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PHYTOCHROME-DEPENDENT REGULATION OF MELON RESISTANCE TO FUSARIUM WILT

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The effect of pre-sowing seed treatment with light in the red spectral region on the resistance of melon plants (*Cucumis melo*) of the cultivar Kichkintoy to Fusarium wilt damage caused by *Fusarium oxysporum* f. sp. *melonis* was investigated. The directly-opposite effects of red and far red light on the degree of plant damage by the pathogen, which was determined by the special symptoms of the disease on the leaves and stems of plants, were revealed. When alternating seed treatment with red and far red light, the final effect was determined by the type of irradiation that acted last. The results of photobiological testing made it possible to establish the participation of the phytochrome system in the control of the resistance of melon plants of the cv. Kichkintoy to Fusarium wilt. It is shown that there is a high positive correlation between the parameters of chlorophyll fluorescence induction of leaves reflecting the functional activity of the photosynthetic apparatus and the degree of damage to plants grown from non-irradiated seeds and seeds irradiated with red light. The results of the conducted studies establish the possibility of effective regulation of the resistance of the melon cv. Kichkintoy to the defeat of *F. oxysporum* f. sp. *melonis* through photoactivation of the phytochrome system of seeds before sowing.

Keywords: chlorophyll fluorescence, *Cucumis melo*, far red light, *Fusarium oxysporum* f. sp. *melonis*, pathogen, photosynthesis, resistance to red light

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INTRODUCTION

Among the various diseases of vegetable and melon crops, a special place is occupied by Fusarium wilt, which is caused by fungi of the *Fusarium* genus living in the soil, on plant debris and seeds (Petkar, Ping, 2017). Among these crops, melons (*Cucumis melo* L.) are most susceptible to Fusarium wilt (Pan et al., 1996; Trionfetti-Nisini et al., 2002; Egel, Martyn, 2007; Alvarez, 2009; Matsumoto et al., 2011, Registeri et al., 2012), while the most significant damage to this crop *Fusarium oxysporum* f. sp. *melonis* inflicts on loamy and clayey soils (Zuniga et al., 1997; Namiki et al., 1998; Kurt et al., 2002; Elena, Pappas, 2006; Matsumoto, 2012), typical for Uzbekistan. Such soils are easily colonized by the pathogen due to the presence in them of the remains of the stems and roots of agricultural plants grown in crop rotation, and favorably influencing the increase of these resistant pathogenic populations (Banihashemi, Dezeeuw, 1975; Gordon et al., 1989; Zuniga et al., 1997; Martyn, 2014). This fungal disease manifests itself at different stages of plant vegetation, especially during active growth, the appearance of the first leaves and fruit formation, which leads to wilting of the leaves and, in most cases, to the death of plants. Ultimately, this leads to extremely high yield losses and a decrease in its quality.

With modern technologies of melon cultivation, as well as many agricultural crops, it is necessary to carry out certain preventive measures aimed at increasing the resistance of plants to Fusarium wilt. At the same time, various methods of seed etching and spraying crops with pesticides are used (Jahanshir, Dzhalilov, 2010). However, these methods of control are not environmentally safe, therefore, the development of less toxic plant protective is required (Maksimov et al., 2015). In addition, as noted in the work by Novikova (2005), plant protection through the use of chemicals and mineral fertilizers leads to the formation of resistant races of pathogens, depletion of the quantitative and qualitative composition of natural microbiocenoses and accumulation of toxic residues in the environment. In this regard, an alternative to chemical methods of plant protection, is the use of biological products based on live cultures of microorganisms to regulate the population density of phytopathogenic microorganisms and

phytosanitary optimization of agroecosystems (Novikova, 2005; Egel, Martyn, 2007; Baysal, Calskan, 2008; Matsumoto, 2012; Registeri et al., 2012; Okungbowa, Shittu, 2012; Maksimov et al., 2015; Alekseeva, Smetanina, 2019; Miller et al., 2020; Rao et al., 2021). Despite the significant progress made in this direction, it is necessary to take into account the complexity of these methods and their relatively high cost.

At the same time, the regulatory role of biologically active red light in the processes of plant morphogenesis of various agricultural crops is known (Butler et al., 1959; Volotovsky, 1992; Casal, Sanchez, 1998; Legris et al., 2019). The stimulating effect of red light is based on the photoinduced transition of phytochrome from inactive P_r to active R_{fr} form (Rockwell et al., 2006; Szurmant et al., 2007; Kreslavski et al., 2009; Chen, Chory, 2011; Sineshchekov, 2013; Galvao, Fankhauser, 2015). It is the direct ($P_r - R_{fr}$) and reverse ($R_{fr} - R_r$) photoconversion of the photopigment that allow the plant to respond to the quality, intensity, and duration of illumination by changing the growth and shaping processes, which are commonly called photomorphogenesis (Quail, 2007; Pham et al., 2018; Wu et al., 2019). The role of the photoreceptor in the control of plant resistance to adverse environmental factors (Kuznetsov et al., 1986; Mathews et al., 2006; Kreslavsky, 2010), including pathogenic microorganisms (Horemans et al., 1984; Akhmedzhanov et al., 1992, 2014; Mavlonova, 2011), has been shown. Irradiation of seeds with a helium-neon laser, along with a stimulating effect, already at an early stage of ontogenesis induces an increase in the general nonspecific resistance of cucumber plants to root rot and sunflower to Fusarium wilt (Koreneva, 1996). In these studies on the seeds of a number of agricultural crops, the role of phytochrome as the main regulator of most physiological processes in plants has been studied. Similar data on the regulatory role of phytochrome in the control of morpho-physiological processes in melon, including resistance to biotic environmental factors, are not available in the literature. In this regard, the purpose of this study was to determine the effect of seed irradiation with light in the red region of the spectrum on the resistance of melon plants to the causative agent of Fusarium wilt. Establishing patterns in plant responses to seed irradiation with red (λ_{max} 660 nm) and far red (λ_{max} 730 nm) light will reveal the presence or absence of phytochrome control of the disease resistance of this crop, and will also create prerequisites for the development of an environmentally friendly, highly effective method for increasing melon resistance to Fusarium wilt injury.

MATERIALS AND METHODS

Melon seeds of the cv. Kichkintoy were sown in sterilized garden soil in plastic trays, where they germinated at a temperature of 26–30°C. The seedlings were grown to the stage of plants with a fully developed first true leaf (Egel, Martyn, 2007).

