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FRUIT QUALITY OF APPLE VARIETIES CULTIVATED IN AN ORGANIC SYSTEM

Viorel STOICA[1, 2] Mihaela PARASCHIV[2], Dorel HOZA[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Marasti Blvd, District 1, Bucharest, Romania
[2]Research - Development Institute for Fruit Growing Pitesti - Maracineni,
402 Marului Street, Pitesti, Arges, Romania

Corresponding author email: mihaela1mail@yahoo.ca

Abstract

Apple is an important crop in many European countries. There is a growing interest, from consumers, for fruits obtained through ecological cultivation techniques. In order to satisfy this demand, some products compatible with ecological agriculture were tested applied to the soil and foliage of an apple crop in the Arges Meadow. The aim of this study was to evaluate the impact of organic fertilizers on production quality. Larger fruits were obtained from the organic treatments. The results also indicate a surplus of malic acid, sugars and total phenols in all varieties compared to those in the control variant. We conclude that through radicular and extraradicular fertilization, the apple varieties 'Romus 3', 'Idared' and 'Golden Delicious' have a higher nutritional quality.

Key words: *apple, organic fertilization, fruit quality, biochemical characteristics.*

INTRODUCTION

The apple (*Malus domestica* Borkh.) is one of the most important fruit crops in many countries (Cornille et al., 2012), including in Romania, and their quality is very important in consumer acceptance. In 2022, the apple occupied the third place as the most consumed fruit, worldwide (Dodocioiu & Buzatu, 2023).
Fertilizer management systems used in apple cultivation worldwide correspond to organic farming (only use of organic fertilizers), natural conditions (no fertilizers or pesticides) and the use of organic fertilizers combined with chemical ones (Kai & Kubo, 2020; Peck et al., 2006). In order to reduce the risks to health and the environment, new methods are being tried to reduce the administration of pesticides and chemical fertilizers. Organic cropping systems exclude the use of chemical fertilizers and pesticides, allowing the use of manure, compost, copper compounds, organic insecticides, pheromonal traps and other means of biological control (Holb et al., 2003; Peck et al., 2006; Jönsson, 2007). Biopreparations are fertilizers that contain one or more organic compounds such as enzymes, plant hormones, amino acids or vitamins. Bio-preparations can also contain macro or micro elements (Tarozzi et al., 2008). Although at the national level there have been major increases in organic agricultural commodities (25-50% per year) (Oltramari et al., 2002 cited by Amarante et al., 2008), the production of apples grown in organic systems in Romania is incipient.
If until the middle of the 19th century, the only way to provide plant nutrients at the soil level consisted in the application of manure (Zuoping et al., 2014), at the moment culture technologies use a wide range of products. According to Xu et al. (2008) administration of organic manure improves soil quality. Edmeades (2003) reported lower soil bulk density due to continuous manure application and buffering capacity of sand with higher porosity. So, continuous management of manure for apple production can be of great value (Zuoping et al., 2014). Previous research in other crops has shown that providing organic fertilizers can improve plant growth and development (Kai et al., 2020a; Kai et al., 2020b). Therefore, reduced rates of nitrogen release by organic fertilizers can cause nitrogen deficiencies that could cause an increased accumulation of phenolic flavonoids in some fruits affecting their flavor and nutritional quality (Lester & Saftner, 2011). In apple, the administration of fertilizers significantly

influenced the level of several chemical compounds related to taste and aroma, such as the level of sugars and organic acids or some volatile substances responsible for aroma. Significant differences were observed in several sensory attributes in apples as a result of different fertilization systems (Raffo et al., 2014). Thus, due to the higher doses of K, a higher level of organic acids was obtained, which has the consequence of changing the taste due to the change in the ratio of sugar/organic acids (Dodocioiu & Buzatu, 2023). Research results show that biological fertilization can be a sustainable and economically efficient alternative to standard fertilization (NPK) in apple production. Testing a large number of products have shown a positive influence on vegetative growth and productivity in apple. The impact of biopreparations on the quantity and quality of the harvest is observed after more time of application (Mosa et al., 2015). A sensory evaluation of horticultural products obtained from organic crops showed an improvement in sugar content and aromatic substances (Liu, 2012).

