ЭЛЕКТРОТЕХНОЛОГИИ, ЭЛЕКТРООБОРУДОВАНИЕ И ЭНЕРГОСНАБЖЕНИЕ АГРОПРОМЫШЛЕННОГО КОМПЛЕКСА / ELECTROTECHNOLOGY, ELECTRICAL EQUIPMENT AND POWER SUPPLY OF THE AGRO-INDUSTRIAL COMPLEX

DOI: https://doi.org/10.60797/JAE.2024.51.20

STUDY OF THE EFFECT OF ULTRAVIOLET RADIATION OF THE UV-B AND UV-C RANGE ON THE SOWING QUALITIES OF WHEAT SEEDS «ZERNOGRADKA-9»

Research article

Belenov V.N.[1,] *, Gracheva N.N.[2], Ponomareva N.Y.[3], Rudenko N.B.[4], Kosteletskii Y.S.[5]
[4] ORCID : 0000-0001-5468-3626;
[1, 2, 3, 4, 5] Azov-Black Sea Engineering Institute — branch of the Don State Agrarian University, Zernograd, Russian Federation

* Corresponding author (vetal_belenov[at]mail.ru)

Abstract

Pre-sowing seed treatment contributes to increasing the productivity of crops. One of the effective physical methods of pre-sowing treatment is the treatment of seeds with ultraviolet radiation, which, depending on the selected range of parameters, can have both a stimulating effect and a bactericidal effect.

The article presents the results of a study of the effect of the dose of exposure and the wavelength of ultraviolet radiation of the UV-B and UV-C ranges on the length of sprouts, germination energy and germination of seeds of winter wheat "Zernogradka-9". Regression equations reflecting the relationship between the parameters characterizing the sowing qualities of seeds and the wavelength and dose of exposure to ultraviolet radiation were obtained.

Ultraviolet radiation from region B at a wavelength of 313 nm has been found to have a stimulating effect on seeds in the dose range of 24–120 W·s/m2. Sprout length, germination energy and germination were higher than in the control. Radiation from the UV-C region during seed germination is a deterrent.

Keywords: ultraviolet radiation, stimulating effect, bactericidal effect, sowing qualities of seeds.

ИССЛЕДОВАНИЕ ВЛИЯНИЯ УЛЬТРАФИОЛЕТОВОГО ИЗЛУЧЕНИЯ УФ-В И УФ-С ДИАПАЗОНА НА ПОСЕВНЫЕ КАЧЕСТВА СЕМЯН ПШЕНИЦЫ «ЗЕРНОГРАДКА-9»

Научная статья

Беленов В.Н.[1,] *, Грачева Н.Н.[2], Пономарева Н.Е.[3], Руденко Н.Б.[4], Костелецкий Е.С.[5]
[4] ORCID : 0000-0001-5468-3626;
[1, 2, 3, 4, 5] Азово-Черноморский инженерный институт — филиал Донского государственного аграрного университета, Зерноград, Российская Федерация

* Корреспондирующий автор (vetal_belenov[at]mail.ru)

Аннотация

Повышению продуктивности сельскохозяйственных культур способствует предпосевная обработка семян. Одним из эффективных физических методов предпосевной обработки является обработка семян ультрафиолетовым излучением, которое в зависимости от выбранного диапазона параметров может оказать как стимулирующий эффект, так и бактерицидное действие.

В статье приведены результаты исследования влияния дозы воздействия и длины волны ульрафиолетового излучения УФ-В и УФ-С диапазонов на длину ростков, энергию прорастания и всхожесть семян озимой пшеницы «Зерноградка-9». Были получены уравнения регрессии, отражающие взаимосвязь между параметрами, характеризующими посевные качества семян, и длиной волны и дозой воздействия ультрафиолетового излучения.

Было установлено, что ультрафиолетовое излучение области В при длине волны 313 нм оказывает стимулирующий эффект на семена в диапазоне доз воздействия 24–120 Вт·с/м^2. Длина ростков, энергия прорастания и всхожесть были выше, чем в контроле. Излучение области УФ-С на этапе прорастания семян является сдерживающим фактором.

Ключевые слова: ультрафиолетовое излучение, стимулирующий эффект, бактерицидное действие, посевные качества семян.

