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THE PECULIARITIES OF UTILIZATION OF SPARE SUBSTANCES IN HOURSE BEAN SEEDS UNDER SCOTO-AND PHOTOMORPHOGENESIS

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Principal changes in source-sink system performance of *Vicia faba* L. during germination periods under light and darkness influence were studied. The linear sizes of organs and total seedling increased under darkness influence. The indicators of organs' dry matter were increased and, accordingly, dry matter mass of cotyledons in scotomorphic plants was decreased. Nutritive substances were diverted vigorously under dark conditions. Higher utilization rates for needs of organs formation during germination evidenced by that fact. Germination processes were connected with intensive outflow of resources for *Vicia faba* organogenesis. The changes indicated intensive protein hydrolysis in dark that started after the starch breakdown. There is no specific impact of mineral matters' outflow for vegetative growth in comparison to dry seeds, which suppose due supply with mineral matters in both experimental variants.

Keywords: germination, utilization rates, morphogenesis, source-sink system, dark.

Introduction. Light is one of the most important exogenous factor that has the influence on morphogenesis. Phytochromes, cryptochromes, phototropins and UVR8 provide transmission and formation of a complex network where excitation of one photoreceptor can enhance or inhibit another [6]. Light activates the photomorphogenesis through this network of photoreceptors [4, 5, 11]. Photomorphogenesis ensures the restructuring of chloroplasts, green leaves' development and the transition to proper photosynthesis. Usually, plants form a hypocotyl loop, yellow cotyledons and elongated epicotyl or hypocotyl in complete darkness. Rapid elongation of these organs provides intense light output, as well as the tightly wrapped apical loop allows easy passage through substrates, preventing damage to small deployed cotyledons and meristematic tissues. The economical use of limited seed reserves during growth guarantees a necessary condition for the photoautotroph's survival [2, 7].

Aim. To establish the effect of light absence on the germination processes of *Vicia faba* L.

Materials and methods. The experiment was conducted on seedlings of horse beans (*Vicia faba* L.) of variety Vivat. The influence of light and its absence was used for creation of different tensions in source-sink system during the heterotrophic period of horse bean seeds sprouting. The seeds were soaked in distilled water and sown in ditches with sand. The biological repeatability was fivefold. The experiment was performed under the

action of light (natural lighting of the Laboratory of Plant Physiology, Biology Department of Mykhailo Kotsyubynsky State Pedagogical University) and in dark for investigation of the implementation of photo- and scotomorphogenesis programs. Morpho-biometric parameters were determined on the day of 18 of germination. Determination of the non-structural carbohydrates (sugars and starch) content in the organs was performed by iodometric method, phosphorus content – by the intensity of phosphorus-molybdenum complex formation, potassium – by flame-photometric method, total, protein and non-protein nitrogen content – by the Kjeldahl method [1]. Analytical repeatability of studies is fivefold. Statistical processing of the results was performed using the software package Statistica-6. The reliability of the difference was determined by Student's t-test. Arithmetic values and their standard errors are shown in the tables and graphs.

Results and discussion. The obtained data analysis showed that the light absence significantly affected the growth rate of organs and the intensity of utilization of seed reserves for growth processes (Table 1). In plants that developed according to the scotomorphogenesis program, a significant increase in the growth indicators of organs and total seedlings was found.

Table 1.

The effect of photo- and scotomorphogenesis programmes on the growth and spare substances utilization rates of Vicia faba L. seeds

Indicator	Photomorphogenesis	Scotomorphogenesis
Epicotyl length, cm	14.0±0.86	19.5±0.98*
Root length, cm	8.1±0.41	9.3±0.47*
Total seedling, cm	22.1±1.26	28.8±1.44*
Dry matter mass of epicotyl, g	0.034±0.002	0.039±0.002*
Dry matter mass of root, g	0.017±0.001	0.021±0.001*
Dry matter mass of cotyledons, g	0.513±0.01	0.449±0.02*
Coefficient of use of reserve substances for above-ground part formation, %	6.0±0.33	7.7±0.38*
Coefficient of use of reserve substances for the root system formation, %	3.0±0.15	4.1±0.22*

Note: *- the difference is significant at $P \leq 0.05$

The utilization of spare substances seeds was slower in light than in the dark. Seed substances were used more vigorously under the scotomorphogenesis conditions. Minimum dry matter mass of cotyledons in plants grown in dark and higher coefficient of use of reserve substances for above-ground and underground parts formation on the day 18 of germination evidence that notion.

