Utilization of spare substances of *Zea mays* L. seeds during germination under the combined effect of growth regulators and presence or absence of light

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Functional changes in the source-sink system of maize sprouts under combination of external (light/dark) and hormonal (gibberellic acid/retardant) factors during germination were studied. It was found that the phytohormone action significantly increased the coleoptile, root and seedling length, dry matter mass of organs, both in light and in dark. Tebuconazole caused the opposite effect due to its retardant action. The inactivation of endogenous phytohormone was confirmed by less intensive use of seed substances, the minimum dry matter of root and coleoptile and lower reserve utilization rates under tebuconazole influence, in particular under photomorphogenesis condition. The non-maximum mass of cotyledons may indicate a kind of optimization of use of reserves under tebuconazole treatment. Gibberellin stimulated starch breakdown in both light and dark, but starch usage was higher in dark. The lower content of sugar in the seeds of skotomorphic plants in control and under gibberellin action was explained by intense outflow for the organogenesis needs. Gibberellin stimulated the hydrolysis of reserve protein after intensive starch hydrolysis in dark. Specific gibberellin regulation of phosphorus outflow for the organogenesis processes under the photo- and skotomorphogenesis conditions and no regulation for potassium under photomorphogenesis conditions were found.

Keywords: growth regulators, seed germination, morphogenesis, source-sink system, light action

INTRODUCTION

Recent advances in the study of the mechanisms of the source-sink system functioning allow regulating the activity of physiological processes, optimizing growth rate, affecting yield, and redistributing the flow of assimilates according to the fruit formation and growth needs (Kuryata, Golunova, 2018; Liesche, Schulz, 2018; Abeledo et al., 2020). Source-sink relations are regulated in plants at different levels, in particular, hormonal (Tegeder, 2014; Bai et al., 2016; Cho et al., 2017).

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Nowadays, the most studied type of these relationships is the interaction of photosynthesis (source) and the processes of vegetative growth (sink) of the assimilates (Sugiura et al., 2015; Humplík et al., 2015; Chikov, 2017; Khodanitska, Kuryata, 2018; Shevchuk et al., 2019). Furthermore, the issues of the source-sink system functioning during heterotrophic phase of plant development as the period of seed germination and formation of other organs remain practically unspecified. The peculiarities of the usage of deposited spare substances of various chemical structures and nutrients for the needs of organogenesis are also little known (Poprotska et al., 2019; Kuryata et al., 2020).

Light is one of the most essential external factors that significantly affect morphogenesis. The ability to switch from skotomorphogenetic to photomorphogenetic development is vital for seed survival. The system of photoreceptors (phytochromes, cryptochromes, and phototropin) that regulate photomorphogenesis activation is central to this mechanism (Yamauchi et al., 2004; Wang, Lin, 2020). Photoreceptor proteins of plants, such as phytochromes (five different types with partially different functions), cryptochromes (two types), phototropins (two types), and UVR8 promote signal transmission thus forming a complex network. Nevertheless, the excitation of one photoreceptor can enhance or inhibit the activity of another (Jiang, Li, 2015). The spectral composition and light intensity have a significant effect on seedling growth. There is evidence of significant inhibitory effect of low doses of red light (660 nm) on the potato sprouts growth. Red light with a wavelength of 735 nm had a similar effect at higher doses (Molmann, Johansen, 2019). In another study, the destruction of the columnar parenchyma is consistent with prolonged exposure to red rays in cucumber plants, while the spongy parenchyma, which assumes the main functional load, undergoes minor changes (Miao et al., 2019). It is known that photoreceptors mediate the response to light by changing the shoot growth rate in the transition from skotomorphogenesis to photomorphogenesis. Germinating in complete dark, plants develop according to the programme of skotomorphogenesis. Such sprouts are characterized by elongation of the epicotyl or the hypocotyl, formation of the hypocotyl loop, yellowing of cotyledons and formation of corrugated first leaves, and reduction of the quantity of leaves in the future (Li et al., 2015; Galvão, Fankhauser, 2015). In dark, plants form underdeveloped conductive structures, the apical meristem contains proplastids and etioplasts instead of full-fledged chloroplasts (Bhatla, 2018; Fernández et al., 2020). In this case, monocotyledonous and dicotyledonous seedlings grown in light and in dark differ from each other in plant morphology (Bhatla, 2018).