Therefore, the aim of the present study was to investigate the effects of organic manure and other organic fertilizers applied radicularly or extraradially on the quality of apple in the apple orchard in Argeșului meadow, southern Romania.

MATERIALS AND METHODS

Experiment location and plant material

The study was carried out in 2023 in a plantation located in southern Romania (44°54'n, 24°52'e) of a private farm, using a seven-year-old apple plantation as study material. Three apple varieties 'Romus 3', 'Idared' and 'Golden Delicious' were tested.

Soil description

The apple crop is on a brown-clay soil with a clay-clay texture in the first 70 cm.

Plant fertilization

Fertilizers were applied in a completely randomized block design with 3 plants per plot with a 3-plant spacing between treatments with three replicates. The experiment was bifactorial. Factor A, apple (*Malus domestica*) had 3 levels: 'Romus 3', 'Idared' and 'Golden Delicious'. Factor B: five different fertilization treatments according to the scheme shown in Table 1.

Table 1. Fertilization variants and applied fertilizer doses

Fertilization variant	Treatment applied		Application time	
	Soil	*Foliar*	*Soil*	*Foliar*
V1	-	-		
V2	Biohumus (0.5 L/ha)	Macys BC (2 L/ha) Cifamin BK (1 L/ha)	Spring (when flowering) Autumn (after the leaves fall)	-after flowering -young fruit
V3	Biohumus (0.7 L/ha)	Macys BC (2 L/ha) Cifamin BK (1 L/ha)		
V4	Biohumus (0.9 L/ha)	Macys BC (2 L/ha) Cifamin BK (1 L/ha)		
V5	Manure (20 t/ha)	-	Autumn (after the leaves fall)	

Biohumus is a 100% organic fertilizer, an active humic preparation, purely ecological. It contains amino acids, salts of humic acids, fulvic acids, humic acids, micro and macro nutrients, live bacteria and other compounds easily absorbed and assimilated by plants.

Cifamin BK is a preparation, very rich in organic compounds with biostimulating action on the physiology of plants, recommended especially for improving the size of fruits and vegetables. It contains amino acids of vegetable origin derived from enzymatic hydrolysis (tryptophan, arginine).

Macys BC is an organic product recommended for foliar administration based on *Macrocystis integrifoglia*. It provides plant-essential algae extracts with direct action on plant physiology, such as natural growth regulators and carbohydrates such as alginic acid.

Fruit quality

The determinations were carried out in 2023, on fruits harvested by hand at the technical harvest maturity. The following quality indicators were determined: fruit mass, firmness, color, soluble dry matter content, total titratable acidity, total sugar content and total polyphenol

content. All determinations were performed in three replicates for each cultivar with the fertilization variants.

Fruit mass, expressed in g/fruit, was determined by weighing 20 fruits from a sample and calculating the average weight of a fruit,

Fruit firmness (expressed in HPE units) was determined using a non-destructive Qualitest HPE penetrometer.

***Total dry matter content* (DM)**

Total dry matter content was determined by a gravimetric method that consists of drying 10 g of fruit tissue at 105°C to constant weight, according to Gergen (2004).

Total soluble solids (TSS) were determined using a refractometer.

Total acidity (TA)

The total acidity expressed as malic acid (%) in apples was determined by the titrimetric method in an aqueous extract neutralized with a 0.1 N NaOH solution using phenolphthalein as an indicator.

Dosage of total sugar

The total sugar content, expressed as a percentage (%), was estimated by the method of Fehling-Soxhlet, 1968 (JAOAC, 1968). The principle of this method consists in the oxidation reaction between the copper in the copper alcoholate of sodium potassium tartrate and the aldehyde and ketone groups of the reducing sugars.

The method allows the determination of the amount of sugar that reduces a certain volume of Fehling's reagent.

Vitamin C content

The dosage of ascorbic acid in the fruits (expressed in mg/ 100 g FW) was carried out, in an acidic environment, by the oxidation of L-ascorbic acid to dehydroascorbic acid in the presence of a blue dye (2,6-dichloroindophenol) followed by the reduction of the dye to the form colorless, and at pH 4.2 it turns red at (PN-A-04019: 1998).

