

# Optimization of the adaptive mechanism of subtropical crops under the influence of innovative forms of fertilizers

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**Abstract.** The research is aimed at developing effective ways to regulate the functional state of plants under stress. It is shown that the functional state of tea and mandarin plants is more favorable under the influence of growth regulators (humic and amino acids, metabolites of mold fungi are used as biologically active substances). In the variants with foliar treatments, there is an increase in bound water (up to 54.8-54.9%); activation of assimilant synthesis, more active formation of proline and ascorbic acid in tea leaves. There was an increase in the number of carotenoids (up to 1.78 mg / g) and active synthesis of ascorbic acid in mandarin leaves during stressful periods; the value of the viability index increased (up to 5.19 – 5.33 units) in accordance with the control (4.37 units). The developed specific surface density of the leaf provides greater productivity of mandarin plants. The optimal functional state of the plants led to an increase in the crop productivity of tea leaves (22.88-32.22 c/ha compared to the control-22.04-26.88 c/ha) and mandarin fruits (6.83 kg/tree compared to the control – 3.80 kg / tree). The use of innovative forms of fertilizers and plant growth regulators should become the main element of the technology of cultivation of subtropical crops, optimizing the adaptive potential, regulating the effective productivity of plants and their quality indicators.

## 1 Introduction

The main limiting factors for the growth of tea (*Camellia sinensis* (L.) O. Kuntze) and mandarin (*Citrus reticulata* var. *unshiu* Tan.) are low air temperatures in winter and early spring periods, insufficient moisture supply in combination with high temperatures and atmospheric drought in the summer months, which lead to a decrease in the productivity of these crops and their quality indicators. Improving plant immunity, frost resistance and drought resistance of crops is possible by using a number of innovative forms of fertilizers and plant growth regulators, which are physiologically active substances [1-7]. In this regard, it is necessary to study a number of fundamental and practical aspects of their application, in particular, long-term observations of the physiology and biochemistry of tea

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and mandarin plants in specific environmental conditions with hydrothermal stress factors. In general, the use of innovative forms of fertilizers and growth regulators will significantly intensify the production processes of these subtropical crops by optimizing the functional state of plants in atypical growing conditions, as well as preserving and improving the quality of tea raw materials, ready-made tea and mandarin fruits.

The study of the effectiveness of various exogenous inducers (innovative forms of fertilizers, plant growth regulators) in increasing the resistance of plants to extreme conditions is relevant.

## 2 Materials and methods

The objects of research are tea plants of the Kimin variety population and mandarin plants of the dwarf variety "Miagawa-Wase". The following products were used:

Within experiments on tea – rocogumin (5 ml/10 l of water); sodium humate (1.5 g /10 l of water) and bombardier (20 ml/10 l of water). This group of organomineral preparations is humic acids with a complex of amino acids and mineral elements. Control - treatment of plants with water. The size of the experimental plots is 8-9 m<sup>2</sup>, the repetition of the experiment is three times. Non-root treatments were carried out three times: at the beginning of the growing season after pruning of tea plants (the second decade of May); after the second wave of growth (the first decade of July); in the second decade of November in preparation for the winter dormancy period. The research was carried out during the years of 2019 - 2020; in the experiment on tangerines - obstactin (5 ml/1l of water); nanoelicitor (5 ml/1l of water); siliplant (5 ml/1l of water). Obstactin is an aqueous solution of the potassium salt 2-(1-naphthyl) acetic acid and an analog of preparations with the effect of auxin; siliplant - a silicon-containing chelated fertilizer; nanoelesitor is a preparation based on biologically active metabolites (*Chaetomium* sp. and *Rhodopsedomonas* sp.). Control treatment of plants with water. The repetition of the experience is 5-fold. For a single repetition, the "tree-plot" is accepted. Non-root treatments were carried out twice: the first-on June 3, the second-30 days before harvesting the fruits. The research was conducted in the years 2018 - 2020.

