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RESEARCH ARTICLE

EXOGENOUS OPTIMIZATION OF THE ANTIOXIDANT PROTECTION CAPACITY OF PLANTS IN MODERATE DROUGHT CONDITIONS

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Abstract

The effect of Thiourea, Galmet and Thiogalmet on the antioxidant protection capacity of plants in moderate drought conditions was studied. Thiogalmet is a new chemical composition that contains Thiourea (Tu) and Galmet - a preparation that consists of a mixture of potassium, ammonium, magnesium gallates, and potassium molybdate and ammonium paramolybdate. Biological tests were performed in the vegetation complex of the Institute of Genetics, Physiology and Plant Protection. As subjects of investigations served the plants *Glycine max* (Merr) L 'Nadejda' variety and *Zeya mays* L'P458' cultivar, grown in the Mitcherlih vegetation pots with 40 kg soil and exposed to the drought stress at the critical stages for water. It has been established that pre-treatment of plants with Thiourea, Galmet and, in particular, with Thiogalmet increases the activity of superoxide dismutase (SOD), catalase (CAT), ascorbateperoxidase (APX), glutathione reductase (GLR) and glutathione peroxidase (GLPX). The high activity of antioxidant enzymes is associated with a decrease in the content of malonic di-aldehyde (MDA). The increase in antioxidant protection capacity of plants pre-treated with Thiogalmet was recorded both in optimal conditions and in conditions of oxidative stress induced by drought. Thiogalmet has been shown to be one of the new biologically active chemicals that can be used in agriculture to reduce the negative impact of oxidative stress caused by reactive oxygen species (ROS).

Introduction:-

Global warming, the phenomenon of a constant increase in average air temperatures and a decrease in precipitation, is one of the most difficult problems facing humanity today. Agriculture is one of the sectors most affected by these changes due to its dependence on meteorological conditions, which at the moment cannot be controlled. The complex effects of climate change cause significant qualitative and quantitative annual crop losses and in severe cases can jeopardize the whole yield. Thus, mitigating the negative impact of extreme natural phenomena and ensuring crop stability I s one of the priorities of agriculture. [IPCC, 2011; Jentsch A., Kreyling J., Elmer M., Gellesch E., et al., 2011; Krasensky H., Jonak C., 2012]. A special attention is paid to developing innovative methods for exogenously regulating plant resilience and productivity, based on knowledge of the mechanisms involved in plant response and tolerance to ecological stress in countries with advanced agricultural technologies. It has become an axiom that under stress conditions there is an eruption of reactive oxygen species formation in plant

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cells, which conditions, depending on their concentration, a different degree of oxidative destruction of cell structures. It is well argued [Bhattacharjee S., 2005, 2012; Mittler R., Blumwald E., 2010; Munne-Bosch S., 2013; Walter J., et al., 2013] that the key mechanisms associated with an adequate response to adverse humidity fluctuations and drought conditions are those associated with the autoregulation of ROSsformation and neutralization through activation or a more complete realization of the antioxidant potential. Plant tolerance to oxidative stress is associated with the activity of antioxidant protective enzymes and high levels of antioxidants in cells [Foyer, Shigeoka, 2011; Ștefîrță A. et al., 2012; 2017; S. Munne-Bosch et al., 2013; Bartolia et al., 2013]. The main antioxidants in higher plants include glutathione, ascorbate, tocopherol, proline, betaine and others, which are also important components of signaling pathways. Enzymatic and non-enzymatic antioxidants in higher plants can protect cells from oxidative damage by eliminating ROSs. In addition to their crucial role in the defense system and as enzymatic cofactors, antioxidants influence the growth and development of plants by modifying the processes of mitosis and cell elongation. The concentration of native protective substances isanother important factor that determines cell and tissue tolerance to adverse conditions. The high level of substances with thiol-groups, the presence of antioxidants, free radical acceptors, and inhibitors of chain peroxide reactions decreases the sensitivity to drought due to free radical scavenging, inhibition of lipid peroxidation in membranes. In general, tolerant plants have a higher level of anti-stress metabolites under normal growing conditions and / or accumulate several metabolites with protective function such as amino acids, soluble carbohydrates, various antioxidants and others under unfavorable conditions. In this sense, the use of physiologically active substances (PHAS) with antioxidant properties presents a possibility of increasing crop productivity and quality under unfavorable conditions. [Asada K. 2006; Paris Sharifi, et al., 2012; Merewitz E., et al., 2015; Ștefîrță et al., 2015, 2021]. An impressive number of studies provide evidence of the effective role of Thiourea in modulating physiological mechanisms and improving plant productivity under both optimal and moderately unfavourable conditions [Wahid, A., S.M.A. Basra, M. Farooq, 2017]. Thiourea is a nitrogen and sulfur-containing compound that has amino-, imino- and thiol- functional groups, each with important biological roles. The main functional groups in the Thiourea molecule are the thiol (-SH) and amino ($-NH_2$) groups, which make it one of the most important molecules in physiological processes. The thiol group helps stabilizing the structure of proteins. Moreover, the thiol group can capture ROSs in living cells. It is believed that Thiourea may be a nutritional supplement or may act as an agent for capturing reactive oxygen species (Pandey S., et al., 2013; Perveen A., et al., 2015).