Introduction

Crop production, as one of the branches of agricultural production, is faced with the task of increasing the number of products. The solution of this problem is facilitated by the use of modern technologies at different stages of growing plants, harvesting, storage, and preparation of seed material.

One of the important stages in this technological cycle is the preparation of seed material before sowing. The goals of this stage are to treat the seeds against pathogens and pests, and to improve the sowing qualities of the seeds.

At present, a many of methods of influencing seeds are known. All these methods can be divided into chemical, biological and physical according to the principles of influence. Chemical methods of pre-sowing seed treatment are widely used in agricultural production. These methods are associated with the use of mordants and growth stimulants. Chemical treatment methods are highly efficient, but their use often requires compliance with increased requirements due to their danger to personnel and the environment. Biological methods are based on the use of microorganisms, phytohormones and vitamins.

Physical methods are associated with the use of electric and magnetic fields, air ions, ultrasound, radiation of various natures, including radiation related to the optical region.

The effectiveness of treating crop seeds with electromagnetic radiation in this area has been proven by numerous studies [1], [3], [5], [6].

The influence of optical radiation (especially ultraviolet radiation) on plant seeds is explained by biophysical processes occurring in seeds due to radiation energy. The stimulating effect of ultraviolet radiation is associated with the structural and functional restructuring of membrane formations and intracellular organelles. As a result, the level of lipid oxidation, pH, ATP activity changes, which leads to an increase in bioenergetics and biosynthetics processes [7, P. 5], increases the energy potential of seeds, mobilizes their hidden resources, which are used to enhance the growth and development of plants [8, P. 32]. Small doses of UV radiation, provoking free radical processes, can change the rate of synthetic processes in the grain, accelerate the biosynthesis of enzymes in the initial period of swelling [9, P. 13].

Increasing crop yields can be achieved not only by stimulating seeds, but also by having a bactericidal effect on pathogens and pests. Ultraviolet (UV) radiation has a destructive and lethal effect on bacterial viruses (phages), single-celled organisms (microbes and protozoa) and fungi. As a rule, the spectra of action of the lethal effect have a pronounced nucleic maximum at 260... 265 nm [7, P. 6]. With the appropriate selection of parameters and regimes of influence, a significant decrease in the number of microbial cells on the surface of seeds is noted. A number of studies have found a 17-20-fold reduction in microbiological contamination compared to the control [9, P. 64], and even up to 99% [10].

But bactericidal radiation not only ensures the effective destruction of phytopathogens, but can also be a deterrent to seed germination and lead to a decrease in seed germination. The addition in yields in this case can be explained by a lowering in losses due to diseases.

Despite numerous studies aimed at studying the effect of parameters and regimes of influence to ultraviolet radiation on the sowing qualities of agricultural seeds, the specifics of the impact of ultraviolet radiation areas on biological objects, the difference in the properties of seeds make work in this direction relevant.

The purpose of the study is to determine the parameters and modes of exposure to ultraviolet radiation of the UV-B and UV-C ranges on the sowing qualities of winter wheat seeds "Zernogradka-9".

Research methods and principles

A laboratory experiment was carried out to study the effect of the parameters and modes of ultraviolet radiation of the UV-B and UV-C ranges on the length of sprouts, sprouting energy and germinating ability of winter wheat seeds "Zernogradka-9". Seed treatment was carried out at the LOS-2 installation. With the help of replaceable filters, radiation with wavelength of 248, 280, 302 and 313 nm were singled out. During processing, the following dose values were maintained – 24; 48; 72; 96; 120 W·s/m2. The indicated dose values were achieved by changing the current of the lamp and the degree of opening of the diaphragm at a constant duration of processing equal to 60 seconds. The magnitude of irradiation was monitored using a UV radiometer of the TKA-ABC model.

The experiment and processing of the results were carried out on the basis of the educational, scientific and production agrotechnological laboratory of the institute in accordance with the methodology set forth in GOST 12038-84 [12].

Statistical processing of experimental data was carried out using the Statistica program.

Main results

The results of the research are shown in Table 1. In the course of the regression analysis, the types of functional dependencies and the values of the coefficients of the regression equations were determined, the significance of the coefficients of the regression equations was assessed according to the Student's criterion and the regression models were evaluated for adequacy.

