Volume 22(1), 136- 143, 2018
JOURNAL of Horticulture, Forestry and Biotechnology
www.journal-hfb.usab-tm.ro

The influence of fertilization and storage conditions on the production quality in watermelon

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Abstract Consumption of watermelon boosts the immune system due to its high content in vitamin C, which is powerful antioxidant, preventing various diseases. Lycopene is an antioxidant very well known for its heart disease prevention properties, but can also prevent prostate cancer. The watermelon contains fibre, potassium (which is good for the nervous system), magnesium, folic acid and beta-carotene (which have antioxidant properties). The objectives of this study were the following: study of the influence that the distinctive application of chemical fertilizers has on the main parameters involved in the watermelon production; the analysis of the main qualitative parameters in the experimental variants. The biological material consisted of three hybrids of watermelon: Arashan, Karistan and Odem. Variants of applied technology were: conventional technology, conventional technology supplemented with nitro lime and conventional technology supplemented with borocal. Harvested fruits were stored under three different temperature conditions: 25 °C, 17 °C and 2 °C. Results showed differences in both applied methodology and between genotypes or storage conditions. The acidity of fruits juice was highly correlated with the storage temperature: overall, the Arashan hybrid juice acidity was the lowest. On the whole of the experimental variants, the most productive genotype was Arashan hybrid followed by Karistan and Odem.

Key words

watermelon, fertilization, soluble carbohydrates, firmness, acidity

Consumption of watermelon boosts the immune system because it has high vitamin C content, which is a powerful antioxidant, preventing various diseases (Davis et al., 2011; Perkins-Veazie et al., 2012). Lycopene is a well known antioxidant for heart disease prevention properties, but can also prevent prostate cancer (Bramley, 2000). The watermelon contains fiber, potassium (which is beneficial for the nervous system), magnesium, folic acid and beta-carotene (which have antioxidant properties) (Naz et al., 2013). L-citrulline is also found in the watermelon and it is converted in L-arginine in kidneys with beneficial effect for vasodilation and heart health (Rimando and Perkins-Veazie, 2005; Collins et al., 2007). In studies conducted at the Agricultural Research Institute of Marigat, Kenya, changes in yields and quality of watermelon have been observed in response to different nitrogen fertilizer sources (Audi et al., 2013). In their research, Audi et al. (2013) applied fertilization with manure (3 t ha^{-1}, 6 t ha^{-1}, 9 t ha^{-1}) and nitro-lime (35 kg ha^{-1}, 70 kg ha^{-1}, 105 kg ha-1). According to the results obtained, the application of manure influenced both the number of fruits harvested on the surface unit and the average weight of the fruit. On the other hand, some parameters such as the shape of the fruit, the colour and thickness of the rind (cortex) or certain qualitative parameters (total content of soluble carbohydrates expressed as ^{0}Brix) did not changed significantly. It has been concluded from the studies that the application of nitrogen in the form of manure or nitro-lime has significantly influenced production especially in arid or semiarid environmental conditions (Audi et al., 2013).

The influence of natural organic complex fertilizers of boron, on some qualitative parameters in watermelons, was studied on psamosols by Ratoi et al (2010). In their research from 2005, the results show the role of boron in plant metabolism: stimulates the accumulation of some biochemical components in the leaves (chlorophyll, carotene), increase the activity of some enzymes (catalyzes) and improves the quality of fruits. In variants where the boron compounds were applied, there was a higher content of chlorophyll, from 4.31 to 4.46 mg g^{-1} of raw plant substance, compared to 2.14 mg g^{-1} of raw plant substances, in the unfertilized variant, and 4.00 mg g^{-1} of raw plant substances when only manure was applied; carotene content of 0.73-0.79 mg g^{-1} of raw plant substances compared to 0.49 mg g^{-1} of raw plant substances in the unfertilized variant and 0.63 mg g^{-1} raw plant substances in the variant where only manure was used. The total dry fruit content increased from 9.35%, in the control variant, to