Inoculation was performed using the root immersion method (Matsumoto et al., 2011). A culture of the fungus *Fusarium oxysporum* f. sp. *melonis* from the collection of the laboratory of mycology and algology of the Institute of Botany of the Academy of Sciences of the Republic of Uzbekistan was cultivated in 100 ml of potato dextrose broth (PDB) in 300 ml flasks on a rotating shaker (about 120 rpm) for one week at 25°C. After cultivation, the conidia suspension was filtered through a two-layer gauze. The concentration of conidia was determined using a Goryaev chamber, and then adjusted to the appropriate density by dilution with sterile distilled water. For artificial inoculation, seedlings were extracted from sterilized soil, the roots were washed in tap water, and then immersed in a conidial suspension (107 spores/ml) for 15 s. Inoculated seedlings were transferred to sterilized garden soil in new plastic pots and grown in a growing chamber at a temperature of 23°C (photoperiod of 16 h).

The resistance of melon plants to the pathogen was evaluated 21 days after inoculation according to the 0–3 severity scale of the disease (0 means no symptoms, 1 – small leaf lesions, 2 – severely affected leaves, 3 – plant death) according to Matsumoto et al. (2012). Resistance was assessed on 20 plants in each variant. The results were expressed as averages and standard errors.

Irradiation of seeds with red light (RL) was carried out with an illuminator made on the basis of red LEDs (radiation maximum is 660 nm, 1000 Lux). Far red light (FRL) was obtained using a KS-19 light filter installed between the sample and the light source.

Determination of the functional activity of the photosynthetic apparatus of assimilating tissues of melon was carried out by the method of chlorophyll fluorescence induction (ICF). The ICF of leaves of control (uninfected) and infected plants was measured on days 5, 10, 15, and 20 after infection with the causative agent of Fusarium wilt using a portable fluorimeter (Akhmedzhanov et al., 2013): light source is LED, 450–470 nm, receiver is P-I-N photodiode; recording time of fluorescence kinetics up to 10 min with a resolution of 0.01 s. In this case, the following ratio of parameters of the induction curve of leaf fluorescence was used: (Fm – Ft)/Ft. The degree of reduction in the intensity of chlorophyll fluorescence, characterizing the integral activity of the photosynthetic apparatus, where Fm is the maximum value of fluorescence induction, Ft is the stationary value of fluorescence after light adaptation of the plant leaf (Lichtenthaler, 1992; Korneev, 2002; Posudin et al., 2010; Romanov et al., 2010). The fluorescence spectra of the leaves were measured on a LIDAR setup (Agishev et al., 2002), the main element base of which is a helium-neon laser emitter, the exciting light wavelength is 632 nm, the radiation power is 100 mW, and the light beam diameter is 1 cm – telescope of the Newton system with a working mirror diameter of 110 mm. Spectral selection of

0 1 2 3

Fig. 1. The degree of damage to melon plants of the cv. Kichkintoy by *Fusarium oxysporum* f. sp. *melonis* in accordance with the severity scale of the disease 0–3 (0 means no symptoms, 1 – small damage on the leaves, 2 – severely affected leaves, 3 – death of the plant).

the signal was carried out using the diffraction grating of the MUM monochromator. The laser operation mode, the scanning of the monochromator over the spectrum, and the output of the results to the display are programmatically set. The intensity ratio I_{690}/I_{730} of the LICF spectra were used as parameters characterizing changes in the fluorescence spectra. LICF measurements were carried out on the 3–4 leaves of the middle tier in 6–10 plants. The results were processed by methods of mathematical statistics according to Dospekhov (1985).

RESULTS

A characteristic feature of the phytochrome system is the direct opposite effect of RL and FRL on photopigment activity: during direct photoconversion, RL leads to the formation of the active P_{fr} form of phytochrome, while FRL, on the contrary, returns it to the inactive P_r form as a result of reverse photoconversion (Volotovsky, 1992; Rockwell et al., 2006; Sineshchekov 2013; Wu et al., 2019). In accordance with this, in order to establish the existence of photochrome control of physiological processes in plants, the method of photobiological testing is used, which consists in fixing the responses of plants to irradiation of RL and FRL, as well as their alternating action. With a combination effect, the latter type of exposure determines the nature of the physiological response (Butler et al., 1959; Kuznetsov et al., 1986; Volotovsky, 1992).

Infection of melon with *Fusarium* most often manifests itself after the formation of the first true leaves, which leads to the appearance of special signs of wilt disease of plant leaves. The leaves of sick melons lose turgor, lighten, become covered with gray spots and fade quickly. Fig. 1 shows the distribution of leaves into 4 groups in accordance with the degree of damage to melon plants of the cv. Kichkintoy by phytopathogen.

The results of studies of the effect of pre-sowing treatment of seeds with light in the red region of the spectrum (RL, FRL, RL + FRL, FRL + RL) on melon resistance to Fusarium wilt, which was evaluated by the method of Matsumoto et al. (2012) according to the characteristic symptoms of the disease at 21 days post inoculation (dpi) are presented in the Table 1.

The data obtained showed a relatively low degree of resistance of melon plants to pathogen infection (var. No. 3), which is expressed in a high percentage of plants with symptoms of wilt damage: with minor leaf damage (group 1–17% of plants), with severely affected leaves (group 2–19% of plants) and death of plants (group 3–11% of plants). Irradiation of seeds with RL before sowing (var. no 4) has an almost complete protective effect against infection, while the percentage of

Table 1. The effect of artificial infection with the *Fusarium oxysporum* f. sp. *melonis* on the distribution (in %) of melon plants of the cv. Kichkintoy in accordance with the severity scale of the disease as a result of various options for pre-sowing seed treatment with light in the red region of the spectrum

Option no	Option	Scale of severity of the disease			
		0	1	2	3
1	Control	99	1	–	–
2	RL	100	–	–	–
3	Infection	53	17	19	11
4	RL + Infection	94	5	1	–
5	FRL + Infection	45	18	21	16
6	RL + FRL + Infection	47	13	32	8
7	FRL + RL + Infection	98	1	1	–

Note. 1–7 – experience options: 1 – control (uninfected plants); 2 – seeds treated with RL, plants not infected; 3 – infected plants; 4 – seeds treated with RL, plants infected; 5 – seeds treated with FRL, plants infected; 6 – seeds treated with RL + FRL, plants infected; 7 – seeds treated with FRL + RL, plants infected.

