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Tree and Fruit Characteristics of Various Apple Genotypes Obtained through Mutagenesis

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Abstract

Apple seeds treated with variable intensity doses of irradiation produce alterations of apple heredity, which are generally characterized by the reduction of tree vigour, change of fructification type, crop capacity, fruit shape, colour and biochemical fruit content. Morphological and productive features of trees derived through mutagenesis and fruit quality were studied on twelve apple genotypes, using 'Jonathan' and 'Golden Delicious' cultivars as control. The analysis of apple genotypes growing potential obtained through mutagenesis showed that there were significant differences in the tree height, trunk diameter, crown diameter and fructification type among the apple trees. Several genotypes ('G-1/7', 'G-1/8', 'G-3/123', 'G-4/131', 'G-9/11') were registered with a high content of total nitrogen and protein in the fruits and 'G-9/11' genotype had the highest content of phosphorus (0.408%). Genotypes 'G-4/101' and 'G-4/131' accumulated a high quantity of nitrates, over the maximum admitted levels of 60 ppm NO_3^- for fresh fruits. Cu and Zn contents were low, under the maximum admitted limits.

Keywords: fruit features, mutation, chemical content

Introduction

In apple breeding, obtaining new genotypes by mutagenesis induction represents an important and useful method for creating new cultivars (Shidakov, 1991; Janick *et al*., 1996; Predieri, 2001). Unlike natural mutations, which occur with a very low rate of frequency, artificial mutations significantly increase the frequency of mutant plants appearance (Jain, 2010), but the same characteristics are affected. Induced mutations, as natural ones, can occur in a single gene that can cause a distinct trait, or act altering the degree of ploidy.

Mutations that produce single gene differences can be most easily induced peculiarities affecting fruit colour and quality, type of growth, plant size (reduction), blooming time, fructification of trees (Broertjes, 1977; Janick *et al*., 1996), despite the low number of cultivars that became established commercial varieties (Predieri, 2002). "Spur" forms (e.g. 'Golden spur', 'Yellow spur', 'Wellspur' etc.), various fruit colours, quality and maturation were obtained in apple by induced mutagenesis (Sestras, 2004).

Mutations can be induced through physical or chemical treatments on seeds, buds, stems, pollen. Physical mutagenic agents like X-rays can be used, gamma rays or thermal neutrons respectively; treatments can also be applied in dormant branches (3-5 Kr), or active buds (2-4 Kr). Thermal neutron treatments are carried out with doses of 3.9-15.6 x 1012 neutroni/cm^2 (Janick *et al*., 1996).

Although scientific interest in mutation breeding has drastically decreased during the last years, mutation induction continues to be an attractive method for creating genetic variability (Schum, 2003) and to produce basic material for intravarietal selection on apple (Zwintzscher, 1977). New apple cultivars, as 'Redix', 'Irisem', 'Iris', 'Real' were obtained and promoted in Romania, using mutagenesis (Petre, 2008). Using gamma rays from ^{60}Co source, mutants of apple rootstocks were obtained and have been registered in Poland (Przybyla *et al*., 2009).

Materials And Methods

The main characteristics of tree and fruit quality regarding useful chemical components of twelve apple genotypes obtained through mutagenesis were studied at the Fruit Research Station Voinesti, Romania. The biological material was obtained through post-maturated seeds, irradiated with 5000-80000 R doses, from open pollinated 'Prima' cultivar, with genetically resistance to apple scab (*Vf*), which has a good response in Romanian ecological conditions (Sestras *et al*., 2005).

From the irradiated biological material, existing in the selection field, the most valuable elites were selected, grafted on MM 106 rootstock and studied in a comparative trial with 1250 trees/ha (Petre, 2008). Measurements of trees growth were height of trees, trunk diameter and crown diameter. Biochemical determination were water content, total dry matter, total sugar, acidity, vitamin C and mineral elements - total nitrogen, protein, phosphorus, potassium, calcium, iron, and heavy metals Cu, Zn, Pb, Cd.

In order to obtain water content and dry matter the drying closet method at 105°C, sugar content Abbe method, total acidity through volumetric method with NaOH 0.1n, vitamin C iodometric method, nitrogen content with Kjeldahl, phosphorus with colorimetric method and potassium with flam photometric method were used. Heavy metal contents were determined with wet mineralization and spectrophotometer method.

The genotypes considered mutants, were studied along with 'Jonathan' and 'Golden Delicious' cultivars, untreated, two of the most cultivated and well-known apple cultivars in Romania (Mitre *et al*., 2009).

Results and discussions

The growing potential analyses of some apple genotypes obtained through mutagenesis induction show significant differences in height, trunk diameter, crown diameter and fructification type of apple trees.