On the other hand, the possibility of optimizing plant growth, development and enhanced productivity under conditions of moderate moisture insufficiency is known by treating seed material and foliar apparatus during vegetation with aqueous solution of Galmet - a preparation, containing K^+, NH_4^+, Mg^{2+} gallates and potassium molybdate and ammonium paramolybdate salts, necessary for plant normal growth and development [Ștefîrță A., Brînză L., Toma S., et al., 2008; Coropceanu E., Ciloci, A., Ștefîrță A., Bulhac, I., 2020]. Gallic acid, widespread in many plant species, is known to have strong antioxidant properties and free radical scavenging activity and can protect cells, tissues and organs from oxidative stress damage, form of free acids, esters, catechin derivatives and hydrolysable tannins. The antioxidant properties of gallic acid and its derivatives have been widely studied with tangents to their use for pharmaceutical purposes. Gallic acid and its derivatives are considered to be a group of natural polyphenolic antioxidants that have recently been shown to have potential healing effects [Singh Manish Pal, Gupta Avneet, Sisodia S Siddhraj. 2018; Bharti Badhani, Neha Sharma and Rita Kakkar, 2021]. Zhongbing Lu, Guangjun Nie, Peter S. et al. (2006) have shown that gallic acid derivatives with high antioxidant activity are generally more effective in preventing oxidative stress injury caused by neurodegenerative diseases.

It is scientifically documented that both Thiourea and Galmet have a positive influence on plant growth under both optimal humidity conditions and long-term drought. Both preparations adjust the optimization of tissue hydration degree, increase leaf turgidity, significantly intensify the assimilation of carbon dioxide and increase the efficiency of water use by plants [Coropceanu E., Ciloci, A., Ștefîrță A., Bulhac, I., 2020; Ștefîrță A., Bulhac I., Coropceanu E., Voloșciuc L., Brînză L., 2021]. Consequently, pre-treated plants are distinguished by a better formation of the assimilation surface, biomass accumulation, formation of the elements of productivity, as well as harvest. However, it should be noted that scientific sources lack the information on the antioxidant effect of Galmet on antioxidant plant protection systems.

Based on the abovementioned, one of the specific objectives of this study was to evaluate the antioxidant properties of Thiourea, Galmet and Thiogalmet and the effect of exogenous use of these preparations on non-specific mechanisms, correlated with the degree of manifestation of plant potential resistance to drought-caused oxidative stress. Tiogalmet is a new preparation containing Thiourea and Galmet.

Materials andMethods:-

Plants of *Zea mays* L., 'P 458' cultivar and *Glycine max* (L.)Merr., 'Nadejda' variety, grown in Mitcherlih containers with 40 kg soil, were used as study objects. The experiments and the investigations were carried out in the Vegetation Complex and laboratories of the Institute of Genetics, Physiology and Plant Protection.

The experiments were performed according to the following scheme:

Series I - plants grown from water-treated seeds (control);

Series II - seed material and plants treated during vegetative growth with aqueous solution of Thiourea;

Series III - seed material and plants treated during vegetative growth with aqueous solution of Galmet in a concentration of 0.005%;

Series IV - seed material and plants treated during vegetative growth with aqueous solution of Thiogalmet of the same concentration. On parallel variants, the effect of pre-treating the plants with the aqueous solutions of the compounds indicated above on the particularities of antioxidant protection of the plants in conditions of oxidative stress, created by reducing soil moisture, was studied. Drought conditions were created during the critical periods for plant: in maize - during panic - flowering; in soybeans - during flowering - the beginning of pod formation. Duration of water stress was of 7 days, followed by a recovery period.

The effect of pre-treatment of maize plants with Thiourea, Galmet and Thiogalmet on the indices characterizing the intensity of oxidative destruction (malonic di-aldehyde (MDA)) content and the activity of antioxidant protection enzymes (SOD, CAT, APX, GLPX, GLR), in the leaves of plants were studied.