Under the conditions of the field experiment, phenological observations were carried out; growth activity was determined, ovary shedding was taken into account by isolating model shoots and counting the number of ovaries/fruits, the productivity of mandarin trees (kg/d.) and tea plantations (c/ha), biometric measurements of leaves were taken into account.

Laboratory studies were carried out in the laboratory of Plant Physiology and Biochemistry of the Subtropical Center: the content of photosynthetic pigments – by the method of A. A. Shlyk on 96% ethanol using the calculated formulas of Smith and Benitez [8]; water forms [10] and water deficiency [11]; the content of proline [12]. The functional state of the plants was assessed by the parameters of slow induction of chlorophyll fluorescence (chlorophyll fluorescence was measured after a 30-minute dark adaptation of the leaves) [9]. The maximum (F<sub>m</sub>) and stationary (F<sub>T</sub>) levels of fluorescence were recorded and the photosynthetic activity index  $Kf_n = (F_m - F_T)/F_m$  was calculated; plant viability was assessed by the relative fluorescence quenching index "viability index - F<sub>m</sub>/F" [9]. The biochemical characteristics were determined: the content of soluble solids (RSV); acidity [12]; the content of ascorbic acid [12]. The content of mono- and disaccharides, as well as organic acids, was carried out using the capillary electrophoresis system "Kapel 105-M". Repeatability of laboratory tests was carried out at a triple repeat sequence. The selection of plant samples for physiological and biochemical studies were carried out in the morning time (from 8 to 10 o'clock) on a monthly basis from May throughout September.

Statistical processing of the research results was carried out using the statistical software package STATGRAPHICS Centurion XV and the mathematical software package MS Excel.

The analysis of hydrothermal conditions is carried out according to the data [www.pogodaklimat.ru](http://www.pogodaklimat.ru). The analysis of weather events in the research area showed that the climate is moderately warm, and the area usually experiences a significant (about 1514 mm per year) amount of precipitation during the year. The Köppen-Geiger climate classification represents Cfa. The lowest amount of precipitation falls in the summer time (on average 80 mm), the highest were from November to January (an average of 194 mm), usually in the form of rain. The difference between a dry and rainy month is about 110 mm. The average air temperature is 14.5 °C, the highest temperatures are in July - August (up to 30-36 °C), the coldest months are January-February (the temperature can drop to 0 °C); in some years, short-term frosts are observed up to -7.0 (1985) ... -5.0 oC (2004).

Observation of the weather conditions in the winter period of 2018-2019 and 2019-2020 showed that there were no low temperatures in the winter period that could lead to freezing of the leaves of subtropical crops. On average, the winters were characterized as warm (from +3 to +10 oC) with little snow (about 54 mm fell, mainly in the form of snow and rain). During the observation period of 2019, the spring period was prolonged, cool (on average +15.7 oC), with moderate precipitation (63.0 mm). This led to some delay in the onset of the growing season of tea and mandarin. Summer period 2019 It was characterized as dry (on average 22.3 mm) and hot (about +30 oC, according to long-term data, as a rule, +24.5 oC). In turn, 2020 was even more stressful, with July and August seeing highs of up to +34 - +35 oC. It is no coincidence that since the second decade of June, there has been a slowdown in the growth of tea flushes, twisting of mandarin leaves and shedding of its fruits, which affected both the crop productivity of plantations and the quality of the collected tea raw materials (there was a greater number of coarse sprouts, so-called "glushok"). The soils of the plots are brown forest slightly unsaturated. On both plantations, fertilizers are applied annually: before the beginning of the growing season (April), 60% of nitrogen, 100% of phosphorus and potassium are applied to the soil (in the tea experiment-N250 P100 K100 kg/ha of active ingredients, on the mandarin plantation-N160 P200 K60 kg/ha of active ingredients); compounds fertilizer is used as a fertilizer with the addition of ammonium nitrate during the main application; top dressing with ammonium nitrate (40% nitrogen) is carried out in June.