10.20-10.35% in variants fertilized with manure + Folibor 5 l ha^{-1} (two treatments). On the organic experimental fertilization of 30 t ha^{-1} manure, by foliar Folibor application, the production increase with 10.7 t ha^{-1} (Răţoi et al., 2010). In an experiment conducted at Kaltungo, Nigeria by Sabo et al., (2013), the effect of nutrition and NPK fertilization on the yield of watermelon production was monitored; three variants of distances were studied both between rows and between plants per row (1x1; 1x1,5; 1x2), and four levels of NPK fertilizer (0, 100, 150 and 200 kg ha^{-1}). During the experiment were studied: the number of flowers, number of fruits per plant, weight of the fruit at harvest. The results showed significant differences concerning the plant height and number of leaves but also in the fruit weight. The interaction of these two factors (the distance of planting and different fertilization) led to the conclusion that the application of 150 kg ha^{-1} NPK fertilizer at a planting distance of 1x1.5 m would bring the highest production yield of watermelon in the studied area (Sabo et al., 2013). Many research results confirm that boron fertilization is very efficient on crop yields, physiological (plant health), morphological and biochemical traits, especially when is applied to plants in natural fertilizers (Mohamed et al., 2015).

Data from research were subjected to the One – Way Anova analysis and significantly different means were separated using the Least Significant Difference test. Linear regression was done to establish relationships between variables. Results revealed significant variation in all the components that were measured.

Material and Method

The biological material was represented by three hybrids of watermelon (*Citrulus lanatus L.*): Odem F1, Arashan F1, Karistan F1. Odem F1 - it is a hybrid of watermelon with extra dark green rind, very sweet and deep red color of the fruit. It is the earliest watermelon in its range - watermelons with dark rind. Arashan F1- it is a new hybrid from super-early watermelons type. The plant is vigorous growth, very strong resistant to sunburn, high sugar content and small seeds; oval fruit weight 8 -12 kg. Karistan F1 – is one of the medium early watermelon type and has the following general characteristics: oval fruits, with weight between 8-10 kg, medium early hybrid (60 days after transplanting, 75 days from sowing); resistant to stress conditions;

The experiment was carried out under farm conditions, and conventional technology was applied using the following foliar fertilization variants: foliar fertilizations were performed taking into account the variants of the experiment, namely: -V1 (control) - Ferticare 1 and Ferticare 3 (after the beginning of fruit set); -V2 - Calcium nitrate (2 kg ha^{-1}); -V3 - Borocal (2kg ha^{-1}). The harvested fruits were stored under the following storage conditions:

- Low temperature conditions (low temperature storage: 2 °C);
- Standard conditions for commercial storages (18 ° C);
- Normal temperature conditions (25 ° C).

The storage interval was 14 days, and during this time was recorded the influence of the different storage conditions on the main quality indices. To determine the influence of fertilization and storage conditions on the quality of fruits, the following physiological indices were evaluated:

- Determination of the soluble carbohydrate percent in the fruit pulp; fruit fertility; acidity (pH) in the juice obtained from the fruit pulp and determination of production.
- Measurement of soluble dry matter which is another way to evaluate the transformation of starch into glucose. Soluble dry substances are measured with a digital refractometer.

Results and Discussions

Regarding the total soluble carbohydrate content, both the influence of the fertilization variant and the influence of different fruit storage conditions were studied. Analysis was made using the digital refractometer, and the juice press from the pulp of the fruit was analyzed. As a result of the variation test, differences were observed regarding both the fertilization variants and the storage conditions of the fruits on the soluble carbohydrate content (Table 1).

Regarding the comparison of the mean for the fertilization variants, it can be noticed that compared to the control (variant a1 - conventional technology), in both the fertilized variant with calcium nitrate and the borocal fertilized variant were obtained lower values of soluble carbohydrates. Among the fertilized variants 2nd and 3rd the best results were obtained in the variant 3rd, the difference between the two fertilization types being very distinctly significant (Table 2).

As concerns the comparison of the three genotypes from the research, it can be concluded that the best results from the point of view of the carbohydrate content, were obtained in the Odem variety followed by Arashan and Karistan. The differences between the three varieties are statistically significant (Table 3).

Regarding the influence of storage conditions on soluble carbohydrate content, it can be noticed that the differences between them are statistically significant. From data analysis it can be seen that the level of soluble carbohydrates is dependent on the temperature at which the fruits were exposed, there was a tendency to increase the level of soluble carbohydrates is directly proportional with the temperature.