Currently, it is known that light can modify the growth and morphogenesis through the rearrangement of the hormonal complex, a mechanism of influence on the source-sink system (Kutschera, Briggs, 2003; Wu, 2014; de Wit, Pierik, 2016). The initial stages of photomorphogenesis are accompanied by considerable metabolic changes, phytochrome modification of the hormonal status of seedlings, in particular, the phytohormone transport and formation of gibberellin gradients in plants, and the intensity of natural inhibitors (Dong et al., 2014; Liang et al., 2020). Changes in light undergo ethylene biosynthesis in tissues, contributing to the final morphogenesis and physiological development (Dong et al., 2014; Ahammed et al., 2020). Current results of analysis of gibberellin and phytochrome genetic mutations indicate interactions between signalling systems under certain physiological conditions, although individual ontogenetic stages of development, such as flowering, are controlled by both systems independently (Casal et al., 2014; Tsygankova et al., 2019). Notably, enhanced expression of UVR8 as a functional regulator in *Zea mays* L. induces photomorphogenic responses in plants (Fernández et al., 2020). It was found that phytochrome B-deficient sorghum mutants have a higher level of GA_1 and GA_{20}, which contributes to increased stem growth under the red light action. The use of inhibitors of gibberellic acid biosynthesis reduces the number of cells and longitudinal growth of stem and

roots cells, leaf narrowing, reducing the ratio of the linear size of shoots to roots, leaves become dark green, and delaying aging in phototrophic plants (Kong, Okajima, 2016; Lee et al., 2017; Kharshiing et al., 2019).

On soil surface, light begins to act as the main exogenous agent, inhibiting the activity of the main protein suppressor of photomorphogenesis COP1. It is synthesized in the nuclear space and can be inactivated extracellularly. There are other transcriptional regulators that perform the implementation of gibberellins (DELLA) and brassinosteroids (BZR1/BES1) as well as activating trans-factors, such as HY5, initiating the transition to autotrophic nutrition (Hirai, Amaki, 2005; Liu et al., 2006; Bhatnagar et al., 2020; Kaur et al., 2020; Li et al., 2021). Given that such phytohormones are involved in light signal transduction system, many of the light-regulated development responses of plants also respond to plant treatment with hormones (Josse, Halliday, 2008; Jiang, Li, 2015). The *AtGA3ox1* biosynthesis gene has a positive impact on the phytochrome activity, increasing the level of bioactive gibberellins. A positive correlation was found between changes in the biomass and length of bean hypocotyl and the gibberellin content in dark. There was a negative correlation between these parameters in light (Golovatskaya, Karnachuk, 2007).

Changes in the intensity of growth of different organs of seedling under conditions of photo- and skotomorphogenesis are obviously accompanied by differences in the intensity of use of deposited spare substances, resulting in changes in the degree of tension between source and sink activity. In some works, data represent the possibility of regulating the rate of utilization of spare compounds for growth and development by external and internal factors (Kutschera, Briggs, 2003; Kuryata, Polyvanyi, 2018; Kuryata et al., 2020). Therefore, the aim of our study was to establish the effect of gibberellin and its antagonist tebuconazole on the functioning of the "depot of assimilates – growth" system during the germination of maize seeds under photo- and skotomorphogenesis conditions.

MATERIALS AND METHODS

The work was carried out with maize (*Zea mays* L.) seedlings of the variety "Fragrant". The combined effect of light, tebuconazole retardant, and gibberellic acid was used to create different tensions of source-sink relations during the germination of maize seeds.

