



THE REGULATION OF THE FUNCTIONAL STATE OF SUBTROPICAL CROPS WITH MICRONUTRIENTS

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ABSTRACT

We studied the chemical composition of tea plants and tangerine at foliar application sulfates Mn, Zn, Cu, Fe, and of boric acid solution. At stopped growing leaves most accurately reflect the degree of security of the tea plant essential micronutrients, the content of which is more stable than in flush, where their concentration is not stable. Concentration of trace elements studied in the semi-finished product prepared from raw experimental batches, does not exceed the allowable state standard values. Our studied that leaf tangerine also revealed the existence of a positive impact on the accumulation of trace elements Mn, Zn, B and Fe as the leaves and fruits at a foliar application of these elements. Was studied that effect of micronutrient foliar application on the functional state of cultures. We showed that effect of trace elements on the adaptability of the plant tea and tangerine, which is reflected in the existence of a clear trend of increasing plant resistance to drought. For example, foliar fertilizing of manganese ($r = -0.69$) and zinc ($r = -0.73$) significantly reduces the concentration of cellular juice flushes of tea; tea processing manganese, zinc, iron contributes to a significant enhancement of the enzymatic activity of the experimental plant; stimulates growth processes, resulting in an increase in leaf area; increases the productivity of plants: the increase in years of research by 11.7 – 25.3 per cent higher than the control (average $65.8 \text{ kg} \cdot \text{ha}^{-1}$). Processing plants copper ($r = 0.68 - 0.72$), manganese ($r = 0.70 - 0.81$) and iron ($r = 0.82 - 0.69$) contribute to the increase in the content of tender fraction ($r = 0.59 - 0.71$) and content (3 – 4%) of tannin in raw materials. manganese and zinc at tangerine plants increased (1.3 – 1.5 times) the water-holding capacity of leaves, decreased water deficit (1.6 times) and promote adaptive responses of plants to stress factors (drought); addition of copper, manganese and boron resulted in the increase of all photosynthetic pigments. It can be concluded that the application of micronutrients is an additional reserve to increase the productivity of the culture of tea and tangerine.

Keywords: tea; tangerine; foliar fertilizing; microelements; sugars; acidity; ascorbic acid; sugar-acid index; market quality

INTRODUCTION

It is known that the adaptive capacity of plants is their resistance to certain stressors associated with providing an optimum fuel ratio (Shakirova, 2001; Abilfazova, 2002; Prytula, 2004; Milenkevich, 2006; Belous, 2006 and other). Therefore, it is appropriate to develop a set of technical measures that would contribute to realize the potential of plants in different agro-climatic conditions. The cultivation of crops should combine farming practices, which include not only fertilizer, but also the means and ways to improve their own plant resistance to the action of unfavorable environmental factors: physical, chemical and biological. This is especially true during prolonged cultivation on one place perennial cultivation.

It is known that as a result of prolonged use of high doses of mineral fertilizers in excess of plant macronutrients found causing micronutrient deficiencies (Milenkevich, 2006; Ryndin et al., 2009; Kourimska et al., 2014. Arvay et al., 2015).

Despite the relatively low doses needed to achieve the effect, minerals are very important part of food crops, including subtropical, since they either are part of enzymes or activate their work, stimulating the biological potential of plants (Belous, 2012; Bozhenko, 1976; Toma, 1983 and others). The researchers in the study of trace elements (in comparison with a variant without incorporation) was shown the inability of the normal development of plants in the absence of minerals, such as manganese, zinc, copper, and for some plants – iron (Abilfazova, 2000; Belous, 2006; Ryndin 2009; Sennovskaya 2006; Musilova et al., 2013 and others).

These elements were found absolutely necessary. The lack of microelements reduces crop productivity, and the complete absence - causes disease and death of plants due to the rapid metabolism disorders (Toma, 1983; Zehtab-Salmasi et al., 2008 and others). Plant nutrition trace elements in which they are deficient stabilizes metabolism. But this does not mean that the minerals can replace

making basic fertilizer. Moreover, the efficiency increases with the introduction of micronutrients against the background of complete fertilizer (Argesanu et al., 2009).

