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INFLUENCE OF LIGHTING SPECTRAL COMPOSITION ON THE DEVELOPMENT OF POTATO PLANTS IN VITRO

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ABSTRACT

The spectral composition of lighting at the stage of microclonal potato propagation is significant factor regulating physiological and biochemical processes. Optimization the lighting spectrum is promising not only for reducing energy costs in the production of healthy planting material, but also for increasing the reproduction rate. Two lighting treatments were used in laboratory experiment fulfilled in Perm Agricultural Research Institute in 2024.The first treatment was the OSRAM L 30W/77 T8 Fluora fluorescent phytolamp (PPF-R – 40.8%, PPF-B – 32.2%, PPF-G – 27.0%), which has the necessary predominance of blue and red waves in spectrum necessary for plant photosynthesis as a whole. The second variant was LED lighting with a spectrum (PPF-R - 62.4%, PPF-B - 21.6%, PPF-G - 16.0%) recommended according to literature data specifically for in vitro potatoes. The experiment was carried out for 28 days. The influence of spectral composition of illumination on the stem, length, leaves and internodes number, potato tops mass, the content of photosynthetic pigments were explored. Five potato varieties: Shah, Nevsky, Irbitsky (ripeness group: mid-early), Terra, Legend (ripeness group: early) were studied. As a result of the study, it was demonstrated that the use of optimized spectrum lighting led to the increase in the reproduction rate of potato during in vitro cuttings due to formation of internodes and leaves additional number, and stem length increase. The joint effect of lighting factors and genotype (hereditary factor) on morphological parameters was analyzed. It was revealed that the factor of lighting spectral composition influenced mainly on the length of plants and the number of internodes.

Keywords: potato, culture *in vitro*, light spectrum, photosynthetic pigments.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important crop for the economy of many countries. The quality of planting material determines the success of harvesting (Fedorova, 2016). Potato propagation in vitro culture is carried out to obtain healthy planting material. Light is a regulating factor for potato, so optimization of this particular factor plays significant role at the in vitro propagation stage. The spectral composition of the light source can be used to control the growth and morphogenesis of potato tissues and organs in vitro (Lisina, 2023). Optimizing the lighting spectrum is promising due not only for reducing energy costs in the production of healthy planting material, but also for increasing the reproduction rate (Nakonechnaya, 2021). The necessity for the potato plant to receive the full spectrum of artificial lighting has been experimentally confirmed (Martirosyan, 2016). Many studies note the heterogeneity and inconsistency of the results obtained when studying plant growth processes under lighting of different spectral compositions, which is explained by the specific reaction of different plant varieties to light the spectral composition (Basiev, 2022). To achieve the greatest efficiency in the process of producing healthy potato seed material, it is important to develop technologies that take into account the biological characteristics of the genotypes under study. The purpose of our research is to study the influence of lighting of different spectral composition on morphological parameters and the content of main photosynthetic pigments in the leaves of potato microplants in vitro, varieties Shah, Nevsky, Irbitsky (ripeness group: mid-early), Terra, Legenda (ripeness group: early), identifying varietal characteristics reactions to lighting conditions.

MATERIAL AND METHODS

The study was carried out from December 2023 to June 2024 in Perm Agricultural Research Institute – division of Perm Federal Research Center Ural Brunch Russian Academy of Sciences. Employees of agrobiophotonics laboratory constructed special research growbox. The growbox was located in a light-insulating cover to exclude the influence of natural light. Two lighting treatments were used in described laboratory experiment. The first treatments (A) was the use of OSRAM L 30W/77 T8 Fluora fluorescent phytolamp (PPF-R – 40.8%, PPF-B – 32.2%, PPF-G – 27.0%), which has the necessary predominance of blue and red waves in spectrum necessary for plant photosynthesis as a whole. The second variant (B) was LED lighting with a spectrum (PPF-R - 62.4%, PPF-B - 21.6%, PPF-G - 16.0%) recommended according to the literature data specifically for potato in vitro (Kulchin, 2018; Lisina, 2023; Shanina, 2023). Lighting parameters were measured using a portable spectrometer UPRtek MK350S with a measurement range from 380 to 780 nm. Microclonal propagation of potato was carried out by cuttings under sterile conditions with further growing on Murashige-Skoog agar nutrient medium (Murashige, 1962). Chemical test tubes with 5 ml of nutrient medium were used as culture vessels. The nutrient medium was autoclaved at the temperature of 120°C for 22 minutes under 1.0 atm. pressure. Onwards 60 meristem plants of each variety were placed to growbox (30 plants of each variety per experimental variant) and cultivated at a temperature of 21-24°C and a 16-hour photoperiod. The experiment lasted 28 days (Fig.1).

