PHYSIOLOGICAL EFFECTS OF THIOUREA ON BIOLOGICAL PERFORMANCE OF PLANTS UNDER DROUGHT CONDITIONS: II. ENHANCEMENT OF WATER USE EFFICIENCY

EFECTUL FIZIOLOGIC AL TIOUREEI ASUPRA PERFORMANȚELOR BIOLOGICE ALE PLANTELOR ÎN CONDIȚII DE SECETĂ: II. OPTIMIZAREA EFICIENȚEI UTILIZĂRII APEI

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Abstract. *The greenhouse and field experiments were conducted to evaluate the effect of grain pre-soaking and foliar application of thiourea (TU) and thiourea in combination with Composite (TU+C) – the preparation, containing trace elements iron, cobalt, zinc, magnesium, boron, vitamin PP, but iron, cobalt and boron in the form of biologically active coordination compounds (pat. MD 813), on the photosynthesis intensity, transpiration and productivity of maize and soybean plants. It has been established that the use of TU+C made the improvement of water status, increased the content of assimilating pigments, photosynthesis intensity, water use efficiency, growth and productivity of plants. Pre-treated with TU+C plants distinguished by more economically consumption and enhancement of water use efficiency.*
Key words: plants, drought, thiourea, water, productivity

Rezumat. *În experiențe de vegetație şi de câmp s-a studiat efectul pre-tratării semințelor pentru semănat şi aparatului foliar al plantelor de porumb şi soia cu tiouree (TU) şi tiouree + Compozit (TU+C), - preparat, ce conține microelemente fier, cobalt, zinc, magneziu, bor, vitamina PP, iar fierul, cobaltul şi borul sunt incluşi în formă de compuşi coordinativi biologic activi, (br. MD 813), asupra intensității fotosintezei, transpirației şi productivității plantelor. S-a stabilit, că utilizarea TU+C condiționează ameliorarea status-ului apei, majorarea conținutului pigmenților asimilatori, intensității fotosintezei, eficienței utilizării apei, creşterii şi productivității plantelor. Plantele pre-tratate cu TU+C se deosebesc prin consum mai economicos şi utilizare mai eficientă a apei.*
Cuvinte cheie: plante, secetă, tiouree, apă, productivitate

INTRODUCTION

Application of agricultural technologies, that provides water saving, including the cultivation of drought-resistant specia of plants, gets a special importance at acute soil water deficit. In these conditions the problem of

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increasing of water use efficiency (WUE) in the growth and formation of the harvest is of exclusive significance. Processes that ensure plant survival under severe soil water content deficiency are associated with reduced consumption of water by reducing evaporation surface due to closing of stomata and growth inhibition, but which decrease productivity. The closure of stomata reduces water loss through transpiration, but inevitably leads to diminishing photosynthesis, as a result of chlorophyll content decreasing and access of carbon dioxide to the chloroplast (Asada, 1999). WUE is considered an important determinant of productivity under limited water content (Turner, 2004; Blum, 2009; Medrano, Tomas, Martorell *et al*., 2015). Moreover WUE is estimated as the drought tolerance component in natural systems and is seen as an alternative way of tolerance increasing (Jones, 1993).

Therefore, a better WUE by plants can be obtained by: a) increasing soil fertility; b) application of anti-transpiration agents; c) cultivation of specia with high potential for resistance, etc. A widely accepted way to increase drought resilience is considered the possibility of increasing WUE by applying physiologically active substances (PhAS). Given the aforementioned, the aim of the work was to evaluate the effect of thiourea (TU) and combination thiourea+Composite (TU+C**)** - preparation containing micronutrients iron, cobalt, zinc, manganese, boron, vitamin PP, wherein iron, cobalt and boron included in the form of biologically active coordination compounds - on the intensity of photosynthesis, transpiration and productivity of plants under moderate insufficiency of soil water content.

MATERIALS AND METHODS

As the study objects served plants *Zea mays* L., cultivar (cv.) P458. The greenhouse experiments were performed on plants grown in Mitcherlih containers with a capacity 30 kg absolutely dry soil under controlled water content conditions. The scheme of experiences provided the following treatments: a) control plants, grown on permanent soil water content – 70 % of the total water capacity (TWC) of soil; b) plants exposed to the drought (30 % TWC) for 10 days. The parallel treatments included the exogenous pre-treated plants with cytokinin (CK) (0.0001%), TU (0004%) and TU (0.0004%) + C (0.0001%) in 1:1 ratio. The analyses were performed after 10 days of water stress at the initial stage of growth and during flowering of plants. The intensity of CO_2 assimilation, transpiration, stomatal conductance, and WUE were determined by using a portable LCA-4 gas analyzer in experiments performed under the same conditions of temperature and soil water content. WUE was calculated as the relationship between CO_2 assimilation and the intensity of transpiration. The contents of chlorophyll *a* and *b* and carotenoids were determined spectrophotometrically in 80% acetone extract. Statistical analysis of results was performed using the computers program "Statistics 7".