Research carried out by us for a long time that has shown that reducing stress subtropical crops caused by drought conditions, the application of micronutrients, which leads to an increase in the total resistance of plants.

To determine the effect of trace elements on the functionality and Subtropical Crops Production processes were established field trials with foliar feeding tea plants (1997 – 2007) and dwarf tangerine (1997 – 2002).

MATERIAL AND METHODOLOGY

The problem is solved at the level of field and laboratory studies. Laboratory tests carried out on the basis of laboratory biotechnology, plant physiology and biochemistry Institute of Floriculture and Subtropical Crops. Field experiments were located on the basis of Institute's "Experimental field" and tea plantations "Dagomyschay."

Object of research is physiologically homogeneous leaves (for tea and tangerine) and flushes (tea) the following crops:

- Tea plant (*Camellia sinensis* L.) varieties Karatum (landing 1990), dedicated in 1976 by clonal selection of plants of the Georgian population. The variety has macrophylla, has a strong ability for shoot-forming capacity (Tuov, 1998). Tea leaf is characterized by high biochemical parameters. The sort was transferred to a Government grade testing institution in 1991, and passed the regionalization in 1996;

- Plant dwarf tangerine (*Citrus unshiu* Marc.) varieties Miagava-Base grafted on *Pontirus trifoliata* (landing 1986).

Determination of physiological and biochemical characteristics of the condition of the plants was performed by classical methods: the concentration of the cell sap (CCS) flashes using the refractometric method by Filippov (Filippov, 1968); water scarcity (Baslavskaya, Trubetskova, 1964); heat drought factor – by Kouchnirenko (Kouchnirenko, 1986); Activity of catalase enzyme – gasometric technique (Gunnar, 1972); content of photosynthetic pigments by AA Shlyk, using the calculation formulas Ziegler and Egle (Shlyk, 1971).

While conducting research on the influence of trace elements on tea plants and tangerine before laying experience during and after the studies were selected samples of soil in the root zone 0 – 20 and 20 – 40 cm, in the period of relative quiescence of plants (before the vegetation and fertilizer application – March and September). Agrochemical soil analysis was performed by conventional methods (Kuznetsov, Fecun, Camochvalov, 1985).

Preparation of plant samples for chemical analysis, wet and dry ashing batches of the dissolution of ash and determination of macro and trace elements was performed by the procedures CINAO set out in the Guidelines for determination of trace elements in soils and plants (Kuznetsov, Fecun, Camochvalov, 1985), as well as guests on the food plant.

The treatment is carried out in the form of trace elements foliar treatment plant tea and tangerine as follows:

The patterned experience of tea until 2004 included 6 variants in 4 fold repetition: control (spraying water without minerals); solution of copper sulphate at a concentration of 0.06%; manganese sulphate 0.4%; zinc sulphate 0.3%; iron sulfate 0.3%. Since 2004, in connection with the transition of mature plants in the state have changed concentration insertion elements, and the scheme has gained as follows: control (spraying water without minerals); solution of copper sulphate at a concentration of 0.06%; manganese sulphate 0.6%; zinc sulfate 0.3%; iron sulfate 0.5%. Area pilot area 0.4 hectares, the size of plots were 9 linear meters, separated by protective portions 1 m. Row spacing of 1.25 m. Accommodation options – randomization. Foliar treatment is carried out at the beginning of the growing season (the last decade of April – early May) and during the depression years of growth processes (July). When introducing context macro fertilizers (60%) was used NPK with ammonium nitrate (at a dose of N360 P60 K50 kg.ha⁻¹); during the summer feeding (40%) was added ammonium nitrate, according to the Guidelines for the technology of cultivation of tea (Tuov et al, 1977).