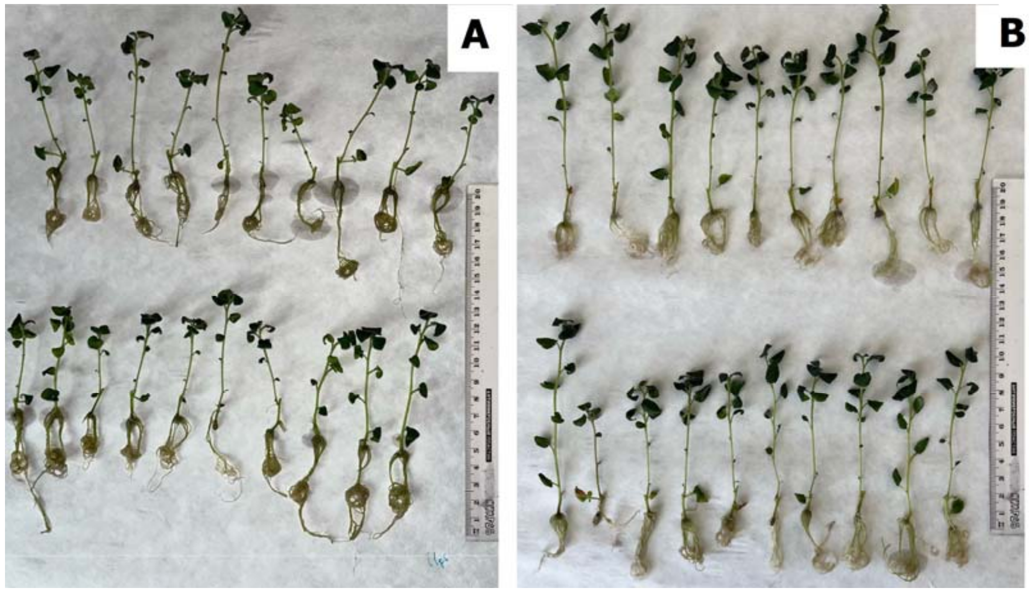

Figure 1. Meristem plants of the Irbitsky variety on the 28th day of the experiment. A - OSRAM L 30W/77 T8 Fluora fluorescent phytolamp (PPF-R – 40.8%, PPF-B – 32.2%, PPF-G – 27.0%), B - LED lighting with a spectrum (PPF-R - 62.4%, PPF-B - 21.6%, PPF-G - 16.0%).

After this, scientists determined the mass of above-ground parts of the plants and root system mass. The content of photosynthetic pigments was determined by spectrophotometric method. The studied plant leaves were weighed and homogenized in 70% acetone. Carotenoids were determined at 440.5 nm wavelength, chlorophyll – 665 nm, and chlorophyll – 649 nm. Chlorophyll concentration in the extract were calculated using the Vernon formula (Trifonov, 2011). We used the Vertshtein formula to determine the concentration of carotenoids in the total extract of pigments (Trifonov, 2011). We determined the content of pigments in the studied material, taking into account the volume of the extract and the sample mass. Scanned images of plants were processed in ImageJ program to determine plant length and number of internodes. The obtained data were statistically processed using descriptive statistics, Student's t-tests and shift/position to determine the significance of differences between treatments (depending on the normality of the sample distribution). Differences between the compared values were considered significant with a confidence level of 95% or higher ($P \leq 0.05$).

RESULTS AND DISCUSSION

It was determined that significant excess in plant length was noted for all potato varieties participating in this experiment (Table 1). The number of per plant meristem is an important morphological indicator, as it determines the reproduction coefficient (Bakunov, 2021). A significant excess of internodes number in B treatment compared with A was recorded for potato plants of Terra and Legend varieties (Table 1). Both varieties are early ripening. For Shah and Nevsky Irbitsky varieties (mid-early group), no significant differences in the number of internodes and leaves were recorded. The mass of plants above-ground parts for all varieties was higher in the experimental variant with LED lighting of the optimized spectrum. The mass of root system was higher under LED lighting in plants of Shakh, Irbitsky and Legenda varieties (Table 1).

Table 1. Morphometric parameters of plants cultivated under lighting of different spectral composition

Lighting treatment	Potato variety				
	Shakh	Nevsky	Irbitsky	Terra	Legenda
Length of regenerated plants, mm					
OSRAM L 30W/77 T8 Fluora	65,3±3,5	66,6±1,7	55,7±2,9	81,4±1,7	46,8±2,1
LED light	81,9±4,2*	73,4±2,5*	97,4±3,8*	111,3±3,2*	86,2±3,2*
Number of internodes, mm					
OSRAM L 30W/77 T8 Fluora	7,3±0,3	5,8±0,3	6,6±0,2	7,05±0,3	4,9±0,2
LED light	7,2±0,4	5,7±0,4	6,5±0,2	7,5±0,2*	7,4±0,2*
Number of leaves					
OSRAM L 30W/77 T8 Fluora	10,2±0,3	7,7±0,3	9,0±0,2	8,85±0,2	8,3±0,2
LED light	10,1±0,2	7,8±0,2	9,5±0,8	9,7±0,2*	10,7±0,2*
Mass of root part, g					
OSRAM L 30W/77 T8 Fluora	0,129±0,010	0,162±0,014	0,138±0,009	0,145±0,011	0,112±0,010
LED light	0,209±0,011*	0,183±0,015	0,171±0,010*	0,141±0,008	0,166±0,010*
Mass of above-ground part, g					
OSRAM L 30W/77 T8 Fluora	0,133±0,010	0,155±0,011	0,135±0,011	0,135±0,006	0,198±0,009
LED light	0,252±0,012*	0,235±0,019*	0,218±0,011*	0,255±0,009*	0,236±0,008*

Notes:
* – significant differences between lighting treatments.

