PHYSIOLOGICAL AND BIOCHEMICAL MECHANISMS ENSURING THE REGULATORY ACTION OF TRACE ELEMENTS ON PLANT RESISTANCE TO UNFAVOURABLE GROWING CONDITIONS

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ABSTRACT

The trace element action on the activity of the principal enzymes of the nitrogen metabolism, content of nitrates, aminoacids, carbohydrates, chlorophyll and its key predecessor (5-ALA) under limiting conditions was studied. The favourable influence of some trace element on plant resistance to the insuficient humidity and nutrient element imbalance that provoke chlorosis was revealed. The possible physiological and biochemical mechanisms of plant resistance regulation with Mo, B, Fe, Mn were determined.

Key words: microelements, carbohydrates, aminoacids, nitrates, 5 - aminolevulinic acid, chlorosis, resistance.

INTRODUCTION

The most frequent extreme situations in our region that reduce plant productivity and longevity of perennial cultures are caused by weather condition changes and antropogenic pressure. First of all, it is drought and the physiologic diseases, resulting from element imbalance in nutritive medium and in plant tissue. The harm of unfavourable growing conditions can be reduced by the influence on the systems of regulation of plant organism stability. One of these systems is trophic. It is known that a lot of metabolic processes change in dependence on providing plant tissues with a definite quantity and ratio of nutritive elements. (Mengel and Kirkby, 1982; Marschner, 1986; Toma and Veliksar, 1992).

The objective of this study was to determine the possible mechanisms of trace elements regulatory action ensuring plant resistance to unfavourable growing conditions.

MATERIALS AND METHODS

The experiments were performed in the greenhouse and in the field in 1992-1995. The cultivars studied were sugarbeet, soia, grape. The following methods were used: quantitative content of sugars – according to Bertrane; their qualitative content – using thin-layer chromatography; free aminoacids (AA) – with the aid of the aminoacid analyser AAA 881; nitratreductase activity (NR) – according to Mulder; nitrate nitrogen – using ion meter; chlorophyll concentration – in acetone extract; concentration of 5 – amino-levulinic acid (5-ALA) – according to Miller's method modified by N. Averina et al.; trace element content – using atom absorption spectrophotometer after dry ashing.

RESULTS AND DISCUSSIONS

The influence of B and Mo on the carbohydrate content and nitrogen metabolism was studied in the leaves and apoplast under normal humidity and short-term water stress. The increase of the monosaccharides content in sugarbeet apoplast was established after treatment with B, especially under water stress. It is caused by aggravation of organic compounds transport from leaves to roots. The action of Mo was more evident on the nitrogen metabolism. It increased key enzymes activity and the process of nitrogen utilization, it maintained the protein synthesis at a higher level (Tables 1 and 2).

The sum of free AA in leaves and apoplast is higher under the water stress. B and Mo treatment contributes to the decrease of AA content under these unfavourable conditions and accelerates the process of ammonium utilization.

In the recent years a lot of species are often damaged by edaphic chlorosis caused by disturbance nutritive conditions. Our investigation showed that chlorosis appearance is connected

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Table 1. The influence of Mo, B and soil moisture conditions on NR activity of sugarbeet
Sandy culture

Treatments	NR activity, mkg NO_2/g wet stuff	
	35 % FWC	70 % FWC
	The second day after stress	
	leaves	
Control	0.627±0.005	0.658±0.004
+ Mo	0.766±0.031	0.813±0.019
+ B	0.716±0.013	0.756±0.021
	The tenth day after stress	
	leaves	
Control	0.221±0.002	0.217±0.01
+ Mo	0.198±0.002	0.222±0.002
+ B	0.217±0.004	0.222±0.001
	roots	
Control	0.137±0.002	0.151±0.004
+ Mo	0.158±0.003	0.162±0.003
+ B	0.149±0.004	0.151±0.002

Table 2. The influence of B and Mo on the aminoacid content in leaves and apoplast of sugarbeet in relation to moisture condition. 1995, mg/100 g

Treatments	Total content	From them			
		ASP	GLU	ALA	VAL
	leaves				
Contr.70%FWC	146.707	15.064	37.089	10.281	3.092
B 70 % FWC	163.232	19.303	43.294	9.511	4.312
Mo 70 % FWC	178.186	18.650	42.949	11.674	4.605
Contr.35%FWC	214.321	10.785		15.841	7.138
B 35% FWC	194.246	19.328		10.466	6.960
Mo 35% FWC	208.970	22.848		11.263	7.925
	apoplast				
Contr.70%FWC	10.544	1.574	0.826	1.380	0.140
B 70% FWC	8.294	1.239	0.848	1.307	0.382
Mo 70% FWC	8.850	1.329	0.781	1.016	0.363
Contr.35%FWC	20.523	1.833	3.729	2.77	0.722
B 35% FWC	14.192	1.169	1.768	1.765	0.531
Mo 35% FWC	14.575	1.843	1.900	1.530	0.536

mainly with decrease of first chlorophyll predecessor - 5-ALA content (Veliksar et al., 1993). The compounds containing Fe, especially in chelate form, accelerate the 5-ALA and chlorophyll synthesis (Table 3).