The results of the regression analysis of the dependence of sprout length on dose and wavelength are shown in Table 2. The main influence on the length of sprouts is exerted by the wavelength of ultraviolet radiation. Since the coefficients of the equation related to the dose of exposure were insignificant, the analysis was performed with refined coefficients (see Table 3 and Figure 1).

Table 1 - Results of studies of the influence of UV radiation on the length of sprouts, sprouting energy and germinating ability of wheat "Zernogradka-9"

DOI: https://doi.org/10.60797/JAE.2024.51.20.1

Dose of exposure, W·s/m^2	Wavelength, nm	Length of the sprouts, mm	Sprouting energy, %	Germinating ability, %
24	248	76,45	41,00	69,00
24	280	61,87	43,50	70,30
24	302	76,90	54,00	75,75
24	313	88,47	69,00	84,75
48	248	68,07	43,00	70,00
48	280	50,5	43,50	72,60
48	302	83,02	60,50	76,75
48	313	91,74	71,75	85,50
72	248	75,50	63,10	82,30

72	280	75,10	68,50	83,00
72	302	85,90	78,00	86,50
72	313	92,00	85,00	91,30
96	248	77,17	59,25	75,00
96	280	61,78	61,25	77,00
96	302	86,78	61,25	82,30
96	313	92,80	77,00	84,50
120	248	75,00	57,75	75,00
120	280	65,70	60,25	75,25
120	302	70,61	60,00	78,00
120	313	93,47	76,75	83,00

Table 2 - Results of the analysis of the DR=f(ES, L) relationship
DOI: https://doi.org/10.60797/JAE.2024.51.20.2

Regression Summary for Dependent Variable: DR (data.sta)

MULTIPLE REGRESS. R= ,89765111 RI= ,80577752 Adjusted RI= ,75398486
F(4,15)=15,558 p<,00003 Std.Error of estimate: 5,9381

N=20	BETA	St. Err. of BETA	B	St. Err. of B	t(15)	p-level
Intercpt			1412,716	233,6634	6,04595	,000022
ES	,7572	,588133	,260	,2022	1,28739	,217469
L	-21,1902	3,576050	-9,961	1,6810	-5,92559	,000028
V1**2	-,6872	,588133	-,002	,0014	-1,16841	,260876
V2**2	21,7509	3,576050	,018	,0030	6,08239	,000021

Table 3 - Results of the analysis of the relationship DR=f(ES, L) with refined coefficients of the regression equation
DOI: https://doi.org/10.60797/JAE.2024.51.20.3

Regression Summary for Dependent Variable: DR (data.sta)

MULTIPLE REGRESS. R= ,88386578 RI= ,78121872 Adjusted RI= ,75547975
F(2,17)=30,352 p<,00000 Std.Error of estimate: 5,9200

N=20	BETA	St. Err. of BETA	B	St. Err. of B	t(17)	p-level
Intercpt			1421,260	232,8697	6,10324	,000012
V2**2	21,7509	3,565168	,018	,0030	6,10096	,000012
L	-21,1902	3,565168	-9,961	1,6759	-5,94367	,000016

A regression equation reflecting the relationship between the length of sprouts and the wavelength is obtained

$$DR = 1421,26 - 9,961 \cdot L + 0,018 \cdot L^2, \quad (1)$$

where DR – is the length of the sprouts, mm;

L – is the wavelength, nm.

For the convenience of analyzing the obtained dependence, a contour graph of the response function DR=f(ES,L) was also built using the regression equation (1).

The average sprout length of 65.7 mm obtained in the control is achieved after treating wheat seeds with radiation with a wavelength of more than 310 nm.