### 3 Results and discussion

The analysis of the content of water forms in experimental tea plants is carried out, while the main attention is paid to such an indicator as bound water due to the importance of this fraction as a characteristic of plant resistance to stressors, including winter stressors. As is well known, by the time the growth processes are slowed down and the water content is prepared for winter, it stabilizes at a fairly low level, and remains there for a number of cold months with a tendency to some further decrease during the period of stable frosty weather [13]. At the same time, the ratio between different forms of water changes in the direction of reducing free water and increasing the proportion of bound water. We have shown that during the stressful growing season (June-August) in variants with foliar treatments with growth regulators (in particular, rocogumin), there is a slight increase in bound water in physiologically mature tea leaves (Table 1).

**Table 1.** Functional state and productivity of tea plants under treatment with growth regulators (average according to the data of the stressful vegetation periods of 2019-2020)

Variant	bound water, % of total water	ascorbic acid, mg. g <sup>-1</sup> raw weight	proline content, mg. g <sup>-1</sup> of the raw mass	dry matter, g.100 <sup>-1</sup> g	Crop productivity of tea plants, c/ha	
					2019	2020
control	53,5±3,2	131,4±23,0	122,6±15,6	32,5±4,0	22,04±2,56	26,88±2,44
sodium humate	54,9±3,9	226,5±30,1	179,2±11,4	33,4±3,2	19,21±1,52	31,47±1,95
rocogumin	55,2±2,6	183,2±17,5	135,1±17,5	32,6±2,6	22,88±2,50	32,22±1,58
bombardier	54,8±1,2	177,8±19,0	138,7±16,4	31,4±4,6	20,60±1,78	26,31±2,34
<i>HCP05</i>	<i>2,05</i>	<i>10,2</i>	<i>12,7</i>	<i>1,08</i>	<i>1,18</i>	<i>2,20</i>

Determination of the dry matter content in physiologically mature tea leaves (Table. 1), as characteristics of synthetic processes, showed that the greatest synthesis of assimilates is carried out in plants during treatment with sodium humate [14]. Despite the absence of significant differences in this indicator, during the three years of the study, we observed a tendency to increase differences in options, which can be explained by the cumulative effect. In the same variant, a more active formation of proline and ascorbic acid in physiologically mature tea leaves was also noted (Table. 1), which characterizes the active processes associated with the inclusion of mechanisms of non-specific protection. This circumstance also explains the more developed specific surface density of the leaf-UPL (1.39-1.44 mg. cm<sup>-2</sup> with 1.24 mg. cm<sup>-2</sup> in the control), as an indicator of assimilation processes and a more optimal state of plants. The developed APL ensures the active work of the leaves, which is expressed in its greater productivity (Table. 1), compared to control plants. More favorable functional state of plants under the influence of growth regulators, in 2019-2020 this led to a certain increase in crop productivity (Table 1).

The highest crop productivity in the years of research was noted in the variant with non-root treatments with rocogumin, while in the variant with sodium humate, the crop productivity exceeded the control only in 2020, which can be considered a consequence of the cumulative effect.

The positive effect of the preparations on the functional state of the mandarin and the anatomical and morphological characteristics of their leaves was established, the highest density of stomata was noted when treated with obstactin and siliplant (Table. 2); the greatest leaf thickness in plants treated with obstactin (282.7 microns), which is an analog of auxin, due to an increase in the thickness of the spongy parenchyma (183.2 microns). The analysis of photosynthetic pigments, as characteristics of stability and activity of assimilation processes, showed that the greatest amount of chlorophyll in the leaves was observed in the plants of the control variant (Table. 2), however, in the stressful conditions of the growing season, this is not the main characteristic that fully characterizes the state of the plants. In this case, the content of carotenoids is more informative (Table. 2), as components of the nonspecific resistance of plants to adverse abiotic factors (in our case, this is the dry period and high air temperature during the growing season).