The experimental setup for tangerines included 6 variants in 4 fold repetition: control (spraying water without minerals); solution of copper sulphate at a concentration of 0.06%; manganese sulphate 0.4%; zinc sulphate 0.3%; boric acid 0.6 – 1.0%. Tangerine free experience laid by a 4-fold repetition, 5 trees in each. The area of the experimental plot takes 0.25 ha, nutrition area 4 x 1 m. During the growing season spend two foliar feeding: in the first phase of mass flowering and the end of the second – in the beginning phase of fruit filling. Trace elements were added to the context macro fertilizers. Before the vegetation as a main application used NPK dose N160R200K60 kg.ha⁻¹ (Vorontcov et al., 1979). As the summer feeding used ammonium nitrate (40% annual rate).

Processing of experimental data was carried out by methods of correlation, regression and cluster analysis, as well as descriptive statistics using mathematical programs developed VNIIA Pryanishnikov, STATGRAPHICS Centurion XV software and Microsoft Excel.

RESULTS AND DISCUSSION

First of all, we studied the chemical composition of tea plants and tangerine at foliar application sulfates Mn, Zn, Cu, Fe, and of boric acid solution (Ryndin, 2009; Abilfazova, 2006; Belous, 2009; Prytula, 2004).

It is revealed that the minerals have a significant impact on the content of Mn, Zn, Cu and Fe in a physiologically mature tea leaves, and this trend persisted throughout the study period. At the same time, we noted that it stopped growing leaves most accurately reflect the degree of security of the tea plant essential micronutrients, the content of which is more stable than in flush, where their concentration is not stable (Table 1).

Due to the fact that the shoots of the tea used to prepare the finished tea, accumulates significant amounts of trace elements, it was necessary to ascertain the effect of foliar application of nutrients to their content in the final product. Our studies have shown that treatment micro fertilizers significantly increase the total amount of Cu, Mn, Zn and Fe in the case (Table 2).

Table 1 Influence of trace elements on their content in the tea leaves and flushes (mg.kg⁻¹).

Variation	Cu		Mn		Zn		Fe	
	Leaf	Flush	Leaf	Flush	Leaf	Flush	Leaf	Flush
Control	23.24 ±1.19	45 ±10	1034 ±100	406 ±99	30.5 ±1.8	406 ±99	77.3 ±28.5	44 ±18
CuSO4	33.80 ±5.30	45 ±17	961 ±62	362 ±96	31.5 ±1.7	362 ±96	76.5 ±26.5	44 ±14
MnSO4	22.87 ±1.73	42 ±14	1206 ±159	409 ±97	30.8 ±1.2	409 ±97	58.3 ±22.3	45 ±14
ZnSO4	22.59 ±0.86	42 ±14	1014 ±102	471 ±109	40.6 ±2.5	471 ±109	78.6 ±19.4	50 ±14
FeSO4	22.23 ±0.77	42 ±16	855 ±909	445 ±82	29.6 ±1.1	445 ±82	128.4 ±58.3	51 ±14
LSD (<i>p</i> ≤0.05)	8.22		66.3		9.8		19.2	

Table 2 Content of trace elements in tea semi-finished product (mg.kg⁻¹).

Variation	Cu	Mn	Zn	Fe
Control	1.9 ±0.2	329 ±10.0	7.1 ±1.0	37 ±5.0
CuSO4	3.1 ±0.3	322 ±9.5	7.3 ±1.1	34 ±4.8
MnSO4	2.0 ±0.2	339 ±8.2	7.7 ±0.9	39 ±5.6
ZnSO4	2.4 ±0.2	346 ±5.5	8.7 ±0.8	38 ±4.2
FeSO4	2.8 ±0.1	345 ±6.9	6.9 ±0.9	44 ±4.0
LSD (<i>p</i> ≤0.05)	0.8	34	0.5	3.0

Table 3 Content of trace elements in the leaves of tangerine (mg.kg⁻¹).