Total polyphenol content (TPH)

Fruit TPH was assayed using Folin-Ciocalteu reagent (Singleton et al., 1999) and was measured at 760 nm wavelength. Gallic acid was used as a standard and the results were expressed in mg GAE/kg FW.

Statistical analyses

An IBM SPSS 16 program (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The obtained results were subjected to a one-way analysis of variance (Anova). The Duncan Multiple Range test was used to determine the degree of significance. Differences were considered significant at $p \leq 0.05$.

RESULTS AND DISCUSSIONS

The physical indicators of the fruits (mass, firmness) were determined on fresh fruits, immediately after harvesting.

The average weight of apple fruits varied between 111.17 g (variety 'Romus 3', V1) and 147.41 g (variety 'Idared', V4) (Table 2). The variety "Idared" stood out with the largest fruits in the case of all fertilization options.

Table 2. Physical indicators of apple fruit quality (V1-V5)

		V1	V2	V3	V4	V5	Average of cultivars
Weight (g)	Romus 3	111.17±13.17c	119.02±24.24c	123.94±3.82c	169.12±4,70b	145.69±11.70c	133.03±22.58c
	Idared	161.81±18.18a	195.25±37.57a	212.78±29.02a	247.41±34,71a	236.90±34.33a	207.45±43,40a
	Golden Delicious	131.48±19.98b	163.58±15.55b	170.32±18.23b	184.23±20,45b	188.51±20.77b	165.38±27.77b
Firmness (unit HPE)	Romus 3	76.14±3.11a	70.97±5.35b	74.12±7.03b	71.93±4.04c	74.83±4.06b	74.08±4.73c
	Idared	77.16±1.71a	76.35±2.10a	75.54±1.72b	76.12±2.28b	76.10±2.36b	76.29±2.03b
	Golden Delicious	78.94±3.61a	79.47±3.38a	80.19±2.49a	81.74±1.67a	81.73±1.41a	80.28±2.91a

Figure 1 shows that the best results were obtained with option 4 – Biohumus 0.9 l/ha root, Macys BC (2 L/ha) and Cifamin BK (1 L/ha) extraroot. The results show that the supply of organic fertilizers has a positive effect on the average fruit weight. Tamara et al. (2005), Grzyb et al. (2012) observed an increase in average fruit weight in organic farming as a result of the application of organic fertilizers. It may also be influenced by the type or frequency of treatments provided.

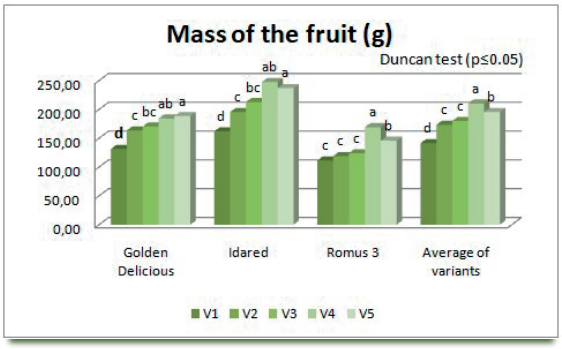

Figure 1. The effect of the applied treatments on the average weight of the fruits (g)

Apple pulp firmness is a particularly important parameter regarding the quality and durability of production in the marketing system. According to the results obtained (Table 2), fruit firmness was significantly influenced by the genetic characteristics of the cultivar. In the variety 'Golden Delicious' the fruits were firmer compared to the varieties 'Romus 3' and 'Idared'. According to the results obtained, this parameter did not vary significantly following the provision of organic fertilizers. In the 'Golden Delicious' variety, an improvement in the firmness of the fruits was observed in the dynamics with the increase in the doses of fertilizer applied to the roots. This tendency was not confirmed in the fruits of the summer variety 'Romus 3' or the late ripening variety 'Idared' (Figure 2).

Determining the biochemical composition of fruits is very important for determining the quality of horticultural products. This influences not only the taste of the fruit, but also its health-promoting properties.

