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PECULIARITIES OF MESOSTRUCTURE AND PIGMENT COMPLEX FORMATION IN LEAVES OF SCOTO- AND PHOTOMORPHIC SEEDLINGS OF HORSE BEANS UNDER THE GIBBERELLIN AND TEBUCONAZOLE IMPACT

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Peculiarities of leaf mesostructure formation, synthesis of photosynthetic pigments under the impact of gibberellic acid and its antagonist tebuconazole in scoto- and photomorphic seedlings of horse beans were analyzed. It was established that gibberellins take an active part in the regulation of scoto- and photomorphogenesis. Gibberellic acid and tebuconazole (retardant) significantly affected the histogenesis in leaves of scoto- and photomorphic seedlings. Under the conditions of photomorphogenesis, leaves were formed thicker in comparison to seedlings that developed in the dark. At the same time, under the influence of tebuconazole the highest thickening of leaves was noted both in the dark and light. There was a decrease in leaf thickness in scotomorphic seedlings under gibberellin action. In the dark, the gibberellin effect caused the formation of thinner tissues complexes — chlorenchyma, abaxial and adaxial epidermis. The ratio between chlorophyll *a* and *b* in the control was 4.3, under the impact of tebuconazole — 4.5, and gibberellin — 3.7. Insofar as the content and ratio of chlorophylls *a* and *b* decreased under the action of gibberellin, and increased under the action of antigibberellic drug tebuconazole, this indicates the gibberellin influence on the formation of photosynthetic apparatus light-harvesting complexes. In scotomorphic seedlings, the process of conversion of unsaturated to saturated fatty acids (FA) was most inhibited by tebuconazole, and under the action of gibberellin the ratio was less. In photomorphic seedlings, this process was not inhibited either by exogenous gibberellin or by retardant, compared to control. Thus, light affects the processes of FA metabolism during the heterotrophic phase of development. Blocking the native gibberellin synthesis by tebuconazole in seedlings leads to a decrease in linolenic acid outflow from the cotyledons due to growth retardation and, consequently, the use of this fatty acid in chloroplastogenesis.

Key words: *Vicia faba* L., morphogenesis, mesostructure, pigment biosynthesis, seed germination, light, gibberellins, retardants.

One of the most important external factors that significantly affect the morphogenesis of plants is light. Light changes the rate and duration of plants growth as a whole and their parts (root, epicotyl, hypocotyl, leaves). Plants that germinate in complete darkness develop according to the pro-

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gram of scotomorphogenesis. The epicotyl or hypocotyl is elongated, the hypocotyl loop is formed, the cotyledons turn yellow and the corrugated first leaves are formed. The program of photomorphogenesis is activated in the light: the hypocotyl and epicotyl are shortened, the hypocotyl loop is completely straightened, the cotyledons and primary leaves turn green, the leaf blades become straighten and expand [1]. Deetiolation or transition from etiolated growth (scotomorphogenesis) to photomorphogenesis is one of the most complex stages of plant ontogenesis. It includes reprogramming of plant cell metabolism, reorganization of the hormonal system and changes in plant morphology, the transition to autotrophic nutrition.

Scotomorphogenesis mainly depends on the concentration and ratio of phytohormones, in which gibberellins, indoleacetic acid, brassinosteroids [2] and abscisic acid [3] play a leading role. The role of individual phytohormones remains poorly understood. Whereas phytohormones are involved in the light signal transduction system, many light-regulated responses of plant development also respond to plant hormone treatment [4, 5]. The AtGA3ox1 biosynthesis gene has a positive effect on phytochrome activity, increasing the level of bioactive gibberellins. A positive correlation was found between changes in the biomass and length of the hypocotyl of beans with the content of gibberellins in the dark, while in the light there was a negative correlation between these parameters [1]. Significant morphophysiological effects on the plant are exerted by modifiers of phytohormones [2, 6]. The ability to switch from scotomorphogenetic to photomorphogenetic development is essential for seedling survival. On the surface of the soil, light begins to act as the main exogenous agent that inhibits the activity of the main photomorphogenesis suppressor protein COP_1, which is synthesized in the nuclear space. Light determines the activity of other transcriptional regulators that provide the realization of gibberellin (DELLA) and brassinosteroids (BZR1/BES1) signals, as well as activates trans-factors such as HY5, initiating the transition to autotrophic nutrition [7, 8]. Central to this mechanism is a system of photoreceptors (phytochromes, cryptochromes and phototropin) that regulate the activation of photomorphogenesis [9, 10, 11, 12]. Plant photoreceptor proteins, such as phytochromes (up to 5 different types with partially different functions), cryptochromes (2 types), phototropins (2 types) and UVR8 promote signal transmission, forming a complex network. In this case, the excitation of one photoreceptor may enhance or inhibit the action of another [5].