RESULTS AND DISCUSSION

The research results demonstrated significant differences in reaction of *Zea mays* L. plants, pre-treated with PhAS, at fluctuation in water supply and insufficient soil water content (tab. 1). The water content (WC) in plant leaves grown at optimum soil water content was authentically more than the degree of hydration of the plants exposed to the drought, and reached the value of 77.23 ± 1.28 g of water in 100 g fresh mass (f. m.). A slight but statistically authentic increase of the degree of hydration of the leaves was recorded in plants pre-treated with PhAS. Changing of soil water content and worsening water supply caused surely a reducing of water quantity, a turgidity reduction and a higher saturation deficiency (SD).

Table 1

Physiologically active substances and drought influence on water status parameters in the leaves of maize plants

Treatments	Water content (WC), g/100 g f. m.		Saturation deficiency (SD), % of full saturation	
	M±m	Δ, %	M±m	Δ, %
70% TWC				
Control	77.23±1.28		7,31±0,22	
Cytokinin	78.20±1.55	+1.25	6.43±0.12	-12.04
Tiourea	78.41±1.78	+1.53	6.00±0.11	-17.92
Tiourea+Composite	78.55±1.57	+1.70	4.36±0.07	-40.35
30% TWC				
Control	72.03±1.48	-6.73	18.43±0.36	152.12
Cytokinin	73.39±1.13	-4.97	17.68±0.28	141.86
Tiourea	74.66±1.09	-3.33	16.89±0.44	131.05
Tiourea+Composite	75.41±1.11	-2.36	16.61±0.37	127.22

Degree of WC under water deficit was reduced for control plants by 6.73%, and for pre-treated ones - in the range of 2.4 – 4.9 %.%. SD in plant leaves pre-treated with CK, TU and TU+C was authentically less even under optimal water content (tab. 1). The value of SD in the leaves of control maize plants increased from 7.31 % to 18.43 % of the full saturation of the tissues after the soil water content decrease from 70% to 30% TWC. While SD value in plant leaves pre-treated by CK and grown in the same conditions increased from 6.43 to 17.68 %. Maximum effect of stabilizing the degree of hydration and minimizing the impact of drought on SD was recorded on maize plants pre-treated with TU and, in particular TU+C. The degree of modification of SD in these plants under drought conditions was significantly lower (tab. 1). The experimental data led to the conclusion that pre-treatment of seeds with TU and TU+C assured optimization of water status of plants exposed to drought action. In dry conditions a certain SD formed in plant tissue, after which it can be judged on the relationship between the absorption of water from the soil, its transportation to the organs and use for transpiration. A considerable increase of SD in leaves can be caused by increased water consumption or decrease its absorption processes by roots, indicating a disturbance of the water balance of the plant. It has been shown that TU and, in particular, the combination TU+C has a significant beneficial effect on key physiological processes related to plant productivity (tab. 2). Using pre-treatment of seeds and plants led to an authentic increase of content of assimilating pigments. The effect of plants treatment by TU+C exceeded the effect of treating plants with TU by 17.87 – 9.54 %.

Table 2

Influence of physiologically active substances and drought on the content of pigments in the leaves of maize plants

Treat-ments	Chlorophyll a, mg/100g f. m.	Chlorophyll b, mg/100g f. m.	Chlorophyll a+b, mg/100g f. m.	Carotenoids,mg/100g f. m.
	M ± m	M ± m	M ± m	M ± m
70% TWC				
Control	142.25±0.9	58.64±0.7	200.89±1.6	36.62±0.9
CK	168.16±0.3	71.53±1.2	239.52±3.6	44.45±0.7
TU	180.73±0.6	68.62±1.9	249.35±3.1	42.77±0.5
TU+C	213.14±0.4	80.77±2.1	293.91±3.2	47.33±0.7
30% TWC				
Control	137.14±0.8	54.41±0.5	191.55±1.2	31.10±0.6
CK	153.10±0.6	68.60±0.5	220.87±2.3	39.37±0.5
TU	156.81±0.5	65.33±0.9	222.14±1.6	40.45±0.2
TU+C	175.5±0.8	67.83±0.7	243.33±2.5	44.39±0.4

One of the early effects of drought progression and water insufficience in soil is a reduction of leaves growth, and by means of it, reducing the interception of solar radiation, and hence the dry matter production rate. Analysis of results obtained using portable gas analyzer LCA-4, in experiments performed under the same conditions of temperature and water content, have highlighted the beneficial effect on WUE of substances used for treating the *Zea mays*, L. plants under shortage of water content (tab. 3).

