Biochemical composition of apple fruits when treated with growth-stimulating agrochemicals

Lyosik Ayba[1], *Viktoriya* Kunina[2], *Nataliija* Platonova[2], *Georgiy* Pantiya[1], *Dima* Sabekiya[1], and *Oksana* Belous[2*]

[1]Agricultural institute, Science Academy of Abkhazia, 22, Gulia str., Sukhum, Republic of Abkhazia
[2]Federal Research Centre the Subtropical Scientific Centre of the Russian Academy of Sciences, 28/2, Fabriciusa str., Sochi, 354002, Russia

Abstract. The objects of research were the fruits of apple trees of the Golden Reinders variety (rootstock M 9) grown on the basis of experimental plantings Agricultural institute, Science Academy of Abkhazia. Complex organic fertilizers have been selected as agrochemicals Antistress Chelate and Chelate Filling. The research is aimed at finding new, highly efficient and environmentally friendly agrochemicals, and also determines the development of technology for their application. It was found that the Golden Reinders variety in the humid subtropical zone accumulates from 10.6% (under control) to 11.6% (with non-root treatments) of sugars. Treatments with agrochemicals affected the main quantitative patterns in the content of mono- and disaccharides in apple fruits. The amount of fructose ranges from 6.63 g/100 g at the control to 7.52 g/100 g during treatments; glucose accumulates on average only 1.1-1.2 g/100 g, depending on the variant. Sucrose in fruits is 2.4-2.6 times more than glucose, which characterizes the ripening processes in fruits. Agrochemicals treatments have an ambiguous effect on the accumulation of organic acids. So, if there is a significant increase in malic, citric and tartaric acid during processing, then the content of lactic, succinic, oxalic and acetic acid drops. The sugar-acid index averages 13.6 units, there is a slightly acidic taste.

1 Introduction

The apple tree is the oldest, still popular and economically important agricultural crop in the Republic of Abkhazia. Only from 2011 to 2013, 162.16 hectares of new orchards were laid in the republic, mainly with varieties of American selection [1]. Moreover, the laying of gardens was a state social program aimed at raising rural settlements, providing jobs and securing the population in the village [1].

The genus apple tree (*Malus* Mill.) belongs to the Rosaceae family (Rosaceae), the Apple tree tribe (Maleae) of the Plum subfamily (Prunoideae) [2]. Since 2013 (according to The Plant List database) there are 62 species in the genus Malus [3]. The most agricultural

* Corresponding author: oksana191962@mail.ru

and nutritional importance is the type of domestic apple tree (*Malus domestica* Borkh.), to which all cultivated varieties belong.

Despite the fact that the apple tree is quite plastic and stable in many growing conditions, the cultivation of culture in the Republic of Abkhazia faces great problems. The conditions of the temperate zone are the most optimal for apple trees, but due to the great popularity of fruits, it is also grown in humid subtropics (both on the territory of the Krasnodar region of Russia and on the territory of the Republic of Abkhazia). However, the peculiarities of humid subtropics cause a number of factors constraining the cultivation of apple trees in the region, connected both with the spread of diseases and pests [1, 4] and the influence of unfavorable conditions of abiotic nature, in particular, hydrothermal stressors [1, 5]. Among the factors constraining the cultivation of apple trees in the subtropics of the Republic of Abkhazia can be attributed high humidity, on average in the Republic of Abkhazia – 79 % depending on the period of the year [6], as well as uneven precipitation with an annual dry period (up to two months) against the background of high air temperatures [5, 6].

Agrochemicals can be used to optimize the condition of plants and control pests and diseases in plantings, but a specific feature of the subtropics of the Republic of Abkhazia is due to the fact that the basis of the republic is recreational facilities – sanatorium complexes. In this regard, there is a question of choosing agrochemicals, the use of which would be possible in a recreational zone. This is what justifies the relevance of research aimed at finding new, highly efficient and environmentally friendly agrochemicals, as well as determines the development of technology for their application.