SOD activity was determined by inhibiting the photochemical reduction of nitroblutetrazolium, described in detail by Becana M., Aparicio-Tejo P.M., Irigoyen J.J., Sanchez-Diaz M. (1986). The incubation medium contains K-Na-phosphate buffer (60 mM, pH 7.8), methionine (13 mM), riboflavin (2 µM), nitroblutetrazolium (63 µM), EDTA (0.1 mM) and 100 µL the extract. The reaction takes 10 minutes at the light intensity of 15W fluorescent lamps. The samples incubated in the dark were used as controls. The enzyme activity that inhibits 50% of the photo-reduction of nitroblutetrazolium was taken for a conventional unit of SOD activity. CAT activity was estimated by the method of Chance B. and Machly A. (1955) by spectrophotometric determination at λ 240 nm of H_2O_2 decomposition; APX - by monitoring the oxidation rate of ascorbate at λ 290 nm [Nacano Y., Asada K., 1981]; GLR - by reducing oxidized glutathione in the presence of NADP·H [Schadle M., Bassham J.A., 1977]. Plant material homogenization and extraction were performedas described in [Keshavkant S., Naithani S.C., 2001]. The activity of antioxidant ferments was expressed in mM of oxidized substrate and was appreciated as a percentage of the activity of ferments in the leaves of control plants. The protocol of the experimental results was documented in paged registers, stamped and approved by the administration of the institute. The results were statistically analysed, using the software package "Statistics 7" for PC.

Thiogalmet preparation, obtained in the Institute of Chemistry of the Republic of Moldova, was used in this study.It is a solid light-brown powder, stable at room temperature, well soluble in water. It was obtained by mixing two mass parts of Thiourea with one mass part of Galmet, which consists of potassium-, ammonium- and magnesium gallates, potassium molybdate and ammonium paramolybdate, taken in a mass ratio of 1:1:1:0.1:0.1 respectively. Bioactive component content in Thiogalmet, %: Thiourea - 66.66; gallate-anion ($(OH)_3C_6H_2COO^-$) - 21.52; K^+ - 1.63; Mg^{2+} - 0.97; Mo(VI) - 0.99; NH_4^+ - 1.07; total nitrogen - 25.36. The IR spectrum of Thiogalmet composition was recorded on a FTIR Spectrum-100 Perkin Elmer spectrometer in Nuiol (400-700 cm^{-1}) and using ATR technique (700-4000 cm^{-1}).

Results And Discussion:-

The IR spectrum of Thiogalmet (Fig. 1) is intricate due to the complexity of the preparations' chemical composition.It should be noted that the IR spectrum of Thiogalmet does not represent a simple sum of the absorption bands of Thiourea and Galmet components, which is explained by the fact that some processes such as association of functional groups, $-NH_2$,-OH, NH_4^+ and others [Bellamy LJ, 1954] take place during homogenization of the components. However, some more intensive absorption bands specific for Thiourea and Galmet components can be identified. As follows, absorption bands of 3364 and 3271cm^{-1} are manifested for Thiourea, which is attributed to $\nu_{as}(NH_2)$ and $\nu_s(NH_2)$ oscillations respectively, associated via formation of hydrogen bonds, due to which they are shifted to the lower frequency region [Bellamy L. J., 1954; Исаков Х, Аскаров И.Р., Усманов С., 2018], and the oscillation band $\delta(NH_2)$ – 1609 cm^{-1} for the same reason moves inversely towards the region of higher frequencies

[Bellamy L. J., 1954]. The absorption band of medium intensity at 1050 cm^{-1} is attributed to the ν(C-N) oscillations in Thiourea molecules [Исаков Х, Аскаров И.Р., Усманов С., 2018].