The seeds of the control variant were soaked in distilled water. Seeds were sown in ditches with wet sand, and the biological repeatability was fivefold. The experiment was performed under the action of light (natural light of the lab) and in dark in order to study the implementation of programmes of skoto- and photomorphogenesis. The seeds were soaked for 24 h in an aqueous solution of gibberellic acid (GA_3) at a concentration of 0.025%. Gibberellic acid is a white crystalline substance with a molecular weight of 346.2 D; its the molecular formula is $C_{19}H_{22}O_6$. The melting point is 227°C. The substance is poorly soluble in water and soluble in organic solvents. Gibberellic acid is a low-toxic compound and belongs to the third class of toxicity. LD50 for rats is 15 630 mg/kg. It does not show carcinogenic, blastomogenic, skin-resorptive, or embryotoxic properties. The residual content of the drug is not normalized, because in plants it is present as a natural metabolite. The drug is non-toxic to bees and other insects and of low toxicity to fish. It is used as a plant growth regulator. The drug is prepared by fermentolysis of fungi of the species *Gibberella fuljukoi* and *Fusarium moniliforme* (Hedden, Thomas, 2016).

The seeds of another experimental variant were soaked in an aqueous solution of tebuconazole at a concentration of 0.05%. Tebuconazole ($C_{16}H_{22}ClN_3O$)-RS)-1-(4-chlorophenyl)-4,4-dimethyl-3-(1H-1,2,4-triazol-1-ylmethyl)pentan-3-ol is a tertiary alcohol. Tebuconazole is a colourless crystalline substance with a molecular weight of 307.8 D. The melting point is 104.7°C. Solubility in water at pH 5-9, 20°C is 36 mg/l. Tebuconazole is resistant to hydrolysis and provides a uniform acropetal distribution of the drug in the middle of the leaf of the plant for a long period of time. LD50 for

rats is 3933–5000 mg/kg. The drug is a low-toxic compound and belongs to the third class of toxicity (National Centre for Biotechnology Information, 2021).

Morpho-biometric parameters (root length, seedling length, dry matter weight of individual organs and of the whole plant) were determined on day 18 of germination. Germination energy was determined on day 3 of germination.

Determination of the content of non-structural carbohydrates (sugar and starch) in the organs of seedlings was performed by the iodometric method, the phosphorus content was determined by the intensity of the formation of phosphorus-molybdenum complex, potassium by flame-photometric method, and the content of total protein and non-protein by the Kjeldahl method (AOAC International, 2010). The analytical repeatability of studies was fivefold. Statistical processing of the re-sults was performed using the software package Statistica 6.0. The reliability of the difference between control and experiment was determined by Student's *t*-test. The tables and figures show arithmetic mean values and their standard errors.

RESULTS AND DISCUSSION

Growth regulators significantly affect the intensity of changes of growth parameters of seedling organs and utilization of seed reserves for growth under conditions of skoto- and photomorphogenesis (Table 1).

It was noted that gibberellin caused a significant intensification of coleoptile, root and total plant growth, both under conditions of photomorphogenesis and skotomorphogenesis. The effect of phytohormone was more obvious under conditions of skotomorphogenesis.

Table 1. **The effect of growth regulators on growth processes and the use of spare substances by maize seeds under conditions of photo- and skotomorphogenesis**

Indicator	GA_3		Control		Tebuconazole	
	a	b	a	b	a	b
Length of the above-ground part, cm	32.60 ±1.63*	36.40 ±1.82*	27.45 ±1.37	29.10 ±1.45	22.52 ±1.12*	25.70 ±1.28*
Length of the root system, cm	28.33 ±1.41*	30.36 ±1.51*	19.85 ±0.99	26.68 ±1.33	12.75 ±0.63*	19.28 ±0.96*
Length of seedlings, cm	60.93 ±6.04*	66.76 ±3.33*	47.30 ±2.36	55.78 ±2.78	35.27 ±1.76*	44.98 ±1.24*
Mass of dry matter of the above-ground part, g	0.068 ±0.003*	0.078 ±0.004*	0.044 ±0.002	0.053 ±0.003	0.028 ±0.001*	0.036 ±0.002*
Mass of dry matter of the root system, g	0.023 ±0.001*	0.027 ±0.001*	0.015 ±0.001	0.017 ±0.001	0.011 ±0.001*	0.015 ±0.001*
Mass of dry matter of cotyledons, g	0.148 ±0.007*	0.126 ±0.006*	0.164 ±0.008	0.152 ±0.007	0.193 ±0.009*	0.174 ±0.008*
Coefficient of use of reserve substances for the needs of above-ground part formation, %	28.45 ±1.42*	33.76 ±1.68*	19.73 ±0.98	23.87 ±1.19	10.33 ±0.52*	16.00 ±0.80*
Coefficient of use of reserve substances for the needs of the root system formation, %	9.62 ±0.48*	11.68 ±0.58*	6.72 ±0.33	7.65 ±0.38	4.05 ±0.20*	6.67 ±0.34*
Germination energy, %	53.75 ±2.68*	58.75 ±2.93*	47.50 ±2.37	51.75 ±2.58	39.75 ±1.98*	42.75 ±2.13*