2 Materials and methods

The objects of research were the fruits of apple trees of the Golden Reinders variety (rootstock M 9) grown on the basis of experimental plantings Agricultural institute, Science Academy of Abkhazia (Sukhumi district Republic of Abkhazia). Golden Reinders is a clone of the variety Golden Delicious, the average yield of plants is 789.5 c/ha [7]; the variety is characterized by average resistance to drought and high temperatures, in the subtropical conditions of the Republic of Abkhazia, the fruits ripen from the end of August to the second decade of September, depending on weather conditions [1, 4]. Variety Golden Reinders included in the State Register for the North Caucasus (6) region [7].

Two drugs were selected as agrochemicals: Antistress Chelate and Chelate Filling (LLC "Ecoharvest", Russia). Both agrochemicals are a complex organic fertilizer, the active substance of which are humic, fulvo - and amino acids, trace elements and microbial cultures. At the same time, Antistress Chelate refers to antistressants and immunomodulators, and Chelate Filling is used to improve the quality of plant raw materials. Previously, the agrochemical Chelate Filling was used only in the cultivation of cereals and we were faced with the question of the possibility of its use on fruit crops to improve quality indicators.

Treatment with agrochemicals was carried out against the background of the recommended doses of mineral fertilizers: in the third decade of February, nitroammophos was applied at the rate of 350-600 g /tree; in addition, ammonium nitrate was embedded in the soil in the first decade of May (400 g/tree) and in the first decade of June (250 g/tree) [1]. Phosphorus and potassium fertilizers in the form of superphosphate and potassium chloride were introduced in the third decade of February every two years.

Treatments with agrochemicals Antistress Chelate were carried out in a non-root way in June, before the onset of a stressful period, Chelate Filling was applied by non-root treatments in August before fruit filling.

The biochemical composition of fruits was studied at the stage of consumer maturity according to the following indicators: mono- and disaccharides, organic acids. The analysis of the content of these components was carried out three times on the basis of the Department of Plant Physiology and Biochemistry FRC SSC RAS (Federal Research Centre "Subtropical Scientific Centre of the Russian Academy of Sciences") (Sochi, Russia), using a capillary electrophoresis system "Kapel 105M" (LCC "Lumex Marketing", Russia).

3 Results and Discussion

Our observations have shown that in addition to biotic problems, the apple tree in the republic is affected by abiotic factors, which leads not only to crop loss, but also to deterioration of quality characteristics. In turn, uncontrolled application of agrochemicals can also lead to poor-quality fruits. Thus, it is known that increased doses of nitrogen delay the ripening of fruits, while potash and phosphorus fertilizers accelerate the ripening processes. In this connection, when conducting experiments on the use of non-root treatments with organic fertilizers, we determined the biochemical composition of apple fruits of experimental variants.

According to a number of sources, it follows that the average fructose content in ripe apple fruits ranges from 5.9-12.6 g, glucose – 2.43-5.35 g and sucrose – 1.90-4.70 g [8-11]. At the same time, the authors note that the fructose content in seed crops (which also includes apple trees) is 2-3 times higher than the glucose content; the amount of sucrose is most often equal to the glucose content, but as apples mature, the glucose content decreases [12-14].

At the moment, the available assortment of apples in the temperate zone does not meet the consumer's requests for the accumulation of sugars in fruits. Their number mainly ranges from 8.5-10.2 % [14-16]. In this regard, the same assortment is of interest, but grown in the subtropical region of both Russia and the Republic of Abkhazia. In this zone, varieties accumulate a sufficiently high amount of sugars as a result of more sunny days. Thus, the Golden Reinders variety in the humid subtropical zone accumulates from 10.6 % (under control) to 11.6 % (with non-root treatments) of sugars. In addition, our studies have shown that agrochemicals treatments have affected the main quantitative patterns in the content of mono- and disaccharides in apple fruits.