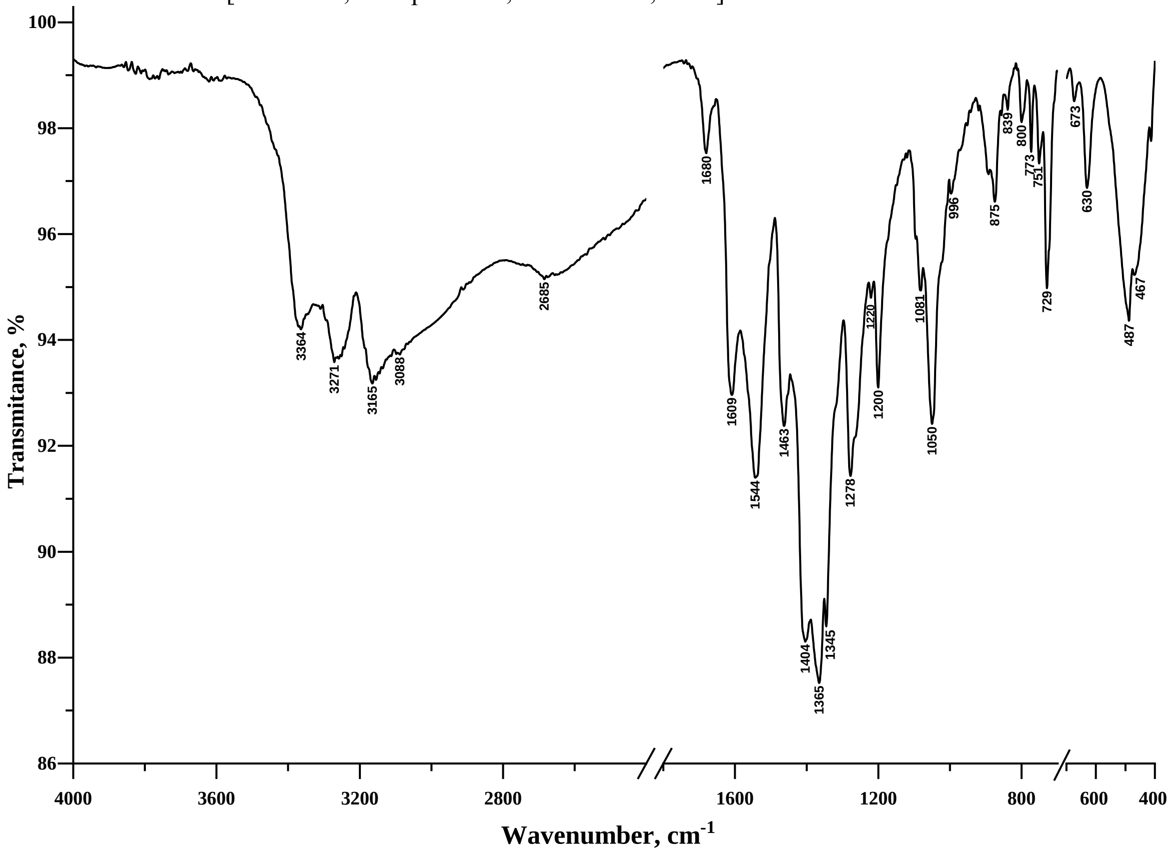

Fig. 1:- Thiogalmet IR spectrum.

The most intensive spectrum absorption band at 1365 cm^{-1} is attributed to ν(C=S)oscillations [Bellamy L. J., 1954], and the average intensity band at 487 cm^{-1} - to δ(NC=S)oscillations (Исаков Х, Аскаров И Р., Усманов С., 2018). Absorption in the 3200-2800 cm^{-1}range is caused by the partial association of -NH_2 groups, -OH groups of gallic acid anions as well as NH_4^+ cations [Nakanishi K., 1962], component parts of Galmet preparation. A wide absorption band of medium intensity in the 2800-1800 cm^{-1} range is attributed to the associated ν(OH) oscillations [Bellamy L. J., 1954; Tarasevich B.N., 2012]. The presence of NH_4^+ cations is also confirmed by an intensive band observed at 1404 cm^{-1} and attributed to δ(N-H) cm^{-1} oscillations in ammonium salts [Nakanishi K., 1962; Tarasevich B.N., 2012].The absorption bands at 1544 and 1345cm^{-1} are attributed to ν_{as}(C-O) and ν_s(C-O) oscillations of the COO^- anions, respectively [Bellamy L. J., 1954; Tarasevich B.N., 2012], and the 875 cm^{-1} band indicates the character of the substitution in gallic acid - 3,4,5-substitute of the benzene ring (the presence of 2 hydrogen atoms isolated in this aromatic ring). The spectrum is recommended as a benchmark for quality control in the reproduction of the preparation.

As mentioned above, ROSs are formed in plant cells under normal conditions and participate in metabolic processes, growth and development [Mittler R., 2002]. However, there is an eruption of ROSs in plants under stress conditions, which, depending on their concentration, causes a different degree of oxidative destruction of cellular structures. Several chemical compounds, known as plant growth regulators or physiologically active substances (PGR, PHAS) modulate plant responses to biotic and abiotic stress at cellular, tissue and organ levels. Their exogenous application modifies the intensity of some key physiological mechanisms, including photosynthesis, nitrogen metabolism, proline metabolism, antioxidant defense systems, increasing plant tolerance to the action of stress-factor. The results of the biochemical analyzes conducted in this study (Table 1) showed that under favorable soil conditions, maize and soybean plants in the control group are characterized by an approximately equal content of Malonic di-aldehyde, which, on the other hand, indicates the existence of moderate oxidative stress, generated by high temperature and relatively low air humidity.

Table 1:- Malonic di-aldehyde content and activity of antioxidant protection enzymes in the leaves of maize and soybean plants, grown under optimal humidity conditions.

