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Biochemical composition of dwarf mandarin cv. 'Miagava-Vase' in the humid subtropics of Russia

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Abstract The influence of growth regulators and biochemical composition of dwarf mandarin fruits was investigsated. It is shown that heavier fruits (44.8-48.2 g at 41.3 g in the control) are formed during treatment with siliplant, nanoelicitor and zerbra agro due to the formation of a thicker peel (20.1-20.9%), which is associated with the protective mechanism of these drugs which thicker peel is a mechanical protection against pathogens and phytoparasites. Siliplatin treatments provided a higher juice output about 54.5% compared to other growth regulators. Treatments with obstactin and silver agro significantly increased the fructose content in fruits (17.53-16.98 g / kg). The nanoelicitor variant has significantly higher sugar content (107.49 g /kg) due to the content is increased (73.12 g/kg). The use of growth regulators leaded to decrease in ascorbic acid (AA) to 30.61 mg / 100 g, which was shown to be an undesirable factor. The most significantly decreased in ascorbic acid (LSD = 8.27) was noted in variants with obstactin and siliplant treatments. Taking into account, the influence of growth regulators on plant resistance are increased AA synthesis under stress and decreased in ascorbic acid is associated with an improvement in the functional state of tangerine under the influence of non-root treatments. With the introduction of growth regulators, there was significantly increased in the amount of polyphenols (up to 9.33 mg /g at 7.72 mg /g in the control), especially on variants with treatments with obstactin (7.53 mg /g), siliplant (7.39 mg /g) and zerebra agro (7.33 mg/g). Treatments with growth regulators leaded to a significant increase in the Rutin in mandarin fruits (from 7.39 to 7.58 mg /g). The highest values of vitamin P were noted in the variant with obstactin and nanoelicitor treatment (7.53-7.58 mg/g at 6.68 mg/g). Nanoelicitor treatments accelerated fruit ripening, which represented to consumer value and economic benefits of growing crops for the resort town/area.

Keywords: Mandarin, Growth regulators, Quality, Fruits, Vitamins, Phenolic components

Introduction

Citrus fruit is one of the most important fruits all over the world, due to

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health-related elements and valuable components which involves vitamins C, carotenoids, flavonoids, pectin, Calcium, Potassium etc. In the humid subtropics of Russia, citrus trees are grown only in the Krasnodar region, but this is due to great difficulties to the geographical location and the harsh climatic conditions inherent in this zone (Ryndin and Kulyan, 2016; Kulyan, 2013). In addition, varietal characteristics, maturation periods and stressful growing conditions affect the biochemical composition of fruits. It is known to be possible to reduce the impact of adverse factors on plants by using growth regulators. Plant growth regulators are physiologically active substances that increase productivity, product quality, improve fruit setting and reduce ovary fall, etc. In addition, these substances affect the drought resistance and frost resistance of plants, increase nonspecific immunity and improve the quality of fruits. The aim was to study the influence of various growth regulators on the qualitative characteristics of mandarin fruits.

Materials and methods

Tested varirties

Varieties are dwarf tangerine ‘Miagava-Vase’ (*Citrus reticulata* var. *unshiu* Tan.), the *Poncirus trifoliata* (L.) Raf. are served as rootstock. Mandarins are grown in 1986 at plantation Subtropical Scientific Centre, Sochi, Russia. The experimental scheme included three options as exogenous growth-regulators: obstaktin (5 ml/l water); nanoelicitor (5 ml/l water), zerebra agro (5 ml/l water), and siliplant (5 ml/l water). The consumption rate of growth regulators is 0.4 l/ha, and the consumption of the working solution is 1000 l/ha. The non-treated control was done by spraying with water.

Obstaktin is phytoregulator for plant growth which related to auxin. Active substance is a potassium salt of 1-naphthylacetic acid. It is used as a plant growth regulator, mainly for spraying the apple trees to prevent premature fruit fall and to delay flowering (when protecting from frost). Obstaktin is developed as a and registered as phytoregulator which produced by Fertico d.o.o., Serbia.

Siliplant is a silicon-containing universal fertilizer. Siliplant effectively replenishes the removal of silicon from the soil, stimulates the development of the root and aboveground parts, relieves various stresses, and activates photosynthesis. The fertilizer is developed, registered and produced by ANO "NEST M" (Russia).