Notes: * – the difference is significant at $P \leq 0.05$; a – photomorphogenesis, b – skotomorphogenesis.

The exploitation of cotyledon spare substances was also more intensive than under the conditions of germination in light. It was confirmed by the increase in dry matter of coleoptile and root, as well as minimization of cotyledon dry matter. The presence of the stimulating effect of gibberellin was evidenced by significantly higher coefficients of germination energy and the use of spare substances for the formation of roots and coleoptiles on day 18 of germination compared to the control.

The opposite effect on biometrics was observed in the seedlings treated with tebuconazole. Notably, the linear sizes of organs and total plants were significantly smaller than in plants of the control variant of the experiment. The dry matter of coleoptile and root, as well as the dry matter of cotyledon, also decreased. The growth-inhibiting effect of the growth regulator was especially pronounced under light

condition. It was verified by the minimum indicators of the utilization of reserves for the needs of coleoptile formation and significantly lower germination energy indicators in comparison with the control.

The ability to stimulate the release of α-amylase by the embryo into endosperm, leading to the splitting of starch grains, is the main determining factor of the phytohormone effect on seed germination (Smith, Hooley, 2002; Rademacher, 2016; Sun et al., 2018). The data shows a significant effect of gibberellic acid on the rate of starch hydrolysis under conditions of photo- and skotomorphogenesis (Table 2). The rate of the usage of the deposited starch by seeds was higher under dark conditions during germination, although the starch splitting was stimulated by gibberellin both in light and in dark. The starch content in cotyledons of skotomorphic plants was significantly lower than in

Table 2. **The effect of growth regulators on the content of non-structural carbohydrates in the organs of seedlings of maize under conditions of photo- and skotomorphogenesis (day 18 of germination, % by weight of dry matter)**

Plant organ	Variant of the experiment	Total sugar, %		Sucrose, %		Starch content, %	
		a	b	a	b	a	b
Root	GA$_3$	2.10 ±0.10*	5.94 ±0.29*	1.47 ±0.07*	0.64 ±0.03*	24.40 ±1.22*	15.50 ±0.77*
	Control	4.57 ±0.23	2.90 ±0.15	0.74 ±0.04	0.57 ±0.03	34.90 ±1.74	36.0 ±1.80
	Tebuconazole	6.30 ±0.31*	4.14 ±0.20*	0.50 ±0.25*	0.31 ±0.01*	23.40 ±1.17*	24.0 ±1.2*
Coleoptile	GA$_3$	6.53 ±0.32*	4.81 ±0.24	2.20 ±0.11*	1.21 ±0.06*	10.60 ±0.53*	16.45 ±0.82*
	Control	5.38 ±0.25	4.62 ±0.23	1.05 ±0.05	0.69 ±0.03	28.50 ±1.42	25.0 ±1.25
	Tebuconazole	2.26 ±0.11*	5.75 ±0.28*	0.86 ±0.04*	0.31 ±0.01*	24.30 ±1.21*	26.60 ±1.33
Cotyledon	GA$_3$	11.54 ±0.57*	10.13 ±0.51	4.09 ±0.20*	1.43 ±0.07*	41.30 ±2.07*	38.60 ±1.93*
	Control	10.04 ±0.50	10.71 ±0.54	1.09 ±0.05	0.81 ±0.03	46.0 ±2.30	42.40 ±2.12
	Tebuconazole	6.14 ±0.31*	8.35 ±0.42*	0.19 ±0.01*	0.1 ±0.01*	51.10 ±2.55*	47.50 ±2.38*

Notes: * – the difference is significant at $P \leq 0.05$; a – photomorphogenesis, b – skotomorphogenesis.

photomorphic ones. Thus it may be explained by more intensive growth rates and the increase in the demand for deposited compounds by acceptors (roots and coleoptiles). A higher sugar content in seeds of the skotomorphic plants under the retardant action compared to other variants of the experiment was explained, according to our opinion, by less intensive outflow for the formation of root and coleoptile structures, reduced demand for assimilates due to blocking gibberellin synthesis, and reduction of amylase and meristems activity.