The initial stages of photomorphogenesis are accompanied by active metabolic changes in the plant, the phytohormones transport and gradients formation, in particular gibberellins, and changes in the activity of natural inhibitors [13, 14].

In order for transition to autotrophic nutrition, the plant should form a photosynthetic apparatus, and protect it from possible minor injuries [15]. Recent work confirms the role of light or its absence in the regulation of chloroplast biogenesis, transcription of their genes, protein factors [16, 17, 18]. It is known that some prolamellar bodies can participate in the accumulation of lipids that allows to form rapidly a full lamellar-granular structure of plastids as soon as the plant enters the conditions of suf-

ficient light. When light intensity is below a certain level or there is no light, proplastids differentiate into etioplasts [19].

The formation of the main pigment-protein complexes of photosynthetic apparatus is a multistage process. It primarily concerns changes in the native pigment apparatus, and the emergence of the electron transport chain photochemical reactions, closely related to photosystems I and II [20, 21, 22].

However, in the literature there is no data on the regulatory role of phytohormones, in particular gibberellins, in the formation of the photosynthetic apparatus during the transition from scotomorphogenesis to photomorphogenesis at the heterotrophic period of development (germination period). In this regard, the aim of our study was to establish the peculiarities of leaf mesostructure formation, synthesis of photosynthetic pigments in scoto- and photomorphic seedlings of horse bean under the impact of gibberellic acid and its antagonist tebuconazole.

Materials and methods

The work was carried out on seedlings of horse bean (*Vicia faba* L.) cv. Vivat. This is a medium-ripe variety with a growing season of 100—105 days; high-yielding, potential seed yield 4.9 t/ha, the protein grain content 34.3 %, vitamin C content is 1.4 mg per 100 g, total sugar — 5.7 %. It is technological, resistant to major diseases, has a high resistance to lodging, shedding of beans, and their cracking.

At the heterotrophic period of growth (germination period) seeds were treated with solutions of gibberellin and the inhibitor of gibberellin synthesis — the triazole-derived drug tebuconazole, to model the various tensions in the source-sink system of seedlings. The seeds were soaked for 24 hours in an aqueous solution of gibberellic acid (GA_3) at a concentration of 0.025 % and in an aqueous solution of tebuconazole at a concentration of 0.05 %.

Gibberellic acid is a white crystalline substance with a molecular weight of 346.2 *D*, 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 3rd class of toxicity. LD_{50} 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 presents 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 species *Gibberella fuljukoi* and *Fusarium moniliforme* [23].

The seeds of other experimental group were soaked in 0.05 % tebuconazole. Tebuconazole is ($C_{16}H_{22}ClN_3O$)-RS)-1p-chlorophenyl-4,4-dimethyl-3-(1H-1,2,4-triazol-1-yl-methyl)pentan-3-yl, a triazole-derived drug. It is a crystalline translucent substance with a molecular weight of 307.8 *D*. The melting point is 104.7 °C. Its solubility in water at 20 °C is 32 mg/l. It is resistant to hydrolysis, provides a uniform acropetal distribution inside of leaf for a long period of time. LD_{50} for rats is 3933—5000 mg/kg. The substance belongs to the 3rd class of toxicity [24].

Seeds were sown in ditches with wet sand. The biological repeatability was fivefold. The experiment was performed under the action of day light (about 500 lux) and in dark in order to study the implementation of programs of scoto- and photomorphogenesis.

The leaf mesostructure was analyzed on the 18th day of germination. Plant material was fixed in the mixture of ethyl alcohol, glycerin, water taken in equal parts with the addition of 1 % of formaldehyde. The primary leaves of the seedlings were selected for anatomical analysis. The analysis of anatomical elements was determined using a microscope Mikmed-1 (RF) with ocular micrometer MOV-1-15x (RF). The content of photosynthetic pigments was determined spectrophotometrically by using spectrophotometer Ulab-102UV (China). The oil was extracted from the seedlings cotyledons in the Soxhlet apparatus by petroleum ether with a boiling point of 40-65 °C. The determination of fatty acids content in oil was performed by gas chromatography using Chrom-5 chromatograph (Czech Republic) [25]. Carrier gas was nitrogen (50 ml/min). Chromatography was carried out under isothermal conditions (200 °C), evaporation temperature was 230 °C, and temperature of flame ionization detector was 240 °C. Chromosorb W AW100-120 mesh served as the solid carrier for packing the column (length — 3.5 m, inner diameter — 3 mm) with applied SP-2300 2 % and SP-2310 3 % stationary phases.

