Ways to increase stress resistance of grapes in conditions of moisture deficit

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Abstract. For optimal conditions of grapevine development, a relatively uniform distribution of precipitation is needed during all phases of active plant growth. However, often there are dry periods in summer months in areas of unstable moistening. At the present time, in intensive technologies of grape cultivation, foliar treatments with agrochemicals are widely used to increase stress resistance of plants to moisture deficit with the goal to protect and increase cropping capacity and gain optimal conditions of viticultural products. Our research, carried out in the conditions of Crimea, have shown that using of the studied systems of mineral nutrition with micronutrient fertilizers of the Wuxal group in conditions of air and soil drought contributed to an increase in the average bunch weight by 17.4-51.9 g and an cropping capacity of grapes by 9.5-35, 3% (1-1.5 t / ha). It was experimentally proven that test treatments have led to a significant increase (by 4.7-15.5%) in the growth of green matter of bushes and in the structure index of table grape bunch by 19.1-37.8%. Against the background of using the studied systems of nutrition, an increase in the content of sugars and phenolic substances in the must of 'Saperavi' grape variety by 8.5% and 70.4%, respectively, was observed in comparison with the control.

1 Introduction

According to the intergovernmental group of experts, the planet Earth experiences significant warming of the atmosphere and oceans. The concentration of greenhouse gases has increased, while stocks of snow and ice have reduced, and the sea level has raised. Each of the last three decades was characterized by higher temperature near the surface of Earth in comparison with any previous decade since 1950 [1, 2].

An increase in average daily air temperature, uneven distribution of precipitation or a long absence of rains leads to a moisture deficit - the air and soil drought. The effect of drought causes significant changes in the hormonal system of plants: the content of growth-activating hormones - auxin, cytokinin, gibberellin, phenolic growth stimulators decreases, and the level of abscisic acid and ethylene increases [3, 4].

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Insufficient moistening of the vineyard is one of the main environmental factors limiting the vegetative growth of arms, shoots and leaves of the grapevine, changing the microclimate of crown and level of illumination in the area of bushes, making berries more sensitive to the heat stress, especially with a high level of solar radiation [5, 6].

Water deficit, like other stressors, can limit sugar absorption and starch accumulation in the growing pollen grains, impeding the process of fertilization and fruit setting, even though leading to the loss of entire inflorescences [5, 7]. The amount of available water affects the rate of sugar accumulation and the size of grape berries, insufficient moistening leads to a decrease in plant productivity and a change in the physicochemical composition of grapes and wine.

To increase stress resistance of plants to a lack of moisture, foliar treatments with micronutrient fertilizers are widely used in plant cultivation. They can be carried out during the entire growing period, especially during stress periods of plant nutrient requirements, without interaction with the components of soil, sedimentation, adsorption on the soil surface or the risk of losses as a result of erosion [8]. In the studies of Dewdar M. and Rady M. on determining the effect of K on photosynthesis and water exchange parameters of plants under drought conditions, it was found that the use of potassium micronutrient fertilizers has led to a significant decrease in the stress of plants [9].

Since viticulture is a highly profitable and intensive branch of the Crimean agro-industrial complex, which belongs to the regions of unstable moistening, the purpose of this work was to study the effect of various grapevine nutrition systems on the productivity and quality parameters of grapes against the background of moisture deficit.

2 Study objects and methods

Field experiments were carried out on commercial plantations of wine and table grape varieties during 2019-2020 in the soil and climatic conditions of two viticultural zones of Crimea: Mountain-valley – on widely distributed table and wine varieties ‘Italia’ and ‘Saperavi’ (Malorechenskoye branch of FSUE PJSC Massandra); south-west - on the table variety ‘Cardinal’ (JSC Chernomorets Agrofirma) and the wine variety ‘Saperavi’ (LLC Zakharyin House).

The objects of research were the micronutrient fertilizers of the Wuxal group, productivity, phytometric, uvological and quality parameters of table and wine grape varieties.

The type of research - field farmscale experiment. The area size of the variant is 2 ha. Each variant includes 45 recording bushes in triplicate. Distribution of experimental variants was provided using method of elongated working plots. Application technology - truck spraying (OPV-2000). The working liquid rate of consumption was 800 l / ha.

The research scheme included four experimental plant nutrition systems and the control systems (systems of grape nutrition used in farming, Table 1).

