

## **Morphological and genetic peculiarities of fruits in several winter apple varieties which confer resistance to damage**

R. Sestras<sup>1</sup>, E. Tamas<sup>1</sup> and A. Sestras<sup>2</sup>

<sup>1</sup>University of Agricultural Sciences and Veterinary Medicine, Faculty of Horticulture,  
No. 3-5 Manastur St., 3400 Cluj-Napoca, Romania; e-mail: rsestras@email.ro

<sup>2</sup>Horticultural Research Station, 3-5 Horticultorilor St., Cluj-Napoca, Romania

**Abstract.** Among 15 winter apple varieties studied for their resistance to the damage of fruits, Golden Delicious was susceptible to fruit injury, while the Florina, Idared and Granny Smith can be considered resistant to pricking, cutting and hitting of the fruits. The variability of the morphological characteristics of the fruits was relatively low, the fruit volume being averagely variable and the fruit resistance to injury being the character with the highest variability ( $s\% = 26.4$ ). The resistance of the fruits to injury was not correlated with their height, diameter, weight, shape and volume. The characteristics of the fruits have a strong genetic determinism, but the additive effects of the genes do not play the most important role in all cases. For the fruit resistance to injury the big differences between heritability coefficients values in a broad and narrow sense signify the fact that the resistance to injury of apples is influenced not only by additive effects but also by the dominance and epistasis effects of the genes.

**Key words:** apple, fruits, resistance, storage, damage, heritability

### **INTRODUCTION**

The damage on apple fruits caused during picking, manipulation and transportation has an important economic weight. Dathe (1988) quoting from Sargent et al. (1987), shows that during manual harvest of apples, 81% of fruits present pressure points, 3% pricks and 1% cuts, a totally surprising percent of damaged fruits (85%).

Even though the resistance of apple fruits to transportation and manipulation has not been a special breeding apple objective, due to important economic losses by damage during harvest, transportation and manipulation, lately it has become a matter of interest (Sestras, 1992; 1997; 2004).

After studying several years the resistance to manipulation of fruits in some apple varieties, Dathe (1988) appreciated as resistant, in comparison to 'Golden Delicious', the following cultivars: Summerred, Vista Bella, Alkmene, Jubilee, Kent, Monroe, Pilot, Red Delicious group, Starkrimson, Rome Beauty, Winesap and Empire. Susceptible, resembling the Golden Delicious variety, were: Gloster, Idared, Jonagold, Melrose, Mutzu, Champion, Smoothee and others, and very susceptible, but less than James Grieve (extremely susceptible), proved to be: Jersey mac, Juno, McIntosh, Mollie's Delicious, Slava pobediteliam.

## MATERIAL AND METHODS

The biological material studied was represented by 15 winter apple varieties. From each variety there were analysed 30 fruits, randomly taken and separated into 3 repetitions (10 fruits/repetition). At the beginning of November, each fruit was "treated", in fact damaged, through pricking, cutting (both wounds made exactly at a depth of 1.5 cm in the pulp of the fruit) and hitting (the break of the skin being avoided). All treatments were perfectly uniform, executed upon the diameter of the fruits, at equidistant points, and on the same day. After 5, 10, 15 and 20 days since the hurting of the fruits, their resistance to damage was appreciated by marks on a scale from 1 to 5 (1 = fruits without altering of the initial wounds; 5 = fruits strongly altered, some with rot aspect, but all of them improper for consuming).

The marks were statistically processed as average values per repetition and cultivar. Statistic calculi were made to mark out the differences between varieties (analysis of variances – ANOVA), the variability and heritability of the fruit characteristics and the correlations among them (methods by Botez et al., 1995).

## RESULTS AND DISCUSSIONS

The main characteristics of fruits in the studied apple varieties are presented in Table 1.

The height of the fruits had different values, oscillating between 5.20 and 7.07 cm. The cultivars London Pepping, Generos, Wagener Premiat, Falticeni, Jonagold and Feleac had the smallest height of fruits, and the tallest ones were registered in 'Florina', 'Gloria', 'Golden Delicious', 'Ancuta', 'Jonathan', 'Starkrimson' and 'Granny Smith'. The mean of the trait in experiment was 6.40 cm.

In the apple, it is generally admitted that the minimum fruit diameter accepted is 65 mm (Janick et al., 1996). Close values to this minimum diameter were registered in 'Gloria', 'Florina', 'Feleac', 'London Pepping' and 'Sir Prize'. The opposite pole with large fruits included 'Falticeni', 'Ancuta', 'Granny Smith', 'Golden Delicious' and 'Starkrimson'.