Series indices	Control	Thiourea		Galmet		Thiogalmet	
	M ± m	M ± m	Δ, %M*	M ± m	Δ, %M*	M ± m	Δ, %M*
***Zea mays* L. 'P458'**							
MDA, µM · g^{-1}fr.m.	33,7±0,2	31,4±0,0	-6,6	26,8±0,1	-20,3	24,9±0,04	-26,0
SOD, conv. un. · g^{-1} fr.m.	17,4±1,1	19,9±0,8	13,9	20,9±1,2	19,8	22,1±0,57	26,6
CAT, mM · g^{-1}fr.m.	7,9±0,02	8,6±0,1	7,8	9,6±0,4	20,2	10,7±0,47	34,5
APX, mM · g^{-1}fr.m.	4,2±0,1	5,5±0,5	30,9	5,4±0,2	28,6	5,6±0,26	32,3
GLPX, mM · g^{-1}fr.m.	46,4±0,4	52,8±0,2	13,9	58,9±0,3	26,9	62,5±4,98	34,7
GLR, mM · g^{-1}fr.m.	69,4±6,5	82,2±4,3	18,4	86,5±4,6	24,6	85,0±3,67	22,5
***Glycine max* (L .) Merr., 'Nadejda' variety**							
MDA, µM · g^{-1}fr.m.	32,9±0,1	27,1±0,1	-17,6	26,2±0,1	-20,4	24,7±0,70	-24,9
SOD, conv. un. · g^{-1} fr.m.	26,3±1,5	28,2±1,8	7,1	29,2±0,6	11,4	30,3±1,73	15,3
CAT, mM · g^{-1}fr.m.	6,0±0,2	6,5±0,1	7,5	6,9±0,3	14,7	7,5±0,25	25,0
APX, mM · g^{-1}fr.m.	5,3±0,2	6,0±0,1	14,4	6,5±0,8	23,2	6,5±0,27	23,7
GLPX, mM · g^{-1}fr.m.	59,6±0,6	63,7±2,0	7,0	68,3±0,4	14,3	68,1±1,33	14,3
GLR, mM · g^{-1}fr.m.	106,6±3,7	117,5±7,0	10,	121,6± 4,5	14,1	126,6±3,2	18,7

* - compared with the control plants; fr. m. – fresh mass

Under favorable humidity conditions, pre-treatment of seeds before sowing and plant leaf area during vegetative growth with Tu, Galmet and, in particular, with Thiogalmet conditioned a decrease in the MDA content for both crops: in pre-treated with Thiourea maize and soybean plants there was a decrease of 6.6% and 17.6% respectively. The use of Galmet solution for pre-treatment ensured a decrease in lipid peroxide oxidation processes and a reduction of Malonic di-aldehyde content by 20.32% compared to the values in the leaves of control group for both cultures. In the pre-treated maize and soybean plants with the new composition - Thiogalmet, the degree of decrease in the MDA content was 26.00% and 24.95%, respectively, compared to the leaf MDA content in plants of thecontrol group. The use of Thiogalmet solution under normal humidity conditions reduced the MDA content in maize and soybean plants by 20.77% and 2.79% compared to the reduction degree conditioned by plant pre-treatment with Thiourea and by 7.12% and 5.8% compared to the series pre-treated with Galmet (Table. 1). Exogenous application of these preparations also induces a significant increase in the activity of the enzymatic system of antioxidant protection.The major effect of decreasing the MDA content in plants pre-treated with the indicated preparations is due to the more significant intensification of the activity of antioxidant protection enzymes. Thus, Thiogalmet composition ensured an increase of the SOD, CAT, APX, GLPX and GLR activity in maize plants by 9.45; 6.08; 8.23; 7.26 and 37.48% compared to the plants pre-treated with Thiourea. In soybean plants pre-treated with Thiogalmet, the degree of increase in the activity of these enzymes was respectively: 8.17; 31.63; 22.64; 16.06 and 15.10%.

It follows that Thiogalmet preparation possesses antioxidant properties and its use for plant pre-treatment under optimal humidity conditions ensures an improvement of the redox status by activating antioxidant enzymes and decreasing MDA content.

The beneficial effect of maize and soybean pre-treatment with the new composition was also recorded when determining the antioxidant properties of plants under conditions of oxidative stress caused by moderate moisture insufficiency (Table 2, Fig. 2 and 3).

Table 2:- Malonic di-aldehyde content and activity of antioxidant protection enzymes in the leaves of maize and soybean plants grown under moderate drought conditions.