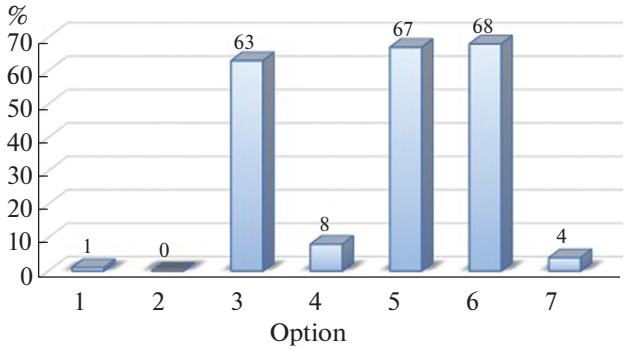

Fig. 2. The effect of pre-sowing treatment of seeds with red, far red light or their combined effect on the number of infected with the causative agent of Fusarium wilt melon plants of the cv. Kichkintoy with a characteristic change in the color of the vascular system, in % of their total number. 1–7 – experience options: 1 – control (uninfected plants); 2 – seeds treated with RL, plants not infected; 3 – seeds not treated with RL, plants infected; 4 – seeds treated with RL, plants infected; 5 – seeds treated with FRL, plants infected; 6 – seeds treated with RL + FRL, plants infected; 7 – seeds treated with FRL + RL, plants infected.

plants belonging to group 1 decreases by more than 3 times, and group 2 accounts for only 1 percent of all plants used in the experiment.

A completely different picture is observed in variant no 5 with pre-sowing treatment of seeds with FRL, where a significant, compared with the control variant, drop in the percentage of plants in group 0 and their increase in the 3-lethal group is recorded. This indicates a directly opposite effect of RL and FRL on the wilt resistance of melon plants. This is supported by the data on the distribution of plants by disease severity groups in variant no 6 with seed treatment with FRL after RL irradiation, which is very close to the variants with infection of plants without seed irradiation (no 3) and with their pre-treatment with FRL (no 5). In addition, photostimulation of seeds by RL cancels the inhibitory effect of FRL (var. no 7), which leads to almost complete resistance of plants to infection. The obtained data testify to the stimulating effect of RL on melon wilt resistance. On the contrary, FRL lowers the effectiveness of the defense system, compared to plants obtained from seeds untreated with light. Thus, the directly-opposite effects of pre-treatment of seeds with RL and FRL and the cancellation of the effects of one type of irradiation by another indicates the participation of phytochrome in the regulation of melon resistance to Fusarium wilt.

Another diagnostic symptom of Fusarium wilt in plants of the *Cucurbitaceae* family is a discoloration of the vascular system, which can be easily observed on a longitudinal or transverse section of roots or stems (Egel, Martyn, 2007). In this regard, the presence of a change in the color of the xylem at 21 dpi was investigated, depending on the pre-sowing treatment of seeds with RL, FRL, or their combined effect. The results of these experiments are presented in Fig. 2.

The data obtained showed that infection of plants (var. no 3) leads to a change in the color of the xylem, which acquires a brown-withered hue in 63% of plants. Photo stimulation of seeds by RL before sowing has a protective effect against infection, which is expressed in a sharp 8-fold decrease in the number of plants with a changed color of the vascular system. On the contrary, FRL, both by itself (var. no 5) and after RL (var. no 6), has an inhibitory effect on the protective reactions of infected plants against wilt, the number of which with signs of damage increases markedly. Whereas the treatment of seeds with RL after FRL (var. no 7) cancels its inhibitory effect on the ability of infected plants to resist infection. At the same time, the minimum number of plants is fixed, on the sections of which a brown-brown color of the xylem is detected. Thus, the presented data indicate directly opposite effects of RL and FRL on the ability of melon plants to resist the causative agent of Fusarium wilt. Cancellation of the action of red light by far red and, conversely, far red by red light, allows us to state that the melon system protective against *Fusarium* infection is controlled by the phytochrome system. At the same time, these data indicate the possibility of regulation of melon resistance to the pathogen by pre-sowing stimulation of seeds with RL.

To confirm this assumption, we studied the effect of pre-sowing seed treatment with RL on the functional state of the photosynthetic apparatus (PSA) of melon plants under the influence of Fusarium wilt. The expediency of these studies is determined by the fact that the activity of PSA is a reliable indicator of the physiological state of plants, both under normal growing conditions and under the influence of adverse environmental factors (Voronkov et al., 1976; Pikulenko, Bulychev, 2007; Kreslavsky, 2010; Akinshina et al., 2016). An effective way to study the activity of the photosynthetic apparatus of plants is the method of induction of chlorophyll fluorescence (ICF) (Kshirsagar et al., 2001; Mandal et al., 2009; Ptushenko et al., 2014; Babar et al., 2018), since chlorophyll, located in photosynthetic membranes, serves as a kind of natural sensor of the state of algal and higher plant cells under changing environmental conditions (Veselovsky, Veselova, 1990; Korneev, 2002). Fig. 3 shows the results of a comparative assessment of the effect of photostimulation of seeds with RL on the parameters of the kinetic curves of ICF of the leaves of melon plants infected with the causative agent of Fusarium wilt. To evaluate and compare kinetic curves, we used the value (Fm – Ft)/Fm, where Fm is the amplitude of the ICF maximum, Ft is the amplitude of the stationary level.

An analysis of the induction curves showed that the value of the ratio (Fm – Ft)/Fm for the kinetics at a wavelength of 690 nm sharply decreases by the 10th day after infection and, starting from the 15th day after infection, becomes more than 2 times lower compared to