Table 1. The scheme of research

Phenological stage of grape growth	Experimental variant	Consumption rate, l(kg)/ha	Farmscale variant (control)	Consumption rate, l(kg)/ha
Experiment 1: Malorechenskoye branch of FSUE PJSC Massandra, ‘Saperavi’ variety, 2019				
1. Before flowering	Wuxal Boron pH	1,5	Ultramag B	1
2. Berries groat-sized	Wuxal Microplant	0,5	Potassium humate	2
3. Berries pea-sized	Wuxal Microplant	0,5	Potassium humate	2

4. Berries touching	Wuxal Microplant	0,8	-	-
5. Beginning of ripening	Wuxal Aminocal	2	-	-
Experiment 2: Malorechenskoye branch of FSUE PJSC Massandra, 'Italia' variety, 2019				
1. Before flowering	Wuxal Boron pH	1,5	Ultramag B	1
2. Berries groat-sized	Wuxal Microplant	0,5	Potassium humate	2
3. Berries pea-sized	Wuxal Microplant	0,5	Potassium humate	2
4. Berries touching	Wuxal Microplant	0,8	-	-
5. Beginning of ripening	Wuxal Aminocal	2	-	-
Experiment 3: JSC Chernomorets Agrofirma, 'Cardinal' variety, 2019				
1. Before flowering	Wuxal Boron pH	1,5	Agris B	1
2. Berries groat-sized	Wuxal Microplant	1,5	Ultramag B	1
3. Berries touching	Wuxal CalciumBoron	2,5	Humifilin	2
4. Beginning of ripening	Wuxal Aminocal	2	Humifilin	2
Experiment 4: LLC Zakharyin House, 'Saperavi' variety, 2020				
1. Before flowering	Wuxal Boron pH	1,5	Agris B	1
2. After flowering	Wuxal Microplant	0,8	Ultramag B	1
3. Berries groat-sized	Wuxal Microplant	1,0	Humifilin	2
4. Berries touching	Wuxal Aminocal	2,5	Humifilin	2
5. Beginning of ripening	Wuxal Aminocal	2,5	Humifilin	2

Wuxal Boron pH is an innovative micronutrient fertilizer with excellent buffer properties, neutralizes pH of the working solution, contributing to the rapid penetration of the active substance of pesticides into the plant, while providing plants with Boron and nutrients. The preparation contains (g / l): N - 70, P₂O₅ - 183, B -108, SO₃ - 5.5, Cu - 0.7, Fe - 1.4, Mn - 0.7, Zn - 0.7, Mo - 0.014.

Wuxal Microplant is a micronutrient fertilizer with high content of a wide range of trace elements with additional effect of sticking agent and surfactant. It eliminates deficit of trace elements, leading to an increase in plant productivity. The preparation contains (g/l): N - 78, K₂O - 157, MgO - 47, SO₃ - 203, B - 4.7, Cu - 7.9, Fe - 15.7, Mn - 23.6, Zn - 15.7.

Wuxal Aminocal is a complex micronutrient fertilizer consisting of mineral nutrients and biologically active substances (Ca - 202, Mn - 6.7, Zn - 6.7, polypeptides and amino acids - 68%), developed to eliminate and prevent calcium deficit. The composition includes Mn and Zn, as well as polypeptides that promote better calcium penetration and increase plant resistance to adverse environmental factors.

During the research we used generally accepted methods used in viticulture and winemaking [10-11]. The experimental data obtained were subjected to mathematical processing by generally accepted methods of descriptive statistics using the Microsoft Excel software package. The credibility level of statistical analysis rated 0.95 (95%).

3 Results and discussion

In the Mountain-valley Crimea, the weather conditions of the growing season of 2019 were mostly hot and dry. Average monthly air temperatures during the period from April to September exceeded long-time average annual parameters by 0.2-4.7 ° C, with a maximum excess in June (Table 2). During the growing season, there was 32.5% less precipitation in comparison with the long-time average annual and amounted 200.8 mm. Average monthly air temperatures in 2020 during the period from June to September also exceeded the long-time average annual data by 1.2-4.1 ° C, with a maximum value in September. During the growing season, the amount of 181.1 mm of precipitation was recorded, which was 90.2% of the long-time average annual indicator (Table 2).