Table 1

Comparing averages for fertilization variants

Variants	Average		%	Difference	Significance
2^{nd}- 1	8.3778	9.1222	91.84	-0.7444	ooo
3^{rd}- 1	9.1133	9.1222	99.90	-0.0089	o
3^{rd}- 2^{nd}	9.1133	8.3778	108.78	0.7356	***
	DL 5%	**DL 1%**	**DL 0.1%**		
	0.065	0.099	0.159		

Table 2

Comparison of the averages for the three studied genotypes

Variants	Average		%	Difference	Significance
b2-b1	7.9667	9.0689	87.85	-1.1022	-
b3-b1	9.5778	9.0689	105.61	0.5089	ooo
b3-b2	9.5778	7.9667	120.22	1.6111	ooo
	DL 5%	**DL 1%**	**DL 0.1%**		
	0.201	0.277	0.381		

Table 3

Comparison of the averages for the three studied genotypes

Variants	Average		%	Difference	Significance
c2-c1	9.789	8.969	109.14	0.820	***
c3-c1	7.856	8.969	87.59	-1.113	ooo
c3-c2	7.856	9.789	80.25	-1.933	ooo
	DL 5%	**DL 1%**	**DL 0.1%**		
	0.107	0.145	0.194		

Thereby, after fruit storage at 25 °C for 14 days was found a level of 9.78% soluble carbohydrates, while the fruits stored in the standard storage conditions (17 °C) had a carbohydrate level of 8.69%; fruits storage under low temperature conditions induced a lower percent of soluble carbohydrates of only 7.96%. The results obtained can be explained due to the biochemical changes that occur in the fruit pulp. Due to the post-maturation processes, the starch present in the fruits is metabolized in glucose, this process being influenced by the temperature. Gil et al. (2006) studied the influences of watermelon storage on the nutritional content and quality indices on whole fruit and fresh-cut stored at 5 ^{o}C up to 9 days. They found that after 9 days, fruits were marketable and after 6 days, losses in vitamin C were $\leq$ 5%. No losses in phenolics or carotenoids were found after 6 days at 5 ^{o}C. Kyriacou and Soteriou (2015) found in their research that soluble solids content and soluble carbohydrates declined after harvest while sucrose continued to increase; flesh firmness also decreased during storage and quality can be compromised in less than 14 days.

The structure of product is defined by the size or type of cells components and their placement in the tissues (Ahmed, 1996). The texture of the same product is given by the joining type (association) of the different tissues that develop the plant organs (Agauayo et al., 2017). Structure-textural firmness or firmness degree results from the interdependence between structure and texture and indicates the resistance of fruits against exerting external pressure (Şumălan, 2004). Firmness is due to the characteristics of the structure, texture, chemical composition, etc., which are influenced by the agro-climatic conditions as well as the degree of maturation (Radulovic´ et al., 2007).

Based on analysis of variance, differences were found regarding both the fertilization variants and the conditions of fruit storage. In some species the firmness of tissues is a guarantee of maintaining the quality during handling, transport, marketing or processing (Maynard, 2001; Hour et al., 1980). The firmness of fruits is determined by the enzymatic transformation of insoluble protopectin from tissues, which has a high degree of polymerization and numerous molecular-chain links (Brown and Summers, 1985). Tissues softening are due to a whole series of hydrolysis and depolymerization reactions which are special for each species and variety (Chilsom and Picha, 1986). During maturation in some species there is an increase in intracellular spaces which contributes to the increase of the loosen degree in tissues (Fish and Davis, 2003). Structural-textural firmness serves to determine the time and the method of harvesting, packaging, transport, to the shelf time and to the method of industrial processing (Ahmad and Siddiqui, 2016; Ahmad et el., 2014).

Regarding the comparison of the average for the fertilization variants, it can be seen (Table 4), that compared to the control (variant a1 - conventional technology) the variant fertilized with calcium nitrate recorded lower values, very distinctively significant, while the variant fertilized with borocal has obtained higher, distinctly significant values for fruit firmness. Among fertilized variants a1 and a3 the best results were obtained in variant a3, the difference between the two types of fertilization being distinctly significant.

Concerning the influence of genotype on fruit fertility, it can be observed that the differences between them are statistically assured (Table 5). From data analysis, it can be observed that a lower fertility was registered in Arashan genotype compared to both Karistan and Odem. The highest firmness occurred in the Karistan genotype.