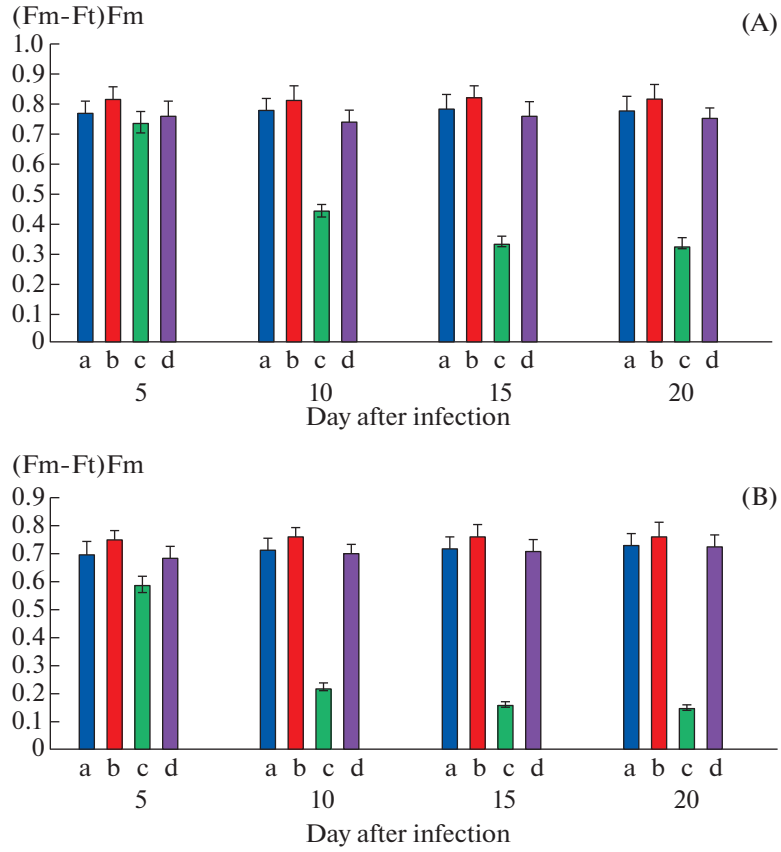

Fig. 3. Change in the characteristics of the induction curves of chlorophyll fluorescence (Fm – Ft)/Fm depending on the period of infection of melon plants of the cv. Kichkintoy by the causative agent of Fusarium wilt. A – at a wavelength of 690 nm, B – at a wavelength of 730 nm: a – control (plants were not infected); b – seeds were irradiated with RL before sowing; c – seeds were not irradiated with RL before sowing, plants were infected with a pathogen; d – seeds were irradiated with RL before sowing, plants were infected with a pathogen. The confidence interval of the mean values was at least 95% ($P \leq 0.05$).

the control (Fig. 3, a). The same ratio for the kinetics at a wavelength of 730 nm already at the first stages of plant damage decreases by 20%, and on days 10, 15 and 20, the decrease in the value of the parameter (Fm – Ft)/Fm reaches 69, 77 and 80%, respectively (Fig. 3, b). The photoconversion of phytochrome into the active Pfr form in seeds as a result of their pre-sowing treatment with RL has a protective effect against the negative influence of infection on the PSA activity of plants affected by wilt. So, in this case, the decrease in the ratio of the measured parameter of the FSA does not exceed 5 percent for both the IFC kinetics at 730 nm and the kinetics at 690 nm.

The revealed changes in the parameters of the kinetic curves of the ICF of the leaves of plants affected by the pathogen may be associated with a violation of the interaction of two pigment photosystems (PSI and PSII) and energy migration between them. Violations of this kind should be reflected in the characteristics of the ICF spectra of the leaves of healthy and diseased plants. In this regard, to confirm the above results, indicating the protective effect of RL on the photosynthetic activity of leaves, we studied the spectral characteristics of the ICF of infected plants grown from photostimulated and non-irradiated seeds.

Changes in the fluorescence spectra were controlled with respect to the intensity ratio I_{690}/I_{730}. The results averaged for each group of plants (Fig. 4) show that during the entire period of measurement of fluorescence spectra (from 5 to 20 days after infection), the value of the ratio I_{690}/I_{730} for control (uninfected) plants remained approximately at the same level, varies slightly within the measurement error. At the same time, already at the 5 dpi of melon seedlings, the ratio I_{690}/I_{730} increases by 42%, at the 10 dpi this trend will continue and at the 15–20 dpi the increase in the value of the measured ICF parameter reaches a 3-fold value relative to the control. Pre-sowing treatment of seeds with RL almost completely prevents the negative impact of the infection on the value of parameter I_{690}/I_{730} throughout the entire period of measurement of ICF spectra. At the same time, the greatest difference in the value of the measured fluorescence spectra of the leaves of control (uninfected) and pathogen-infected plants grown from seeds photostimulated by RL does not exceed 4–5%.

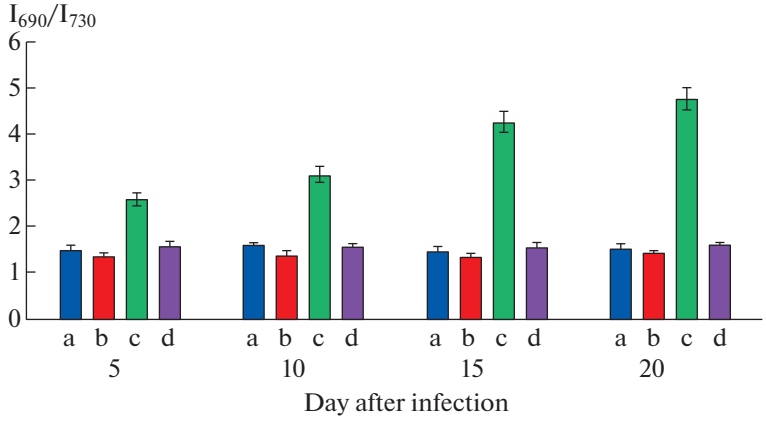

Fig. 4. Changes in the spectral characteristics of laser-induced chlorophyll fluorescence (I_{690}/I_{730}) depending on the period of infection of melon plants of the cv. Kichkintoy by the causative agent of Fusarium wilt: a – control (plants were not infected); b – seeds were irradiated with RL before sowing; c – seeds were not irradiated with RL before sowing, plants were infected with a pathogen; d – seeds were irradiated with RL before sowing, plants were infected with a pathogen. The confidence interval of the mean values was at least 95% ($P \leq 0.05$).

An increase in the fluorescence intensity at 690 nm can be associated with damage to the electron transport chain (ETC) between PS I and PS II by the fungal metabolites embedded in membranes, which leads to the waste of the energy of excited molecules for luminescence. Thus, the retention of the I_{690}/I_{730} ratio in the fluorescence spectra of the leaves of infected plants as a result of RL irradiation of seed indicates its protective effect, which prevents the disruption of ETC PSA activity due to the negative influence of phytopathogen metabolites.

Comparison of the experimental data on the effect of RL on the degree of infection of melon, which was controlled by the characteristic symptoms of the disease of artificially infected plants, and the IFC parameters showed the presence of certain dependencies between them. Thus, the calculation of the Pearson correlation coefficient (rp) between the change in the total number of plants affected by causative agent of Fusarium wilt and the value of the parameter (Fm – Ft) / Fm of the ICF of their leaves as a result of pre-sowing seed treatment with RL allowed us to establish the value rp = 0.87 with an average error of the correlation coefficient mr = 0.072. Thus, a high positive correlation was revealed between the compared indicators of resistance of the melon cv. Kichkintoy to the causative agent of Fusarium wilt: photostimulation of seeds almost completely prevents the manifestation of various symptoms of Fusarium wilt in plants and a decrease in the values of the ICF parameters of leaves, reflecting the activity of FSA.