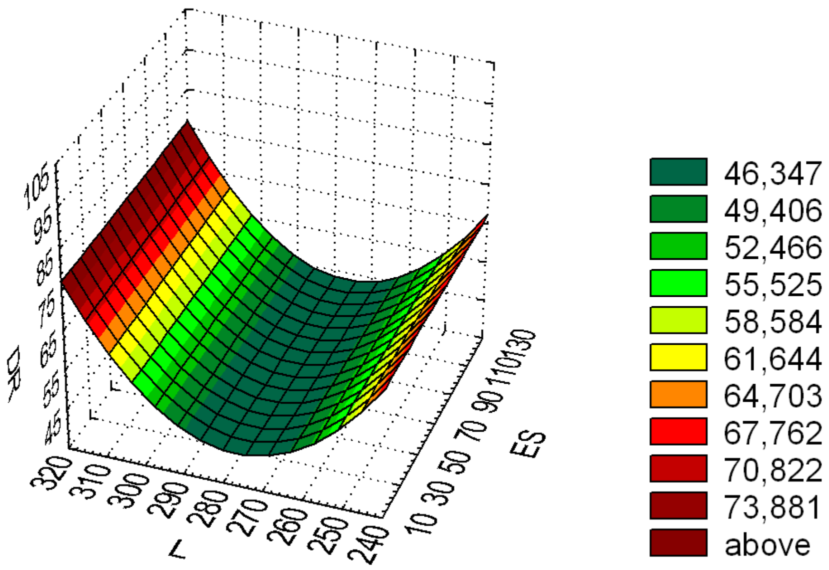

Figure 1 - Surface of the dependent variable DR=f(ES, L) constructed on the regression equation (1)
DOI: https://doi.org/10.60797/JAE.2024.51.20.4

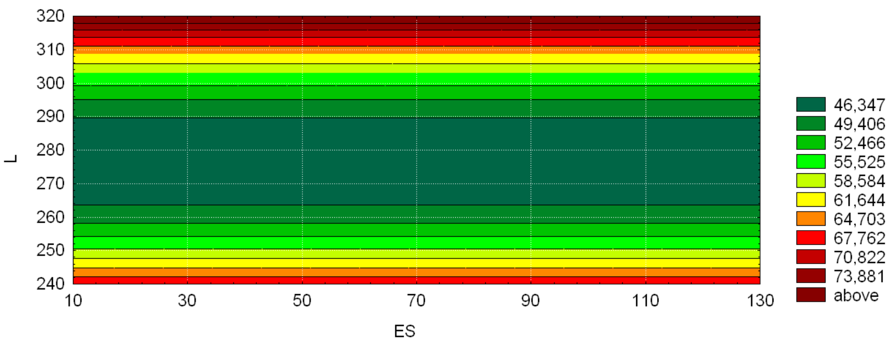

Figure 2 - Contour graph of the dependent variable DR=f(ES, L) constructed on the regression equation (1)
DOI: https://doi.org/10.60797/JAE.2024.51.20.5

Similarly, a regression analysis of the dependence of sprouting energy on dose of exposure and wavelength was performed (see Table 4 and Figures 3, 4).

Table 3 - Results of EP=f(ES, L) dependence analysis
DOI: https://doi.org/10.60797/JAE.2024.51.20.6

Regression Summary for Dependent Variable: EP (data.sta)

MULTIPLE REGRESS. R= ,88753196 RI= ,78771297 Adjusted RI= ,73110310
F(4,15)=13,915 p<,00006 Std.Error of estimate: 6,5160

N=20	BETA	St. Err. of BETA	B	St. Err. of B	t(15)	p-level
Intercpt			656,9508	256,4049	2,56216	,021669
ES	2,14752	,614876	,7749	,2219	3,49260	,003273
L	-9,77953	3,738656	-4,8252	1,8446	-2,61579	,019477
V1**2	-1,79314	,614876	-,0044	,0015	-2,91625	,010638
V2**2	10,42248	3,738656	,0092	,0033	2,78776	,013796

The regression equation has the form

$$EP = 656,9508 + 0,7749 \cdot ES - 4,8252 \cdot L - 0,0044 \cdot ES2 + 0,0092 \cdot L^2, \qquad (2)$$

where EP – is sprouting energy, %;
ES – is the dose of exposure, W·s/m^2.

Results of the effect dose of exposure and wavelength on sprouting energy are not so single. At exposure doses of 73–95 W·s/m^2, sprouting energy values were obtained higher than 57.7% in the control even in the UV-C region.