The fruits' shape, appreciated on the basis of the index of shape (as the rapport height/diameter) can be considered high at cultivars Gloria, Florina, Starkrimson, Sir Prize, Golden Delicious and Feleac, and spherical flat at cultivars Falticeni, London Pepping, Jonagold, Wagener Premiat. As a matter of fact, in the cultivars of the first group, with values of shape around 1, the fruits are rather spherical (except for 'Starkrimson', and perhaps 'Sir Prize', whose fruits have an almost oblong conical shape).

The mean weight of the fruits in the 15 varieties went on a scale from 128 g to 198 g. The lowest values were registered in Jonathan, London Pepping, Feleac, Wagener cultivars, while Starkrimson, Ancuta, Granny Smith and Sir Prize presented significantly superior values.

The fruit volume, estimated according to the formula  $\text{Volume (ml)} = [(\text{height-mm} \times \text{radius-mm}^2)/1000] \times 2.7$ , used by Brown (1960), varied between 157 ml (London Pepping) and 270 ml (Ancuta), with an average experience of 215 ml.

**Table 1.** Main characteristics of the fruits in the apple varieties studied.

Cultivar	Height (cm)	Diameter (cm)	Index of shape	Weight (g)	Volume (ml)
Gloria	6.8 <sup>xxx</sup>	6.4 <sup>ooo</sup>	1.06 <sup>xxx</sup>	141 <sup>o</sup>	197 <sup>o</sup>
Jonagold	5.7 <sup>ooo</sup>	6.9 <sup>-</sup>	0.83 <sup>ooo</sup>	142 <sup>o</sup>	188 <sup>oo</sup>
Feleac	6.2 <sup>(o)</sup>	6.5 <sup>ooo</sup>	0.96 <sup>x</sup>	137 <sup>oo</sup>	180 <sup>ooo</sup>
London Pepping	5.2 <sup>ooo</sup>	6.6 <sup>ooo</sup>	0.79 <sup>ooo</sup>	137 <sup>oo</sup>	157 <sup>ooo</sup>
Sir Prize	6.4 <sup>-</sup>	6.6 <sup>oo</sup>	0.97 <sup>xx</sup>	168 <sup>x</sup>	196 <sup>o</sup>
Golden Delicious	7.0 <sup>xxx</sup>	7.2 <sup>xx</sup>	0.97 <sup>xx</sup>	163 <sup>-</sup>	257 <sup>xxx</sup>
Ancuta	6.8 <sup>xxx</sup>	7.5 <sup>xxx</sup>	0.91 <sup>-</sup>	193 <sup>xxx</sup>	269 <sup>xxx</sup>
Generos	6.0 <sup>ooo</sup>	7.1 <sup>-</sup>	0.85 <sup>ooo</sup>	166 <sup>-</sup>	211 <sup>-</sup>
Florina	6.5 <sup>x</sup>	6.4 <sup>ooo</sup>	1.01 <sup>xxx</sup>	143 <sup>o</sup>	188 <sup>oo</sup>
Falticeni	5.7 <sup>ooo</sup>	7.4 <sup>xxx</sup>	0.77 <sup>ooo</sup>	148 <sup>-</sup>	217 <sup>-</sup>
Wagener Premiat	6.1 <sup>ooo</sup>	7.1 <sup>-</sup>	0.85 <sup>oo</sup>	154 <sup>-</sup>	214 <sup>-</sup>
Idared	6.3 <sup>-</sup>	6.9 <sup>-</sup>	0.92 <sup>-</sup>	142 <sup>o</sup>	208 <sup>-</sup>
Jonathan	6.7 <sup>xxx</sup>	7.1 <sup>-</sup>	0.94 <sup>-</sup>	128 <sup>ooo</sup>	236 <sup>xx</sup>
Starkrimson	7.2 <sup>xxx</sup>	7.1 <sup>x</sup>	1.00 <sup>xxx</sup>	198 <sup>xxx</sup>	252 <sup>xxx</sup>
Granny Smith	6.7 <sup>xxx</sup>	7.3 <sup>xx</sup>	0.93 <sup>-</sup>	173 <sup>xx</sup>	248 <sup>xxx</sup>
Mean of exp. (Control)	6.4	6.9	0.92	155	215
<i>DL 5%</i> =	0.1	0.1	0.04	11	15
<i>DL 1%</i> =	0.2	0.2	0.05	15	20
<i>DL 0.1%</i> =	0.3	0.3	0.07	19	27

Explanation of signs for the differences:

P value	Significance of differences	
	Positive	Negative
< <i>DL 5%</i>	-	-
Between <i>DL 5%</i> and <i>DL 1%</i>	x	o
Between <i>DL 1%</i> and <i>DL 0.1%</i>	xx	oo
> <i>DL 0.1%</i>	xxx	ooo

The results, acquired as a consequence of the marks given for the behaviour of the fruits to artificially inflicted wounds, after 5, 10, 15 and 20 days from the pricking, cutting and hitting 'treatment' appear in Table 2.