Analysis of variance of the obtained data allowed us to make conclusions about the contribution to the overall variability of the studied parameters separately from the lighting factor and the genotype factor, as well as their joint contribution (Table 2).

The factor of spectral composition of lighting made the greatest contribution to the variability of plant length and internodes number. Other factors, probably the composition of the nutrient medium, made a greater contribution to root system mass and the mass of the above-ground parts of regenerated potato plants.

Table 2. Contribution of the studied factors to the overall variability of the studied parameters, %

Factors	The studied parameters			
	Length of regenerated plants	Number of internodes	Mass of above-ground part	Mass of root part
Heredity factor (genotype, variety)	26	25	23	12
Lighting factor	42	33	19	12
Interaction of factors	13	17	18	18
Other factors	19	25	40	58

Assessing the functioning of the photosynthetic apparatus by determining the concentration of photosynthetic pigments is important indicator of plants response to changes in lighting quality (Nikonovich, 2018). The efficiency of photosynthetic apparatus of regenerating plants affects the synthesis of carbohydrates, which in turn affects the formation of mini-tubers (Golovackaja, 2013). The nature of changes in chlorophylls and carotenoids concentrations depending on the lighting spectrum turned out to be different for potato varieties taken as the objects of study (Table 3).

Table 3. Content of photosynthetic pigments in leaves , mg/g

Lighting treatments	Potato variety				
	Shakh	Nevsky	Irbitsky	Terra	Legenda
Chlorophyll a					
OSRAM L 30W/77 T8 Fluora	232,87± 11,89	234,89± 12,53	234,07± 13,38	182,12± 12,57	301,46± 17,96
LED light	265,52± 16,46*	259,66± 10,50*	265,98± 16,56*	288,76± 12,72*	347,51± 16,88*
Chlorophyll b					
OSRAM L 30W/77 T8 Fluora	204,12± 12,86	203,46± 9,25	158,91± 10,11	167,76± 8,12	174,73± 10,45
LED light	258,62± 11,48*	253,80± 15,20*	183,79± 13,75*	189,64± 11,62*	208,28± 14,25*
Carotenoids					

Lighting treatments	Potato variety				
	Shakh	Nevsky	Irbitsky	Terra	Legenda
OSRAM L 30W/77 T8 Fluora	188,20± 16,53	191,01± 11,99	155,44± 13,85	163,85± 11,21	170,94± 14,37
LED light	229,80± 11,84*	223,09± 16,20*	159,06± 14,94	157,25± 11,07	184,61± 18,16

Notes:
* – significant differences between lighting treatments

Analysis of chlorophyll *a* and chlorophyll *b* content shows that when potato microplants are grown in vitro under optimized spectrum lighting, the chlorophyll content in the leaves is significantly higher compared with fluorescent lamp. Significant differences were determined for all five studied varieties. Increased concentrations of photosynthetic pigments provide better adaptation of meristem potato plants to non-sterile growing conditions in vivo due to a rapid and stable transition to autotrophic nutrition (Belyaeva, 2017). The content of carotenoids significantly increased in plants of Shah and Nevsky varieties. Carotenoids are of keen interest as a non-enzymatic antioxidant defense system. Carotenoids are involved in the quenching of singlet oxygen and peroxide radicals that are generated when chlorophyll is overexcited (Mansour, 2017).

CONCLUSIONS

The influence of the spectral composition of lighting was discovered on the stem length, the leaves and internodes number, photosynthetic pigments content of five potato varieties: Shah, Nevsky, Irbitsky (ripeness group: mid-early), Terra, Legend (ripeness group: early). As a result of the study, it was demonstrated that the use of optimized spectrum lighting can lead to an increase in the reproduction rate of potato during in vitro cuttings through the formation of an additional number of internodes and an increase in stem length. The combined influence of lighting factors and genotype (hereditary factor) on morphological parameters was analyzed. It has been determined that the factor of the spectral composition of lighting has the greatest influence on the length of plants and the number of internodes. The fulfilled studies show that when choosing a lighting treatment, it is necessary to assess the specific reaction of the propagated variety to various combinations of the spectrum, since the influence of the heredity factor (variety) contributes to the overall variability of traits no less than the lighting factor. The optimized spectral composition can significantly increase the amount of photosynthetic pigments in meristem potato plants. The research results be used in seed potato production, at the initial breeding stage with growing plants under artificial lighting.

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