In particular, the amount of fructose is 5-7 times higher than the glucose content: with non-root spraying, there is a significant increase in the fructose content in fruits, its amount ranges from 6.63 g / 100 g at the control to 7.52 g / 100 g during treatments (Figure 1). At the same time, glucose accumulates on average only 1.1-1.2 g / 100 g, depending on the variant. Considering that the sweetest form of sugars is fructose, an increase in its amount is a positive fact. Sucrose in fruits is 2.4-2.6 times more than glucose, which characterizes the ripening processes in fruits.

As it is known, the taste characteristics of fruits are determined not only by the sugar content, but also by organic acids, and most importantly, the ratio of sugars to acids (the so-called sugar-acid coefficient). The content of organic acids in fruits varies depending on climatic conditions, varietal characteristics of plants, agrotechnical approaches, and differences are observed not only in quantitative characteristics, but also in qualitative composition. Thus, organic acids that determine the nutritional value of apples are mainly represented by malic, citric, succinic (6-7 %) acids [17, 18]. According to a number of authors, their number ranges from 6-7 % (succinic acid) to 17 % (citric acid). Apple is predominant and its quantity is estimated at 72 % [19-21].

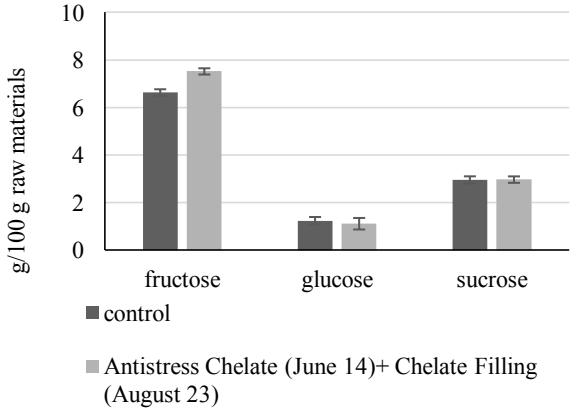

Fig. 1. The content of mono- and disaccharides in apple fruits when treated with agrochemicals.

At the same time, in addition to the listed acids, oxalic, succinic, acetic and lactic acids were determined by us in the composition of the fruits of the prototypes. In addition, our studies have shown that agrochemicals treatments have an ambiguous effect on the accumulation of organic acids. So, if there is a significant increase in malic, citric and tartaric acid during processing, then the content of lactic, succinic, oxalic and acetic acid drops. Quantitatively, the accumulation of malic acid varies from 6.6 at the control to 7.2 g / kg during processing (which is 82-84 %, this is slightly more than the average values); the content of citric acid is only 7 % (which is significantly lower than the average values) and in fruits its amount ranges from 568.7 mg / kg (control) to 651.7 mg / kg (during processing). We have determined lactic acid as the third quantitative acid in the experimental apple fruits, an average of 4 % is passed on it – its content drops during non-root treatments and varies from 262.8 mg / kg (fertilizer) to 347.1 mg / kg (control). The accumulation of tartaric acid, succinic and acetic acid, depending on the variant, reaches an average of 118.0 mg/kg (acetic) to 135.8-138.1 mg/kg (tartaric and succinic acids).