DISCUSSION

The results of our studies, which testify to the specific protective action of RL against Fusarium wilt, are consistent with the data of a number of authors on the role of the phytochrome system in the regulation of plant resistance to pathogens (Horemans et al., 1984; Koreneva, 1996; Mavlonova, 2012). Evidence of the specificity of the effects of RL is the opposite direction of action of RL and FRL on the number and degree of damage to melon plants of the cv. Kichkintoy by the pathogen: in contrast to the pre-treatment of seeds with RL, which activates the phytochrome system, seed treatment with FRL, leading to the reverse photoconversion of phytochrome from active P_{fr} to inactive P_r-form, did not affect the resistance of infected plants compared to the control. It is known that the P_{fr}-form of phytochrome is a factor that induces the activity of a number of genes responsible for various physiological processes and plant resistance to adverse environmental factors (Quail, 2006). This fact may indicate that the irradiation of seeds with RL through a cascade of phytochrome-dependent reactions contributes to an increase in the integral resistance of melon to infection of plants with the fungus *F. oxysporum* f. sp. *melonis*, which was effectively recorded by the methods of phytopathological control and ICF.

Indeed, many researchers (Pavlovskaya et al., 1973; Rubin et al., 1974; Kshirsagar et al., 2001; Martinez-Ferri et al., 2016; Akinshina et al., 2016; Babar et al., 2018) note a significant decrease in the photosynthetic activity of plants when affected by phytopathogenic organisms, which may be associated with a decrease in the content of photosynthetic pigments, a violation of the outflow of photosynthesis products due to PSA damage. At the same time, disturbances in PSA activity are effectively recorded by the ICF method, the parameters of which vary depending on the degree of plant damage (Voronkov et al., 1976; Avazkhodzhaev et al., 1995; Kshirsagar et al., 2001; Pascual et al., 2010; Aleynikov, Mineev, 2019; Cristhian et al., 2019).

The results of various studies have shown that the disorganizing effect of the pathogenic fungus *F. oxyspo-*

rum in plants is manifested in the suppression of the synthesis of photosynthetic pigments and the functional activity of PSII of chloroplast membranes as well as in a change in the nature of the redistribution of absorbed light energy, which leads to a decrease in the intensity of photochemical conversion (qP) and an increase in non-photochemical quenching (qN) of chlorophyll fluorescence (Kabashnikova, 2014; Abramchik et al., 2019; Cristhian et al., 2019). The change in the spectral-kinetic parameters of the fluorescence of leaves of pathogen-infected melon plants of the cv. Kichkintoy can also be explained by a sharp decrease in the effective quantum yield of photochemical energy conversion in the reaction centers of PS II and an increase in heat dissipation. Pre-sowing treatment of seeds with RL promotes the formation of adaptive properties of the photosynthetic apparatus in infected leaves of the melon cv. Kichkintoy, which prevents the inhibition of PS II reaction centers and the development of non-radiative energy losses. Taking into account the results of the correlation analysis given above, the data of the fluorescent analysis of the functional state of PSA indicate the protective role of RL in the resistance of melon to infection with the phytopathogenic fungus *F. oxysporum* f. sp. *melonis*.

Thus, the results of the studies made it possible to establish the regulatory role of the phytochrome system in the control of the resistance of melon plants of the cv. Kichkintoy to the causative agent of Fusarium wilt, the fungus *F. oxysporum* f. sp. *melonis*. At the same time, it was shown that an effective way to increase the resistance of the melon cv. Kichkintoy to the negative impact of the phytopathogen is pre-sowing seed treatment with biologically active red light.

REFERENCES

Abramchik L.M., Domanskaya I.N., Makarov V.N. et al. Effect of immunity inducers on the structural and functional state of the photosynthetic apparatus and the oxidative status of cucumber plants (*Cucumis sativus* L.) infected with *Fusarium oxysporum*. Trudy Nastionalnoy Akademii nauk Respubliki Belarus. Seriya Biologicheskie nauki. 2019. V. 64 (2). P. 43–47 (in Russ.).

Agishev V.S., Khusainov I.A., Zinoviev A.V. et al. Investigation of the spectral and temporal characteristics of the luminescence of higher plants upon excitation by laser radiation with various energy and time parameters. Uzbekskiy Biologicheskiy Zhurnal. 2002. N 5–6. P. 80–83 (in Russ.).

Akhmedzhanov I.G. The regulation of phytoalexins biosynthesis in infected by *Verticillium* wilt pathogen cotton tissues. Fiziologia rasteniy i genetika. 2014. V. 46 (6). P. 535–540 (in Russ.).

Akhmedzhanov I.G., Agishev V.S., Dzholdasova K.B. et al. The use of a portable fluorimeter to study the effect of water deficit on the characteristics of delayed fluorescence of cotton leaves. Doklady Akademii nauk Uzbekistana. 2013. № 3. P. 58–60 (in Russ.).

Akhmedzhanov I.G., Gussakovsky E.E., Tashmukhamedov B.A. et al. A method for increasing the resistance of cotton to damage by the causative agent of Verticillium wilt. Author. certificate no 1782387 State Committee for Inventions of the USSR, 1992 (in Russ.).

Akinshina N.G., Rashidova D.K., Azizov A.A. Seed encapsulation in chitosan and its derivatives restores levels of chlorophyll and photosynthesis in wilt-affected cotton (*Gossypium* L., 1753) plants. Selskokhozyaistvennaya biologiya. 2016. V. 51 (5). P. 696–704 (in Russ.). https://doi.org/10.115389/agrobiology.2016.5.696eng

Alekseeva K.L., Smetanina L.G. Biological protection of tomato from Fusarium wilt. Glavniy Agronom. 2019. № 11. P. 62–65 (in Russ.).

Aleynikov A.F., Mineev V.V. Effect of the fungus of *Ramularia tulasnei* Sacc. on chlorophyll fluorescence in garden strawberry. Sibirskiy vestnik selskokhozyaistvennoy nauki. 2019. 49 (2). P. 94–102 (in Russ.).

Alvarez J.M. Morphological and molecular characterization of melon accessions resistant to Fusarium wilts. Euphytica. 2009. V. 169. P. 69–79.

Avazkhodjaev M.Kh., Zeltzer S.S., Nuritdinova H. et al. Phytoalexins as a factor in Wilt Resistance of Cotton. In: Handbook of phytoalexin metabolism and action. N.Y. etc., 1995, pp. 129–160.

Babar M.A., Saleem M., Hina A. et al. Chlorophyll as biomarker for early disease diagnosis. Laser Physics. 2018. V. 28 (6). P. 158–163.

Banihashem Z., DeZeeuw D.J. The behavior of *Fusarium oxysporum* f. sp. *melonis* in the presence and absence of host plants. Phytopathology. 1975. V. 65. P. 1212–1217.

Baysal O., Calskan M. An inhibitory effect of a new Bacillus subtilis strain (EU07) against *Fusarium oxysporum* f. sp. *radicis-lycopersici*. Physiological and Molecular Plant Pathology. 2008. V. 73 (1/3). P. 25–32.

