SEL'SKOKHOZYAISTVENNAYA BIOLOGIYA
[AGRICULTURAL BIOLOGY], 2014, № 5, pp. 120-126 ISSN 313-4836 (Online)

Abiotic stresses in strawberry

UDC 634.75:631.559.2:631.8
doi: 10.15389/agrobiology.2014.5.120rus
doi: 10.15389/agrobiology.2014.5.120eng

FOLIAR FEEDING TO INCREASE YIELD VALUE AND QUALITY IN STRAWBERRY (*Fragaria ananassa*) UNDER METEOROLOGICAL STRESSES

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Received December 5, 2013

Abstract

In formation of fruit quality, an application of bio-stimulants that can protect plants against external unfavorable factors and regulate specifically the plant growth, development and metabolism, is prospective, enabling full realization of a varietal potency. In this paper, the data are summarized on studying influence of meteorological conditions of the growing season and the growing factors on the yield and quality of strawberries grown in the southern Russia in 2006-2010. There are reported the results of using GUMI 20K fertilizer and growth regulators Mival-Agro, Stimolante 66f, Alga mix B Mg at the phases of stem extension, early flowering and ripening of berries to control yield formation and chemical composition of strawberries under extreme weather conditions. Due to application of tested preparations, in the varieties Cleary, Arosa, Marmolada the weight of a berry was by 0.7-2.2 g higher as compared to the control. That improves trade quality and ultimately has a positive effect on productivity. Joint use of growth regulators Mival-Agro and fertilizer GUMI 20K improves the quality according to the content of dry matter and sugars (by 7-10 %), organic acids (by 10-15 %), vitamin C (by 9-14 %), and P-active substances (by 3-12 %). It was found out that the use of growth regulators Stimolante 66f and Alga mix B Mg on the Marmolada plants contribute to increased resistance to late spring frosts occurred in 2009. The number of flowers exceeded the control by 9.1 %, and the number of berries was higher by 18.5 % with an average weight of a berry increased by 1.7 g. The berries also accumulated more soluble dry matters (9.0 %) and sugars (6.8 %), their acid content increased (1.0 %), but the synthesis of vitamin C and P-active substances slowed. A response of varieties to the treatments differed. In Arosa variety the similar treatments resulted in decrease of sugar content and acidity, but the concentration of biologically active substances increased as compared to the control. Thus, the application of fertilizers together with growth stimulants can reduce the impact of stresses, improving productivity, fruit quality and content of biologically active substances in strawberries.

Keywords: strawberry varieties, foliar feeding, productivity, product quality, biologically active substances.

Strawberry (*Fragaria ananassa*) is one of the main berry crops in southern Russia due to its early ripening, little time before fruiting, high yield, excellent taste and medicinal properties (1-6). Quality attributes of the berries are the genetically controlled parameters but they can vary considerably under the influence of environmental factors. Weather stresses impact both yield production and quality, including chemical composition of the berries (7-10). Late spring frosts and lack of rainfall together with the elevated temperatures in late May—early June are the main weather extremums for the strawberry in Krasnodarskii region.

Plant metabolism activation is known to be influenced by the levels of lightening, water supply and the sum of active temperatures. Excess rainfall together with insufficient heat, the same as excessively high temperature combined with low humidity, adversely affect the vitamin content in berries. Under water deficit the synthetic processes are depressed, while the respiration energy and consumption of vitamins for the formation of enzymes increase (11-14). Therefore, strawberry cultivation without effective mineral nutrition is not

profitable (15-19).

Our goal herein was studying yield formation and quality in strawberry as influenced by foliar nutrition and the stimulators of a new generation.