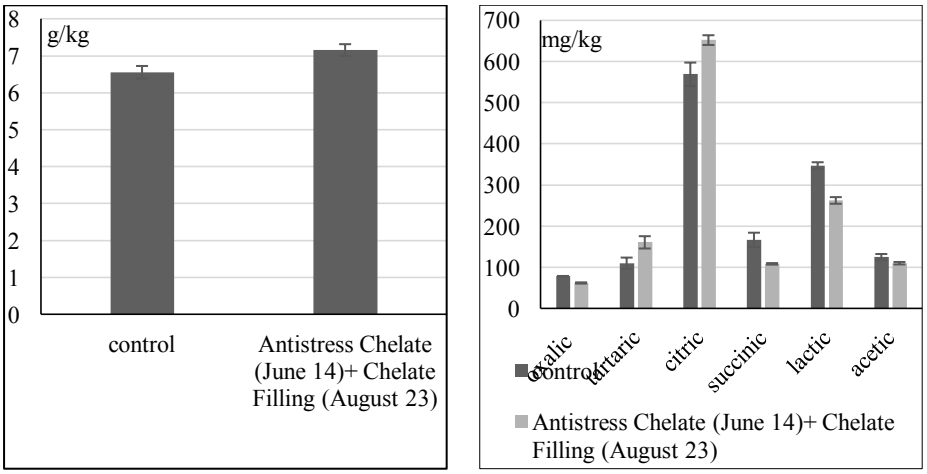

Fig. 2. The content of organic acids in apple fruits when treated with agrochemicals: a) the content of malic acid; b) the content of other organic acids.

It is known that mono- and disaccharides are characterized by different sweetness, i.e., they have a different threshold of feeling sweetness [22]. We calculated the taste advantages of the prototypes, taking into account the different sweetness of the sugars included in their composition. As a result, this value was 2011.8 units at the control, and 2196.3 units during processing, which is explained by the large accumulation of fructose under the influence of agrochemicals treatments. In addition, an increase in the amount of the main non-volatile organic acids, which are biologically active substances (malic, citric and tartaric) during non-root treatments with agrochemicals is a significant fact. Organic acids are not only representatives of biologically active substances in fruits, but also are important metabolites of metabolic processes, which, among other things, underlie anti-stress reactions. The change in their accumulation occurs in response to unfavourable environmental conditions, which reduces the taste characteristics of fruits. To assess the saturation of the taste of fruits, it is not so much the amount of sugars or organic acids that is of interest, but their ratio. Thus, it is known that the most comfortable combination of sugar and acid in organoleptic terms is observed with a sugar-acid index equal to 16.0 units [23]. If the ratio of sugar to acid is 25-30, the sour taste is practically not manifested, the fruits feel too sweet. With a sugar-acid index of 10-20 units, the taste is estimated as a slightly acidic taste, which is typical for most apple varieties [24-26]. We determined the sugar-acid index of fruits in our experience and showed that its value is on average 13.6 units, i.e., there is a slightly acidic taste. There were no differences in the value of the sugar-acid index of fruits in the control and in plants treated with agrochemicals.

4 Conclusion

Thus, it can be said that treatment with agrochemicals Antistress Chelate and Chelate Filling enhance the stress resistance of plants, improve the taste characteristics and nutritional value of apple fruits. The ability to control the accumulation of sugars and organic acids in fruits by introducing agrochemicals is of practical interest.

Acknowledgement

The study was funded by the state assignment research of FRC SSC RAS FGRW-2022-0012, project No.121120700353-5

References

1. G.G. Pantoja, *The effectiveness of the use of immunoinducers in apple tree protection technology in the Republic of Abkhazia*, Ph.D. thesis, Sochi (2021)
2. V.L. Vitkovskij, Fruit plants of the world (Publishing House "Lan", St. Petersburg, 2003)
3. Malus. The Plant List. Version 1.1. Date of application: 04.04.2023
4. G.G. Pantija, E.B. Yanushevskaya, E.V. Mikhailova, and N. N. Karpun, Evaluation of the effectiveness of immune inductors in increasing the nonspecific resistance of apple trees to scab, Plant protection and quarantine, **7**, 33 (2019)
5. N.V. Pshenichny, and O.G. Belous, *Assessment of the adaptive potential of columnar apple varieties in the conditions of the Black Sea zone of the central gardening subzone*, Subtropical and ornamental horticulture, **46**, **1**, 45 (2012)
6. S.A. Sabekija, *Economic and biological assessment of mandarin in the Republic of Abkhazia,* Ph.D. thesis, Sochi (2016)