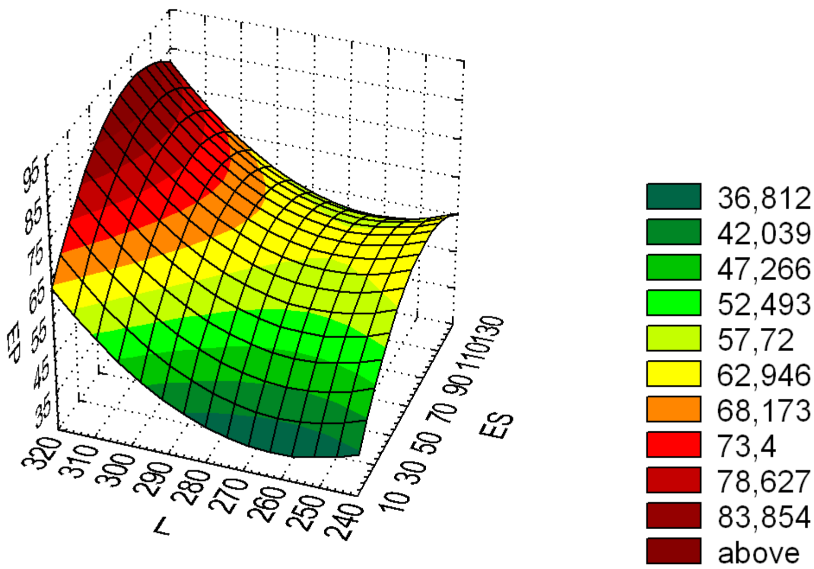

Figure 3 - Surface of the dependent variable EP=f(ES, L) constructed on the regression equation (2)
DOI: https://doi.org/10.60797/JAE.2024.51.20.7

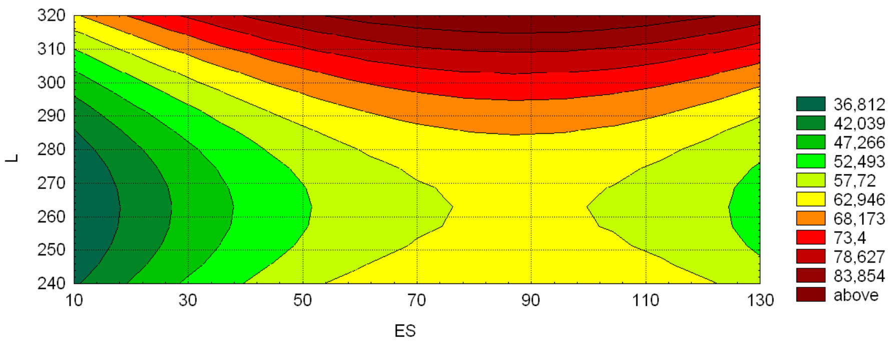

Figure 4 - Contour graph of the dependent variable EP=f(ES, L), constructed on the regression equation (2)
DOI: https://doi.org/10.60797/JAE.2024.51.20.8

The results of the regression analysis of the dependence of germinating ability on the dose of exposure and wavelength are shown in Table 5 and in Figures 5 and 6.

Table 3 - Results of VS=f(ES, L) dependence analysis
DOI: https://doi.org/10.60797/JAE.2024.51.20.9

Regression Summary for Dependent Variable: VS (data.sta)

MULTIPLE REGRESS. R= ,88181091 RI= ,77759048 Adjusted RI= ,71828128
F(4,15)=13,111 p<,00009 Std.Error of estimate: 3,2922

N=20	BETA	St. Err. of BETA	B	St. Err. of B	t(15)	p-level
Intercpt			360,8540	129,5475	2,78550	,013859
ES	2,41482	,629365	,4301	,1121	3,83692	,001617
L	-9,45475	3,826753	-2,3027	,9320	-2,47070	,025963
V1**2	-2,24168	,629365	-,0027	,0008	-3,56180	,002840
V2**2	10,12267	3,826753	,0044	,0017	2,64524	,018365

The dependence of germinating ability on the dose of exposure and the wavelength is described by the equation

$$VS = 360,854 + 0,4301 \cdot ES - 2,3027 \cdot L - 0,0027 \cdot ES^2 + 0,0044 \cdot L^2, \quad (3)$$

where VS – germinating ability, %.