Table 3. Effect of Fe - containing compounds on the 5-ALA and chlorophyll content in vine leaves

Treatments	5-ALA	Chlorophyll (mg/g f.w.		
	nmol/g f.w	a	b	a + b
Fe - deficient plants (before treatment)	5.2	0.49	0.34	0.83
$FeSO_4$	6.1	0.56	0.38	0.94
Fe – DTPA	6.7	0.93	0.45	1.38
Gasazot (liquid)	6.9	0.72	0.32	1.04
Gasazot (powder)	7.1	0.76	0.39	1.15

The photosynthetic activity increases. The content of ammonium in chlorotic leaves decreases (Table 4).

Table 4. Effect of Fe - containing compounds on the ammonium content in vine leaves

Treatments	Before treatment	After treatment
Green leaves	5.21	6.44
Chlorotic leaves	9.54	11.50
Gasazot	-	5.74
Sequestrene – Fe	-	4.76
Control (water)	-	-

The sum of free AA in chlorotic leaves is higher than in sound ones. After the second treatment with trace element solutions the difference in AA content between chlorotic and sound leaves decreases, especially when Fe was used (Table 5).

Table 5. Effect of Fe - containing compounds on the free AA content in vine leaves (mg/100 g f.w)

Free AA	Before treatment	$FeSO_4$	Fe-DTPA	Gasazot
Cysteic	7.34	6.43	5.06	5.75
Aspartic	19.81	16.45	12.23	17.35
Threonine	1.76	2.32	1.34	2.79
Serine	1.97	2.76	1.91	3.41
Glutamic	49.66	5.35	34.36	44.23
Glutamine	9.76	8.05	5.76	7.27
Proline	5.60	4.45	0.00	1.44
Glycine	0.44	0.34	0.24	0.39
Alanine	23.90	13.39	11.89	12.77
Valine	5.62	2.45	3.07	2.65
Isolecucine	1.36	2.01	1.29	2.28
Leucine	0.72	2.72	1.69	2.97
Tyrosine	1.67	1.34	0.83	1.15
Phenylalanine	1.07	8.77	1.36	1.73
γ-Amino-butyrate	32.32	23.55	19.28	22.91
Ammonium	3.61	3.89	4.02	3.92
Lysine	0.63	0.47	0.22	0.55
Histidine	0.44	0.51	0.00	0.00
Arginine	0.00	0.00	0.00	0.00
Asparagine	3.50	0.00	0.00	0.00
SUM of AA	171.80	140.31	105.88	134.39

This distinction is mostly the result of the monoaminodicarbonic and heterocyclic aminoacid changes.

The positive influence of the microelements on the nitrogen metabolism processes can be explained due to microelement containing enzymes which catalized the chain of nitrogen reduction biochemical reactions.

The trace elements (Fe, Mn) enhance the accumulation of saccharobiose and fructose in chlorotic leaves and fructose in berry. Berry rippening is accelerated and its quality is improved (Table 6).

Table 6. Carbohydrate content in vine bush parts at the phase of intensive growth and development, Feteaska variety (% of soluble solids)

Treatments	Monosaccharides	Disaccharides	Total sugars	Hemicellulose
leaves				
Control (H_2O)	0.36	0.28	0.65	1.18
$MnSO_4$	1.57	0.16	1.73	3.53
$ZnSO_4$	1.13	0.57	1.73	3.53
Gasazot (Fe)	1.81	0.97	2.83	3.53
shoots				
Control (H_2O)	0.14	0.05	0.19	10.26
$MnSO_4$	0.23	0.19	0.43	11.67
$ZnSO_4$	0.20	0.19	0.39	11.49
Gasazot (Fe)	0.11	0.05	0.17	13.5

More intensive starch and hemicellulose accumulation in perennial organs treated with trace element solution results in increasing frost resistance and productivity of chlorosis affected vine bushes.

CONCLUSIONS

It is possible to influence upon certain metabolic processes using trace elements and to enhance the plant resistance to unfavourable growing conditions. Wide application of optimal doses and ration of all vitally essential for plant nutrition elements alow to rise the agricultural production and its sustainability.

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REFERENCES

Marschner, H., 1986. Mineral nutrition in higher plants. Academic. Press, London.

Mengel, K. and Kirkby, E., 1982. Principles of plant nutrition. 3rd Edition.

Toma, S.I., Veliksar, S., 1992. Ecologia şi aplicarea îngrăşămintelor în viticultură. Ecologia şi protecţia mediului. Călimăneşti, Romania: 63-65.

Veliksar, S., Syrcu, R., Busuioc, V., Toma, S., Litvac, A., 1993. The 5-ALA content in vine leaves in relation to plant provision with iron. 7th Internatioal Symposion on Iron Nutrition and Interactions in Plants, Spain: 104.

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glutamine	9.76	8.05	5.76	7.27
proline	5.60	4.45	0.00	1.44
glycine	0.44	0.34	0.24	0.39
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leucin	0.72	2.72	1.69	2.97
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phenylalanine	1.07	8.77	1.36	1.73
γ amino-butyrate	32.32	23.55	19.28	22.91
ammonium	3.61	3.89	4.02	3.92
lysin	0.63	0.47	0.22	0.55
histidine	0.44	0.51	0.00	0.00
arginine	0.00	0.00	0.00	0.00
asparagine	3.50	0.00	0.00	0.00
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