7. Golden Reinders, State Register of Breeding Achievements, https://reestr.gossortrf.ru/sorts/8058937/
8. FitAudit, https://fitaudit.ru/categories/fvs/fructose
9. M.V. Bakhanova, T.P. Antsupova, *Chemical composition of the fruit of the berry apple tree (Malus baccata (L.) Borkh.) in the conditions of Buryatia*, Proceedings of the Samara Scientific Center of the Russian Academy of Sciences, **19**, **2-3**, 416 (2017)
10. Ya.S. Nesterov, *Geographical variability of apple varieties*, Byul. All-Union Research Institute of Plant Growing named after N. I. Vavilov, **126**, 3 (1982)
11. M.A. Makarkina, T.V. Yanchuk, A.R. Pavel, S. E. Sokolova, *Biochemical assessment of promising forms of apple and currant*, Bulletin of Agrarian Science, **57**, **6**, 71 (2015)
12. E.N. Sedov, M.A. Makarkina, N.S. Levgerova, Biochemical and technological characteristics of the fruits of the apple tree gene pool (VNIISPK, Orel, 2007)
13. Komal Sindhi, Jaymit Pandya, Sudhir Vegad, *Quality evaluation of apple fruit: A Survey*, International Journal of Computer Applications, **136**, **1**, 32 (2016)
14. T. Prichko, E. Ulyanovskaya, N. Droficheva, *Evaluation of biochemical indicators of apple fruits quality for the complex selection of the valuable source material for breeding*, BIO Web Conf., **25**, 02019 (2020)
15. E. Bazba, O. Belous, *Comparative analysis of apple fruits with a high content of basic chemical substances for the selection of promising assortment* in Annual Congress on Plant Science & Biosecurity (ACPB-2018), Valencia, Spain (2018)
16. O. Belous, E. Bazba, and A. Kochurina, *Biochemical composition of Abkhazian fruit apple* in Food Hygiene and Technology - 46th Lenfeld´s and Hökl´s Days, Brno, Czech Republic (2016)
17. O.S. Rudenko, N.B. Kondratiev, M.V. Osipov, I.A. Belova, M.A. Lavrukhin, *Assessment of the chemical composition of fruit raw materials by the content of organic acids and macronutrients*, Vestnik VGUIT, **82**, **2**, 146 (2020)
18. S. Sha, J. Li, J. Wu, and S. Zhang, Characteristics of organic acids in the fruit of different pear species, African Journal of Agricultural Research, **6**, **10**, 2403 (2011)
19. O.V. Trineeva, M.A. Rudaya, Comprehensive study of the profile of free organic acids of buckthorn buckthorn fruits (*Hippophae rhamnoides* L.) of various varieties, Chemistry of plant raw materials, **4**, 231 (2021)
20. Yu.G. Skripnikov, Technology of fruit and berry processing (Urozhaj, Kiev, 1991)
21. L.V. Metlitsky, Fundamentals of biochemistry of fruits and vegetables (Ekonomika, Moscow, 1976)
22. A.V. Verzilin, Yu.V. Trunov, Cultivation of apple fruits with a high content of biologically active substances *(*Michgau, Michurinsk, 2004)
23. Masoud Ahmadi-Afzadi, Genetic and biochemical properties of apples that affect storability and nutritional value (Swedish University of Agricultural Sciences, 2021)
24. E.G. Bazba, O.G. Belous, A.P. Kachurina, *Biochemical characteristics of apple varieties in the conditions of the Republic of Abkhazia*, Subtropical and ornamental horticulture, **61**, 129 (2017)
25. O.G. Belous, E.G. Bazba, *Chemical analysis of the fruits of apple hybrids for the selection of a promising assortment in the Republic of Abkhazia*, Pomiculture and small fruits culture in Russia, **53,** 47 (2018)
26. I. Tahir, *Control of pre- and postharvest factors to improve apple quality and storability*, Ph.D. thesis, Sweden (2006)