**Table 2.** Functional state and productivity of tangerine plants under treatment with growth regulators

Variant	Stomatal cell density, pcs. mm <sup>2</sup>	Content of photosynthetic pigments, mg. g <sup>-1</sup> of raw weight		Water deficit, %	Kf_n, units	Crop productivity, kg. tree <sup>-1</sup>
		Σ хл.	Σ кар.			
control	662,50±3,50	2,11±0,09	2,51±0,06	35,15±1,56	0,46±0,01	3,80±0,16
obstaktin	698,33±6,60	1,46±0,05	2,23±0,04	41,31±1,53	0,54±0,02	3,26±0,14

siliplant	693,33±10,1	1,93±0,06	3,78±0,04	31,75±1,40	0,57±0,01	6,83±0,09
nanoelicitor	642,50±14,7	1,37±0,05	2,69±0,08	40,81±0,99	0,55±0,01	2,95±0,26
<i>HCP05</i>	<i>6,86</i>	<i>0,45</i>	<i>0,98</i>	<i>2,31</i>	<i>0,17</i>	<i>0,95</i>

Studies have shown that the greatest amount of carotenoids is synthesized in the leaves during treatment with siliplant (Table. 2), which is not accidental, because this drug is a good stressant due to the content of silicon in it.

Treatment with growth regulators led to an improvement in the state of the photosynthetic apparatus and, in general, the functional state of the entire plant [14]. As is known, in plants, the efficiency of light utilization during photosynthesis (the so - called coefficient of photosynthetic activity-Kf<sub>n</sub>) is 0.6 or higher, and in pathologies of various origins it decreases in proportion to the weakening of the photosynthetic function [9]. In our experience, treatment with regulators led to a smaller weakening of the photosynthetic function (Table. 2), which was also expressed in a higher value of the viability index (Fm/F), especially in the variants with the introduction of nanoelicitor (5.19 units) and siliplant (5.33 units), in accordance with the control (4.37 units).

It is shown that in conditions of acute water insufficiency against the background of high air temperatures, treatment with siliplant leads to a decrease in water deficiency in the leaves (Table. 2), which affects the productivity of plants – this variant has the highest fruit crop productivity (Table 2).

When analyzing the quality characteristics of fruits (Table. 3) it was found that the use of growth regulators increases the accumulation of ascorbic acid to 36-47 mg. g<sup>-1</sup> of the raw weight, while increasing the juice yield within 19%. It is shown that the largest amount of sugars is present in the control fruits (about 1400 mg. g<sup>-1</sup> of raw weight), however, the most optimal ratio of mono-and disaccharides is observed in fruits with nanoelicitor treatment (1:1:1).

**Table 3.** Biochemical and qualitative characteristics of mandarin fruits when treated with growth regulators

Variant	Content of sugar, mg. g <sup>-1</sup> of raw mg. g <sup>-1</sup> of raw weight			Ascorbic acid, mg. g <sup>-1</sup> raw weight	SDS*, %	Juice output, ml
	glucose	fructose	sucrose			
control	482,5±10,5	452,1±9,5	477,1±4,9	46,93±1,37	20,98±2,09	65,95±3,65
obstaktin	475,3±9,15	250,1±10,1	514,8±5,0	44,07±1,10	20,00±1,41	66,74±3,44
siliplant	317,6±10,2	383,8±8,8	440,1±9,0	39,74±2,25	17,82±1,15	75,88±0,20
nano elicitor	435,3±3,00	402,9±6,9	407,4±6,4	43,32±2,49	18,50±2,12	69,46±2,96
<i>HCP05</i>	<i>5,8</i>	<i>6,1</i>	<i>6,9</i>	<i>5,68</i>	<i>2,15</i>	<i>3,15</i>

\*SDS – soluble dry substances

## 4 Conclusion

Experimental data describing the state of the main components of the agroecosystem of tea plantations and mandarin plantations under non-root treatment with innovative forms of fertilizers and growth regulators, which showed the activation of plant defense mechanisms, were obtained. Research contributes to the development of effective ways to regulate the functional state of plants under stress, ensuring an increase in crop productivity and its stability in varying climatic conditions, preserving and improving the quality of products. The use of innovative forms of fertilizers and plant growth regulators should become the main element of the technology of cultivation of subtropical crops, optimizing the adaptive potential, regulating the effective productivity of plants and their quality indicators.

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