Table 3

Influence of drought on water use efficiency by maize plants

Soil water content, % of TWC	Stomatal conductance, $Mm/m^2/h$	Intensity of transpiration, $Mm/m^2/h$	Intensity of photosynthesis, $Mm/m^2/h$	WUE, Mm CO_2/ Mm water
Leaf phase IX, the XII-day of drought				
70	0.020	2.25	11.52	5.12
30	0.003	1.08	3.13	2.90
Flowering stage, the VII-day of drought				
70	0.10	2.64	9.86	3.73
30	0.04	0.77	1.95	2.53

At the flowering stage, when the water content of the air has decreased further, and the temperature and solar radiation has increased significantly, the assimilation of carbon dioxide decreased even by plants on the background of a favorable water content (70% TWC). The intensity of photosynthesis by them constituted 85.6% of the intensity recorded in phase "leaf IX". During this period, the insufficient soil water content caused inhibition of stomatal conductance by 60.0%, transpiration and assimilation of carbon, respectively, by 70.8% and 80.2% in comparison with the corresponding parameters characteristic of the control plants. Pre-treated by PhAS plants, due to optimization of the water status, have maintained a higher level and a process of assimilation, and a efficiency of water use, and, as a result, their reproductivity (tab. 4).

Table 4

The influence of physiologically active substances and drought on intensity of assimilation by soybean and maize plants

Treat-ments	Intensity of photosynthesis, $mM/m^2/sec$		Intensity of transpiration, $mM/m^2/sec$		WUE, $mM\ CO_2/mM\ H_2O$	
	M ± m	Δ, %	M ± m	Δ, %	M ± m	Δ, %
cv. Enigma						
Control	8.65±0.24		4.01±0.11		2.16±0.05	
CK	14.95±0.37	72.83	4.90±0.09	22.19	3.05±0.09	41.20
TU	15.95± .45	84.39	5.18±0.14	29.18	3.08±0.08	42.59
TU+C	22.77±0.61	163.24	5.82±0.12	45.13	3.91±0.08	81.02
cv. P 459						
Control	24.25±0.56		3.92±0.02		6.18±0.07	
CK	26.10±0.45	7.63	4.12±0.06	5.10	6.33±0.04	2.43
TU	27.31±0.48	12.62	4.28±0.04	9.18	6.38±0.05	3.24
TU+C	31.4±0.21	29.45	4.49±0.05	14.54	6.99±0.07	13.11

Table 5

Effect of physiologically active substances on the biological performance of maize plants during drought conditions

Treat-ments	Height, dm		Leaf area, dm^2		Productivity, g/pl	
	M±m	**Δ, %**	**M±m**	**Δ, %**	**M±m**	**Δ, %**
Under optimal water content						
Control	12.2±0.3		37.8±0.4		52.8 ± .5	
CK	14.3±0.1	+17.5	39.0±0.3	+3.2	61.7±0.4	+16.8
TU	16.1±0.4	+32.5	39.2±0.2	+3.6	69.3±0.6	+31.3
TU+C	13.0±0.2	+7.2	39.3±0.4	+4.0	70.0± 0.9	+32.6
In drought conditions						
Control	9.8±0.1	-18.9	30.2±0.3	-20.1	34.8±0.5	-39.0
CK	11.2±0.1	-7.8	32.3±0.3	-14.6	38.9± 0.3	-26.2
TU	10.7±0.2	-11.2	34.0±0.4	-10.2	37.7± 0.6	- 28.6
T+C	12.2±0.2	0.0	35.7±0.3	-5.6	39.7±0.9	-24.7

The dynamics and intensity of physiological processes that occured in plants during ontogenesis in drought conditions inevitably impacted on growth and development of plants (tab. 5).

Pre-treatment of plants with TU, especially with TU+C mixture, significantly reduced impact of hydric stress on the formation foliar apparatus. Reduction of leaf area under drought is key to decreasing grain harvest because the development of leaf area determines the accumulation of dry mass during the flowering and grain filling, and influences harvest index through its effect on balancing of water use before and after flowering. Treatment with PhAS compared to control plants ensured better productivity, reducing drought impact on biological performance. The drought had a 1.5 times less influence on plants treated with TU and 2.14 times less on those treated with TU+C in comparison to the impact on the untreated plants. Therefore, plants treated according to the invention, possessed a higher capacity of adjustment of the water status, which was manifested by increasing the capacity of plant tissues to retain water through the efficient water use, enabling biosynthesis and accumulation of biomass, which, ultimately, ensured the formation of more vigorous plants and reduced crop losses under sub-optimal water content.

CONCLUSION

1. Exogenous application of physiologically active substances (PhAS), particularly in case of combination of thiourea with the preparation Composite cased the increase of gas exchange, stomatal conductance rate, net - photosynthesis, transpiration, and as a result - of water use efficiency.

2. The effect of plant pre-treatment with thiourea and thiourea+Composite on the contents of assimilating pigments and carotenoids in dry conditions exceeded that produced by citokynin.

3. The effect of PhAS application by optimizing of the water status, assimilating pigment content, and photosynthesis also had the positive consequences on growth, development, and productivity of plants.

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