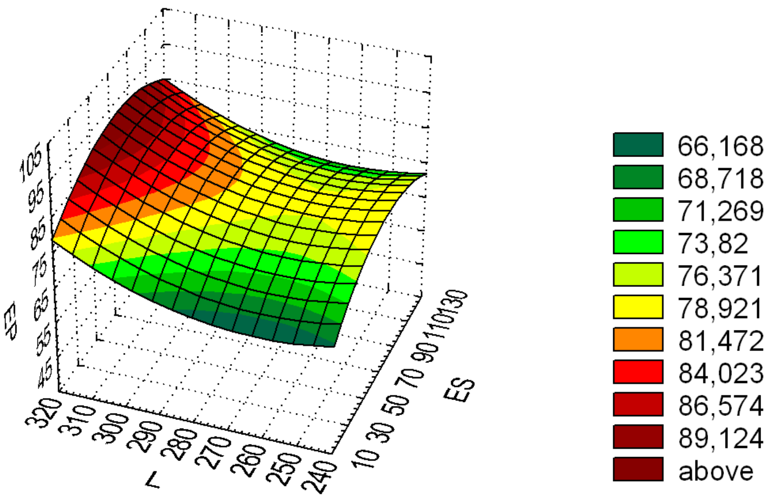

Figure 5 - Surface of the dependent variable VS=f(ES, L) constructed on the regression equation (3)
DOI: https://doi.org/10.60797/JAE.2024.51.20.10

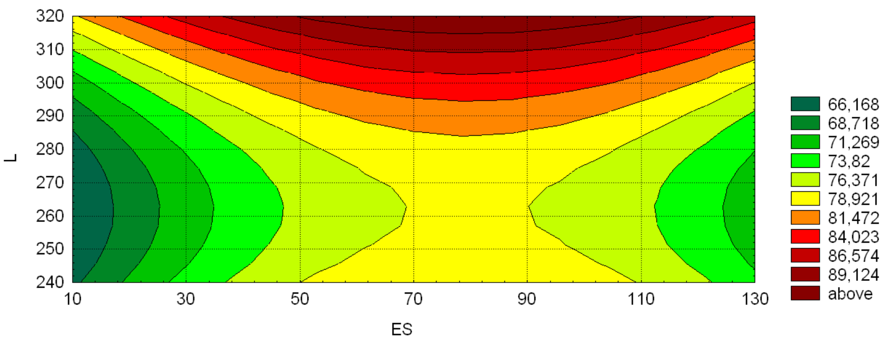

Figure 6 - Contour graph of the dependent variable VS=f(ES, L) constructed on the regression equation (3)
DOI: https://doi.org/10.60797/JAE.2024.51.20.11

The analysis of the dependence of germinating ability on the dose of exposure and wavelength also indicates that ultraviolet radiation of the UV-C region in the dose range of 59–90 W·s/m^2 has a positive effect on the germinating ability of Zernogradka-9 wheat seeds. The germinating ability rate of seeds exceeds the 77.75% obtained in the control.

The obtained regression equations adequately describe the relationship between the parameters characterizing the sowing qualities of seeds (sprout length, sprouting energy and germinating ability) and the parameters characterizing ultraviolet radiation (exposure dose and wavelength). The obtained values of the Fisher criterion based on the results of regression analysis are higher than the theoretical values of the criterion. Changes in sprout length, sprouting energy and germinating ability by more than 77% are explained by changes in the dose of exposure and wavelength.

Conclusion

Ultraviolet radiation of the UV-B region has a stimulating effect on the seeds of wheat "Zernogradka-9". The greatest effect in this spectral range is achieved at a wavelength of 313 nm. The increase in germination compared to the control is more than 13%. The stimulating effect of radiation in the UV-C region is insignificant (about 1%), it is achieved in the dose range of 59–90 W·s/m2. Basically, the radiation of the UV-C region is a deterrent to germinating ability of the seed. A positive effect in the form of increased yields can be achieved by reducing losses due to diseases.

Конфликт интересов

Не указан.

Рецензия

Шкиндеров М.С., Казанский национальный исследовательский технический университет им. А.Н. Туполева – КАИ, Казань, Российская Федерация
DOI: https://doi.org/10.60797/JAE.2024.51.20.12

Conflict of Interest

None declared.