Technique. Experiments were held as described (9) in 2006-2010 at the experimental field in Krasnodar region using differently ripening strawberry varieties, namely Cleary (early ripening), Marmolada (medium to early ripening) and Arosa (middle ripening). Mulching black perforated film and a drip irrigation were applied under 90-40×40 sm scheme of planting, the plot size was 3,5 m^2 with 30 plants in each random sample group. The soil (pH 6.5-7.0) was leached chernozem with 2.7-3.0 % humus, 140 mg/kg exchangeable potassium and 250-270 mg/kg mobile phosphorus in the plow layer. For foliar treatments during plant development we used the complex of humic salts GUMI 20K (BashIncom, Russia), the biostimulants Mival Agro (AgroSil, Russia) and Stimolante 66f (L. Gobbi, Italy), and also the growth activator Alga mix B Mg (L. Gobbi, Italy). Experiments were held in a 3-fold repetition, each lasting for 2 years. In the first experiment (2006 to 2007) the Cleary, Marmolada and Arosa plants were examined in control (no treatment) (i), under 3-fold GUMI 20K treatments (0,5 l/ha) at the phases of stem extension, early flowering and berry ripening (ii), and under 1-fold GUMI 20K treatment (0.5 l/ha) at the phase of stem extension together with 2-fold treatments with biostimulant Mival Agro (0.01 l/ha) at the phases of early flowering and berry ripening (iii). In the second experiment (2009 to 2010) the Marmolada and Arosa plants were investigated in control (no treatment) (i), under 3-fold foliar treatments with biostimulant Stimolante 66f (0.1 l/ha) at the phases of stem extension, early flowering and berry ripening (ii), and under 2-fold foliar treatments with biostimulant Stimolante 66f (0.1 l/ha) at the phases of stem extension and ovary formation together with 1-fold treatment with the growth activator Alga mix B Mg (0.2 l/ha) at mass flowering.

The efficacy of foliar treatments was estimated basing on yield value and merchantability and biochemical parameters in berries including a soluble dry matter content according to GOST 28561-91, sugars according to GOST 8756-13.87, acids according to GOST 25555.0-82, vitamin C according to A.Ya. Tribunskaya's method, and P-active substances according to L.I. Vigorov (20-21).

Data were processed (22) by means of dispersion analysis using Microsoft Office Excel 2003.

Results. In Kuban region the low winter temperatures are atypical, except the winter season of 2006 when the temperature dropped to –27 °C, while the spring frosts, which damage the flowers and cause a decrease in yield, are characteristic. The droughts were mostly observed in the plains and steppe zones of Kuban territory in spring and summer when the humidity decreases and temperature increases. In these parts the average humidity in summer was 35-40 %, ranging from 16 to 26 % in 2007 and from 14 to 39 % in 2010. Together with an average temperature of 35 °C, which reached up to 40 °C in 2007 and 2010, it results in yield and quality losses. In these areas the plants cultivated without drip irrigation are much suffering.

More favorable weather conditions are formed at humidity of 70-75 % in the Black Sea coast and in the foothill areas of Krasnodar region, where the plants are less exposed to overheating in the summer, when the temperature exceeds 30 °C and the surface of the soil warms up to 50-60 °C. Here, in the morning dew drops, reducing the effects of stress even after long drought.

A crucial time for berry formation begins from flowering. In 2006-2010 the weather conditions fluctuated considerably during April end to June beginning.

These fluctuations influenced considerably the content of biologically active substances in strawberry fruits (Fig. 1).

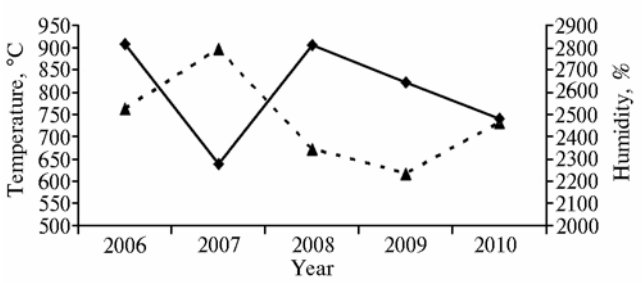

Fig. 1. Sum of average temperature (▲) and average humidity (♦) from the beginning of flowering to the end of berry ripening in strawberry (April 24-May 25) (Krasnodar).

Under the conditions of Krasnodarskii region 8.1-9.0 % soluble dry matters, 6.1-6.8 % sugars, 0.75-0.91 % organic acids, 64.3-69.0 mg/100 g vitamin C, 78.8-110.9 mg/100 g catechins and also 71.4-75.2 mg/100 g anthocyanins were accumulated in berries of the investigated varieties (23).

