






Pre-sowing treatment of winter wheat and spring barley seeds with the extremely high frequencies electromagnetic field

V.V. Bezpal'ko ¹, S.V. Stankevych ^{2*}, L.V. Zhukova ², A.V. Matsyura ³, I.V. Zabrodina ²,
V.P. Turenko ², V.V. Horyainova ², A.A. Poedinceva ², O.Yu. Zayarna ²,
O.V. Lazarieva ⁴, M.H. Tsekhmeistruk ¹, O.V. Pankova ¹, S.A. Chygryna ¹,
Yu.Ye. Ogurtsov ⁵, I.I. Klymenko ⁵

¹Petro Vasylenko Kharkiv National Technical University of Agriculture, Kharkiv, 61002, Ukraine

²V.V. Dokuchaev Kharkiv National Agrarian University, v. Dokuchaevske, Kharkiv region, 62483, Ukraine

³Altai State University, Barnaul, Russian Federation

⁴Petro Mohyla Black Sea National University, 10 Marines St, Mykolaiv, Ukraine, 54000

⁵V.Ya. Yuryev Plant Production Institute, National Academy of Agrarian Science, Kharkiv, 61060, Ukraine

*Corresponding author E-mail: sergejstankevich1986@gmail.com

Received: 13.12.2020. Accepted 25.01.2021

The increase in the yield capacity of cereal spike crops under the current change of the climatic conditions in Ukraine will have a positive tendency in the nearest future. However, sustainable grain production under sharp weather fluctuations is possible only with the agro-technological systems' improvement. The pre-sowing seed treatment with chemical synthesis pesticides remains the primary method in the agricultural industry today. However, pesticides inevitably have a negative influence on the ecosystem of any level. A more environmentally friendly seed treatment method under the intensive technology is the combination of microwave seed irradiation and seed incrustation with the plant growth regulators that increase the cereal crops' yield capacity up to 15–20 %. It is possible to reduce the negative influence of chemical measures on the quality of the cereal crops seeds by using for the seed treatment a mixture of a treatment agent with the preparations having the stimulating properties. The most promising among all physical methods of the pre-sowing seed treatment is the microwave technology, which suppresses the entire complex of the seed infection and can become an alternative to the chemical method of plant protection. The universal character and practical importance of MW technologies combined with the growth-regulating substances consist not only in the increase in the yield capacity of the field crops but also in reducing the technogenic load on the environment. The peculiarity of EMF of EHF application in agricultural production is the necessity to consider the crops' specific electro-physical, technological, and biological properties. High heterogeneity greatly influences the electromagnetic action energy and the final result.

Keywords: disinfection, pathogens, seeds, grain, winter wheat, spring barley, microwaves.

Introduction

Increasing the crop yield capacity and improving product quality is among the most essential tasks for agricultural scientists in many countries worldwide. Cereal crops form the basis of agricultural production. They are the most valuable and most common in the world among all field crops. The cereals and legumes make up about 70% of the structure of food products. Grain production globally is increasing mainly due to the improvement of varietal resources and the modernization of zonal technologies for growing cereals, including wheat, barley, rye, and oats.

Wheat always has been and remains the leading grain crop in the world and Ukraine. The total area under this crop occupies about 240 million hectares globally and 7 million hectares in Ukraine. In 2017 the world wheat production amounted to about 750,1 million tons, and in Ukraine, it was 21 million tons. Naturally, wheat is a staple food product in 43 countries, with more than 1 billion people (Adamenko, 2008).

The total share of Ukraine in the world production of spring barley grain is about 8,2 % (Sajko et al., 1994; Sajko, 1997). Barley is an indispensable component for producing mixed feed and raw materials for the food and brewing industries.