It is well-known fact that sucrose is the main transport form of sugar in the plant. It is noteworthy that the lowest sucrose content in germinated seeds was observed in skotomorphic plants under tebuconazole influence. Given the data on the lowest values of the coefficient of the use of spare substances of seeds for growth and formation of vegetative organs of

the seedling in this variant, it can be argued that the retardant inhibited the transport of sugar from the cotyledon.

Starch and protein represent the main stocks of maize seeds. Only limited data contain information about the use of deposited proteins and lipids under the effect of gibberellins (Poprotska et al., 2019).

Nitrogen-containing compounds were used slower compared to carbohydrates in the germination of corn seeds as well as changes in the nitrogen content in the cotyledons of scotomorphic and photomorphic plants on day 18 of germination were much smaller than the changes in the starch content (Table 3). The content of total and protein forms of nitrogen was significantly increased in cotyledons under the tebuconazole action in photo- and skotomorphic plants. Under the action of gibberellin, the nitrogen content was significantly

Table 3. **The effect of growth regulators on the content of nitrogen compounds in the organs of maize seedlings under conditions of photo- and skotomorphogenesis (day 18 of germination, % by weight of dry matter)**

Plant organ	Variant of the experiment	Total nitrogen, %		Protein nitrogen, %		Non-protein nitrogen, %	
		a	b	a	b	a	b
Root	GA_3	0.56 ±0.03	0.79 ±0.04*	0.49 ±0.02*	0.63 ±0.04*	0.07 ±0.01	0.16 ±0.01*
	Control	0.54 ±0.03	0.58 ±0.03	0.44 ±0.02	0.51 ±0.02	0.10 ±0.05	0.07 ±0.01
	Tebuconazole	0.99 ±0.05*	1.32 ±0.07*	0.60 ±0.03*	0.83 ±0.04*	0.39 ±0.02*	0.49 ±0.02*
Coleoptile	GA_3	2.85 ±0.14*	3.09 ±0.15*	1.98 ±0.01*	1.83 ±0.09*	0.87 ±0.43*	0.77 ±0.04*
	Control	2.47 ±0.12	2.73 ±0.14	1.60 ±0.08	1.96 ±0.10	1.02 ±0.005	0.87 ±0.04
	Tebuconazole	3.20 ±0.16*	3.25 ±0.16*	2.18 ±0.11*	2.18 ±0.11*	1.07 ±0.05	1.26 ±0.05*
Cotyledon	GA_3	0.72 ±0.04	0.73 ±0.04*	0.59 ±0.03	0.70 ±0.04*	0.18 ±0.01*	0.09 ±0.01*
	Control	0.76 ±0.04	0.88 ±0.04	0.62 ±0.03	0.64 ±0.03	0.13 ±0.01	0.18 ±0.01
	Tebuconazole	0.86 ±0.04*	0.98 ±0.05*	0.68 ±0.03*	0.88 ±0.04*	0.14 ±0.01	0.1 ±0.01*

Notes: * – the difference is significant at $P \leq 0.05$; a – photomorphogenesis, b – skotomorphogenesis.

lower than under the action of retardant. In our opinion, this indicates that in dark, gibberellin stimulates the hydrolysis of seed reserve protein, but the process of starch hydrolysis is paramount. The usage of tebuconazole did not promote the outflow of hydrolyzed protein from the seed due to the inhibition of apical meristem activity and inhibition of maize seedling growth. Retardant-treated seeds showed significantly higher values of the non-protein nitrogen content both in dark and under light in comparison to control. No significant difference during processing was found.