In 2006 the tested parameters were higher comparing to 2007 due to lower berry weigh and decreased yield resulted from the damage caused by winter frost. The content of soluble dry matters, sugars, vitamin C and P-active catechins ranged from 8.5 to 10.6 %, from 6.4-8.0 %, from 61.6 to 70.4 mg/100 g and from 76.0-109.8 mg/100 g, respectively. In 2007 by the end of flowering and at early ripening the abnormally hot and dry weather with a maximum average temperature up to 34.9 °C, or 3.6-7.7 °C above the norm, and an average relative humidity of 54 % did not allow to form the high quality strawberry fruits. In 2008, as yield increased and dry matter and sugars correspondingly decreased, a sufficient accumulation of vitamins was detected, in particular the vitamin C content reached up to 83.1 mg/100 g. It was due to more favorable conditions, 16.3-21.5 °C and 67 % humidity, during the ripening time. In 2010 similar to 2007, at May end to June beginning the weather was hot and dry with 30,6 °C maximum daily temperature and 58 % humidity, resulting in a decrease by 2-8 % in vitamin C and polyphenols content.

To increase stress tolerance, the plants were treated with adaptogens and immunostimulants. Foliar treatments with mineral fertilizers during plant development were shown to reduce negative effect of weather stress, contributing higher quality in berries (Table 1).

1. Quality parameters in strawberry varieties (*Fragaria ananassa*) as influenced by foliar treatment with mineral and biologically active substances (Krasnodar, 2006-2007)

Variant	1	2	3	4	5	6	7	8
Cleary variety								
Control	11.8	8.6	6.6	0.61	10.8	61.7	76.3	69.0
GUMI 20K	12.2	8.3	6.3	0.69	9.0	61.7	78.2	69.0
Mival Agro + GUMI 20K	12.5	9.4	7.1	0.70	10.1	64.0	84.3	77.6
Least mean difference$_{05}$	0.47	0.77	0.55	0.07	1.20	1.80	5.70	6.70
Arosa variety								
Control	11.0	10.2	7.7	0.59	13.0	62.4	90.6	77.6
GUMI 20K	11.4	10.6	8.0	0.68	11.8	63.8	100.8	72.2
Mival Agro + GUMI 20K	12.0	10.9	8.2	0.67	12.2	69.9	109.8	80.4
Least mean difference$_{05}$	0.68	0.08	0.34	0.08	0.83	5.40	13.00	5.60
Marmolada variety								
Control	15.8	7.7	5.8	0.62	9.4	53.3	70.6	73.1
GUMI 20K	16.4	7.8	5.9	0.62	9.4	55.7	79.0	77.6
Mival Agro + GUMI 20K	16.6	8.5	6.4	0.69	9.3	59.6	84.2	80.2
Least mean difference$_{05}$	0.57	0.59	0.43	0.06	0.20	4.30	9.30	4.90

Примечание. 1 — berry weight, g; 2 — dry matters, %; 3 — sugars, %; 4 — total acidity, %; 5 — sugar ti acidity index; 6 — vitamin C, mg/100 g; 7 — catechins , mg/100 g; 8 — anthocyanins, mg/100 g. For more detail see *Tenique*.

At 3-fold foliar treatments with GUMI 20K the humic salts had an ex-

pressed protective effect against stresses. According to the reports, it is due to optimal composition of biogenic microelements, which stimulate plant growth and immunity, and also enhance the biosynthesis of the substances determining fruit quality in strawberry. Due to good combination of biologically active components the biostimulant Mival Agro provides for activation of the antioxidation complex, and increases plant immunity and tolerance under biotic and abiotic stresses caused by weather conditions (24, 25).

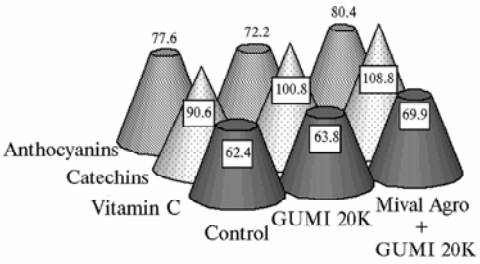

Fig. 2. Changes in content of biologically active components (mg/100 g) **in fruits in strawberry (*Fragaria ananassa*) variety Arosa as influenced by foliar treatment with mineral and biologically active substances** (Krasnodar, 2006-2007).

Under foliar application of all tested preparations on plantations of fruit-bearing strawberry varieties Cleary, Arosa, Marmolada, grown with mulching black perforated film and drip irrigation there was a general trend of increasing berry weight by 0.7-1.0 g comparing to the control. This improves fruit quality and eventually increases the yield. A combination of Mival Agro and GUMI 20K provides for 7-10 % increase in dry matter and sugar levels, up to 15 % increase in organic acid level and 9-14 % increase in vitamin C level when compared to control (Fig. 2).