In Ukraine, the stable grain production in the second half of the 1990s was characterized by an average annual bulk yield of 50–52 million tons, which is almost 1000 kg per capita (Sytnyk, 2002; Babich, Himich & Poberezhna, 1994). However, the sharp climatic changes (mostly in the form of temperature rise, a tendency that has been observed in the last two decades) have led to fluctuations in agrometeorological conditions for growing cereal crops. During the droughts of 2008–2009, the world wheat grain production decreased significantly. The drought in these years has affected the countries leading exporters of grain,

namely Australia, Argentina, Brazil, Canada, Eastern Europe, and Ukraine. As a result, the global demand for food grains has increased. During the last seven years, the food grain shortage has constituted 310 million tons annually (Sajko, 2008). Therefore, grain production has been and remains a priority in agricultural development.

The world experience shows that in countries with high agro-technical support, the increase in grain yield reaches a critical limit. The use of "intensive" technologies in agricultural crop production since the 1980s of the last century has sharpened the economy and the environment's contradictions. The intensive application of pesticides and mineral fertilizers in agriculture, including chemicals for the pre-sowing seed treatment, and increasing plants' productivity can cause several undesirable effects of ecological and economic characters.

One of the obligatory elements of the technological process of cultivating cereal crops, which affects crop production yield and quality, is the pre-sowing treatment of seeds with chemical and biological products of different origin. However, today in Ukraine, the problem of seed sanitation and selecting the most viable biotypes with high productive properties by the pre-sowing treatment with the ecologically friendly methods have not yet been solved.

The search for new alternative methods for seed disinfection to reduce the negative influence of agrochemicals on the environment has been recently carried out in Ukraine and abroad. The physical methods such as the treatment with ozone, microwave, ultrasonic radiation are of great interest (Tuchnyj et al., 2007; Shevchenko et al., 2007; Tuchnyj et al., 2012).

One of the most ecologically friendly and cost-effective pre-sowing seed treatment methods is irradiation with an extra-high frequency microwave field (MWF of EHF). Along with the physical method of seed treatment with the microwave field, the plant growth regulators and biological preparations which are used to increase the resistance of plants to the adverse factors and the yield capacity of many crops have become widespread in the agricultural practice (Anishin, 2002; Lyhochvor, 2003).

Material and methods

Two varieties of spring barley and one variety of soft winter wheat are the materials of the research. The characteristics of spring barley varieties are given below.

The *Aspect* variety. The originator is the Plant Production Institute named after V.Ya. Yuryev of NAAS. It has been listed in the State Register of Varieties since 2007 and recommended for cultivation in the Forest-Steppe and Polissia Regions (Katalog sortiv..., 2013). The spike is tow-rowed; it has a moderate wax coating; it is cylindrical, loose (11.7 short segments of spike rachis per 4 cm), and medium length. The straw is of a medium-length (51.4–89.0 cm) and concrete. The sterile spike occupies a position from parallel to slightly deflected. The floral glumes are fine-wrinkled, with a slight venation expression and gradual transition to the awn; the grain is elliptical, yellow, and filmy; the main bristle is long-fibred. The weight of 1000 grains is 46–52 g.

Biological characteristics. The variety is semi-late; the duration of vegetation is 79–97 days. The resistance to lodging is 8.2–9.0 points; the average drought resistance is 6.5–7.0 points. The variety is a source of the group resistance to the powdery mildew infection (7 points) and reticular helminthosporiosis (7 points). It is suitable for intensive cultivation technology. The grain yield capacity is up to 8.5–9.0 t/ha. The grain has good brewing qualities: the extraction is 81.1 %, the protein content is 9.0–10.0 %, and the uniformity of seeds is 98.8 % (Katalog sortiv..., 2013).