The analytical repeatability of studies was fivefold. Statistical processing of the results 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 show arithmetic mean values and their standard errors.

Results and discussion

Regulation of the plant photosynthetic activity occurs at different photosynthetic apparatus organization levels, in particular at the stage of leaves mesostructure formation. We have previously found that exogenous use of gibberellic acid and antigibberellins (retardants) significantly affects the leaves histogenesis, and as a result changes the photosynthetic activity per leaf area unit [24]. However, these data relate to the stage of active plant growth. There are no data in the literature on the formation of mesostructure elements under conditions of scoto- and photomorphogenesis.

Our data indicate a significant effect of exogenous gibberellin and the antigibberellic drug tebuconazole on the formation of leaf blade under conditions of light and its absence (Table 1). The analysis of the obtained results shows that under the conditions of photomorphogenesis leaves were formed thicker in comparison to seedlings that developed in the dark. At the same time, under the influence of tebuconazole the highest thickening of leaves was noted both in the dark and light. There was a decrease in leaf thickness in scotomorphic seedlings under gibberellin action. Changes in leaf thickness were determined by the peculiarities of the leaves main tissues histogenesis.

Under the influence of the antigibberellic drug tebuconazole the thickness of adaxial and especially abaxial epidermis increased in comparison to control both during development in the light and in the dark.

TABLE 1. The effect of gibberellic acid and tebuconazole on the anatomical structure of horse bean seedlings primary leaves (the 18th day of germination)

Indices	Control		GA_3		Tebuconazole	
	A	B	A	B	A	B
Leaf thickness, μm	492.3±24.6	412.6±20.6	516.4±25.7	376±18.8*	541.6±27.0	459.0±22.9
Adaxial epidermis thickness, μm	106.5±5.3	81.4±4.1	117.3±5.8	73.6±3.7*	118.2±5.9*	88.3±4.4
Chlorenchima thickness, μm	312.0±15.6	267.4±13.3	330.4±16.5	236.8±11.8*	348.2±17.4*	301.8±15.1*
Abaxial epidermis thickness, μm	73.8±3.7	63.8±3.2	68.7±3.4	65.6±3.3	75.2±3.7	68.9±3.4
Stomata number per 1 mm^2 of leaf abaxial surface, pcs.	29.4±1.4	27.9±1.4	26.5±1.3*	25.7±1.3	38.2±1.9*	32.6±1.6*
Stomata diameter, μm	72.5±3.6	77.2±3.9	79.6±4.0	76.6±3.8	67.9±3.4	62.3±3.1*

Notes. * — significant difference at $p < 0.05$; A — photomorphogenesis; B — scotomorphogenesis.

Similarly, in this experimental variant, the leaves were characterized by a thicker layer of chlorenchyma under conditions of both scoto- and photomorphogenesis. In general, it should be noted that thickness of these tissue complexes was higher during development in the light.

It was found that the action of tebuconazole significantly increases the stomata number per leaf area unit, reducing their diameter.

The clearer effect of tebuconazole on the leaves mesostructural characteristics of photo- and scotomorphic bean seedlings compared to exogenous gibberellic acid is explained, in our opinion, by the fact that the action mechanism of this drug is to block the synthesis of gibberellins. Less effective influence of exogenous gibberellin on these indices is explained, obviously, by sufficiently high content of native phytohormone in seedlings.

We revealed a significant effect of gibberellic acid and tebuconazole on the pigment composition of the leaves of scoto- and photomorphic horse bean seedlings on the 18th day of germination (Table 2). In the light there was an increase in the total chlorophyll content, primarily due to chlorophyll *a* content, under the influence of the antigibberellin drug tebuconazole, and decrease in the content of this pigment under the action of gibberellic acid. In our opinion, this indicates the inhibition of chlorophyll synthesis by gibberellins.