According to the trunk diameter there are small vigorous genotypes like 'G-6/42', middle 'G-1/8', large in 'G-4/101' and super large in 'G-3/123'. The highest trees have upright trunks, with 'G-1/123' genotype and the ones with small trunks are from 'G-6/42' genotype. Large crowns were presented 'G-3/123' and 'G-9/11' genotypes and tight crowns 'G-6/42' and 'G-5/56' genotypes.

It is likely that tree force differences recorded among varieties be due to gene recombinations that arise from crosses among various genotypes, as the force of the apple tree is a feature with a polygenic determinism (Janick *et al*., 1996; Sestras *et al*., 2009).

Biochemical features were also studied. Medium values of biochemical characteristics of apple genotypes and were

Tab. 1. The vigour of apple trees and productivity (fruit yield)

No	Genotypes	Trunk diameter (cm)	Tree height (cm)	Crown diameter (cm)	Tree vigour	Fruit yield (kg/tree)
1	'Jonathan'	34.2^{b}	485^{ab}	350^{b}	Medium	18.7^{c}
2	'Golden Delicious'	35.8^{ab}	486^{ab}	310^{bc}	Medium	23.4^{b}
3	'G-1/7'	34.1^{b}	456^{b}	275^{c}	Medium	28.3^{ab}
4	'G-1/8'	34.3^{b}	420^{c}	230^{d}	Medium	25.6^{b}
5	'G-1/26'	33.1^{c}	380^{de}	240^{d}	Medium	26.5^{ab}
6	'G-3/123'	36.7^{a}	460^{b}	460^{a}	Very large	32.5^{a}
7	'G-4/50'	32.1^{c}	510^{a}	204^{de}	Large	18.0^{c}
8	'G-4/56'	34.8^{b}	495^{a}	215^{de}	Medium-Large	16.6^{cd}
9	'G-4/101'	32.6^{c}	489^{ab}	240^{d}	Large	15.5^{d}
10	'G-4/131'	33.1^{c}	401^{cd}	310^{bc}	Medium	28.1^{ab}
11	'G-5/56'	35.2^{b}	495^{a}	210^{de}	Large	14.5^{d}
12	'G-5/79'	34.3^{b}	480^{ab}	350^{b}	Medium-Large	17.4^{cd}
13	'G-6/42'	30.6^{d}	365^{e}	190^{e}	Low	25.6^{b}
14	'G-9/11'	32.5^{c}	385^{de}	330^{b}	Medium	18.3^{c}

Tab. 2. The biochemical features of apple trees

No	Genotypes	Water (%)	Dry matter (%)	Total sugar (%)	Acidity (%)	Vitamin C (mg/100g fruit)	Mineral substances (%)
1	'Jonathan'	86.30	13.70	10.61	0.210	9.21	1.66
2	'Golden Delicious'	85.90	14.10	11.36	0.156	12.63	1.93
3	'G-1/7'	85.60	14.40	12.10	0.188	8.31	1.86
4	'G-1/8'	85.10	14.90	11.80	0.195	15.20	1.25
5	'G-1/26'	86.90	13.10	12.03	0.244	17.31	1.76
6	'G-3/123'	87.34	12.66	9.84	0.345	7.66	1.58
7	'G-4/50'	88.46	11.54	9.53	0.173	7.89	1.73
8	'G-4/56'	86.20	13.80	9.75	0.214	8.75	2.10
9	'G-4/101'	86.30	13.70	10.96	0.310	19.21	2.30
10	'G-4/131'	85.90	14.10	9.81	0.293	9.35	2.30
11	'G-5/56'	87.62	12.38	10.00	0.195	7.56	1.98
12	'G-5/79'	85.18	14.82	9.53	0.157	17.40	1.26
13	'G-6/42'	89.32	10.68	10.94	0.232	7.67	1.35
14	'G-9/11'	90.15	9.85	9.53	0.127	7.19	1.36

influenced by the mutagenesis process. They are presented in Tab. 2.

The highest values of the water content of fruits were registered in genotypes 'G-9/11', 'G-6/42' and 'G-4/50'; values were between 88.46-90.15%. The highest content of dry matter were in genotypes 'G-5/79', 'G-5/56' and 'G-6/42' and the smallest contents were in genotypes 'G-9/11', 'G-6/42'.

Regarding the sugar content, there was normal accumulation in all genotypes comparatively with values obtained in ordinary orchards (Sestras *et al*., 2005) or even as biological crop (Campeanu *et al*., 2009). High contents of sugar were registered in 'G-1/7' and 'G-1/26'.

Vitamin C contents had superior values in all variants comparatively with 'Jonathan'. In genotypes 'G-1/8', 'G-1/26', and 'G-5/79' vitamin C contents were double and triple comparatively with the content of 'Jonathan' and 'Golden Delicious'.