The *Vyklyk* variety. The originator is the Plant Production Institute named after V.Ya. Yuryev of NAAS. It has been listed in the State Register of Varieties since 2008 and recommended for cultivation in the Forest-Steppe and Polissia Regions (Katalog sortiv..., 2013). The spike is tow-rowed; it has a moderate wax coating; it is cylindrical, loose (12.2 short segments of spike rachis per 4 cm), and medium length. The sterile spike occupies a position from parallel to slightly deflected; the floral glumes are fine-wrinkled, with a slight expression of venation and gradual transition to the awn; the grain is elliptical, yellow, and filmy. The main bristle is long-fibred, the weight of 1000 grains is 46–52 g. The variety has a high productive tillering capacity of 2.0 stems. Biological characteristics. The variety is semi-early. The height of the plants is 68–76 cm. The awns are jagged. The growing season is 88–96 days. The resistance to lodging is very high (9.0 points). The drought resistance is high (9.0 points). The variety is resistant to the infection caused by the reticular helminthosporiosis pathogen (7 points). The grain yield capacity is up to 8.5–9.5 t/ha. The grain has good brewing qualities: the extraction is 81.1 %, the protein content is 10.0–10.9 %, and the uniformity of seeds is 98.0 %. The characteristics of the soft winter wheat variety are given below.

The *Astet* variety. The originator is the Plant Production Institute named after V.Ya. Yuryev of NAAS. It has been listed in the State Register of Varieties since 2005 and recommended for cultivation in the Forest-Steppe and Steppe Zones of Ukraine (Katalog sortiv , 2013). The stem has a medium wax coating on the upper internode. The spike has a slight spindle-shaped covering of 8–9 cm long; it is of a medium density. The awns are long (10 cm), jagged, and after the ear formation, they have the anthocyanin color. The grain is red, of a medium size, oval with a broad pubescent tuft. The anthers have the anthocyanin color. The weight of 1000 grains is 39–43 g.

Biological characteristics: the variety is mid-ripening; the ear formation and ripening take place in terms close to the standards; the variety has short stems (the plant height is 79–85 cm), it is resistant to lodging. The stem is thin, has an excellent tillering capacity, and can form 700 or more productive shoots per 1 m². The winter hardiness is relatively high (8.2–8.7 points). In the field conditions, it is tolerant to the primary harmful diseases. It is suitable for intensive cultivation technology.

The potential yield capacity is up to 9.5 t/ha. The grain, depending on the place and conditions of cultivation, contains 12.4–14.5% of protein and 25–29.9% of gluten; the strength of flour is 280–431 alveograph units, and the volume of bread is 660 cm³. Seed treatment agents. Vitavax 200 FF, manufactured by Crompton/Universal Chemical. It is a compound preparation, a factory mechanical mixture of two active fungicidal substances: carboxin, 200 g/L + thiram, 200 g/L. Vitavax 200 FF; is a contact and systemic fungicide of protective and therapeutic action. It is designed to destroy fungal pathogens on the surface and inside the seeds; it prevents the crop seedlings' infection on which it is applied. A wide range of fungicidal action characterizes the preparation. It inhibits the development of pathogens of all kinds of smut, root and stem rots, seed snow mold, anthracnose,

and some other phytopathogenic fungi. The preparation is included in the List of pesticides and agrochemicals authorized for use in Ukraine. The seeds of cereal crops were treated with the preparation at a consumption rate recommended by the producer, 2.5–3.0 L dissolved in 10 L of water per 1 ton of seeds. The reduced rates were also examined in the experimental cases. Electro-technological factor: Microwave field (MWF) of extra-high frequency (EHF).

Plant growth regulators: Mars EL contains Polyethylene oxide of 400 molecular weight (Emulsifier, Cryoprotectant) – 23.2 %; Polyethylene oxide of 1500 molecular weight (Coat-forming emulsifier) – 54.5 %; Endophyte L1 (Stimulant) – 5.0–10.0 %; Sodium humate – 1.2 %, and Potassium humate – 2.0 %.