Chlorophyll *a* and chlorophyll *b* perform different functions in the photosynthetic apparatus. Chlorophyll *a* has the ability to transfer excited electrons to the electron transport chain of photosystem (PS) I and II. The main role of chlorophyll *b* as a component of light-harvesting antenna is to stabilize the peripheral part of the antenna complexes. It is known that the light-harvesting complex of PS II contains 80 % of total chlorophyll *b* [21, 26]. Its content increases with adaptation to low light levels due to the increase in the size of the PS II light-harvesting antenna, expanding the range of waves absorbed by adapted chloroplasts [27, 28].

TABLE 2. Content of pigments (% per fresh weight) in horse bean seedlings (the 18th day of germination)

Indices	Chlorophyll *a* content	Chlorophyll *b* content	Total chlorophyll content (*a*+*b*)	Carotenoid content, *C*	$Chl_{(a+b)}/C$
			Photomorphogenesis		
Control	1.16±0.06	0.27±0.01	1.43±0.07	0.46±0.02	3.11
GA_3	0.97±0.05	0.26±0.01	1.23±0.06*	0.31±0.02*	3.97
Tebuconazole	1.27±0.06*	0.28±0.02	1.55±0.08	0.37±0.02*	4.17
			Scotomorphogenesis		
Control	0.0050±0.0002	0.023±0.001	0.028±0.001	0.084±0.004	0.32
GA_3	0.0070±0.0003*	0.018±0.001*	0.025±0.001*	0.117±0.005*	0.21
Tebuconazole	0.0080±0.0004*	0.022±0.001	0.030±0.002*	0.075±0.004*	0.40

Note. * — significant difference at $p < 0.05$.

The obtained results make it possible to assess generally the process of formation of structures involved in light phase of photosynthesis. Changes in the chlorophyll *a* and *b* ratio under the influence of various factors are interpreted in modern literature as an indicator of stoichiometric relationships between PS I and II. Analysis of our results shows that the ratio between chlorophyll *a* and *b* in control was 4.3, under tebuconazole action — 4.5, and under the action of gibberellin — 3.7. It is known that chlorophyll *a* is localized basically in intergranular thylakoids, and chlorophyll *b* — mostly in granal [22]. Chlorophyll *b* is formed from chlorophyll *a*, and its synthesis begins only after complete saturation of chlorophyll *a*-binding apoproteins. In our opinion, the decrease in chlorophyll *a* under the action of gibberellin is due to the effect of phytohormone on the intergranular and granal thylakoids of chloroplasts, where the localization of PS I and II and their light-harvesting complexes are spatially separated. Since the chlorophyll content decreases under the action of gibberellin, and increases under the action of the antigibberellic drug tebuconazole, this, in our opinion, indicates inhibition by gibberellin of the PS I and II light-harvesting complexes formation.

Under conditions of scotomorphogenesis, the presence of trace amounts of chlorophyll was established in the seedlings leaves. At the same time, the tendency of the ratio of different forms of chlorophyll under the action of applied growth regulators persisted similarly to phototropic seedlings. There are literature data that a small amount of chlorophyll *b* was accumulated in the dark in the cotyledons of cucumber [29]. A small amount of pigment was also found in pea epicotyl, despite germination in the dark. However, it should be noted that the exact pigment content in some samples could not be determined [30]. Other studies have shown that synthesis of chlorophylls is not absent, but limited in etioplasts, which is determined primarily by the stage of development (the presence of chlorophylls in cotyledon etioplasts, not in true leaves) [19]. According to our opinion, it is possible that there is a slight accumulation of chlorophyll during the extraction of pigments in the light from scotomorphic seedlings.

It is believed that the pigment apparatus of etioplasts is represented by protochlorophylls, and carotenoids are the predominant form of pigments

in etiolated plants. It is noteworthy that in scotomorphic seedlings the content of carotenoids and the ratio of $Chl_{(a+b)}$/C was much lower than in photomorphic. Since it is known that light does not affect the synthesis of carotenoids, this, in our opinion, indicates the lack of a complete membrane structure and protein factors, which are responsible for the synthesis and localization of carotenoids in etioplasts.