Comparing of the three types of storage, it can be seen (Table 6), that the best results for the fruits firmness were obtained when storage was in low temperature conditions at 2 °C, while a lower firmness can be observed in case of storage under high temperature conditions (25 °C). From data analysis it can be concluded that between the content of soluble carbohydrates in the fruit pulp and firmness there is an inversely proportional relationship. In their research of fresh-cut watermelon, Ebadi et al. (2013) found that throughout storage, firmness decreased while weight loss and titratable acidity increased; they recommended 4-5 °C, for watermelon storage. According to Nascimento Nunes (2008), flesh firmness decreased by 11 to 25% after 7 -13 storage days at 13 ^{o}C, but no changes were observed if the fruits are kept at 18 ^{o}C for 9 days. Radulovic´ et al. (2007) observed in their research concerning watermelon storage at 20°C for 7 and 14 days, that pH changes due to enzymatic activity. They also found that there is highly significant correlation between fruit weight loss and decline of reducible sugars (r = 0.96, P = 0.01%); after seven days storage reducible sugars decline with 42.5%; after the first week of storage was lost the greatest part of sweetness; in the second week of storage decline physical properties like flesh firmness.

Table 4

Comparison of the average for the firmness of the fruit between fertilization variants

Variants	Average		%	Difference	Significance
a2-a1	1.3711	1.4022	97.78	-0.0311	ooo
a3-a1	1.4900	1.4022	106.26	0.0878	**
a3-a2	1.4900	1.3711	108.67	0.1189	**
	DL 5%	**DL 1%**	**DL 0.1%**		
	0.051	0.077	0.123		

Table 5

Comparison of the average for genotypes concerning the fruits fertility

Variants	Average		%	Difference	Significance
b2-b1	1.6341	1.4307	114.21	0.2033	***
b3-b1	1.1985	1.4307	83.77	-0.2322	ooo
b3-b2	1.1985	1.6341	73.35	-0.4356	ooo
	DL 5%	**DL 1%**	**DL 0.1%**		
	0.026	0.035	0.049		

Table 6

Comparison of the average for storage conditions concerning the fruits firmness

Variants	Average		%	Difference	Significance
c2-c1	1.191	1.298	91.75	-0.107	ooo
c3-c1	1.779	1.298	137.04	0.481	***
c3-c2	1.779	1.191	149.36	0.588	***
	DL 5%	**DL 1%**	**DL 0.1%**		
	0.026	0.035	0.046		

The acidity of the fruit juice in the conventional fertilization variant (V1), can be noticed the differences between the genotypes studied and between the different variants of storage (Figure 1).

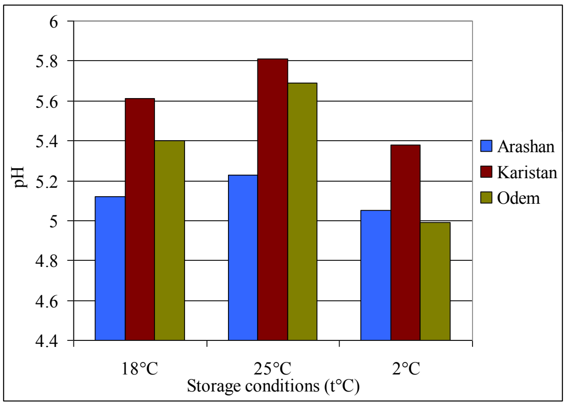


Fig. 1. Influence of storage conditions on the pH of fruits juice - variant V1

Thereby, there is a trend to increase the acidity of the fruit juice in close connection with the decrease of the fruit storage temperature. Regarding the behaviour of the studied genotypes, it can be noticed that the Odem hybrid showed a higher acidity of the fruit juice while the Karistan hybrid recorded higher values for this quality trait. Comparing the watermelon fruits stored and not stored, Perkins-Veazie and Collins (2006), found that watermelons stored at 21°C had increased croma, carotenoid and pH content compared with fresh watermelon, while at 13 °C little changes were observed; they concluded that carotenoids in watermelon fruits are influenced by storage and temperature.

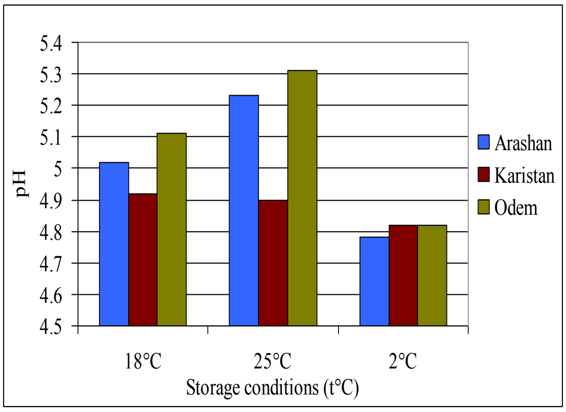


Fig. 2. Influence of storage conditions on the pH of fruits juice - variant V2

In V2 variant (fertilized with calcium nitrate) for the trait "fruit juice acidity", there can be noticed differences between the genotypes from the study and between the different storage variants (Figure 2). Thereby, there is a trend to increase the acidity of the fruit juice in close connection with the decrease of the fruit storage temperature. Regarding the behaviour type of the studied genotypes, it can be noticed that the Karistan hybrid showed a higher acidity of the fruit juice while the Odem hybrid recorded higher values for this quality trait. It is found that the variant with calcium nitrate fertilization has another genotyping hierarchy compared to the V1 control variant where conventional technology has been applied.