Previously, a lower content of protein nitrogen under conditions of skotomorphogenesis in control seedlings of horse beans than in photomorphic ones was found. The content of protein nitrogen decreased and the content of non-protein form significantly increased under gibberellin action (Kuryata et al., 2020).

As a result of the experiment on germination of maize seeds, we found significant increase of the values of total and protein nitrogen in the organs of seedlings treated with both retardant and phytohormone. Under conditions of skotomorphogenesis same indicators were lower. Under photomorphogenesis conditions the nitrogen content in roots and coleoptiles treated with tebuconazole was significantly higher compared to the control. The GA_3-treated plants did not distinguish significantly from the control ones under photomorphogenesis or were significantly higher. The content of non-protein nitrogen fraction in seeds was significantly higher in photomorphic seedlings under gibberellin treatment.

It was found that GA_3 increased the growth of sprouts and roots of plant seedlings that contained another types of spare substances as starch (maize), protein (beans) and oil (zucchini) (Poprotska, 2017). At the same time, the process took place predominantly in the dark. Under the action of retardants, which block the synthesis of gibberellins, the germination process was inhibited both in light and in dark. The utilization rate of reserve substances under the action of gibberellin was maximal but it was minimal in both scotomorphic and photomorphic seedlings

under the action of antigibberellin drugs tebuconazole and chlormequat chloride (Kuryata et al., 2017; Poprotska et al., 2019). Therefore, regardless of the type of seed reserve, the use of gibberellin in the germination process was effective. Its effect was enhanced in dark.

The absorption, motion, and inclusion of mineral nutrients into the metabolic processes are significantly affected by the hormonal system of plants (Tegeder, Hammes, 2018; Ivanov, Kudoyarova, 2019). The study of the mechanism of redistribution of mineral nutrients of the plant under the influence of growth regulators under photo- and skotomorphogenesis conditions within the concept of "source-sink" needs particular attention.

Significant difference was found in the phosphorus content in the organs of photo- and scotomorphic maize seedlings on day 18 of germination (Fig. 1). A higher content of the element was observed in GA_3-treated roots and coleoptiles of skotomorphic plants in comparison to photomorphic seedlings. This is due to the specific effect of gibberellin on the phosphorus evacuation from seeds for the more intensive formation of epicotyl and root in dark, while light has the inhibitory effect on the aboveground part growth in photomorphic seedlings. In photomorphic tebuconazole-treated plants, the phosphorus content also increased in roots. The phosphorus content was lower in the roots under skotomorphogenesis conditions and retardant influence than in those treated with gibberellin. Nevertheless, its content was still significantly higher than in control. A significantly lower content was found in experimental cotyledons under skotomorphogenesis conditions compared to control. Thye phosphorus content was the lowest in light in cotyledons of seedlings treated with gibberellin; in our opinion, it was due to the stimulating effect of phytohormone on organogenesis.