Nanoelicitor is contructed from active metabolites of *Chaetomium cupreum* CC3003 and nano-chitosan using electron spinning method by Dr.

Kasem Soytong, Thailand which applied to increase the disease immunity. (Udompongsuk *et al.*, 2018; Song *et al.*, 2020a; Song *et al.*, 2020b). Nanoelicitor is registered by BioAgriTech Vietnam, and BioHitech Cambodia namely "Nano-mocabi".

Zerebra agro is a silver-based growth stimulator with fungicidal properties. The regulator is developed and produced on the territory of the Russian Federation using domestic raw materials.

Foliar spraying during the growing season was carried out for tree data at ovary phase, dm ovary = 1.5 cm (late May - beginning June); of fruits dm = 3.0 cm (late June) and before 45-50 days at harvest in September. Experience repeatability were 5-fold randomized. Field experiments were performed in triple repetitions which were conducted in accordance by Sedov (1999). In the field experiment, growth activity was determined accounting for ovaries falling provided by selecting model shoots and counting the number of ovaries/fruits; and accounting for the productivity of trees in the garden (kg / tree) by weight methods.

Laboratory studies were conducted at the the Laboratory of Plant Physiology and Biochemistry (Subtropical Scientific Centre of the Russian Academy of Sciences, Sochi, Russia).

The content of mono-, disaccharides and vitamin C was carried out using the capillary electrophoresis system "Kapel 105-M" (Lumex-marketing, Russia).

The total content of phenolic compounds was determined using the Folin-Chocalteu reagent, using gallic acid as a standard.

Flavonoid compounds with P-vitamin activity (Rutin) were determined by titration in accordance with the method of vitamin analysis (Pochinok, 1976).

The quantitative determination of Rutin is based on its ability to be oxidized by permanganate. Indigo carmine is used as an indicator, which reacts with permanganate after all Rutin is oxidized.

Statistical analysis was done. All chemical analyses were performed in triple repetitions. Statistical processing of experimental data were performed using the ANOVA package in STATGRAPHICS Centurion XV (version 15.1.02, StatPoint Technologies) and MS Excel 2007. Statistical analysis included one-dimensional variance analysis (a method of comparing averages using variance analysis, t-test). The significance of the difference between the mean values at $p < 0.05$ is considered statistically significant. All experiments were performed in six-fold repetitions. Differences between treatments were evaluated using an unpaired t-test. The results of the study are expressed as an arithmetic mean with a standard deviation.

Results

The technological parameters of mandarin fruits are determined. Heavier fruits (44.8-48.2 g with 41.3 g at the control) are formed during treatment with siliplant, nanoelicitor and zerbra agro due to the formation of a thicker peel (20.1-20.9%), which is associated with the protective mechanism of these drugs (thicker peel is a mechanical protection against phytopathogens and phytoparasites). At the same time, siliplant treatments provide a higher juice yield (compared to other growth regulators), which is a positive factor in the influence of this agrochemicals on the quality of fruits (Table 1).

Table 1. Technological parameters of tangerine fruits when treated with growth regulators

Option	Fruit weight, g	Peel weight, %	Juice output, %	SDS*, %
Control	41.3 ±7.72	20.0 ±3.1	52.9 ±2.8	10.3 ±0.5
Obstactin	39.6 ±7.01	19.0 ±0.6	45.9 ±1.0	10.4 ±0.4
Siliplant	45.9 ±8.35	20.9 ±2.1	49.2 ±3.2	9.9 ±0.5
Nanoelicitor	44.8 ±7.99	20.7 ±0.0	54.5 ±0.0	11.0 ±0.7
Zerebra agro	48.2 ±8.65	20.1 ±2.9	49.9 ±2.9	9.9 ±0.5
LSD (p ≤0.05)	*1.15*	*0.59*	*1.21*	*0.97*

*SDS - soluble dry substances

The content of mono-, disaccharides and vitamin C

Results are shown that growth regulators such as obstactin and zerebra agro significantly increased the fructose content in fruits (Figure 1). And in the variant with a nanoelicitor, the sugar content was significantly higher (107.49 g. kg-1) due to the increased sucrose content. The higher sucrose content in fruits is an indicator of their maturity, therefore, it can be explained that the nanoelicitor is not only affected the sweetness of mandarin fruits but also accelerated their maturation.