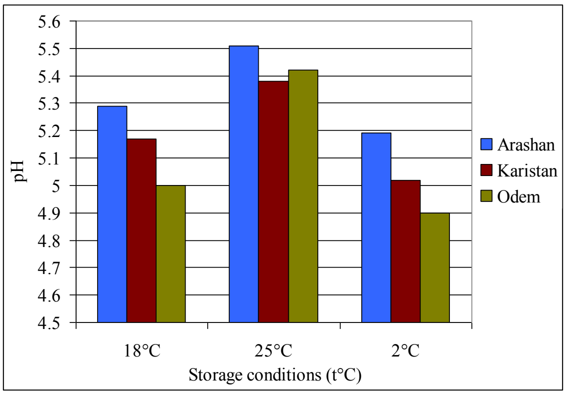


Fig.3. Influence of storage conditions on the pH of fruit juice - variant V3

Studding the physical-chemical properties in watermelon fresh juice, Ishita and Athmaselvi (2017), found a pH of 5.2±0.048, total soluble solids of 7.8±0.047 °Brix, acidity of 1.85%±0.009, and vitamin C content of 13.83±0.00041 mg/100 ml.

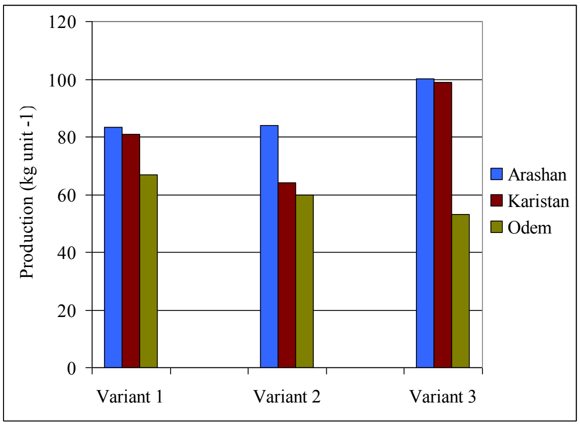
Regarding the acidity of the fruit juice in the conventional fertilization variant (V3) can be noticed the differences between the genotypes from the study and between the different storage variants (Figure 3). This maintains the trend to increase the acidity of the fruit juice in close connection with the decrease of the fruits storage temperature. Regarding the behaviour of the studied genotypes, it can be noticed that the Odem hybrid showed a higher acidity of the fruit juice while the Karistan hybrid recorded higher values for this quality trait.

Concerning the achievement of production in all five harvest date, there can be noticed differences between the genotypes and between the applied fertilization variants (Figure 4 a,b,c,d). Thereby, in the first harvesting time (a), the most productive genotype was the Arashan hybrid with an average production of 83.3 kg unit^{-1}, while lower production results were recorded for the Odem hybrid (66.9 kg unit^{-1}).

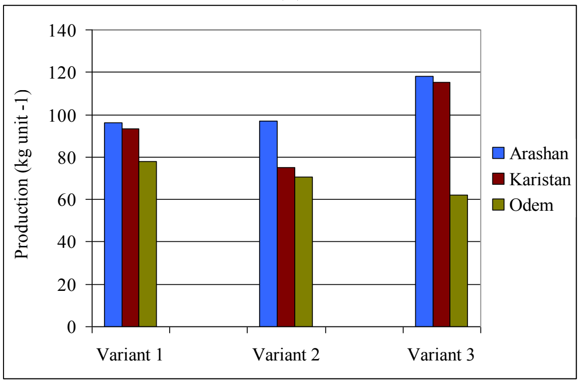
It can be noticed the fertilization influence in V3 variant (borocal fertilized) with increased yields, while in the variant V2 (supplemented with nitro lime) was obtained lower production compared to control variant (conventional technology). For the second harvest date, the same trend of productivity is maintained, the Arashan hybrid recording the highest values of production.