The Radostim preparation. Its active ingredients are Emistim S 0.3 g/L, the potassium salt of alpha-naphthylacetic acid – 1.0 g/L, and microelements. It is used for the pre-sowing seed treatment (250 ml/t) and spraying plants (50 ml/ha) of cereals, legumes, industrial crops, and perennial legumes. It increases yield capacity. Its producer is the National Enterprise Interdepartmental Science and Technology Centre "Agrobiotech," Ukraine. The Albit preparation contains the purified active substance poly-beta-hydroxybutyric acid from the soil bacteria *Bacillus megaterium* and *Pseudomonas aureofaciens*. These bacteria live on plants' roots in natural conditions, stimulate their growth, protect against diseases and unfavorable environmental conditions. The preparation includes the substances that enhance the effect of the primary active substance; they are a balanced initial set of macro- and microelements (N, P, K, Mg, S, Fe, Mn, Mo, Cu, Co, B, I, Se, Na, Ni, and Zn) and the terpenic acids of the coniferous extract. Albit does not contain any living microorganisms (but only the active substances), making the preparation action more stable and less prone to environmental conditions.

The irradiation of winter wheat and spring barley seeds with the electromagnetic fields of extra high frequencies (MWF of EHF) was carried out by using the equipment of Kharkiv Technical University of Radio Electronics (Fig. 1).



Fig. 1. Equipment for seed irradiation with MWF of EHF developed by Kharkiv National Technical University of Radio Electronics, installation of a microwave design of the "UMVK-1" brand

Treatment with the microwave oscillation of extra high-frequency microwave field (MWF of EHF), which is widely used for many radio and household microwave devices, was carried out at the frequency range of 2.5–3.4 GHz at the power of 0.9–1.8 kW/kg during 5–95 sec. The pre-sowing treatment of seeds with the irradiation (MWF of EHF) was carried out both separately and with the subsequent application of the Vitavax 200 FF seed treatment agent (at a half consumption rate of 1.25 L/t) or the plant growth regulators Radostim (250 mL/t) and Albit (30 mL/t) for spring barley and growth regulator Mars EL (200 mL/t) for winter wheat.

The sowing qualities of the seeds before and after treatment were determined according to the current State Standards of Ukraine 4138–2002 (Nasinnya silskogospodarskih kultur..., 1994; Nasinnya silskogospodarskih kultur..., 2003). at the laboratory of Seed Production and Seed Science of the Plant Production Institute named after V.Ya. Yuryev. The samples of 100 seeds in quadruplicate recurrence for each treatment case were selected for this purpose. The germination was carried out in a thermostat at a temperature of +20°C on the moistened filter paper. The sprouting energy was calculated in 4 days, and the laboratory germinating power was calculated in 7 days.

Results

Sprouting energy and germinating power of winter wheat and spring barley seeds depending on the mode of treatment with the extra high frequencies microwave field

The high sprouting energy characterizes the ability of seeds to sprout quickly and all at once. The healthy seed, aligned with the physiological state, has this property. Fast and even germination of seeds indicates that seedlings will be strong and resistant to unfavorable environmental conditions during the sowing and germination (Izhik, 1976).

The main manifestations of the electromagnetic field influence on the seed as a biological object are:

- thermal effect (temperature increase);
- functional effect (rupture of hydrogen bonds and the emergence of starch hydration processes with the formation of the final biochemical components, namely glucose and fructose and other enzyme transformations, which in turn influences the stimulation and intensification of germination) (Manzhos, 1971; Dindorogo et al., 2009). The indicated effects are manifested simultaneously. However, it is possible to conclude the degree of the biological effect due to the pre-sowing irradiation of seeds with the extra high frequencies microwave field only by determining the seed quality indices, and first of all, the sprouting energy and germinating power.

In this regard, we have carried out the search experiments to determine the optimum modes for the irradiation of spring barley and winter wheat seeds with the extra high frequencies microwave field at the range of 2.5–3.4 GHz by the equipment of Kharkiv National University of Radio Electronics. The optimum seed irradiation mode does not lead to a decrease in the germinating power or causes its increase, but the effect of seed sanitation is preserved at the subsequent stages of the plant development. The seed samples weighing 200 g each were irradiated with the extra high frequencies microwave field. The irradiation at 0.9 or 1.8 kW per 1 kg of seeds at the variable exposure (duration of the irradiation) has been studied at the intervals of 5 sec – from 5 to 95 sec. We found out that, depending on the exposure, the seed temperature increased from 20 to 87 °C. The samples were sown seven days after the irradiation to determine the laboratory germination according to the State Standard of Ukraine 4138–2002 (Nasinnya silskogospodarskih kultur..., 1994; Nasinnya silskogospodarskih kultur..., 2003).