The period of seedling formation is characterized by a heterotrophic type of nutrition. Cytogenesis and histogenesis occur due to reserve compounds that are localized in the cotyledons. In our previous work, gibberellic acid stimulated the use of reserve carbohydrates and nitrogen-containing compounds for ontogenetic needs of seedlings, and the use of gibberellin biosynthesis inhibitor tebuconazole, in contrast, retarded the use of seed reserves [31, 32]. However, in the literature there are only single data on seedlings lipid metabolism under conditions of scoto- and photomorphogenesis under the action of gibberellins [33]. It is known that some prolamellar bodies can participate in the accumulation of lipids, which allows to form a full lamellar-granular structure of plastids as soon as the plant enters the conditions of sufficient light [19]. Nevertheless, the formation of plastid thylakoids and granules requires the accumulation of lipids, proteins and pigments in a certain ratio, ensuring the proper formation of integrated membrane protein structures of photosystems and light-harvesting complexes, which are typical for chloroplasts with differentiated thylakoids.

Analysis of the cotyledon fatty acid composition allows to conclude that there is a significant restructuring of lipid metabolism during seed germination and seedling formation. In the process of ontogenesis in all variants of the experiment there was a decrease in the content of unsaturated and an increase in the content of saturated higher fatty acids (Table 3).

Chromatographic analysis of the extracted oil revealed the presence of ten higher fatty acids (FA) — saturated myristic, palmitic, stearic, arachidonic and behenic, and unsaturated — palmitoleic, oleic, linoleic, linolenic and gondoinic. There was a clear pattern of changes in the content of saturated and unsaturated acids during the germination process in comparison with dry seed oil, as well as under the impact of growth regulators on this process. There was a total increase in the content of saturated and a decrease in the content of unsaturated FA in the seed on the 18th day of germination compared to dry seed oil, decreasing the ratio of unsaturated/saturated FA in all variants of the experiment. We found a similar pattern in the study of the action of gibberellic acid and paclobutrazol on the germination of sunflower [24] and maize seeds [34]. In scotomorphic seedlings, the process of conversion of unsaturated to saturated FA was most inhibited by tebuconazole, and under the action of gibberellin the ratio was less. In photomorphic seedlings, this process was not inhibited either by exogenous gibberellin or by retardant, compared to control. Thus, light affects the processes of FA metabolism during the heterotrophic phase of development.

The content of linolenic acid in the cotyledon oil of germinated seeds is important — it did not differ significantly from the control under the action of gibberellin, and was significantly higher under the action of tebu-

TABLE 3. Fatty acids content (%) in the cotyledons oil of scoto- and photomorphic horse bean seedlings under the action of gibberellic acid and tebuconazole (the 18th day of germination)

Indices	Dry seed	Control		GA_3		Tebuconazole	
		A	B	A	B	A	B
Myristic	0.04±0.01	2.45±0.12	2.31±0.11	2.21±0.11*	2.13±0.10*	1.31±0.07*	1.34±0.07*
Palmitic	9.81±0.49	9.16±0.46	10.37±0.52	9.22±0.46	9.54±0.48	10.13±0.51*	10.85±0.54
Palmitoleic	0.12±0.01	0.24±0.01	0.23±0.01	0.23±0.01	0.21±0.01*	0.23±0.01	0.28±0.01*
Stearic	3.90±0.20	4.87±0.24	3.63±0.18	5.12±0.26	5.13±0.26*	5.36±0.27*	3.41±0.17
Oleic	25.81±1.29	22.95±1.15	21.44±1.07	23.06±1.15	23.17±1.16	24.20±1.21	19.77±0.99
Linoleic	52.28±2.61	52.25±2.61	52.25±2.61	52.56±2.62	52.54±2.62	49.79±2.49	56.30±2.81
α-Linolenic	7.35±0.37	6.95±0.35	6.88±0.34	6.72±0.34	6.30±0.32*	8.11±0.41*	7.15±0.36*
Arachidic	0.25±0.01	0.24±0.01	0.23±0.01	0.23±0.01	0.21±0.01*	0.23±0.01	0.28±0.01*
Gondoic	0.21±0.01	0.30±0.01	0.28±0.01	0.28±0.01*	0.22±0.01*	0.32±0.02	0.25±0.01*
Behenic	0.23±0.01	0.57±0.03	0.49±0.03	0.34±0.02*	0.54±0.03	0.31±0.02*	0.36±0.02*
Saturated FA	14.23	17.31	18.92	17.38	17.56	17.35	16.25
Unsaturated FA	85.77	82.69	80.08	82.62	82.44	82.65	83.75
Unsaturated/saturated FA ratio	6.03	4.77	4.23	4.75	4.69	4.76	5.15