The increase of the potassium content was found in coleoptiles and seedling roots as the result of the study (Fig. 2). The roots and coleoptiles of gibberellin-treated plants forming in dark had a higher element content than
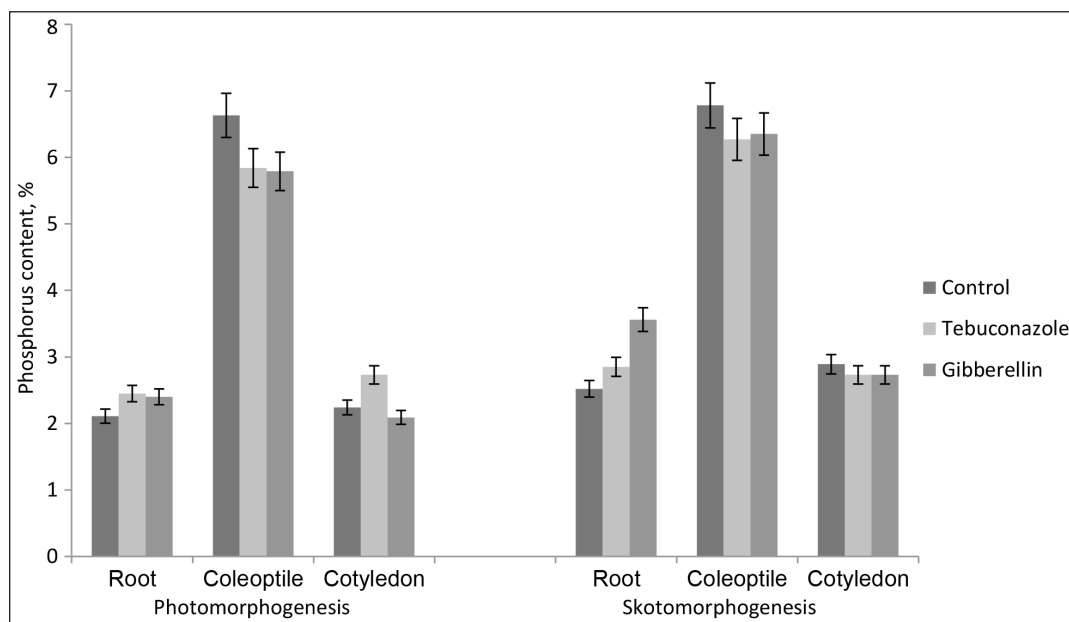
Fig. 1. The effect of growth regulators on the phosphorus content in the organs of maize seedlings under conditions of photo- and skotomorphogenesis (% by weight of dry matter)
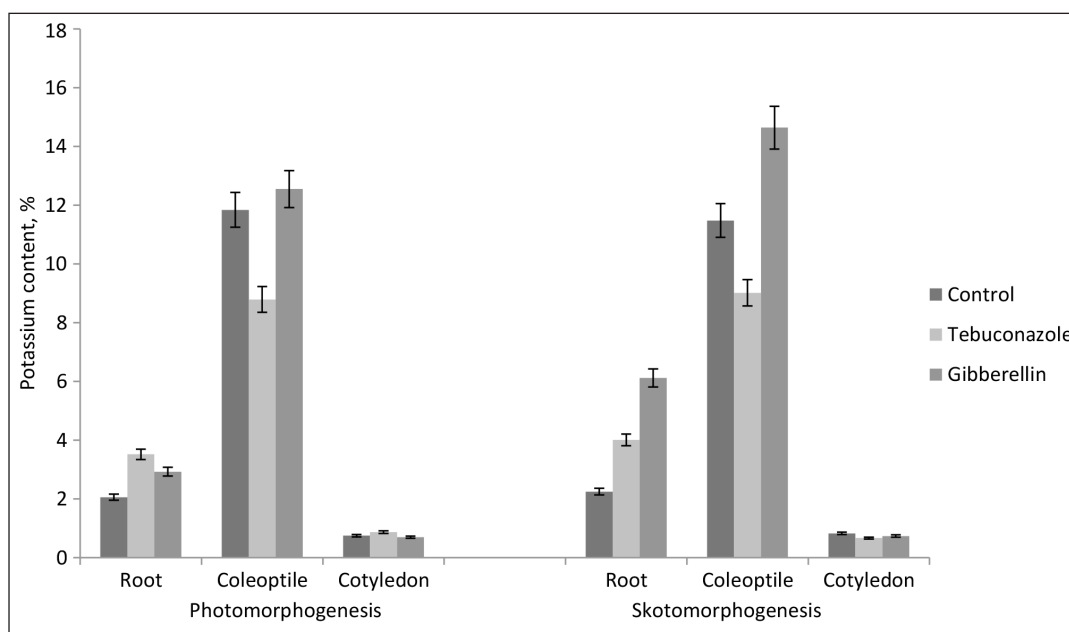

Fig. 2. The effect of growth regulators on the potassium content in the organs of maize seedlings under conditions of photo- and skotomorphogenesis (% by weight of dry matter of the plant)

photomorphic seedlings, due to the specific effect of gibberellin on the evacuation of potassium from seed for the needs of intensive growth of coleoptile and root in dark. Compared to the control, the potassium content also increased in roots of skotomorphic and photomorphic plants treated with tebuconazole. The opposite phenomenon was observed for the above ground part formed under the action of both light and dark.