The same trend was found in regard to P-active substances, particularly the level of catechins was higher in the treated plants of all the varieties tested. The peak value of 109.8 mg/100 g was found in the Arosa plants. Mival Agro together with GUMI 20K also intensified berry coloration, and this fact was confirmed by the data on the accumulation of anthocyanins exceeding the control by 3-12 %.

The varieties differed in their response to the treatment. In Arosa the greatest effect of dry matter, sugars, acids and P-active polyphenols assimilation was observed when the plants were treated with Mival Agro together with GUMI 20K.

2. Yield parameters in strawberry varieties (*Fragaria ananassa*) as influenced by foliar treatment with mineral and biologically active substances (Krasnodar, 2006-2007)

Variant	Number per 1 m of bed		Weight of berries		Yield	
	peduncles	berries	average, g/pcs	per 1 m of bed, kg	ton/ha	to control
Marmolada variety						
Control	131	365	7.3	2.648	17.0	
Stimolante 66f	152	452	8.3	3.728	24.0	+7.0
Stimolante 66f + Alga mix B Mg	144	448	9.0	4.036	26.1	+9.1
Least mean difference$_{05}$	14.4	66.9	1.3	0.99	6.6	
Arosa variety						
Control	59	230	9.0	2.020	13.0	
Stimolante 66f	72	212	11.2	2.175	14.0	+1.0
Stimolante 66f + Alga mix B Mg	102	347	9.5	3.296	20.4	+7.4
Least mean difference$_{05}$	30.0	99.9	1.8	0.95	5.5	

Comments. For more detail of applied preparations see *Technique* section.

Plant stimulant Stimolante 66f was reported to activate metabolism and facilitate stress overcoming caused by extremal temperture and water deficit, while the growth activator Alga mix B Mg accelerates the assimilation of nuntrients due to microements. This also was confirmed by our data of yield formation in the varieties (Table 2). It was found that a 3-fold foliar treatments

with Stimolante 66f or its combination with Alga mix B Mg contributed to the increase in plant tolerance to late spring frosts in 2009. In Marmolada variety at Stimolante 66f together with Alga mix B Mg treatment there were observed 9.1 % more peduncles, 18.5 % more berries and 1.7 g higher berry weight resulting in 9.1 ton/ha more yield compared to control.

Also the plants were more tolerant to heat and drought, especially in May to June 2010. This led to higher weight and better chemical composition (Table 3). The specific reaction to foliar treatment was also revealed. When Alga mix B Mg was used together with Stimolante 66f on middle ripening Arosa plants the sugar and acid contents decreased and the concentration of biologically active substances increased as the berry weight increased compared to control. In contrast, in higher yielding Marmolada variety with middle ripening under the same treatment the dry matter content, sugar content and acid concentration were 9.0 %, 6.8 % and 1.0 % higher, while the synthesis of vitamin C and P-active substances slowed down.

3. Main parameters of berry quality in strawberry varieties (*Fragaria ananassa*) as influenced by foliar treatment with biologically active substances (Krasnodar, 2009-2010 год)

Variant	1	2	3	4	5	6	7
			Arosa variety				
Control	7.6	5.7	0.91	6.3	59.0	106.0	60.0
Stimolante 66f	6.8	5.1	0.95	5.4	63.4	103.0	69.5
Alga mix B Mg + Stimolante 66f	6.4	4.8	0.84	5.7	65.4	109.8	66.8
Least mean difference$_{05}$	0.80	0.62	0.04	0.62	4.40	4.60	6.60
			Marmolada variety				
Control	8.8	6.6	0.98	6.9	72.2	97.8	68.9
Stimolante 66f	7.3	5.6	1.12	4.9	73.6	97.8	69.5
Alga mix B Mg + Stimolante 66f	9.0	6.8	1.00	6.7	60.0	79.0	61.3
Least mean difference$_{05}$	1.20	0.90	0.09	1.50	14.00	14.20	6.20

Comments. 1 — dry matters, %; 2 — sugars, %; 3 — total acidity, %; 4 — sugar to acidity index; 5 — vitamin C, mg/100 g; 6 — catechins, mg/100 g; 7 — anthocyanins, mg/100 g. For more detail see *Tenique*.

So, the foliar treatment with a complex mineral fertilizer and qrowth stimulants at different phases of strawberry vegetation increases the plant tolerance to weather stresses due to activating defence mechanisms. As a result, the yield increased by 32-46 %, and the parameters of quality in berries were 9-23 % higher with the nutritive value and medicinal properties also improved by 6-19 %.

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