Butler W.L., Norris K.H., Siegelman H.W. et al. Detection, assay, and preliminary purification of the pigment controlling photoresponsive development of plants. Proc. Natl. Acad. Sci. USA. 1959. V. 45. P. 1703–1708.

Casal J.J., Sanchez R.A. Phytochromes and seed germination. Seed Science Research. 1998. V.8. P. 317–329.

Chen M., Chory J. Phytochrome signaling mechanisms and the control of plant development. Trends Cell Biol. 2011. V. 21. P. 664–671. https://doi.org/10.1016/j.tcb.2011.07.002

Cristhian C.C.A., Sandra G.C., Herman R.D. Physiological, biochemical and chlorophyll fluorescence parameters of *Physalis peruviana* L. seedlings exposed to different short-term waterlogging periods and Fusarium wilt infection. Agronomy. 2019. V. 9 (5). P. 213–219.

Dospekhov B.A. Field experiment technique (with the basics of statistical processing of research results). Agropromizdat, Moscow, 1985 (in Russ.).

Egel D.S., Martyn R.D. Fusarium wilt of watermelon and other cucurbits. Plant Health Instruct., 2007. https://doi.org/10.1094/PHI-I-2007-0122-01

Elena K., Pappas A.C. Race distribution, vegetative compatibility and pathogenicity of *Fusarium oxysporum* f. sp. *melonis* isolates in Greece. J. Phytopathol. 2006. V. 154. P. 250–255.

Galvao V. C., Fankhauser C. Sensing the light environment in plants: photoreceptors and early signaling steps. Curr. Opin. Neurobiol. 2015. V. 34. P. 46–53.

Gordon T.R., Okamoto D., Jacobson D.J. Colonization of muskmelon and nonsusceptible crops by *Fusarium oxysporum* f. sp. *melonis* and other species of *Fusarium*. Phytopathology. 1989. V. 79. P. 1095–1100.

Horemans S., Van Oncelen H.A., Greef J.A. Phytochrome control mechanisms in leaf expansion of *Phaseolus vulgaris* cv Limburg. Plant, Cell and Environ. 1984. V. 7 (5). P. 309–315.

Jahanshir A., Dzhalilov F. The effects of fungicides on *Fusarium oxysporum* f. sp. *lycopersici* associated with Fusarium wilt of tomato. J. Plant Prot. Res. 2010. V. 50 (2). P. 172–178.

Kabashnikova L.F. Photosynthetic apparatus and stress in plants. Nauka, Minska, 2014 (in Russ.).

Koreneva I.V. The influence of electromagnetic radiation on the development and non-specific stability of different genotypes of agricultural crops. Thesis ... Cand. Agric. Kharkov, 1996 (in Russ.).

Korneev D.Yu. Information possibilities of the method of inducing fluorescence of chlorophyll. Alterpres, Kiev, 2002 (in Russ.).

Kreslavski V.D., Carpentier R., Klimov V.V. et al. Transduction mechanism of photoreceptor signals in plant cells. J. Photoch. Photobiol. C. Photochem. Reviews. 2009. V. 10. P. 63–80 (in Russ.).

Kreslavsky V.D. Regulation of stress-resistance of the photosynthetic apparatus by inductors of various nature. Diss. ... Doct. Biol. Moscow, 2010 (in Russ.).

Kshirsagar A., Reid A.J., McColl S.M. et al. The effect of fungal metabolites on leaves as detected by chlorophyll fluorescence. New Phytol. 2001. V. 151 (2). P. 451–457.

Kurt S., Baran B., Sari N. et al. Physiologic races of *Fusarium oxysporum* f. sp. *melonis* in the southeastern Anatolia Region of turkey and varietal reactions to races of the pathogen. Phytoparasitica. 2002. V. 30. P. 395–402.

Kuznetsov E.D., Sechnyak L.K., Kindruk N.A. et al. The role of phytochrome in plants. Agropromizdat, Moscow, 1986 (in Russ.).

Legris M., Çaka Y., Fankhauser C. Molecular mechanisms underlying phytochrome-controlled morphogenesis in plants. Nature Communications. 2019. V. 10. https://doi.org/10.1038/s41467-019-13045-0

Lichtenthaler H.K. The Kautsky effect: 60 years of chlorophyll fluorescence induction kinetics. Photosynthetica. 1992. V. 27 (1–2). P. 45–55.

Maksimov I.V., Veselova S.V., Nuzhnaya T.V. et al. Plant growth-stimulating bacteria in the regulation of plant resistance to stress factors. Physiologia rasteniy. 2015. V. 62 (6). P. 763–775 (in Russ.).

Mandal K., Saravanan R., Maiti S. et al. Effect of downy mildew disease on photosynthesis and chlorophyll fluorescence in *Plantago ovata* Forsk. J. Plant Dis. Prot. 2009. V. 116. (4). P. 164–168.

Martinez-Ferri E., Zumaquero A., Ariza M.T. et al. Nondestructive detection of white root rot disease in avocado root-stocks by leaf chlorophyll fluorescence. Plant Dis. 2016. V. 100. P. 49–58. https://doi.org/10.1094/PDIS-01-15-0062-RE

Martyn R.D. Fusarium wilt of watermelon: 120 years of research. Horticultural Reviews. 2014. V. 42. P. 349–441.

Mathews S. Phytochrome-mediated development in land plants: red light sensing evolves to meet the challenges of changing light environments. Mol. Ecol. 2006. V. 15. P. 3483–3503. https://doi.org/10.1111/j.1365-294X.2006.03051.x

Matsumoto Y. Evaluation of *Cucumis ficifolius* A. Rich. Accessions for Resistance to Fusarium wilt. Amer. J. Experimental Agriculture. 2012. № 2 (3). P. 470–476.

Matsumoto Y., Ogawara T., Miyagi M. et al. Response of wild *Cucumis* species to inoculation with *Fusarium oxysporum* f. sp. *melonis* race 1,2 y. J. Japan. Soc. Hort. Sci. 2011. V. 80. P. 414–419.

Mavlanova S.A. Physiological and biochemical features of the induced resistance of cotton to sucking insect pests and the causative agent of verticillous wilt. Diss. ... Cand. Agric. Tashkent, 2012 (in Russ.).

Miller N.F., Standish J.R., Quesada-Ocampo L.M. Sensitivity of *Fusarium oxysporum* f. sp. *niveum* to prothioconazole and pydiflumetofen in vitro and efficacy for Fusarium wilt management in watermelon. Plant Health Progress. 2020. V. 21. P. 13–18. https://doi.org/10.1094/PHP-08-19-0056-RS

Namiki F., Shiomi T., Nishi K. et al. Pathogenic and genetic variation in the Japanese strains of *Fusarium oxysporum* f. sp. *melonis*. Phytopathology. 1998. V. 88. P. 804–810.