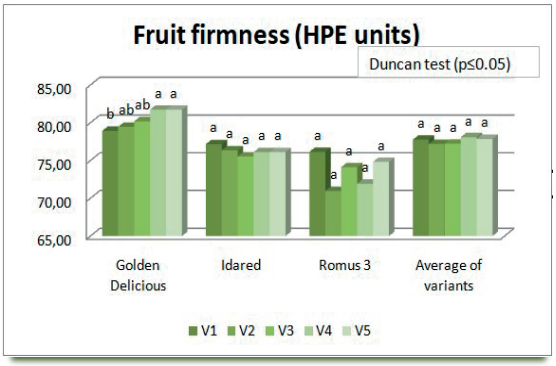

Figure 2. The effect of the applied treatments on the fruit firmness (HPE units)

According to the obtained results, the fruits of the 'Idared' variety had a higher level of TSS in their composition (Figure 3). Moreover, it was shown that all applied organic treatments affected the TSS of the fruits of this variety. On the cultivar average, TSS (Figure 3) was higher in the case of the control variant (V1) and variant 3. Arabloo et al. (2017), Ilie et al. (2017) showed that foliar application of organic fertilizers increased fruit TSS and yield quality.

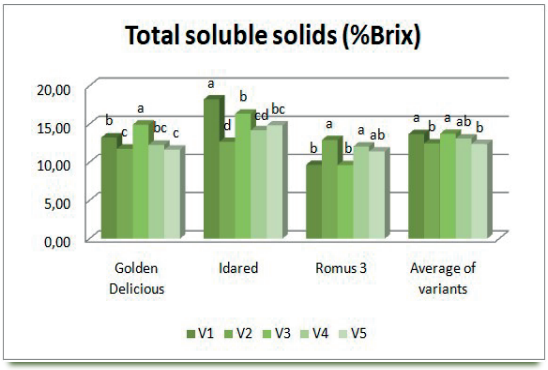

Figure 3. The effect of the applied treatments on the total soluble solids (%Brix)

The study showed that DW also differed depending on the genetic characteristics of the cultivar. Analogous to TSS, DW was higher in the cultivar 'Idared'. The percentage of DW was generally higher in V3 (Biohumus - 0.7 L/ha) and V4 (Biohumus - 0.9 L/ha) variants. The behavior of the summer variety 'Romus 3' was different from the behavior of the autumn varieties following the administered fertilizers. In this variety, an increase in DW dynamics was observed with increasing doses of Biohumus. In the case of manure administration, the increase of this biochemical quality indicator was insignificant. The autumn variety 'Idared', on the other hand, had a higher DW in the case of the variant fertilized with manure 20 t/ha (Figure 4). In conclusion, to increase this quality indicator, the root administration of Biohumus fertilizer in doses greater than 0.5 L/ha is recommended.

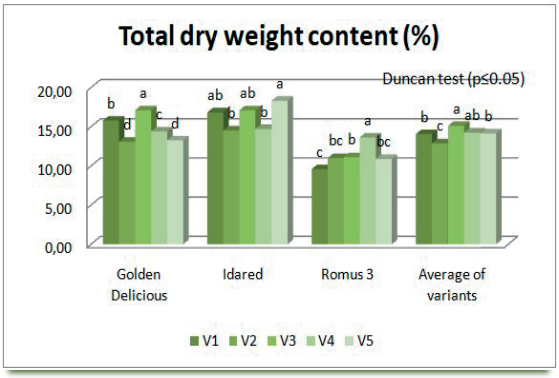

Figure 4. The effect of the applied treatments on the total dry weight content (%)

Titratable acidity (TA%) of fruits and vegetables depends on several factors, including genotypic differences, climatic conditions before harvest, as well as cultivation technologies (Lee & Kader, 2000). It is known that in colder areas or during periods of heavy precipitation, TA values become higher (Gherghi et al., 1986).

The dynamics of TSS accumulation in apple fruits was identical to that of DW. Testing the influence of the experimental factors (fertilization variant and variety) on fruit acidity in the three varieties studied, we emphasize the following (Figure 5): - The varieties 'Idared' and 'Romus 3' recorded a higher content of malic acid in the fruits. The biosynthesis of organic acids was significantly influenced by genetic characteristics. In the 'Idared 'variety, there was a slight decrease in AT with the increase in the doses of applied organic fertilizers. However, on the average of the variants, the highest values of the content of organic acids were found in the V3 variant (Biohumus 0.7 L/ ha) followed by variant V5

(manure 20 t/ha). A possible increase of this quality indicator in some apple varieties was also reported by Ilie et al. (2017) in organic crops.