After the first 5 days following the wounding of the fruits, the most powerfully affected cultivar was Golden Delicious, with an average mark of 2.33, significantly superior to the experiment average. It is worth mentioning that 5 varieties (Ancuta, Florina, Idared, Starkrimson and Granny Smith) were not subject to any seizable modifications of the fruits.

After 10 days from the 'treatment', it was still 'Golden Delicious' that presented the higher average mark (3.0), which confirms the susceptibility of the well-known cultivar to fruit injury, according to the data published by Dathe (1988). It may be added that, with the Golden Delicious variety, any kind of injury upon its fruits determines also rapidly enough their degradation. From the 5 cultivars with unaffected fruits at the first check, after the next 5 days, only 4 remained, 'Ancuța' being excluded due to the appearance of the susceptibility symptoms.

**Table 2.** Synthesis of the acquired results for the marks given after the injury “treatment” applied to the fruits, for the studied apple varieties.

Cultivar	The average of the marks after:			
	5 days	10 days	15 days	20 days
Gloria	1.6 -	2.3 -	3.0 -	4.0 -
Jonagold	1.6 -	1.6 -	2.0 -	2.6 -
Feleac	2.0 -	2.0 -	2.6 -	3.6 -
London Pepping	1.6 -	1.6 -	2.0 -	2.6 -
Sir Prize	1.6 -	2.0 -	2.6 -	3.3 -
Golden Delicious	2.3 (x)	3.0 x	3.3 -	4.3 -
Ancuta	1.0 -	1.6 -	3.0 -	4.0 -
Generos	1.6 -	2.0 -	2.6 -	3.6 -
Florina	1.0 -	1.0 -	1.0 -	1.0 °
Falticeni	1.3 -	1.6 -	2.3 -	3.6 -
Wagener Premiat	1.6 -	1.6 -	3.0 -	3.6 -
Idared	1.0 -	1.0 -	1.0 -	1.0 °
Jonathan	2.0 -	2.0 -	2.3 -	3.3 -
Starkrimson	1.0 -	1.0 -	2.0 -	2.0 -
Granny Smith	1.0 -	1.0 -	1.0 -	1.0 °
Mean of exp. (Control)	1.5	1.7	2.2	2.9
<i>DL 5%</i> =	0.8	1.1	1.6	1.8
<i>DL 1%</i> =	1.1	1.5	2.1	2.5
<i>DL 0.1%</i> =	1.5	2.0	2.8	3.3

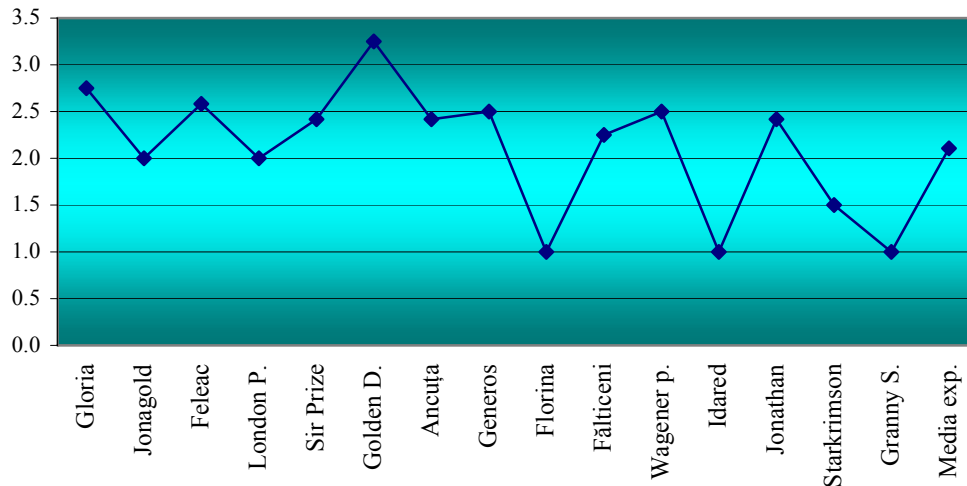
After 15 days from the “treatment”, the differences between the tested cultivars are not statistically sustained, but the most susceptible cultivar remains Golden Delicious, with the maximum average mark of the experiment (3.3). The fruits of 3 varieties (Florina, Idared and Granny Smith) did not present any symptom of alteration of the inflicted wounds.