Series indices	Control	Thiourea		Galmet		Thiogalmet	
	M ± m	M ± m	Δ, %M*	M ± m	Δ, %M*	M ± m	Δ, %M*
***Zea mays* L. 'P458' cv.**							
MDA, μM · g^{-1} fr. m.	47,1±0,91	43,4±0,03	-7,85	39,9±0,2	-15,28	38,8±0,07	-17,62
SOD, conv. un. · g^{-1} fr. m.	25,2±1,15	32,8±0,62	30,15	34,6±1,0	37,30	35,9±0,75	42,4
CAT, mM · g^{-1}fr. m.	10,5±0,32	11,5±0,30	9,52	11,7±0,4	11,42	12,2±0,33	16,19
APX, mM · g^{-1}fr. m.	7,0±0,28	8,5±0,78	21,43	9,0±0,4	28,57	9,2±0,30	31,42
GLPX, mM · g^{-1}fr. m.	69,8±1,80	81,2±0,24	16,33	84,4±0,7	20,91	87,1±1,90	24,78
GLR, mM · g^{-1}fr. m.	97,7±3,07	115,0±2,9	17,71	140,8±4,2	44,11	158,1±1,7	61,82
***Glycine max* (L.) Merr., 'Nadejda' variety**							
MDA, μM · g^{-1} fr. m.	49,9±0,40	44,9±0,04	-10,0	43,4±0,1	-13,08	38,8±0,1	-22,2
SOD, conv. un. · g^{-1} fr. m.	39,8±1,04	47,7±2,42	19,66	51,6±1,5	29,64	51,6±0,6	29,64
CAT, mM · g^{-1}fr. m.	7,7±0,02	9,8±0,42	27,90	11,5±0,3	49,35	12,9±0,6	67,53
APX, mM · g^{-1}fr. m.	9,0±0,54	10,6±0,54	18,00	11,8±1,1	31,11	13,0±1,2	44,44
GLPX, mM · g^{-1}fr. m.	86,7±1,70	102,1±4,1	17,83	114,7±1,6	32,29	118,5±2,2	36,67
GLR, mM · g^{-1}fr. m.	147,9±1,9	156,2±2,7	5,59	169,8±2,4	14,81	179,8±8,0	21,57

* - compared with the control plants; fr. m. – fresh mass

It has been shown that drought causes an increase in MDA content in the leaves of untreated maize and soybean plants by 39.84% and 51.67% of the values in control plants not exposed to drought. The MDA content of plants pre-treated with Thiourea, Galmet and Thiogalmet under conditions of moderate drought was maintained at a lower level by 7.85; 15.28 and 17.62% for maize and 10.0; 13.08 and 22.24% for soybean plants, compared to the values in untreated and exposed to drought plants. The MDA content in plants pre-treated with Thiourea and Thiogalmet due to insufficient moisture was higher than the MDA level in control plants under optimal humidity conditions by 28.78 and 14.92% for maize and by 36.47 and 17.93% in soybean plants, which represents a significantly lower degree of MDA content change compared to the untreated plants but exposed to the action of drought-induced oxidative stress.

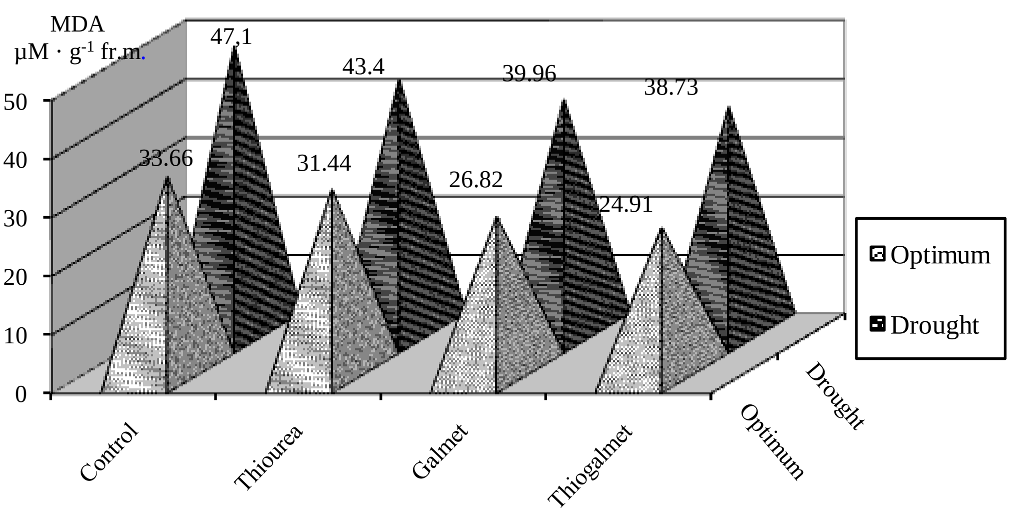

Fig. 2:- Malonic di-aldehyde content in the leaves of 'P 458' maize plants pre-treated with Thiogalmetunder different humidity conditions.