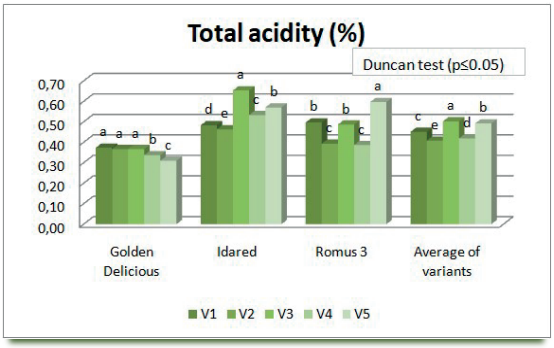

Figure 5. The effect of the applied treatments on the content of organic acids in fruits

In apples, sugars determine the organoleptic quality, especially the taste. Gündoğdu (2019) reported that climatic conditions and culture and rootstock technologies can influence the level of biochemical compounds such as sugar, phenolic compounds and organic acids in fruits. The total sugar content varied between 6.01% ('Romus 3' - V1) and 12.42% ('Golden Delicious' - V5). The 'Golden Delicious' variety had the highest sugar content, significantly higher than the other two varieties tested. The analysis of variance (Anova) showed a significant effect determined by the cultivar of 94.1% and of the treatments applied by 97.2% on the sugar content of the fruits of the studied apple cultivars.

In the summer variety 'Romus 3' (Figure 6), the maximum sugar content was obtained in the case of variant 4 (Biohumus 0.9 l/ha) and in the autumn varieties in the variant consisting of 20 t/ha of manure (V5). In addition to the quality of taste, the level of sugary substances in merestabiles also determines their caloric value.

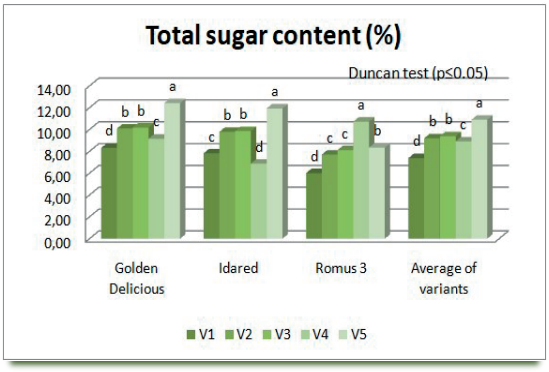

Figure 6. The effect of the applied treatments on the total sugar content of the fruits (%)

A negative interdependence between vitamin C content and nitrogen fertilizer rates supplied has often been reported (Weston & Barth, 1997 and Lee & Kader, 2000). And in the present experiment, the concentration of vitamin C in apples decreases with the increase in the dose of applied fertilizers (Figure 7). The minimum concentration of vitamin C was obtained after fertilization with manure (V5).

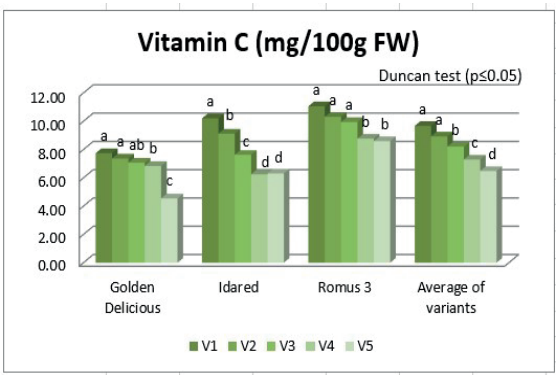

Figure 7. The effect of the applied treatments on the vitamin C content of the fruits (mg/100 g FW)

Phenolic compounds can contribute to the aroma of horticultural products and can be responsible for the sweet, bitter, pungent or astringent taste of fruits. Simple (volatile) phenols have a special role in establishing aroma (Tomás-Barberán & Espín, 2001). The results for TPH in the fruit of the apple cultivars analyzed varied between 1076.81 mg GAE/kg FW ('Idared' - V4) and 2230.44 mg GAE/kg FW ('Romus 3' - V3). Valavanidis et al. (2009) showed concentrations ranging from 800-1960 (mg GAE/ kg FW). Higher values were reported by Imeh and Khochar (2002), in the range of 3000-5350 (mg GAE/kg FW). The influence of applied fertilizer rates on fruit TPH was inconsistent. The data from the specialized literature, most of the time, were inconclusive Young, et al. (2005). According to Rosa et al. (2007), an explanation of the influence of culture technology on the biosynthesis of secondary metabolites in fruits is difficult due to the multitude of factors that affect their concentration.