Novikova I.I. Biological rationale for the creation and use of polyfunctional biological products based on antagonist microbes for phytosanitary optimization of agroecosystems. Diss. ... Dr. Biol. St. Petersburg, 2005 (in Russ.).

Okungbowa F.I., Shittu H.O. Fusarium wilts: an overview. Environmental Research Journal. 2012. V. 6 (2). P. 83–101.

Pan R.S., More T.A. Screening of melon (*Cucumis melo* L.) germplasm for multiple disease resistance. Euphytica. 1996. V. 88. P. 125–128.

Pascual I., Azcona I., Morales F. et al. Photosynthetic response of pepper plants to wilt induced by *Verticillium dahliae* and soil water deficit. J. Plant Physiol. 2010. V. 167 (9). P. 701–708.

Pavlovskaya N.E., Tukhtaeva G.M., Khoyaev A.S. On the quantitative change in pigments and photochemical activity of cotton chloroplasts under the influence of the fungus *Verticillium dahlia*. Uzbekskiy Biologicheskiy Zhurnal. 1973. № 2. P. 26–28 (in Russ.).

Petkar A., Ping S.J. Infection courts in watermelon plants leading to seed infestation by Fusarium oxysporum f. sp. niveum. Phytopathology. 2017. V. 107 (7). P. 828–833. https://doi.org/10.1094/PHYTO-12-16-0429-R

Pham V.N., Kathare P.K., Huq E. Phytochromes and phytochrome interacting factors. Plant Physiol. 2018. V. 176. P.1025–1038. https://doi.org/10.1104/pp.17.01384

Pikulenko M.M., Bulychev A.A. Using the parameters of fluorescence and the generation of electric potentials in the membranes of plant cells to assess the state of biological objects. Byulleten Moscovskogo obshestva ispitateley prirody. Seriya Biologiya. 2007. V. 112 (1). P. 80–84 (in Russ.).

Posudin Yu.I., Godlevska O.O., Zaloilo I.A. et al. Application of portable fluorometer for estimation of plant tolerance to abiotic factors. Int. Agrophysics. 2010. V. 24 (4). P. 363–368 (in Russ.).

Ptushenko V.V., Ptushenko O.S., Tikhonov A.N. Induction of chlorophyll fluorescence, chlorophyll content and leaf

color characteristics as indicators of the aging of the photosynthetic apparatus in woody plants. Biokhimiya. 2014. V. 79 (3). P. 260–272 (in Russ.).

Quail P.H. Phytochrome signal transduction network photomorphogenesis in plants and bacteria, 3rd edition. Springer, Dordrecht, 2006. P. 335–356.

Quail P.H. Phytochome-interacting factors. In: *G.C. Whitelam and K.J. Halliday* (eds). Light and plant development. Blackwell Publishing Ltd, Oxford, 2007, pp. 81–105.

Rao V.G., Dhutraj D.N., Navgire K.D. et al. Efficacy of *Trichoderma* fortified organic amendments on Fusarium wilt suppression, growth and yield of eggplant. Asian J. Advances in Agricultural Research. 2021. P. 1–16.

Registeri R., Taghavi S.M., Banihashemi Z. Effect of root colonizing bacteria on plant growth and Fusarium wilt in *Cucumis melo*. J. Agricultural Science and Technology. 2012. V. 14 (5). P. 1121–1131.

Rockwell N.C., Su Y.S., Lagarias J.C. Phytochrome structure and signaling mechanisms. Ann. Rev. Plant Biol. 2006. V. 57. P. 837–858.

Romanov V.A., Galeluka I.B., Sakharan E.V. Portable fluorimeter and features of its application. Sensornaya elektronica i mikroscopicheskiye technologii. 2010. V. 1 (7). P. 146–152 (in Russ.).

Rubin B.A., Voronkov L.A., Perova I.A. et al. Changes in the pigment composition of cotton leaves with *Verticillium* wilt disease. Biologicheskie Nauki. 1974. № 9. P. 57–63 (in Russ.).

Sineshchekov V.A. Phytochrome A: polymorphism and multifunctionality. Moscow, 2013 (in Russ.).

Szurmant H., White R.A., Hoch J.A. Sensor complexes regulating two-component signal transduction. Curr. Opin. Struct Biol. 2007. V. 17. P. 706–715.

Trionfetti-Nisini P., Colla G., Granati E. et al. Rootstock resistance to Fusarium wilt and effect on fruit yield and quality of two muskmelon cultivars. Sci. Hortic. 2002. V. 93. P. 281–288.

Veselovsky V.A., Veselova T.V. Luminescence of plants. Theoretical and practical aspects. Moscow, 1990 (in Russ.).

Voronkov L.A., Perova I.A., Shvyreva V.V. The effect of *Verticillium* wilt infection on the structure and functions of the photosynthetic apparatus of cotton. In: Pathological physiology and plant immunity. Moscow, 1976, pp. 172–188 (in Russ.).

Wu G., Zhao I., Sen R. et al. Characterization of maize phytochrome-interacting factors in light signaling and photomorphogenesis. Plant Physiol. 2019. V. 181. P. 789–803. https://doi.org/10.1104/pp.19.00239

Zuniga T.L., Zitter T.A., Gordon T.R. et al. Characterization of pathogenic races of *Fusarium oxysporum* f. sp. *melonis* causing Fusarium wilt of melon in New York. Plant Dis. 1997. V. 81. P. 592–596.

Абрамчик Л.М., Доманская И.Н., Макаров В.Н. и др. (Abramchik et al.). Влияние индукторов иммунитета на структурно-функциональное состояние фотосинтетического аппарата и окислительный статус растений огурца (Cucumis sativus l), инфицированных Fusarium oxysporum // Известия НАН Беларуси. Сер. биол. наук. 2019. Т. 64. № 2.

Агишев В.С., Хусаинов И.А., Зиновьев А.В. и др. (Agishev et al.). Исследование спектральных и временных характеристик люминесценции высших растений при возбуждении лазерным излучением с различными энергетическими и временными параметрами // Узб. биол. журн. 2002. № 5–6. С. 80–83.

Акиншина Н.Г., Рашидова Д.К., Азизов А.А. (Akinshina et al.). Капсулирование семян препаратами хитозана и его производных восстанавливает фотосинтез у растений хлопчатника (Gossypium L., 1753) на фоне вилта // Сельскохозяйственная биология. 2016. Т. 51. № 5. С. 696–704.