It is well-known fact that sugars are transported in the plant mainly in the sucrose form. It is noteworthy that the lowest content of this sugar in germinated seeds was observed in photomorphic plants (Table 2). Given the data on the lower coefficient of the utilization rate of nutrients for growth and formation of vegetative organs in the light, as well as a slight increase in sucrose content in the cotyledons of scotomorphic plants compared to dry seeds may indicate a decrease in sugar transport from seeds in

photomorphic seedlings due to the inhibitory effect of light and a significant reduction in nutrient demand by the acceptor [8].

Table 2.

The effect of photo- and scotomorphogenesis programmes of development on non-structural carbohydrates content in organs of horse beans (on the day of 18, % by dry matter weight)

Organ	Total sugar		Sucrose		Starch	
	a	b	a	b	a	b
Root	1.34 ±0.07	1.27 ±0.06	0.35 ±0.02	0.33 ±0.17	1.13 ±0.06	1.06 ±0.06
Epicotyl	3.43 ±0.16	1.78 ±0.09*	0.84 ±0.04	0.80 ±0.04	0.47 ±0.02	0.38 ±0.02*
Cotyledons	10.54 ±0.53	8.76 ±0.44*	3.14 ±0.16	4.12 ±0.21*	24.17 ±0.20	17.53 ±0.88*
Dry seed	9.24±0.46		4.03±0.20		30.52±1.52	

Notes: a – photomorphogenesis, b – scotomorphogenesis; *– the difference is significant P≤0.05

The main reserves of horse bean seeds are represented by both starch and protein. There are limited data on the effect of dark on the use of non-starch spare substances, in particular proteins and lipids [9].

Slower use of nitrogen-containing compounds in comparison with reserve carbohydrates was indicated during germination of bean seeds (Table 3). Changes in the nitrogen content in the seeds of scotomorphic and photomorphic plants on the 18th day of germination were much smaller than changes in the starch content.

Table 3.

The effect of photo- and scotomorphogenesis programmes of development on nitrogen-containing substances in organs of horse beans (on the day of 18, % by dry matter weight)

Ogran	Nitrogen forms					
	Total		Protein		Non-protein	
	a	b	a	b	a	b
Root	3.16 ±0.16	2.74 ±0.14*	1.9 ±0.09	1.5 ±0.08*	1.26 ±0.06	1.24 ±0.06
Epicotyl	7.56 ±0.38	5.57 ±0.28*	3.47 ±0.17	1.53 ±0.08*	4.09 ±0.20	4.04 ±0.20
Cotyledons	4.74 ±0.24	4.21 ±0.21*	2.80 ±0.14	2.60 ±0.13*	1.94 ±0.09	1.61 ±0.08*
Dry seed	3.97±0.20		3.85±0.19		0.12±0.006	

Notes: a – photomorphogenesis, b – scotomorphogenesis; *– the difference is significant P≤0.05

The protein fraction content of nitrogen in scotomorphic plants significantly decreased in comparison to non-protein nitrogen content in seeds. This suggests that endogenous gibberellin in dark stimulates the hydrolysis of seed reserve protein. The process of protein utilization may be started after starch hydrolysis. The content of total nitrogen and its fractions in the epicotyl and root of scotomorphic seedlings was decreased

due to the biodilution of the element by the organic matter of these organs and increasing growth rates of scotomorphic plants.