Table 2. Meteorological parameters of the grape growing season

PARAMETERS	MONTHS					
	April	May	June	July	August	September
Alushta meteorological station						
<u>Air temperature, °C</u>						
a) long-time average annual	10,5	15,8	21,0	24,1	24,2	19,2
b) 2019	11,6	17,7	25,7	24,3	25,9	20,9
c) 2020	10,8	15,4	22,3	26,0	25,4	23,3
<u>Precipitation, mm</u>						
a) long-time average annual	25,3	28,5	37,1	34,3	41,5	34,1
b) 2019	32,1	14,6	17,3	23,4	17,1	31,0
c) 2020	6,4	13,9	30,6	29,7	30,0	70,5
Sevastopol meteorological station						
<u>Air temperature, °C</u>						
a) long-time average annual	10,8	16,2	21,2	23,8	23,8	19,2
b) 2019	10,3	17,6	24,1	22,7	23,7	19,0
c) 2020	9,6	14,8	21,2	23,9	23,4	20,7
<u>Precipitation, mm</u>						
a) long-time average annual	23,2	26,9	34,7	24,6	26,1	41,9
b) 2019	31,5	3,5	55,2	42,5	41,8	2,5
c) 2020	9,0	17,3	45,0	5,5	0	68,5

In the south-western Crimea, a reliable positive deviation from the long-time average data in 2019 was registered in May (1.4 ° C) and June (2.9 ° C). In the period from April to September, 177 mm of precipitation was recorded, which corresponded to the long-time average annual indicator. The analysis of meteorological data for 2020 shows that, in general, the average daily air temperatures in the viticultural research zone were close to the long-time average annual indicators, not including April and May (lower by 1.2 ° C and 1.4 ° C, respectively), as well as September (1.5 ° C higher). During the active growing season of grapes, the rate of precipitation was 145.3 mm, which was 18.1% lower than the average annual rate (Table 2).

Thus, in Crimea in 2019-2020 there was a tendency of the last decade of increasing the average daily air temperature with uneven distribution of precipitation throughout the entire growing period of grapes.

In the course of the research, the phytometric parameters of grapes were determined. They characterize growth processes and peculiarities of their passage as important criteria for the grape bush design. Treatments of table grape varieties with the studied preparations contributed to an increase in the growth of green matter of the bush in the Experiment 2 by 15.5% (320.3 cm³) and in the Experiment 3 by 4.7% (87.4 cm³, Table 3). There was no difference in cultivation of annual grape shoots.

Table 3. The effect of the Wuxal group microfertilizers on phytometric parameters of grape bushes of table varieties

Variant	Average shoot length (L), cm	Average shoot diameter (D), cm	Bush growth gain (P), cm ³	Ripening degree, %
Malorechenskoye branch, 'Italia' variety, 2019				
Control	166,0	0,81	2064,9	85,5
Experiment 2	176,5	0,83	2385,2	84,5
HCP ₀₅	8,6	0,03	78,5	-
JSC Chernomorets Agrofirma, 'Cardinal' variety, 2019				
Control	195,9	0,91	1843,8	89,1
Experiment 3	202,2	0,91	1931,2	90,6
HCP ₀₅	6,1	0,06	85,6	-

Recording of the quantitative and qualitative parameters of the grape yield showed that for all the studied indicators the experimental variants were superior to the control (Table

4). Using of experimental systems of nutrition on table grape varieties contributed to an increase in the average bunch weight by 50-51.9 g, in the cropping capacity by 1.1-1.5 t / ha and in the concentration of sugars in the grape juice by 5-12 g / dm³ in comparison with the control. Statistical and mathematical processing of the obtained data showed that a significant increase in sugar content was observed for the ‘Cardinal’ (7.5%) and ‘Saperavi’ (8.5%, south-west of Crimea) varieties. The increase in yield of wine grape variety ‘Saperavi’ in the Experiment 1 amounted 1 t / ha (12.8%), in the Experiment 4 it was 1.2 t / ha (35.3%, Table 4).