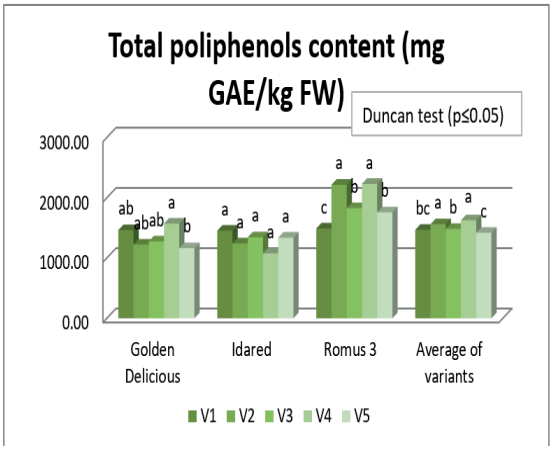

Figure 8. The effect of the applied treatments on the total poliphenols content of the fruits (mg GAE/kg FW)

Following the results obtained in the tests performed on the fruits of the three apple varieties analyzed regarding the quality parameters, some positive or negative, statistically significant interdependencies were obtained between most of the studied indicators (Table 3).

Table 3. Correlation between the values of the quality indicators studied in the fruits of the 'Romus 3', 'Idared' and 'Golden Delicious' apple cultivars fertilized with organic products.

	Mass of the fruit (g)	Firmness (HPE units)	TSS (%Brix)	DW (%)	TA (%)	Total sugar (%)	Vitamin C (mg/100g FW)	TPH (mg GAE/kg FW)
Mass of the fruit (g)	1							
Firmness (HPE units)	-0,051	1						
TSS (%Brix)	0,376(**)	0,138	1					
DW (%)	0,537(**)	0,263	0,780(**)	1				
TA (%)	0,316(*)	-0,308(*)	0,275	0,121	1			
Total sugar (%)	0,333(*)	0,153	0,322(*)	0,432(**)	-0,243	1		
Vitamin C (mg/100g FW)	-0,086	-0,526(**)	-0,218	-0,388(**)	0,221	-0,267	1	
TPH (mg GAE/kg FW)	-0,522(**)	-0,426(**)	-0,160	-0,413(**)	-0,119	-0,202	0,358(*)	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The obtained data demonstrated a positive linear correlation, distinctly significant, between the fruit weight of the analyzed cultivars and TSS (r = 0.376), between fruit weight and DW content (r = 0.537) and a negative linear interdependence between fruit weight and TPH content (r = -0.522).

A negative linear relationship was also obtained between fruit firmness and ascorbic acid level (r=-0.526), between fruit firmness and TPH concentration (r = -0.426; p<0.01).

The relationship between TSS and DW was positive, distinctly significant, with a high intensity (r = 0.780).

The correlation between DW level and total sugar content was positive, distinctly significant (r = 0.432) and the relationship between DW and vitamin C or TPH content was linearly negative (r =-0.388 or r = -0.413).

CONCLUSIONS

Physical quality parameters (fruit weight and firmness) indicated variations determined by genetic diversity. The applied treatments did not significantly influence the firmness of the fruits.

The fruit weight of the three apple cultivars analyzed improved with the increase in the doses of fertilizers supplied.

It was observed that the level of organic compounds in the fruits of the studied apple varieties depends mainly on the genetic characteristics of the cultivar and the nature and doses of fertilizers administered.

The provision of organic products in apple crops influences the taste of the fruit (it improves the level of carbohydrate compounds and influences the biosynthesis of organic acids). A negative influence on the biosynthesis of ascorbic acid determined by increasing the doses of administered fertilizers was noted.

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