Tab. 3. Mineral elements apples contents

No	Genotypes	Nt %	Protein %	P_2O_5 %	K_2O %	CaO %	FeO %
1	'Jonathan'	1.7514	10.60	0.295	0.65	0.451	2.301
2	'Golden Delicious'	1.8513	10.75	0.346	0.68	0.255	2.341
3	'G-1/7'	2.0131	11.21	0.321	0.75	0.265	2.307
4	'G-1/8'	1.9615	10.95	0.314	0.65	0.265	2.205
5	'G-1/26'	1.8048	11.24	0.363	0.65	0.148	2.204
6	'G-3/123'	1.8514	11.75	0.310	0.55	0.246	2.305
7	'G-4/50'	1.5792	9.83	0.3285	0.55	0.276	2.341
8	'G-4/56'	1.7776	11.61	0.276	0.45	0.275	2.205
9	'G-4/101'	1.9766	11.45	0.2176	0.30	0.252	2.204
10	'G-4/131'	2.1714	13.52	0.2765	0.50	0.2450	2.352
11	'G-5/56'	1.7672	11.00	0.3285	0.55	0.260	2.212
12	'G-5/79'	1.7390	10.83	0.3460	0.65	0.158	1.896
13	'G-6/42'	1.2690	7.90	0.3805	0.55	0.210	2.488
14	'G-9/11'	2.0304	12.64	0.4150	0.45	0.269	2.526

Tab. 4. Components and potential toxic elements

No	Genotypes	NO_3- (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Cd (ppm)
1	'Jonathan'	210.1	3.5	2.3	Trace	Trace
2	'Golden Delicious'	296.9	2.1	4.2	Trace	Trace
3	'G-1/7'	189.3	3.2	3.1	Trace	Trace
4	'G-1/8'	175.4	3.3	3.2	Trace	Trace
5	'G-1/26'	132.3	3.2	3.8	0.21	Trace
6	'G-3/123'	272.1	3.8	3.6	Trace	Trace
7	'G-4/50'	170.1	4.1	2.2	Trace	Trace
8	'G-4/56'	189.2	3.5	3.8	0.25	Trace
9	'G-4/101'	151.2	2.8	4.2	Trace	Trace
10	'G-4/131'	173.2	3.1	3.6	Trace	Trace
11	'G-5/56'	189.0	3.5	3.8	0.25	Trace
12	'G-5/79'	170.1	4.3	4.8	0.15	Trace
13	'G-6/42'	151.2	3.7	4.9	Trace	Trace
14	'G-9/11'	170.1	3.6	3.7	Trace	Trace

The values of acidity contents were near the control values with the exception of genotypes 'G-1/8', 'G-5/56' and 'G-6/42' in which acidity had higher values.

Mineral elements contents were higher in value in fruits from genotypes 'G-4/56' , 'G 4/131, and 'G-4/101'.

The mineral elements analyses (Tab. 3) showed a high content of total nitrogen and protein in the apples of genotypes 'G-1/7', 'G-1/8', 'G-3/123', 'G-4/131', 'G-9/11' and a small content in variants 'G-6/42', 'G-4/56', 'G-4/50' and 'G-5/79'. With the exception of genotype 'G-9/11' which had the higher content of phosphorus, with the value 0.408%, apples of the other genotypes presented the same values.

The content of other mineral elements analysed were in normal variability for apple species but there were not high differences between genotypes.

Apples from genotypes 'G-4/101' and 'G-4/131' were predicted to accumulate high quantities of nitrates and 'G-6/42' and 'G-1/26' accumulated small quantities of nitrates. All nitrates quantities accumulated in apple genotypes were over the maximum admitted levels of 60 ppm NO_3^- mentioned in the legislation regarding security consumption conditions for fresh fruits.

The accumulation levels of Cu and Zn were low (Tab. 4), under the maximum admitted limits for those elements. The levels of lead and cadmium were in trace values, which showed the good fruit quality.

Conclusions

The analyses for the growing potential of some apple genotypes obtained through mutagenesis induction show that there are significant differences in height, trunk diameter, crown diameter, and yield among apple variants. The mutagenesis process influenced medium values of biochemical features of apple genotypes. The values of dry matter, acidity, sugar and vitamin C had large variability among variants. Apples from genotypes 'G-4/101' and 'G-4/131' were mentioned to accumulate high quantities of nitrates. All nitrates quantities accumulated in apple genotypes were over the maximum admitted levels of 60ppm NO_3^- mentioned in the legislation regarding fresh fruits security consumption conditions. The accumulation levels of Cu and Zn were low and were under the maximum admitted limits for those elements.

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