At the last check, the same 3 cultivars (Florina, Idared and Granny Smith) presented fruits without obvious modifications of the wounded points. Consequently and according to the statistic calculus, these varieties seem to be resistant to injury, at least compared to the average of the marks in the entire experiment. The fruits most affected by injury at the end of the checking period were the ones of the Golden Delicious cultivar (with an average mark of 4.3). Next were, in succession, ‘Gloria’ and ‘Ancuta’ (both with 4.0), ‘Feleac’, ‘Generos’, ‘Falticeni’ and ‘Wagener’ (all with 3.7).

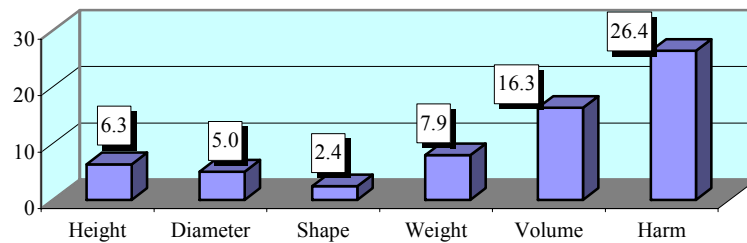
The existent differences between the studied apple varieties, for the average of the marks given with the occasion of the 4 checks at intervals of 5 days are illustrated in Fig. 1.

The variability coefficients calculated for the characteristics of the fruits oscillated between 2.4 and 26.4% (Fig. 2).

A low variability (under 10%) was registered for the index of shape, the height, the diameter and the weight of the fruits. The fruit volume seems to be a trait with an average variability ( $s\%=16.3$ ), while the behaviour to fruit injury is the characteristic with the highest variability (26.4%).



**Fig. 1.** Average of the marks given for the degradation degree of the fruits in the course of the surveillance effected, in four stages of evaluation.



**Fig. 2.** Variability coefficients of the fruit characteristics for 15 apple varieties.

To determine the extent to which the genotype participates to the phenotypic expression of the studied characters, the heritability coefficients (Table 3) were calculated, in a broad ( $H^2$ ) and narrow ( $h^2$ ) sense (Table 3), starting from the hypothesis of the polygenic determinism of resistance to injury in apple fruits (Sestras, 1992).

The heritability in a broad sense was between 0.655 (the resistance to injury after 15 days) and 0.972 (the index of shape of the fruits). It results that all studied characters have, at least under the present experiment conditions, a strong genetic determinism, being powerfully influenced by genotype and in a relatively reduced measure by the medium (including the “treatment” applied to the fruits).

**Table 3.** Values of the heritability coefficients in a broad and narrow sense, for the characteristics studied in 15 apple varieties.

The analysed characteristic	The coefficient of heritability	
	In broad sense ( $H^2$ )	In narrow sense ( $h^2$ )
Height of the fruits	0.849	0.605
Average diameter of the fruits	0.751	0.403
Weight of the fruits	0.871	0.657
Index of shape of the fruits	0.972	0.917
Volume of the fruits	0.706	0.318
Resistance to injury – after 5 days	0.698	0.304
Resistance to injury – after 10 days	0.670	0.255
Resistance to injury – after 15 days	0.655	0.230
Resistance to injury – after 20 days	0.772	0.442
Resistance to injury – average of the marks	0.707	0.320

Even if the studied characteristics present a strong genetic determinism, the additive effects do not play the most important role in all cases. This fact results from the analysis of the values acquired for the coefficients of heritability in a narrow sense, which had limits between 0.230 (the resistance to injury after 15 days) and 0.917 (the index of shape of the fruits).

If for the index of shape of the fruits, with a maximum value of  $h^2$ , additive effects of the genes have an overwhelming weight in the manifestation of the character, for other characters such as the resistance to injury, it is not additive effects, but the effects of dominance and epistasis that influence their phenotypic manifestation/exteriorisation. It results that due to their low activity, these characteristics are transmitted less accurately in hybrid descendants.

To evaluate the relations existing between the characteristics studied in the experiment, the coefficients of correlation were calculated, their values being illustrated in Tables 4 and 5.

**Table 4.** Coefficients of phenotypic correlations between the physical characteristics of the fruits and the average of the marks given for the degradation degree, for 15 apple varieties.