Previously found changes in growth characteristics and utilization of reserve substances of bean seeds (*Phaseoleus vulgaris* L.) was accompanied by a decrease in total nitrogen content, indicating the use of reserve nitrogen-containing compounds for morphogenesis [9]. Our data indicate lower than in photomorphic seedlings the content of protein nitrogen than under scotomorphogenesis conditions. It was also found that gibberellin decrease the duration of the aboveground part and root system growth in the dark regardless of reserve substances' types [9]. Thus, gibberellin plays an universal role in germination processes enhancing its effect in dark.

The main patterns of redistribution of flows of plastic substances in plants during changing in growth parameters of individual organs are fully studied within the concept of functioning of the source-sink system [3, 10, 12]. However. the peculiarities of the redistribution of mineral nutrients between these organs under of photo- and scotomorphogenesis conditions remain virtually unexplored.

Phosphorus content analysis shows a significant difference in the content of this element in the seeds and roots of scoto- and photomorphic plants on the 18th day of germination (Figure 1). At the same time, lower content of the element was observed in the roots and epicotyl that were formed in dark in comparison to photomorphic seedlings. However, it should be noted that the difference was not significant compared to the element content in dry seeds. In our opinion, similarly to nitrogen it is also associated with biodilution.

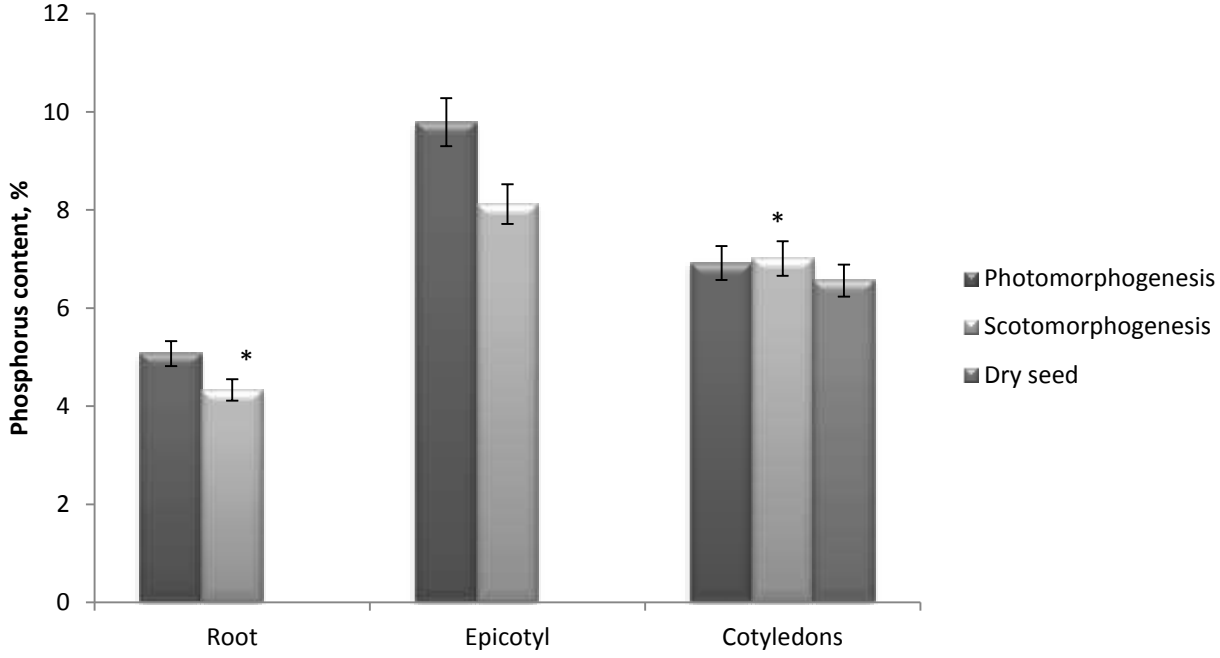

Figure 1. The effect light absence of phosphorus content in organs of horse beans (on the day of 18, % by dry matter weight; *– the difference is significant P≤0.05)

In general, similar patterns were observed for potassium: due to biodilution, scotomorphic plants were characterized by lower potassium content in cotyledons and roots of seedlings and a slight decrease in the element content in cotyledons compared to dry seeds (Figure 2).