Variation	Cu	Zn	Mn	B	Fe
	Opt. 5-10	Opt. 25-100	Opt. 25-100	Opt. 50-170	Opt. 60-120
Control	12.12 ±1.6	33.86 ±14.4	27.76 ±3.8	38.70 ±3.04	43.30 ±10.2
H3BO3	11.92 ±1.5	35.12 ±14.6	28.61 ±4.4	51.90 ±9.0	47.04 ±9.6
MnSO4	11.86 ±1.6	35.20 ±14.6	65.42 ±12.6	53.78 ±14.2	46.78 ±10.7
ZnSO4	11.34 ±2.1	57.50 ±13.1	29.04 ±3.7	44.92 ±6.5	47.12 ±11.9
CuSO4	18.02 ±4.1	36.46 ±11.7	27.70 ±2.7	44.57 ±7.5	47.68 ±10.8
LSD (<i>p</i> ≤0.05)	1.94	3.71	4.97	3.78	2.91

Table 4 Content of trace elements in the pulp and rind (mg.kg⁻¹).

Variation	Pulp					Peel				
	B	Mn	Zn	Cu	Fe	B	Mn	Zn	Cu	Fe
Control	14.6	7.2	2.13	1.27	25.3	33.4	6.5	16.1	12.3	17.5
H3BO3	15.2	6.6	2.32	1.29	30.0	35.1	6.1	16.5	9.9	17.3
MnSO4	16.3	10.2	1.93	1.05	23.2	37.8	13.8	16.8	11.2	14.4
ZnSO4	16.2	7.8	2.56	1.24	23.4	38.3	7.0	35.0	9.5	14.8
CuSO4	15.5	6.4	2.51	1.36	18.0	35.0	6.0	19.4	13.8	11.8
LSD (<i>p</i> ≤0.05)	0.7	0.7	0.4	0.2	3.8	1.1	0.5	1.3	1.0	1.4

At the same time, the concentration of trace elements studied in the semi-finished product prepared from raw experimental batches, does not exceed the allowable state standard values. Thus, the copper content in the tea extract ranged 1.9 – 3.3 mg.kg⁻¹, while the ISO for copper in black tea is 100 mg.kg⁻¹ (Ryndin, 2009; Belous, 2009; Pritula, 2004).

Results of analyzes of leaf tangerine also revealed the existence of a positive impact on the accumulation of trace elements Mn, Zn, B and Fe as the leaves and fruits at a foliar application of these elements (Table. 3).

Trace elements have an impact on the content and accumulation of them in the flesh and tangerine peel (Table 4).

Besides the chemical composition of the test plants, we studied the effect of micronutrient foliar application on the functional state of cultures (Ryndin, 2009; Abilfazova, 2006; Belous, 2009; Prytula, 2004). First, set the effect of trace elements on the adaptability of the plant tea and

tangerine, which is reflected in the existence of a clear trend of increasing plant resistance to drought. So, the concentration of the tea plant cell sap (CCS) flush on versions with microelement treatments on average 1.5 – 2.0 times lower than the control (water treatment), indicating a significant improvement of the water regime. Analysis of changes in the data CCS showed that due to changes in climatic parameters (for the years of study at a repetitive dry hot air temperature has increased by an average of 1 – 2 °C), CCS flush in intense periods of water availability are increasingly raised to 20% and higher in some periods exceeding 24%. However, in cases with the introduction of manganese and zinc CCS has always been 2 – 4% lower than in the controls (Belous, 2009).

Regression analysis confirmed the existence of a close correlation between the foliar fertilizer with microelements and CCS flushes: $Y = 21.2 + 0.8 \text{ Cu} - 2.2 \text{ Mn} - 2.2 \text{ Zn} + 1.0 \text{ Fe}$; $R^2 = 0.58 - 0.62$. With the water regime of plants the transpiration process is directly connected. The

Table 5 Parameters of the water regime of tea leaves when making micronutrients.