Our studies are shown that the use of growth regulators leaded to decreased in ascorbic acid, which is an undesirable factor (Figure 2).

Total phenolic content and content of Ruthin

Mandarin, like other citrus fruits, is a source of various biologically active components, such as polyphnols, flavonoids, etc. Polyphenols are biologically active compounds that have such useful properties as anti-inflammatory, anti-carcinogenic activity, antioxidant and anti-allergic effects, etc.

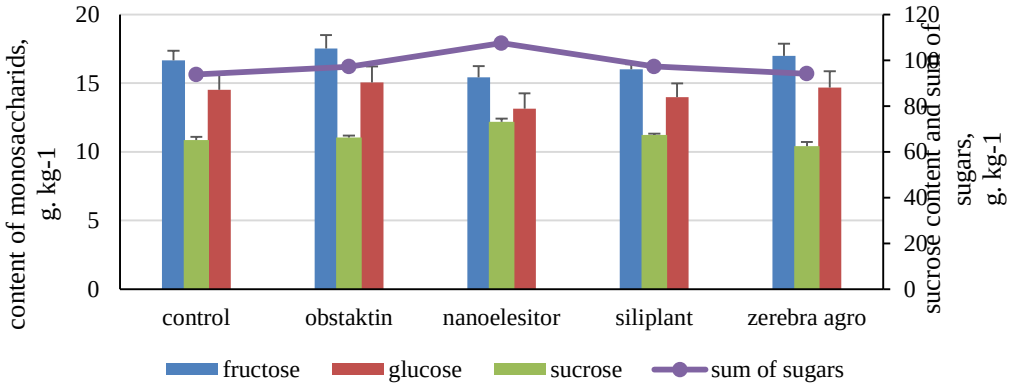

Figure 1. Content of mono-, and disaccharides in fruits during treatment by growth regulators

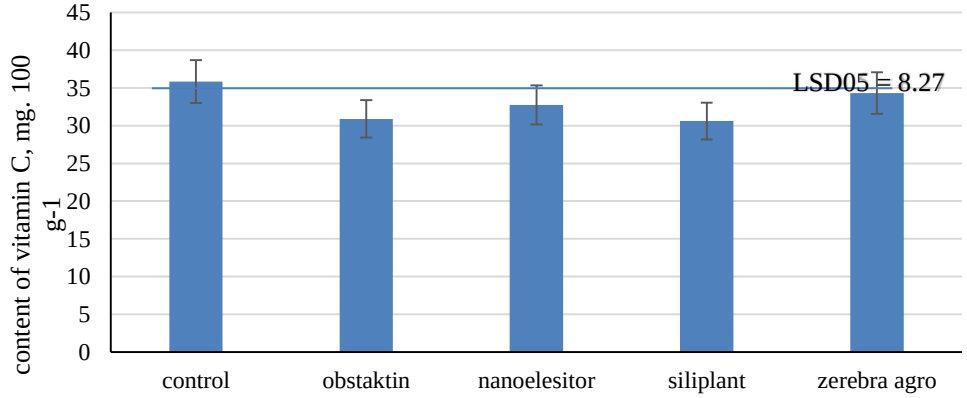

Figure 2. Content of vitamin C in fruits during treatment by growth regulators

Since fresh fruits are of interest to consumers in the resort city of Sochi, Russia. The effect of growth regulators on the content of phenolic components in the pulp of mandarin fruits was investifated. It showed that the introduction of growth regulators found significantly increased in the amount of polyphenols (up to 8.77-9.33 mg/g at 7.72 mg/g on the control), especially on variants with treatments with obstactin, siliplant and zerebra agro (Figure 3).

Further results are shown that all treatments with growth regulators leaded to a significant increase in the Rutin in mandarin fruits (Figure 3). The highest values of vitamin P were noted in the variant with obstactin and nanoelicitor treatment (7.53-7.58 mg/g at 6.68 mg/g).

Thus, the research findings are shown that treatments with growth regulators had a positive effect on the presentation of fruits and their qualitative characteristics. The content of sugars, polyphenols and rutin increases, which

increased the nutritional significance of mandarin fruits grown in humid subtropical conditions of Russia. Nanoelicitor treatment accelerated the ripening of fruits, which is represented to the consumer value and economic benefits of growing crops for the resort town/area.