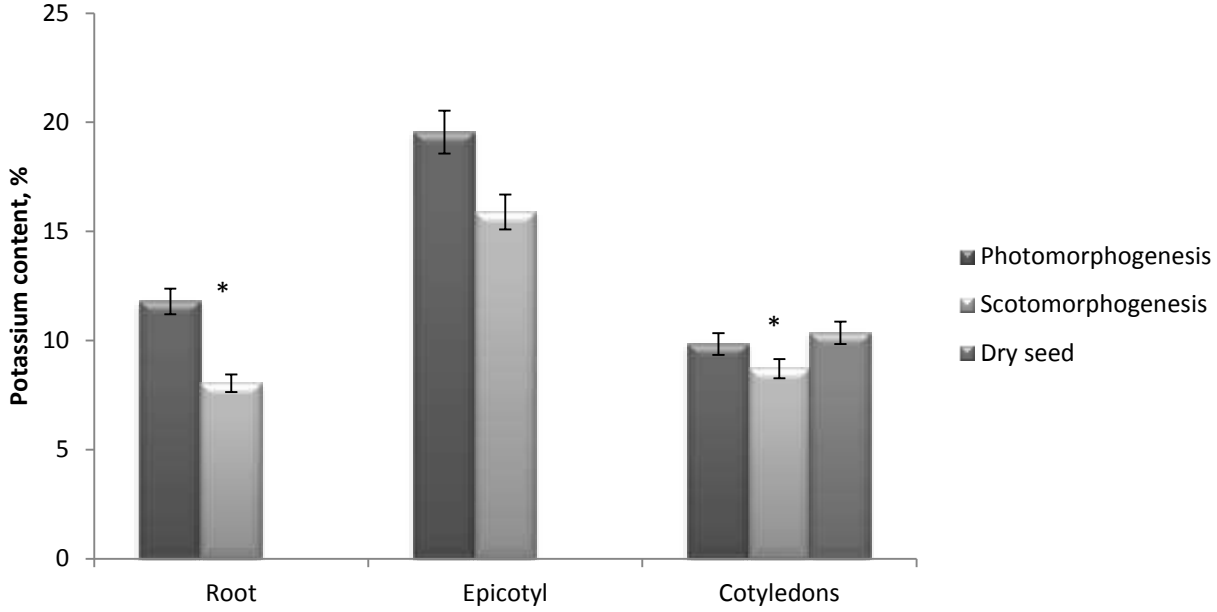

Figure 1. The effect light absence of potassium content in organs of horse beans (on the day of 18, % by dry matter weight; *– the difference is significant P≤0.05)

This, in our opinion, suppose due supply of seeds with phosphorus and potassium to ensure the processes of photo- and scotomorphogenesis.

Conclusions. The influence of darkness during seed germination significantly changed the nature of source-sink relations in horse bean seedlings. Under the action of darkness, the length of the epicotyl, root and total seedling increased significantly. Accordingly, the dry matter mass of the cotyledons decreased and the mass of the seedling organs increased. Seed substances were used more vigorously under scotomorphogenesis conditions. It was evidenced by higher reserve utilization rates for root and epicotyl formation during germination.

The dark stimulated the breakdown of starch due to outflow for organogenesis - the formation of root and epicotyl structures. Content of sugars was decreased in the seeds of scotomorphic plants compared to photomorphic. Quantitative changes in the nitrogen content in the seeds of scotomorphic and photomorphic plants during germination were much smaller than changes in the starch content. This indicates that the scotomorphogenesis programme stimulates the hydrolysis of reserve protein in cotyledons. It was also found that the lack of light does not significantly affect the outflow of mineral nutrients for the needs of organogenesis.

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