Variation	Water content of grain leaves, %	The intensity of transpiration, g/cm ² /h	Water retention the ability (6 hours), %	Water deficiency, %	T2/T1
Control	51 ±2.5	211.1 ±37.2	25 ±1.1	19.48	0.62 ±0.20
CuSO ₄	40 ±3.0	206.6 ±52.4	34 ±2.1	22.45	0.79 ±0.20
MnSO ₄	72 ±2.0	314.3 ±40.8	22 ±1.6	14.05	0.75 ±0.18
ZnSO ₄	69 ±1.9	303.4 ±58.2	20 ±1.6	13.02	0.74 ±0.20
FeSO ₄	45 ±2.5	201.1 ±65.7	38 ±1.9	24.40	0.73 ±0.20
LSD (<i>p</i> ≤0.05)	9.0	102.5	8.2	-	-

Table 6 Effect of trace elements on the water status of the plant tangerine.

Variation	Water content of grain %	Water deficiency %	T2/T1
Control	70	25	0.89
H ₃ BO ₃	73	21	0.91
MnSO ₄	67	20	0.86
ZnSO ₄	71	14	0.94
CuSO ₄	74	19	0.89
LSD (<i>p</i> ≤0.05)	3.19	2.60	-

intensity of transpiration, which characterizes the intensity of water exchange and the level of metabolic reactions, largely linked to the agronomic conditions for growing plants. The calculation of the intensity of transpiration tea leaves showed that treatment with manganese and zinc in the hottest time of the day significantly (by an average of 1.4 – 1.7 times) increased the transpiration process, which is a positive fact that in times of drought, as it is a mechanism that protects the leaf overheating (Table 5). Studies on the effect of trace elements on the adaptive processes of plants, conducted on different cultures have revealed a similar trend (Thoma, 1983; Kouchnirenko, 1967; Cruz de Carvalho et al., 2008 and others), which confirms the promising use of nutrients as a mechanism, enhancing adaptive capacity.

Studies of the water regime of tangerine plants in making micronutrients showed the same pattern as in the study of plant water status of tea (Abilfazova, 2006). Thus, in embodiments with treatments Mn and Zn had a significant decrease in transpiration due to increased water retention tangerine leaves (water content of 2 hours was changed to 1.3 – 1.5 times, and after 24 hours on the average 1.3 times relative to control). While the introduction of copper contributed to a significant reduction in water retention leaf (Table 6). Zinc treatment resulted in a decrease in water deficit is almost 1.6 times (at 25% for the control). The established pattern is expressed by the following equation: $Y = 23.5 + 11.3 \text{ Cu} - 10.5 \text{ Mn} - 10.5 \text{ Zn}$, $R^2 = 0.78$.