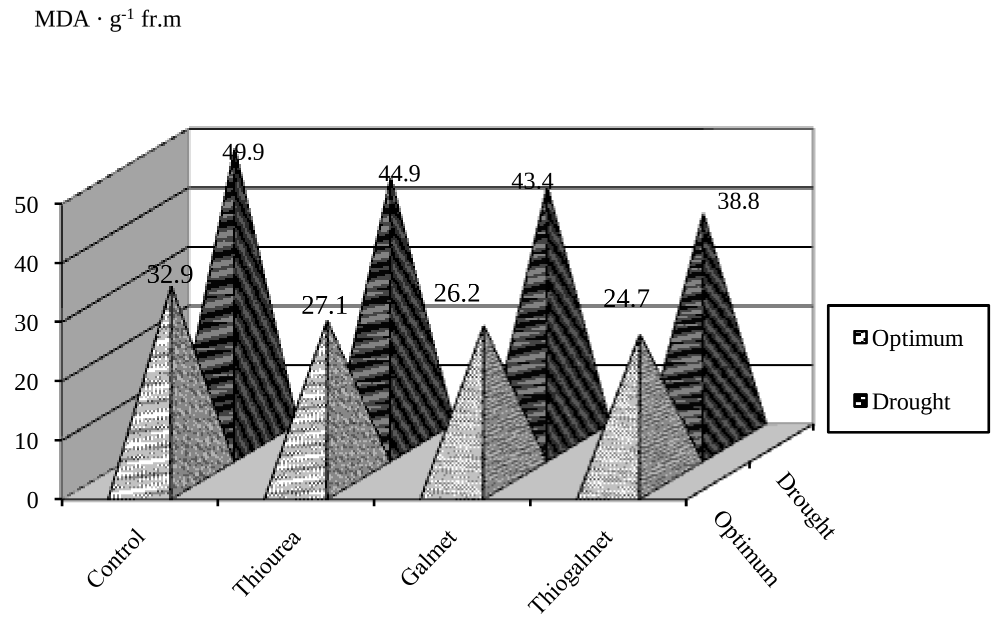

Fig. 3:- Malonic di-aldehyde content in the leaves of soybean 'Nadejda' variety plants pre-treated with Thiogalmet depending on the humidity conditions.

Exogenous application of Thiogalmet conditioned a reduction of MDA content by 8.15 and 11.22% compared to maize and soybean plants pre-treated with Thiourea. As known from scientific sources, there are data that show that the activity of some physiologically active substances manifests itself differently depending on the conditions of the external environment. Thus, the use of Thiourea as an agent for seed and leaf pre-treatment or as an additional remedy is much more effective under stress than under normal conditions [Amin, A.A., A.A.Abd El-Kader, M.A.F. Shalaby, F.A. Gharib, and E. S. M. Rashad, 2013; Wahid A., et al., 2017]. Among the biochemical changes detected in different plant species, seed pre-treatment with Thiourea led to the induction of antioxidant protection and decrease of hydrogen peroxide and Malonic di-aldehyde synthesis [Perveen S., et al., 2016].

Maintaining the redox state in the pre-treated plants is conditioned by activation of plant enzymatic antioxidant protection system under both optimal conditions and oxidative stress (Fig.4; Table 3).

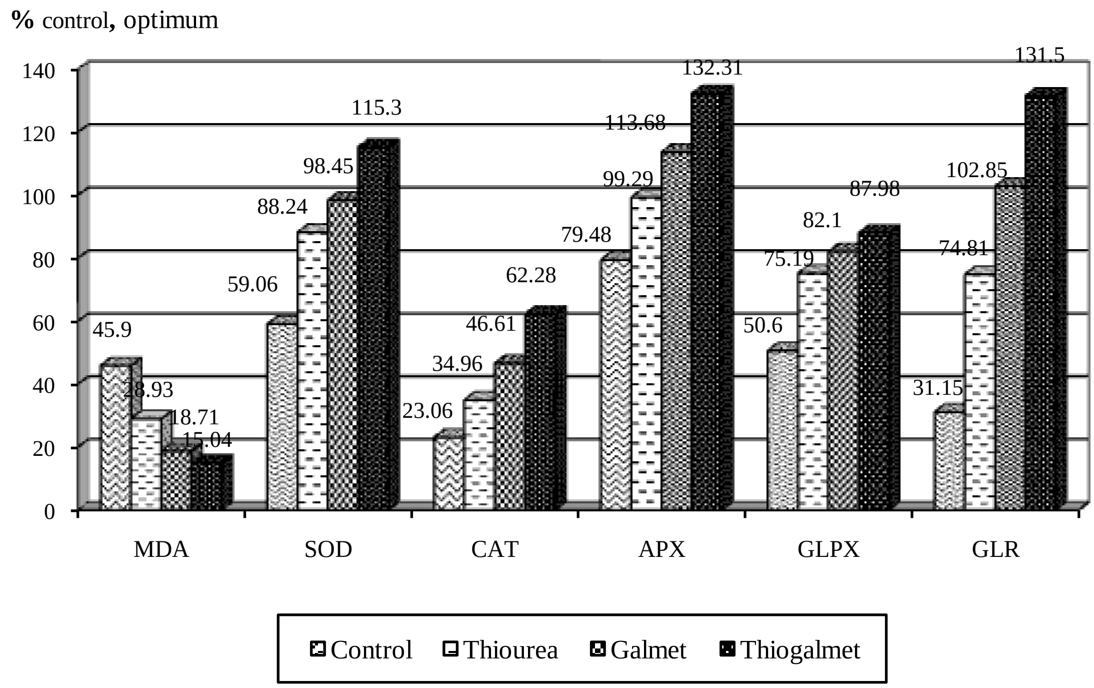

Fig. 4:- The degree of change in Malonic di-aldehyde content and activity of antioxidant protection enzymes (% of the index values in control plants under optimal conditions) in the leaves of maize 'P 458' plants under the influence of pre-treatment with Thiogalmet and exposure to drought.