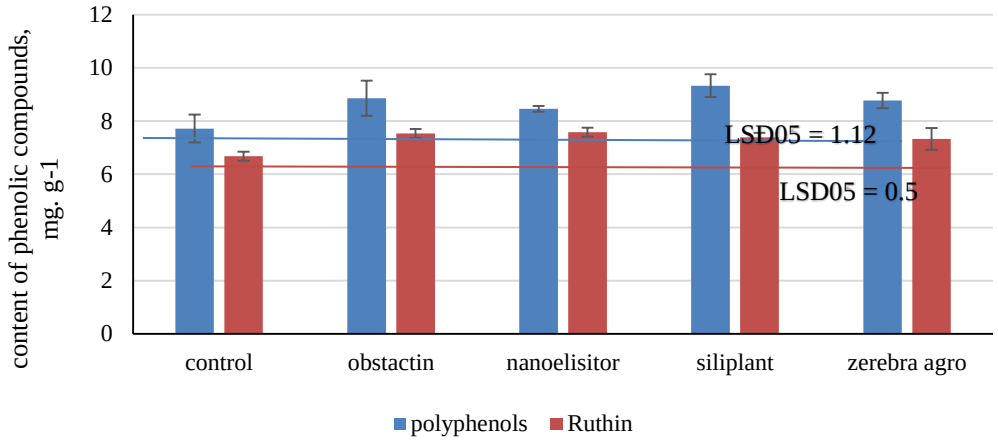

Figure 3. Content of phenolic compounds in fruits during treatment by growth regulators

Discussion

Citrus fruits are known to be a source of ascorbic acid which determines their nutritional significance (Codoñer-Franch and Valls-Bellés, 2010). Ascorbic acid (vitamin C) is a strong antioxidant. The greatest amount of vitamin C was found in oranges, grapefruits and pomelo fruits (on average 50-70 mg/100 g) (Nagy, 1980; Cioroi, 2007; Sanusi *et al.*, 2008; Fatin *et al.*, 2017). There is not much asorbic acid (AA) in mandarin fruits, compared to other citrus fruits – about 26-30 mg / 100 g. Therefore, we studied the effect of growth regulators on the content of vitamin C. However, considering that the increase in AA is usually also associated with the stress state of plants. A response to oxidative stress caused by unfavorable factors (such as heat and high light), with that there is an increase in the amount of ascorbic acid (Tóth *et al.*, 2013; Waszczak *et al.*, 2018; Fenech *et al.*, 2019). Since the growth regulators improve the functional state of dwarf mandarin plants (Belous and Abilphasova, 2019; Belous *et al.*, 2021b), the decrease in AA content in fruits under the action of growth regulators may be due to their stress-protective effect. Moreover, the most significant reduction in ascorbic acid (LSD = 8.27) it was noted on variants with obstactin and siliplant treatment, which in previous studies have shown a strong effect on the resistance of plants to stressors (Belous *et al.*, 2021a; Belous *et al.*, 2021b).

Their increased content in fruits represents their nutritional value (Saini *et al.,* 2019). Citrus peel contains the most phenolic components (from 20 to 30 mg/ g), their amount in the pulp is less (Wang *et al.,* 2008). One of the important components of citrus fruits is Rutin (vitamin P), which has an inhibitory effect on the oxidation of lipoproteins, thereby reducing the risk of atherosclerosis (Sorrenti *et al.,* 2004; Makarova *et al.,* 2010). This is one of the classes of flavonoids that is necessary for the absorption of vitamin C (Tripoli *et al.,* 2007; Başar, 2014).

It is concluded that the growth regulators of the fruits in dwarf mandarin showed that that heavier fruits are occurred during treatments with siliplant, nanoelicitor and zerbra agro with the formation of a thicker peel and associated with the protective mechanism for protection against phytoparasites. Siliplatin treatments provided a higher juice Treatments with obstactin and silver agro increased the fructose content in fruits. Nanoelicitor derived from natural product metabolite of *Chaetomium* sp is shown to be higher sugar content. The decreasing in ascorbic acid was found with obstactin and siliplant treatments. With the introduction of growth regulators, there was significantly increased in the amount of polyphenols in obstactin, siliplant and zerebra agro treatments. All growth regulators treatments leaded to increase Rutin in mandarin fruits. The highest vitamin P was found obstactin and nanoelicitor treatments. Nanoelicitor treatments proved to be accelerated fruit ripening which represented to economic benefits of growing crops.

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