Алейников А.Ф., Минеев В.В. (Aleynikov, Mineev). Изменение флуоресценции хлорофилла земляники садовой при воздействии гриба Ramularia tulasnei Sacc. // Сибирский вестник сельскохозяйственной науки. 2019. Т. 49. № 2. С. 94–102.

Алексеева К.Л., Сметанина Л.Г. (Alekseeva, Smetanina). Биологическая защита томата от фузариозного увядания // Главный агроном. 2019. № 11. С. 62–65.

Ахмеджанов И.Г. (Akhmedzhanov). Регуляция биосинтеза фитоалексинов в инфицированных возбудителем вертициллезного вилта тканях хлопчатника // Физиология растений и генетика (Киев). 2014. Т. 46. № 6. С. 535–540.

Ахмеджанов И.Г., Гуссаковский Е.Е., Ташмухамедов Б.А. и др. (Akhmedzhanov et al.). Способ повышения устойчивости хлопчатника к поражению возбудителем вертициллезного вилта // Автор. свид. № 1782387 Госкомизобретений СССР. 22.10.92 (заявка № 4897312).

Ахмеджанов И.Г., Агишев В.С., Джолдасова К.Б. и др. (Akhmedzhanov et al.). Применение портативного флуориметра для исследования влияния водного дефицита на характеристики замедленной флуоресценции листьев хлопчатника // ДАН РУз. 2013. № 3. С. 58–60.

Веселовский В.А., Веселова Т.В. (Veselovsky, Veselova). Люминесценция растений. Теоретические и практические аспекты. М.: Наука, 1990. 176 с.

Воронков Л.А., Перова И.А., Швырева В.В. (Voronkov et al.). Влияние заражения вертициллезным вилтом на структуру и функции фотосинтетического аппарата хлопчатника // Патологическая физиология и иммунитет растений. МГУ, 1976. С. 172–188.

Доспехов Б.А. (Dospekhov). Методика полевого опыта (с основами статистической обработки результатов исследований). М.: Агропромиздат, 1985. 351 с.

Кабашникова Л. Ф. (Kabashnikova). Фотосинтетический аппарат и стресс у растений. Минск: Беларус. навука, 2014. 267 с.

Коренева И.В. (Koreneva). Влияние электромагнитного излучения на развитие и неспецифическую устойчивость разных генотипов сельскохозяйственных культур. Автореф. дисс. ... канд. с.-х. наук. Харьков, 1996. 26 с.

Корнеев Д.Ю. (Korneev). Информационные возможности метода индукции флуоресценции хлорофилла. Киев: Альтерпрес, 2002. 188 с.

Креславский В.Д. (Kreslavsky) Регуляция стресс-устойчивости фотосинтетического аппарата индукторами различной природы. Автореф. дисс. ... докт. биол. наук. М., 2010. 40 с.

Кузнецов Е.Д., Сечняк Л.К., Киндрук Н.А. и др. (Kuznetsov et al.). Роль фитохрома в растениях. М.: Агропромиздат, 1986. 288 с.

Мавланова С.А. (Mavlanova). Физиолого-биохимические особенности индуцированной устойчивости хлопчатника к сосущим насекомым-вредителям и возбудителю вертициллезного вилта. Дисс. ... канд. биол. наук. Ташкент, 2012. 132 с.

Максимов И.В., Веселова С.В., Нужная Т.В. и др. (Maksimov et al.). Стимулирующие рост растений бактерии в регуляции устойчивости растений к стрессовым факторам // Физиология растений. 2015. Т. 62. № 6. С. 763–775.

Новикова И.И. (Novikova). Биологическое обоснование создания и применения полифункциональных биопрепаратов на основе микробов-антагонистов для фитосанитарной оптимизации агроэкосистем. Дисс. ... докт. биол. наук. СПб., 2005. 755 с.

Павловская Н.Е., Тухтаева Г.М., Ходжаев А.С. (Pavlovskaya, Tukhtaeva, Khojaev). О количественном изменении пигментов и фотохимической активности хлоропластов хлопчатника под влиянием гриба V. Dahliae // Узб. биол. журн. (Ташкент). 1973. № 2. С. 26–28.

Пикуленко М.М., Булычев А.А. (Pikulenko, Bulychev). Использование параметров флуоресценции и генерации электрических потенциалов в мембранах растительных клеток для оценки состояния биологических объектов // Бюлл. Моск. о-ва испыт. природы. Отд. биол. 2007. Т. 112. № 1. С. 80–84.

Птушенко В.В., Птушенко О.С., Тихонов А.Н. (Ptushenko et al.). Индукция флуоресценции хлорофилла, содержание хлорофилла и характеристики цветности листьев как показатели старения фотосинтетического аппарата у древесных растений // Биохимия (Москва). 2014. Т. 79. № 3. С. 260–272.

Рубин Б.А., Воронков Л.А., Перова И.А. и др. (Rubin et al.). Изменение пигментного состава листьев хлопчатника при заболевании вертициллезным вилтом // Биологические науки. 1974. № 9. С. 57–63.

Синещеков В.А. (Sineshchekov). Фитохром А: полиморфизм и многофункциональность. М.: Научный мир, 2013. 162 с.

Фитохром-зависимая регуляция устойчивости дыни к поражению фузариозным вилтом

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Исследовано влияние предпосевной обработки семян светом красной области спектра на устойчивость растений дыни (*Cucumis melo*) сорта Кичкинтой к поражению фузариозным вилтом, вызываемому фитопатогенным грибом *Fusarium oxysporum* f. sp. *melonis*. Выявлена разнонаправленность эффектов красного и дальнего красного света на степень поражения растений патогеном, которую определяли по характерным симптомам болезни на листьях и стеблях растений. При чередовании обработки семян красным и дальним красным светом конечный эффект определялся тем видом облучения, который действовал последним. Результаты фотобиологического тестирования позволили установить участие фитохромной системы в контроле устойчивости растений дыни сорта Кичкинтой к фузариозному вилту. Показано наличие высокой положительной корреляции между параметрами индукции флуоресценции хлорофилла листьев, отражающих функциональную активность фотосинтетического аппарата, и степенью поражения растений, выращенных из необлученных и облученных красным светом семян. Результаты проведенных исследований устанавливают возможность эффективной регуляции устойчивости дыни сорта Кичкинтой к поражению грибом *F. oxysporum* f. sp. *melonis* посредством фотоактивации фитохромной системы семян перед посевом.

Ключевые слова: красный свет, устойчивость к патогену, флуоресценция хлорофилла, фотосинтез, *Cucumis melo*, *Fusarium oxysporum* f. sp. *melonis*