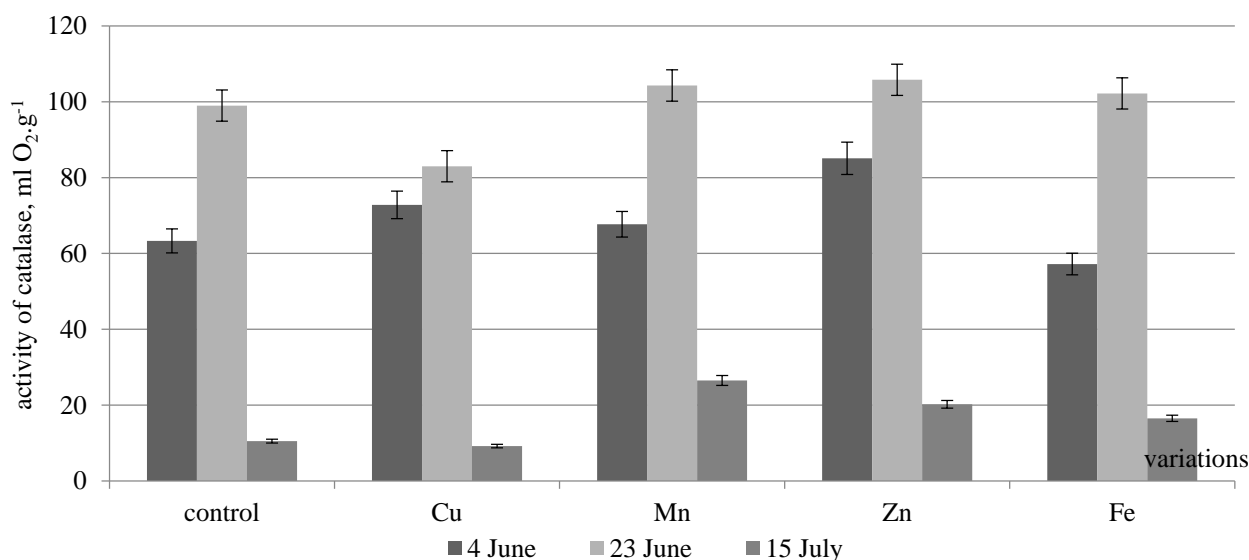


Figure 1 The activity of catalase in tea leaves when foliar feeding micronutrients during stress (June – July), LSD (*p* ≤0.05) = 12.9; 13.3; 13.7.

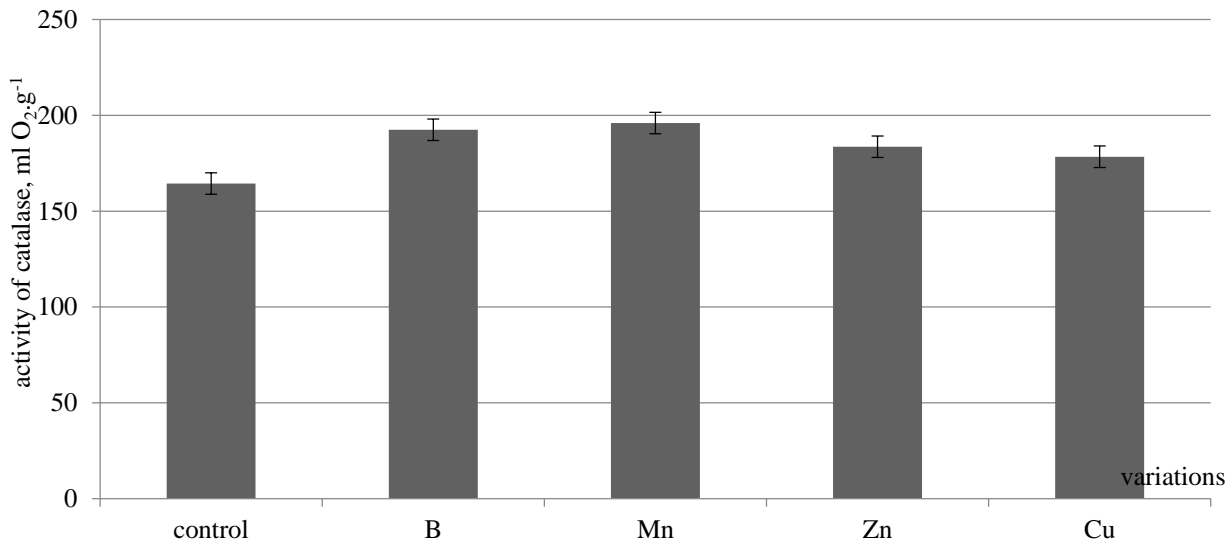


Figure 2 The activity of catalase in leaves tangerine with the foliar fertilizer with microelements, times of stress (June-August), LSD ($p \leq 0.05$) = 10.8.