Review

Shkinderov M.S., Kazan National Research Technical University named after A.N. Tupolev – KAI, Kazan, Russian Federation
DOI: https://doi.org/10.60797/JAE.2024.51.20.12

Список литературы / References

1. Газалов В.С. Оптическая система предпосевной обработки семян / В.С. Газалов, Н.Е. Пономарева, В.Н. Беленов // Вестник аграрной науки Дона. — 2018. — № 3 (43). — С. 21–30.
2. Кондратьева Н.П. Предпосевная обработка семян декоративных растений хвойных пород ультрафиолетовым излучением / Н.П. Кондратьева, Д.А. Корепанов, М.Г. Краснолуцкая [и др.] // Инновации в сельском хозяйстве. — 2017. — № 2 (23). — С. 45–54.
3. Кондратьева Н.П. Сквозные цифровые технологии для реализации энергоэффективных методов обработки семян / Н.П. Кондратьева, Р.З. Ахатов, Р.Г. Большин [и др.] // Агропромышленный комплекс в условиях современной реальности : Сборник трудов международной научно-практической конференции, Тюмень, 01 марта 2023 года. — Тюмень: Государственный аграрный университет Северного Зауралья, 2023. — С. 369–377.
4. Пономарева Н.Е. Влияние дозы ультрафиолетового излучения на посевные качества семян ячменя / Н.Е. Пономарева, Н.Н. Грачева, В.Н. Беленов [и др.] // Сельский механизатор. — 2023. — № 9. — С. 32–33.
5. Гордеев Ю.А. Биоактивация семян культурных растений ультрафиолетовыми и плазменными излучениями / Ю.А. Гордеев, Р.З. Юлдашев // Известия Санкт-Петербургского государственного аграрного университета. — 2011. — № 24. — С. 343–348.
6. Страхов В.Ю. Исследования по влиянию режимов УФ-обработки на всхожесть семян сои / В.Ю. Страхов, А.Н. Мануйленко, Д.А. Лукинов [и др.] // Научное обозрение. Технические науки. — 2024. — № 1. — С. 44–50.
7. Беляков М.В. Оптико-электронная технология и средства управления биологической активностью семян: автореф. дис. ... канд. техн. наук / Беляков Михаил Владимирович. — Москва, 2008. — 18 с.
8. Тертышная Ю.В. Воздействие ультрафиолетового излучения на всхожесть и ростовые процессы семян пшеницы / Ю.В. Тертышная, Н.С. Левина, О.В. Елизарова // Сельскохозяйственные машины и технологии. — 2017. — № 2. — С. 31–36.
9. Рогожин Ю.В. Технология предпосевного УФ-облучения зерен пшеницы / Ю.В. Рогожин, В.В. Рогожин // Вестник Алтайского государственного аграрного университета. — 2013. — № 6 (104). — С. 9–14.
10. Страхов В.Ю. Результаты исследований по применению ультрафиолетового излучения для поверхностного обеззараживания семян от патогенной микрофлоры / В.Ю. Страхов, С.В. Вендин // Инновации в АПК: проблемы и перспективы. — 2022. — № 4 (36). — С. 64–68.
11. Vendin S. Results of studies on the application of UV radiation for disinfecting the surface of soybean seeds from pathogenic microflora / S. Vendin, V. Strakhov, A. Manuilenko // BIO Web of Conferences : International Scientific and Practical Conference “VAVILOV READINGS-2023” (VVRD 2023). — EDP Sciences, 2023. — Vol. 67 — P. 02027.
12. ГОСТ 12038—84. Семена сельскохозяйственных культур. Метод определения всхожести (с изменениями №1,2). — URL: http://docs.cntd.ru/document/gost-12038-84 (дата обращения: 26.10.2024).

Список литературы на английском языке / References in English

1. Gazalov V.S. Opticheskaja sistema predposevnoj obrabotki semjan [Optical system of pre-sowing seed treatment] / V.S. Gazalov, N.E. Ponomareva, V.N. Belenov // Vestnik agrarnoj nauki Dona [Bulletin of Agrarian Science of the Don]. — 2018. — № 3 (43). — P. 21–30. [in Russian]
2. Kondrat'eva N.P. Predposevnaja obrabotka semjan dekorativnyh rastenij hvojnyh porod ul'trafioletovym izlucheniem [Pre-sowing treatment of seeds of ornamental coniferous plants with ultraviolet radiation] / N.P. Kondrat'eva, D.A. Korepanov, M.G. Krasnoluckaja [et al.] // Innovacii v sel'skom hozjajstve [Innovations in Agriculture]. — 2017. — № 2 (23). — P. 45–54. [in Russian]
3. Kondrat'eva N.P. Skvoznye cifrovye tehnologii dlja realizacii jenergojeffektivnyh metodov obrabotki semjan [End-to-end digital technologies for energy-efficient seed treatment] / N.P. Kondrat'eva, R.Z. Ahatov, R.G. Bol'shin [et al.] // Agropromyshlennyj kompleks v uslovijah sovremennoj real'nosti [Agro-industrial complex in the conditions of modern

reality] : Proceedings of the International Scientific and Practical conference, Tyumen, March 01, 2023. — Tyumen: State Agrarian University of the Northern Urals, 2023. — P. 369–377. [in Russian]

