 2002

In the storage trial, fruits with a high seed count were less susceptible to rotting caused by pathogenic fungi such as *Monilia, Gloeosporum* and *Botrytis* (Fig. 6 and 7). However, sometimes this relationship broke down

when the seed count exceeded an optimal level, and apples with too many seeds were more susceptible to fungal rotting.

In this study, better pollinated fruits contained more seeds, were larger, and generally had better external fruit quality characteristics. However, this only happens if the number of apples per tree is at an optimum level.

On the other hand, high seed count seems to accelerate maturation and have a negative impact on internal fruit quality in the ripened apples. Further investigation is needed to determine why apples with a high seed count were less susceptible to fungal rotting. This may be due to some other mechanism, such as increased phenolics content.

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LICZBA NASION, JAKOŚĆ OWOCÓW I WŁAŚCIWOŚCI PRZECHOWALNICZE CZTERECH ODMIAN JABŁONI

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STRESZCZENIE

W trakcie trzyletnich doświadczeń badano zależności pomiędzy liczbą nasion (normalnie rozwiniętych i nierozwiniętych), a parametrami jakości owoców czterech odmian jabłek ('Golden Delicious', 'Nabella', 'Resista' i 'Selena'). Oceniano: masę owoców, stosunek długości do szerokości, długość szypułki, otwarcie kielicha, ordzawienie, obecność wosków, kolor zasadniczy skórki, rumieniec, jędrność miąższu, kwasowość, zawartość cukrów, zawartość ekstraktu, witaminy C i wapnia. Wszystkie parametry jakości owoców zostały indywidualnie poddane analizie statystycznej w celu określenia zależności pomiędzy nimi i ogólną liczbą nasion (normalnie rozwiniętych i nierozwiniętych). Najsilniejsza korelacja wystąpiła pomiędzy liczbą nasion normalnie rozwiniętych, a masą owoców. Lepiej zapylone owoce o większej liczbie nasion były większe i generalnie charakteryzowały się lepszą jakością zewnętrzną. Dotyczyło to jednak tylko jabłek pochodzących z drzew o optymalnej liczbie owoców. Z drugiej strony, duża liczba nasion wydaje się przyspieszać dojrzewanie i negatywnie wpływać na wewnętrzną jakość dojrzałych owoców.

Prowadzono także doświadczenie, w którym podczas przechowywania monitorowano występowanie chorób infekcyjnych i fizjologicznych. Jabłka o zwiększonej liczbie nasion były generalnie mniej podatne na choroby pochodzenia grzybowego.

Słowa kluczowe: jabłka, odmiana, charakterystyka owoców, liczba nasion, wielkość owoców, współzależności, zdolność przechowalnicza, choroby infekcyjne, choroby fizjologiczne