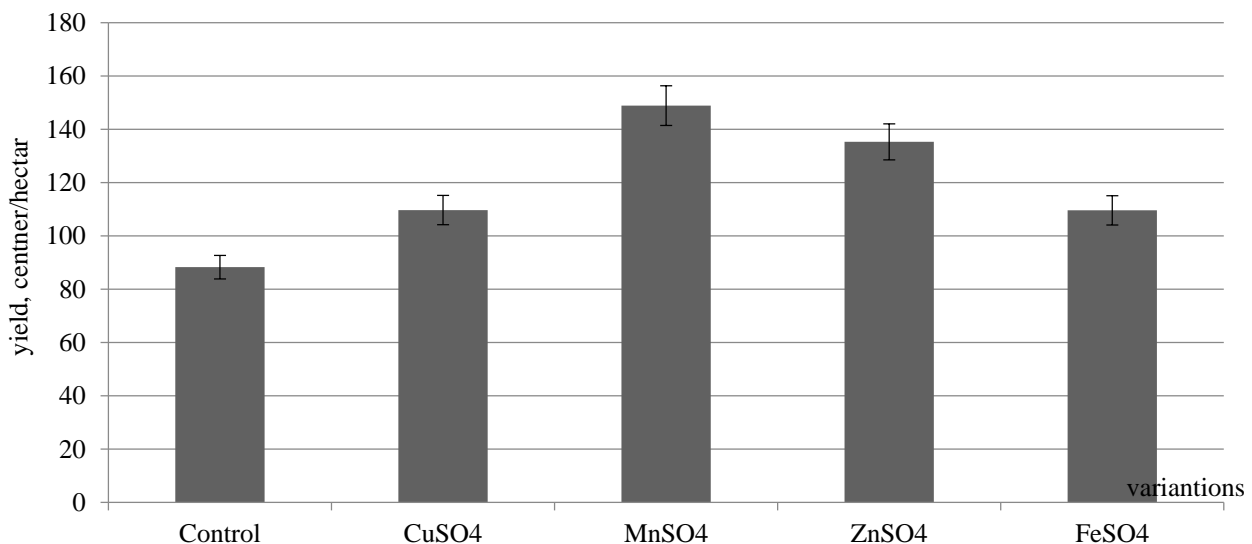


Figure 3 Effect of trace elements on the yield of tea plants, LSD ($p \leq 0.05$) = 8.9

Biogenic minerals made foliar way, may affect the activity of catalase, which is one of non-specific mechanisms of adaptability of plants. Thus, in the most unfavorable for water supply (June – period not only enhance the stress, but also during the biological decay of shoot from tea) catalase tea leaves when making micronutrients (especially, Mn and Zn) significantly (2.5 – 1.9 times) higher than the control (Figure 1).

Analysis of enzymatic activity for the entire study period and have another circumstance: when the tea of mature plants need higher concentrations of trace elements, which was considered by us to adjust doses of micronutrients.

Plants tangerine noted similar patterns of influence of microelements on the enzymatic activity – increased the catalytic activity of the leaves when making Mn and B ($r = 0.8$ and $r = 0.6$) (Figure 2).

Moreover, our data on the influence of microelements on the enzymatic processes of plants tea and tangerine are consistent with the results of other authors in different cultures (Gudkovskiy et al., 2005; Romanova, 2008;

Muhammad Anjum Zia et al., 2011; Kuznetsova et al. 2016).

However, the duration of the stress factor for plants tangerine is more durable and lasts from June to August. The main stressor for this culture is a high temperature, causing the development of non-specific reactions – folding leaf to reduce the transpiration process.

Trace elements may affect the pigment composition of the leaves of the test plants (Table 7 and Table 8), which is consistent with results reported by other researchers (Hochachka et al., 1977; Shakirova, 2001).

It is established that in the processing of nutrients in plants of tea in times of drought significantly changed the content of carotenoids (up to 46 – 50% vs. baseline), leading to higher power pigment system, associated with the quantitative content of all groups of pigments ($r = 0.75 – 0.86$).

In the leaves, tangerine and tea, significant effect of trace elements on the synthesis of chlorophyll and carotenoids.

Table 7 Characteristics of the pigment apparatus of mature tea plants with increasing doses of trace elements (mg.g⁻¹).

Variation	Chlorophyll			Carotenoids	a +b/carotenoids
	a	b	a +b		
Control	1.91 ±0.56	1.27 ±0.45	3.18 ±0.50	0.61 ±0.13	5.21 ±0.32
CuSO ₄	1.94 ±0.52	1.10 ±0.44	3.05 ±0.48	0.60 ±0.13	5.08 ±0.31
MnSO ₄	2.03 ±0.50	1.75 ±0.47	3.78 ±0.49	0.94 ±0.13	4.02 ±0.31
ZnSO ₄	2.13 ±0.50	1.82 ±0.43	3.95 ±0.47	0.91 ±0.11	4.34 ±0.29
FeSO ₄	2.00 ±0.51	1.20 ±0.59	3.20 ±0.55	0.60 ±0.13	5.33 ±0.34
LSD (<i>p</i> ≤0.05)	0.10	0.34	0.36	0.18	-

Table 8 Effect of trace elements on the water status of the plant tangerine.