Under optimal humidity conditions the activity of antioxidant enzymes increased in maize and soybean plants by 9.31 and 8.89% under the influence of Thiourea and by 24.1 and 14.4% respectively after pre-treatment with Galmet solution. Under these conditions, overall enzymatic activity in the maize and soybean plants increased respectively by 27.5 and 16.9% compared to the values in control series.

The degree of change in the activity of antioxidant enzymes conditioned by Thiogalmet pre-treatment compared to pre-treatment with Thiourea, known as a substance with antioxidant properties, for maize and soybeans under optimal humidity was 16.65 and 7.32%, and under conditions of drought - 20.60 and 6.04% respectively. The degree of change in the activity of antioxidant enzymes conditioned by Thiogalmet pre-treatment compared to pre-treatment with Thiourea under drought conditions was 20.60 and 6.04% in maize and soybean respectively and 7.1 and 4.9% compared to the Galmet pre-treated series. The new Thiogalmet preparation had significantly better antioxidant properties compared to Thiourea.

Table 3:- Degree of modification in MDA content and overall activity of antioxidant protection enzymes in the maize and soybean plants induced by pre-treatment under conditions of optimal humidity and moderate drought.

Series		**Control**		**Thiourea**		**Galmet**		**Thiogalmet**	
indices		**M ± m**	**Δ, %M***	**M ± m**	**Δ, %M***	**M ± m**	**Δ, %M***	**M ± m**	**Δ, %M***
***Zea mays* L. 'P458' cultivar**									
MDA, μM · g^{-1} fr. m.	***optimum***	33,7±0,2		31,4±0,1	-6,59	26,8±0,1	-20,3	24,9±0,1	-25,99
	drought	47,1±0,9	39,8	43,4±0,2	-7,79	39,9±0,2	-18.63	39,8±0,1	-15,31
Overall enzymatic	***optimum***	145,4±8,4		158,9±6,8	9,31	180,5±6,4	24,1	185,4±9,9	27,51

activity	***drought***	210,2±6,6	44,5	249,0±6,7	18,44	280,5±6,7	33,4	300,3±4,9	42,85
Glycine max **(L.) Merr., 'Nadejda' variety**									
MDA, μM · g^{-1} fr. m.	***optimum***	32,9±**0,1**		25,4±0,1	-22,78	26,2±0,1	-20,4	24,7±0,**7**	-24,95
	drought	49,9±0,4	51,8	42,7±0,1	-14,40	43,4±0,1	-13,1	37,9±0,1	-24,00
Overall enzymatic activity	***optimum***	203,7±6,5		221,9±6,5	8,89	232,5±6,6	14,14	238,1±6,8	16,87
	drought	291,2±5,3	42,95	326,4±6,9	12,13	339,4±6,9	16,55	356,2±9,5	18,89

Δ, % M ** - compared to control plants under corresponding conditions

Therefore, the obtained results show that plant pre-treatment with Tu, Galmet and, in particular, with Thiogalmet increase the activity of superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), glutathione reductase (GLR) and glutathione peroxidase. (GLPX). High activity of antioxidant enzymes is associated with decreased malonic di-aldehyde (DAM) content. The beneficial physiological effect of Thiogalmet is also confirmed by the higher levels of the assimilation processes and plant growth.

The use of Thiogalmet preparation for seed material and leaf pre-treatment is more effective for improving the biological performance of *Z. mays* plants by increasing the activity of antioxidant enzymes, photosynthesis and plant productivity.

Conclusions:-

1.Thiogalmet, which containing Thiourea and Galmet - a preparation that consists of a mixture of potassium, ammonium, magnesium gallates, potassium molybdate and ammonium paramolybdate, is a complex physiologically active compound that possesses antioxidant properties.
2.The plants treated with Thiogalmet possess a significantly higher capacity of antioxidant protection compared to the plants treated with Thiourea and Galmet, and, in particular, with those from the control group.
3. Thiogalmet can be used to reduce the negative impact of oxidative stress caused by reactive oxygen species (ROS), for antioxidant protection and reduce the oxidative destruction of plant cellular components under drought conditions.
4.The IR spectrum of the preparation Thiogalmet in the region 400-4000 cm^{-1} demonstrates that when homogenizing the components of the preparation (Thiourea and Galmet), the spectral changes are non-essential and refer to the association of groups of atoms (NH_2^-,-OH, NH_4^+ andother) by forming hydrogen bonds. The spectrum is recommended as a benchmark for quality control in the reproduction of the preparation.

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