Notes. * — significant difference at $p < 0.05$; A — photomorphogenesis; B — scotomorphogenesis.

conazole compared to the control. It has been lately established that the formation of green leaves in the light is accompanied by intense accumulation of glycolipids in the membranes of chloroplasts, which include linolenic acid [35]. Obviously, the seedlings are sufficiently provided with native gibberellin, and the additional effect of exogenous gibberellin on the formation of linolenic acid does not occur. Instead, blocking the synthesis of native gibberellin in seedlings by tebuconazole reduces the outflow of linolenic acid from the cotyledons due to slowed seedling growth rate and, consequently, the use of this fatty acid in chloroplastogenesis [34].

Thus, gibberellins are actively involved in the regulation of scoto- and photomorphogenesis. Under the conditions of photomorphogenesis, leaves were formed thicker in comparison to seedlings that developed in the dark. At the same time, under the influence of tebuconazole the highest thickening of leaves was noted both in the dark and light. There was a decrease in leaf thickness in scotomorphic seedlings under gibberellin action. In the dark, the action of gibberellin formed thinner complexes of tissues — chlorenchyma, upper and lower epidermis. Since the content and ratio of chlorophylls *a* and *b* decreased under the action of gibberellin, and increased under the action of antigibberellic drug tebuconazole, this indicates inhibition of the formation of light-harvesting complexes of PS I and II by gibberellin. Gibberellin increased the rate of conversion of unsaturated FA to saturated in bean cotyledons during the formation of scotomorphic seedlings, but had a slight effect on seedling development in the light. The process was slowed down by the phytohormone inhibitor tebuconazole. Blocking the synthesis of native gibberellin by tebuconazole in seedlings leads to a decrease in the outflow of linolenic acid from the cotyledons due to growth retardation and, consequently, the use of this fatty acid during chloroplastogenesis.

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ОСОБЛИВОСТІ ФОРМУВАННЯ МЕЗОСТРУКТУРИ ТА ПІГМЕНТНОГО КОМПЛЕКСУ ЛИСТКІВ СКОТО- І ФОТОМОРФНИХ ПРОРОСТКІВ БОБІВ КІНСЬКИХ ЗА ДІЇ ГІБЕРЕЛОВОЇ КИСЛОТИ ТА ТЕБУКОНАЗОЛУ

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Проаналізовано особливості формування мезоструктури листків, синтезу фотосинтетичних пігментів за дії гіберелової кислоти та її антагоніста тебуконазолу у ското- і

фотоморфних проростків бобів кінських. Встановлено, що гібереліни беруть активну участь у регуляції ското- і фотоморфогенезу. Гіберелова кислота та ретардант тебуконазол істотно впливали на гістогенез листків ското- і фотоморфних проростків. На світлі товщина листків була більшою в обох варіантах досліду порівняно з контролем. Однак за умов скотоморфогенезу під впливом гіберелової кислоти листки ставали тоншими порівняно з контролем та варіантом з інгібітором синтезу гіберелінів тебуконазолом. В темряві за дії гібереліну формувалися тонші комплекси тканин — хлоренхіми, верхнього та нижнього епідермісу. Співвідношення між хлорофілами *a* і *b* в контролі становило 4,3, за дії тебуконазолу — 4,5, а за дії гібереліну — 3,7. Оскільки вміст і співвідношення хлорофілів *a* і *b* зменшувалися під дією гібереліну та підвищувалися під дією антигібереліновго препарату тебуконазолу, це свідчить про вплив гібереліну на формування фотосинтетичного апарату. У скотоморфних проростків процес перетворення ненасичених жирних кислот (ЖК) у насичені найбільше пригнічував тебуконазол, а за дії гібереліну співвідношення було меншим. У фотоморфних проростків цей процес не пригнічувався порівняно з контролем ні екзогенним гібереліном, ні ретардантом. Отже, світло впливає на процеси метаболізму ЖК під час гетеротрофної фази розвитку. Блокування тебуконазолом синтезу нативного гібереліну в проростках призводить до зниження відтоку ліноленової кислоти з сім'ядолей внаслідок уповільнення росту та, відповідно, використання цієї жирної кислоти в процесах хлоропластогенезу.

Ключові слова: Vicia faba L., морфогенез, мезоструктура, синтез пігментів, проростання насіння, світло, гібереліни, ретарданти.