Thus, it can be argued that there is a specific gibberellin regulation of nutrient reutilization for the needs of organogenesis in the process of germination of maize seedlings of variety "Fragrant" under conditions of photo- and skotomorphogenesis.

CONCLUSIONS

During the germination of seeds, the use of exogenous factors, namely, light and darkness, as well as hormonal factors (gibberellic acid and its antagonist tebuconazole) allowed regulating the nature of source-sink relations in maize seedlings. Under the action of the hormone, the length of the coleoptile, root and total seedling, significantly increased both in light and in dark. Similarly, the mass of dry matter of seedling organs increased. Due to its retardant effect, the use of tebuconazole caused the opposite reaction in seedlings. This inactivation of endogenous phytohormone was confirmed by less intensive use of seed substitutes under the influence of tebuconazole, in particular under photomorphogenesis conditions. It was evidenced by the minimum dry matter of root and coleoptile and lower reserve utilization rates.

Gibberellin stimulated starch breakdown in both light and dark, but the rate of use of deposited starch in seeds was higher under conditions of germination in dark. A lower sugar content in the seeds of skotomorphic plants, both in control and under the action of gibberellin, was explained by more intense outflow for the needs of organogenesis – the formation of root and coleoptile structures. The increase in the starch content in the seeds of skotomorphic plants under the tebuconazole influence was caused by blocking the synthesis of gibberellins and reducing the activity of the amylase and meristems functioning. The lowest sucrose content in germinated seeds was observed in skotomorphic plants under the influence of tebuconazole. Given the data on the lowest values the coefficient of utilization of spare substances of seeds for growth and formation of vegetative organs of seedlings in this variant, it can be argued that the transport of sugar from seeds in dark under the action of retardant.

Quantitative changes in the nitrogen content in seeds of skotomorphic and photomorphic plants during germination were much smaller than the changes in the starch content. This suggests that gibberellin stimulates the hydrolysis of seed reserve protein in dark, but the process is started after intensive starch hydrolysis. Specific gibberellin regulation of phosphorus outflow on the processes of organ formation under the conditions of photo- and skotomorphogenesis was found. Such regulation for potassium outflow under the conditions of photomorphogenesis was not established.

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ATSARGINIŲ MEDŽIAGŲ PANAUDOJIMAS *ZEA MAYS* L. SĖKLŲ DYGIMO METU VEIKIANT AUGIMO REGULIATORIAIS ŠVIESOJE IR TAMSOJE

Santrauka

Šio tyrimo metu buvo ištirti kukurūzų daigų produktyviųjų dalių funkciniai pokyčiai dygimo metu derinant išorinius (šviesa – tamsa) ir hormoninius veiksnius (giberelino rūgštis / retardantas). Nustatyta, kad fitohormonas labai padidino koleoptilių, šaknų ir daigų ilgį, organų sausosios medžiagos masę tiek šviesoje, tiek tamsoje. Tebukonazolo lėtinantis veikimas sukėlė priešingą poveikį. Endogeninio fitohormono inaktyvaciją patvirtina ne toks intensyvus sėklinės medžiagos naudojimas, minimalios šaknų ir koleoptilių sausosios medžiagos normos, mažesnis atsargų kiekis veikiant tebukonazolui, ypač fotomorfogenezės sąlygomis. Mažesnė sėklaskilčių masė gali reikšti tam tikrą atsargų naudojimo optimizavimą. Giberelinas skatino krakmolo skilimą tiek šviesoje, tiek tamsoje, tačiau tamsoje krakmolo buvo sunaudojama daugiau. Mažesnis cukraus kiekis augalų sėklose veikiant giberelinu aiškinamas intensyviu nutekėjimu dėl organogenezės. Po intensyvios krakmolo hidrolizės tamsoje giberelinas stimuliavo rezervinių baltymų hidrolizę. Nustatytas specifinis giberelino poveikis fosforo nutekėjimui organogenezės metu foto- ir skotomorfogenezės sąlygomis bei kalio nereguliavimas fotomorfogenezės sąlygomis.

Raktažodžiai: augimo reguliatoriai, sėklų daigumas, morfogenezė, produktyviųjų dalių sistema, šviesos poveikis