Variations	Chlorophyll			Carotenoids	a +b/carotenoids
	a	b	a +b		
Control	1.55 ±0.2	0.91 ±0.1	2.46 ±0.3	0.55 ±0.04	4.47 ±0.1
H ₃ BO ₃	1.85 ±0.04	0.96 ±0.05	2.81 ±0.1	0.61 ±0.1	4.61 ±0.5
MnSO ₄	1.82 ±0.1	0.94 ±0.1	2.76 ±0.1	0.61 ±0.1	4.52 ±0.4
ZnSO ₄	1.78 ±0.1	0.91 ±0.03	2.69 ±0.1	0.54 ±0.02	4.98 ±0.1
CuSO ₄	1.92 ±0.1	0.98 ±0.1	2.90 ±0.1	0.57 ±0.01	5.09 ±0.1
LSD (<i>p</i> ≤0.05)	0.06	0.05	0.10	0.03	0.24

Foliar feeding of plants tea micronutrients (Cu, Mn, Zn, Fe) had a significant impact on their ability called shoot-forming capacity (*r* from 0.56 – 0.62 on the version with the introduction of copper and iron to 0.72 to 0.76 when making manganese and zinc) (Figure 3). On versions with the processing of manganese and zinc were observed less variability in yield (*V* = 11.9 per of 12.3%) compared with the control (*V* = 14.8%). We have established the dependence between the productivity of tangerine and submitted by foliar micronutrients, as evidenced by high correlation coefficients: B (*r* = 0.9), Mn and Zn (*r* = 0.7) (Figure 4).

CONCLUSION

Thus, the search of methods to increase adaptive capacity subtropical crops have shown that reducing stress caused by drought conditions, it is possible by the application of fertilizers, resulting in higher overall plant resistance.

It is revealed that treatment of plants of manganese and zinc contribute to greater conservation of water content in the leaves, causing a decrease of water scarcity, increasing adaptive responses of plants to drought. When you make these elements is increased transpiration process, which not only improves circulation, but also stimulates photosynthetic activity

So, foliar fertilizing of manganese (*r* = -0.69) and zinc (*r* = -0.73) significantly reduces the concentration of cellular juice flushes of tea; tea processing manganese, zinc, iron contributes to a significant enhancement of the enzymatic activity of the experimental plant; stimulates growth processes, resulting in an increase in leaf area; increases the productivity of plants: the increase in years of research by 11.7 – 25.3 per cent higher than the control (average 65.8 kg.ha⁻¹). Processing plants copper (*r* = 0.68 – 0.72), manganese (*r* = 0.70 – 0.81) and iron (*r* = 0.82 – 0.69) contribute to the increase in the content of tender fraction (*r* = 0.59 – 0.71) and content (3 – 4%) of tannin in raw materials.

When processing manganese and zinc at tangerine plants increased (1.3 – 1.5 times) the water-holding capacity of

leaves, decreased water deficit (1.6 times) and promote adaptive responses of plants to stress factors (drought); addition of copper, manganese and boron resulted in the increase of all photosynthetic pigments. We observed correlation between the introduction of boron and decrease (1.6 – 2.3 times) of subsidence of the ovary, which increased by 7.0 – 43.6 per cent for the pigments tangerine crop.

It can be concluded that the application of micronutrients is an additional reserve to increase the productivity of the culture of tea and tangerine.

In conclusion, a comprehensive study of the influence of trace elements on plants tea and tangerine became the basis to develop a practical framework for the application of foliar treatments with the aim of increasing the plant resistance to stressors, and how sustainable productivity of agroecosystems.

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