Paltinieri (2015) mentions in his training manual for food technology that watermelon can be kept 2 up to 3 weeks at 10 to 15 ° C temperature and 90% relative

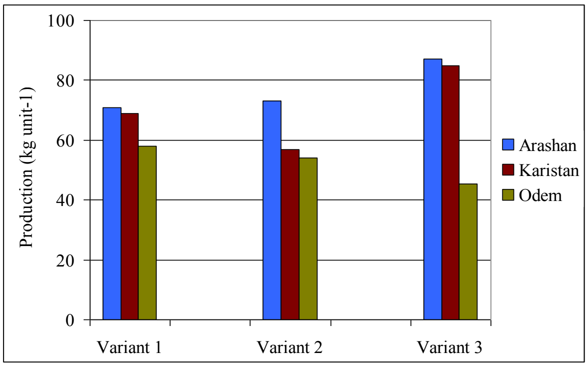
humidity, after harvest; longer storage decline the colour and crispness of fruits.
El-Sayed and Bahnasawy (2016), study the mechanical and physical traits of watermelon fruits influenced by temperature (15 and 30°C) and they found out that fruits weight decline with 11.86 to 13.28% compared with the weight at harvest at 30 ^{o}C and with 4.8 to 6.83% at 15 ^{o}C after 65 storage days.



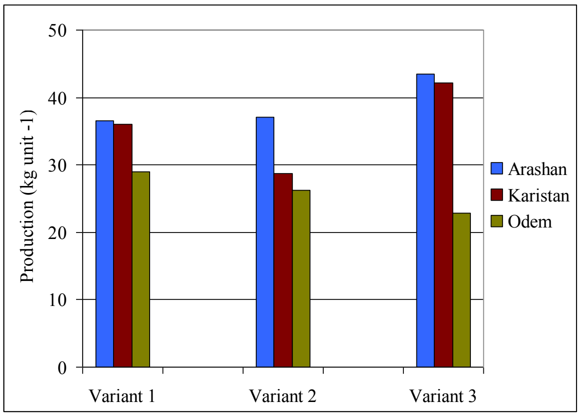
(a)



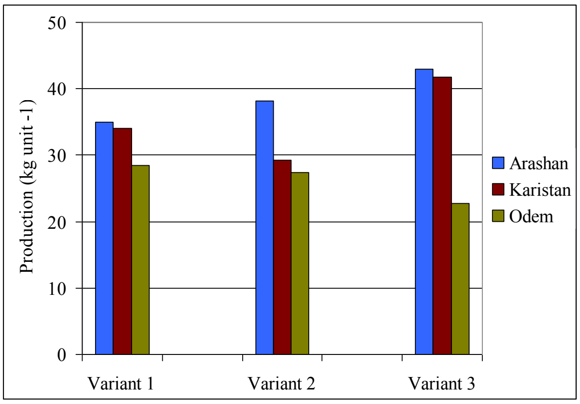
(b)



(c)



(d)



(e)

Fig. 4. Distribution of yields at harvest date for the 3 studied genotypes (kg experimental lot^{-1} - 450m^{2}); (a) - the date of harvest Ist; (b) - the second harvest date; (c) - the third harvest date; (d) - the fourth harvest date; (e) - the V harvest date

Conclusions

Regarding the carbohydrates in the fertilization variants, it can be noticed that higher carbohydrates content was recorded in the conventional technology variant compared to the variants supplemented with lime (a2 and a3). The genotype with the highest percent of soluble carbohydrates, can be noticed the Odem hybrid; regarding the influence of storage conditions, it can be concluded that after 12 days of storage, temperature is a crucial factor in the biochemical changes of the sugar content; the highest percent of soluble carbohydrates was recorded at the highest temperature.
As concerns the firmness of the fruits, can be noticed that the influences of the storage conditions and the level of soluble carbohydrates are inversely correlated. The fertilization variant that induced a higher firmness was supplemented with boracal, and was followed by the variant fertilized with nitro-lime and by control variant. The genotype that showed superior firmness was Karistan. With regard to the acidity of the fruit juice it can be noticed that the temperature has a crucial influence, because the acidity increase as the

temperature decreased. In the Arashan hybrid the juice acidity was lowest. The fertilization variant that induced the highest yields was V3 (supplemented with borocal) followed by variant 2 (supplemented with nitro-lime), compared to the conventional variant. The most productive genotype was Arashan hybrid followed by Karistan and Odem.

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