4. Ponomareva N.E. Vlijanie dozy ul'trafioletovogo izluchenija na posevnye kachestva semjan jachmenja [Influence of ultraviolet radiation dose on sowing qualities of barley seeds] / N.E. Ponomareva, N.N. Gracheva, V.N. Belenov [et al.] // Sel'skij mehanizator [Rural Machine Operator]. — 2023. — № 9. — P. 32–33. [in Russian]

5. Gordeev Ju.A. Bioaktivacija semjan kul'turnyh rastenij ul'trafioletovymi i plazmennymi izluchenijami [Bioactivation of seeds of cultivated plants by ultraviolet and plasma radiation] / Ju.A. Gordeev, R.Z. Juldashev // Izvestija Sankt-Peterburgskogo gosudarstvennogo agrarnogo universiteta [News of St. Petersburg State Agrarian University]. — 2011. — № 24. — P. 343–348. [in Russian]

6. Strahov V.Ju. Issledovanija po vlijaniju rezhimov UF-obrabotki na vshozhest' semjan soi [Studies on the effect of UV treatment regimes on the germination of soybean seeds] / V.Ju. Strahov, A.N. Manujlenko, D.A. Lukinov [et al.] // Nauchnoe obozrenie. Tehnicheskie nauki [Scientific Review. Technical Sciences]. — 2024. — № 1. — P. 44–50. [in Russian]

7. Beljakov M.V. Optiko-jelektronnaja tehnologija i sredstva upravlenija biologicheskoj aktivnost'ju semjan [Optoelectronic technology and means of management of biological activity of seeds]: abstract dis. ... of PhD in Technical Sciences / Beljakov Mihail Vladimirovich. — Moscow, 2008. — 18 p. [in Russian]

8. Tertyshnaja Ju.V. Vozdejstvie ul'trafioletovogo izluchenija na vshozhest' i rostovye processy semjan pshenicy [Effect of ultraviolet radiation on germination and growth processes of wheat] / Ju.V. Tertyshnaja, N.S. Levina, O.V. Elizarova // Sel'skohozjajstvennye mashiny i tehnologii [Agricultural Machines and Technologies]. — 2017. — № 2. — P. 31–36. [in Russian]

9. Rogozhin Ju.V. Tehnologija predposevnogo UF-obluchenija zeren pshenicy [Technology of pre-sowing UV irradiation of wheat grains] / Ju.V. Rogozhin, V.V. Rogozhin // Vestnik Altajskogo gosudarstvennogo agrarnogo universiteta [Bulletin of the Altai State Agrarian University]. — 2013. — № 6 (104). — P. 9–14. [in Russian]

10. Strahov V.Ju. Rezul'taty issledovanij po primeneniju ul'trafioletovogo izluchenija dlja poverhnostnogo obezzarazhivanija semjan ot patogennoj mikroflory [Results of research on the use of ultraviolet radiation for surface disinfection of seeds from pathogenic microflora] / V.Ju. Strahov, S.V. Vendin // Innovacii v APK: problemy i perspektivy [Innovations in the Agro-industrial Complex: Problems and Prospects]. — 2022. — № 4 (36). — P. 64–68. [in Russian]

11. Vendin S. Results of studies on the application of UV radiation for disinfecting the surface of soybean seeds from pathogenic microflora / S. Vendin, V. Strakhov, A. Manuilenko // BIO Web of Conferences : International Scientific and Practical Conference “VAVILOV READINGS-2023” (VVRD 2023). — EDP Sciences, 2023. — Vol. 67 — P. 02027.

12. GOST 12038—84. Semena sel'skohozjajstvennyh kul'tur. Metod opredelenija vshozhesti (s izmenenijami №1,2) [GOST 12038-84. Seeds of agricultural crops. Germination determination method (with changes No. 1,2)]. — URL: http://docs.cntd.ru/document/gost-12038-84 (accessed: 26.10.2024). [in Russian]