Table 4. The effect of the Wuxal group microfertilizers on grape productivity

Variant	Average bunch weight, g	Number of bunches, pcs/bush	Yield, kg/bush	Cropping capacity, t/ha	Mass concentration of sugars, g/dm ³
Malorechenskoye branch, ‘Saperavi’ variety, 2019					
Control	141,8	27,8	3,9	7,8	188
Experiment 1	159,2	27,7	4,4	8,8	191
HCP ₀₅	10,4	0,7	0,6	-	1,8
Malorechenskoye branch, ‘Italia’ variety, 2019					
Control	372,0	15,6	5,8	9,3	157
Experiment 2	422,0	15,5	6,5	10,4	162
HCP ₀₅	14,1	0,7	0,4	-	2,1
JSC Chernomorets Agrofirma, ‘Cardinal’ variety, 2019					
Control	682,8	14,5	9,9	15,8	161
Experiment 3	734,7	14,7	10,8	17,3	173
HCP ₀₅	12,1	0,9	0,5	-	2,4
LLC Zakharyin House, ‘Saperavi’ variety, 2020					
Control	69,7	23,9	1,7	3,4	164
Experiment 4	97,3	23,7	2,3	4,6	178
HCP ₀₅	13,5	0,8	0,4	-	2,9

At the next stage of the work, the analysis of mechanical composition of table grape bunches was carried out. The reliable increase in the average bunch weight, observed in the experimental variants, was due to the gain in the weight of 100 berries by 20.6-26.3 g in comparison with the control, while there was also an increase in the index of the bunch structure by 19.1-37.8% (Table 5).

Table 5. The effect of the Wuxal group microfertilizers on mechanical composition of a grape bunch

Variant	Bunch structure						
	Bunch weight, g	Number of berries in the bunch, pcs	Weight of 100 berries, g	Stem weight, g	% of berries	% of stem	Structure parameter, %
Malorechenskoye branch, ‘Italia’ variety, 2019							
Control	372,0	75,9	524,7	7,7	97,9	2,1	46,6
Experiment 2	422,0	78,6	545,3	6,2	98,5	1,5	65,7
HCP ₀₅	14,1	2,6	13,7	1,3	-	-	-
JSC Chernomorets Agrofirma, ‘Cardinal’ variety, 2019							
Control	682,8	71	738,9	13,7	97,8	2,2	44,5
Experiment 3	734,7	74	765,2	9,1	98,8	1,2	82,3
HCP ₀₅	12,1	2,8	9,4	2,7	-	-	-

The processing of dark-berry wine grape variety ‘Saperavi’ with the studied preparations of the Wuxal group provides a statistically significant increase in the mass concentration of sugars in the grape must by 14 g / dm³ (8.5%, Table 6). The increase in the content of phenolic substances in the experimental sample using the studied grape nutrition

system consisted of 169 mg / dm³ or 70.4% in comparison with the control. The rest of the determined parameters was at the control level.

Table 6. Physicochemical parameters of the must of wine grape variety ‘Saperavi’ (LLC Zakharyin House)

Variant	Mass concentration, g/dm ³		pH	MPhMO activity, units*10 ³ /cm ³	Total content of phenolic substances in the must, mg/dm ³
	sugars	titratable acids			
Control	164	12,3	3,0	0,26	240
Experiment	178	11,7	3,1	0,3	409
HCP ₀₅	2,9	5,48	1,39	0,13	-

4 Conclusion

As a result of the studies carried out in conditions of moisture deficit and showing the positive effect of the studied systems of nutrition with micronutrient fertilizers of the Wuxal group on the productivity and quality of grapes in Crimea, it was established the following:

- a significant increase in the growth of bushes of table grape variety ‘Italia’ by 15.5% (320.3 cm³) and ‘Cardinal’ by 4.7% (87.4 cm³), in after years this tendency can have a positive effect on the productivity of grapes;
- a significant increase in the weight of 100 berries and the parameter of bunch structure of table grape varieties ‘Italia’ and ‘Cardinal’ by 20.6 g, 26.3 g and by 19.1%, 37.8%, respectively, in comparison with controls;
- for all experimental variants, a significant increase in the cropping capacity of grapes was achieved: for table varieties - 9.5-11.8%; for wine varieties - 12.8-35.3%, due to a reliable increase in the average bunch weight by 50-51.9 g and 17.4-27.6 g, respectively;
- positive effect of the studied microfertilizers on the grape yield quality of varieties ‘Cardinal’ and ‘Saperavi’ (south-west zone): the increase in the concentration of sugars in the juice of berries relative to the control was 12 g / dm³ (7.5%) and 14 g / dm³ (8.5%), respectively; the increase in the concentration of phenolic substances in the grape must of ‘Saperavi’ grape variety reached 70.4% (169 mg / dm³).

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