The correlated characteristics	Diameter of the fruits	Index of shape	Weight of the fruits	Volume of the fruits	Resistance to injury
Height of the fruits	0.218 <sup>ˆ</sup>	0.823 <sup>xxx</sup>	0.510 <sup>(x)</sup>	0.728 <sup>x</sup>	0.013 <sup>ˆ</sup>
Diameter of the fruits	-	-0.373 <sup>ˆ</sup>	0.554 <sup>x</sup>	0.825 <sup>xxx</sup>	0.089 <sup>ˆ</sup>
Index of shape	-	-	0.156 <sup>ˆ</sup>	0.211 <sup>ˆ</sup>	-0.034 <sup>ˆ</sup>
Weight of the fruits	-	-	-	0.684 <sup>xx</sup>	-0.068 <sup>ˆ</sup>
Volume of the fruits	-	-	-	-	0.074 <sup>ˆ</sup>

$$r_{5\%} = 0.514; r_{1\%} = 0.641; r_{0.1\%} = 0.760$$

**Table 5.** Coefficients of phenotypic correlation between the marks given for the degradation degree of the fruits, at different intervals of time, for 15 apple varieties.

The correlated characteristics	Marks after:			
	10 days	15 days	20 days	Average
Marks after 5 days	0.877 <sup>xxx</sup>	0.657 <sup>xx</sup>	0.686 <sup>xx</sup>	0.810 <sup>xxx</sup>
Marks after 10 days	-	0.835 <sup>xxx</sup>	0.856 <sup>xxx</sup>	0.937 <sup>xxx</sup>
Marks after 15 days	-	-	0.972 <sup>xxx</sup>	0.963 <sup>xxx</sup>
Marks after 20 days	-	-	-	0.976 <sup>xxx</sup>

$$r5\% = 0.514; r1\% = 0.641; r0.1\% = 0.760$$

From the data presented in Table 4 it can be observed that, in the apple varieties studied during the experiment, there are positive and statistically proved tight bonds between certain morphologic characteristics of the fruits: the height is correlated to the index of shape, the weight and the volume of the fruits, the fruit diameter is correlated to the weight and the volume of the fruits, the weight is correlated to the fruit volume (in the last case, even if not in all cultivars, the sense of the difference significances for the respective characters was the same – e.g. ‘Sir Prize’ and ‘Jonathan’, Table 1). On the other hand, the fruit resistance to injury is not statistically correlated with any of the morphologic characters of the fruits.

For the fruit behaviour to damage, during different stages, after their injury, there are statistically proved and tight correlations (Table 5) that signify also a certain uniformity of reaction in time to fruit injury of the studied cultivars in their ensemble.

## CONCLUSIONS

1. Among 15 studied apple varieties, Golden Delicious was susceptible to fruit injury, while the Florina, Idared and Granny Smith can be considered resistant to pricking, cutting and hitting of the fruits.

2. The variability of the morphological characteristics of the fruits was relatively low, the fruit volume being averagely variable and the fruit resistance to injury being the character with the highest variability ( $s\% = 26.4$ ). The resistance of the fruits to injury was not correlated with their height, diameter, weight, shape and volume.

3. The characteristics of the fruits have a strong genetic determinism, but the additive effects of the genes do not play the most important role in all cases. For the fruit resistance to injury the big differences between heritability coefficients values in a broad and narrow sense signify the fact that the resistance to injury of apples is influenced not only by additive effects but also by the dominance and epistasis effects of the genes.

## REFERENCES

- Botez, C., E. Marin & Elena Tamas. 1995. *Genetica – Indrumator de lucrari practice*. Tipo Agronomia Cluj-Napoca, 168 pp. (in Romanian).
- Brown, A. G. 1960. The inheritance of shape, size and season of ripening in progenies of the cultivated apple. *Euphytica* **9**, 327–337.
- Janick, J., Cummins, J. N., Brown, S. K. & Hemmat, M. 1996. Apples. In Janick, J. & Moore J. N. (eds): *Fruit breeding volume I: Tree and tropical fruits*. John Wiley and Sons, Inc., New York, pp. 1–77.

- Dathe, Barbara. 1988. Beschädigungsempfindlichkeit der Frucht bei michtigs zuchtziel der Apfelzüchtung. *Gartenbau*, Berlin, **35**, 9, 275–277.
- Sestras, R.. 1992. *Ameliorarea marului pentru marirea rezistentei la transport si manipulare*, Mapa documentara ICPP Pitesti-Maracineni, Nr. 22 (in Romanian).
- Sestras, R. 1997. *Ameliorarea marului*. Ed. Quo Vadis, Cluj-Napoca, 308 pp. (in Romanian).
- Sestras, R. 2004. *Ameliorarea speciilor horticole*. Ed. AcademicPres, Cluj-Napoca, 334 pp. (in Romanian).