Table 1. Sprouting energy and germinating power of winter wheat seeds of Astet variety with MWF of EHF irradiation at different power and exposure modes

Irradiation exposure, sec	The temperature of seed heating, °C						Sprouting energy, %						Germinating power, %					
	0.9			1.8			0.9			1.8			0.9			1.8		
	2009	2010	average	2009	2010	average	2009	2010	average	2009	2010	average	2009	2010	average	2009	2010	average
0	19	21	20	19	21	20	86	90	88	86	90	88	87	91	89	87	91	89
5	20	22	21	24	26	25	86	90	88	88	92	90	87	91	89	89 ¹⁾	93 ¹⁾	91 ¹⁾
10	21	23	22	29	31	30	86	90	88	89 ¹⁾	93 ¹⁾	91 ¹⁾	87	91	89	90 ¹⁾	94 ¹⁾	92 ¹⁾
15	23	25	24	34	36	35	87	91	89	91 ¹⁾	95 ¹⁾	93 ¹⁾	87	91	89	91 ¹⁾	95 ¹⁾	93 ¹⁾
20	25	27	26	41	43	42	87	91	89	85	89	87	88	92	90	86	90	88
25	26	28	27	46	48	47	87	91	89	84	88	86	88	92	90	85 ¹⁾	89	87 ¹⁾
30	28	30	29	50	52	51	87	91	89	83 ¹⁾	87 ¹⁾	85 ¹⁾	88	92	90	84 ¹⁾	88	86 ¹⁾
35	30	32	31	-	-	-	88 ¹⁾	92	90	-	-	-	88	92	90	-	-	-
40	31	33	32	-	-	-	88 ¹⁾	92	90	-	-	-	88	92	90	-	-	-
45	33	35	34	-	-	-	89 ¹⁾	93 ¹⁾	91 ¹⁾	-	-	-	89 ¹⁾	93 ¹⁾	91 ¹⁾	-	-	-
50	35	37	36	-	-	-	84 ¹⁾	88	86	-	-	-	86	90	88	-	-	-
55	37	39	38	-	-	-	84 ¹⁾	88	86	-	-	-	85 ¹⁾	89 ¹⁾	87 ¹⁾	-	-	-
60	39	41	40	-	-	-	84 ¹⁾	88	86	-	-	-	85 ¹⁾	89 ¹⁾	87 ¹⁾	-	-	-
65	41	43	42	-	-	-	84 ¹⁾	88	86	-	-	-	85 ¹⁾	89 ¹⁾	87 ¹⁾	-	-	-
70	43	45	44	-	-	-	83 ¹⁾	87 ¹⁾	85 ¹⁾	-	-	-	85 ¹⁾	89 ¹⁾	87 ¹⁾	-	-	-
75	45	47	46	-	-	-	83 ¹⁾	87 ¹⁾	85 ¹⁾	-	-	-	84 ¹⁾	88 ¹⁾	86 ¹⁾	-	-	-
80	47	49	48	-	-	-	83 ¹⁾	87 ¹⁾	85 ¹⁾	-	-	-	84 ¹⁾	88 ¹⁾	86 ¹⁾	-	-	-
SSD ₀₅							1.7	2.7	2.3	2.6	2.8	2.3	1.8	1.7	1.5	1.4	1.5	1.4

¹⁾ Significant difference

Table 2. Sprouting energy and germinating power of spring barley seeds of Aspect variety with MWF of EHF irradiation at different power and exposure modes

Irradiation exposure, sec	The temperature of seed heating, °C						Sprouting energy, %						Germinating power, %					
	0.9			1.8			0.9			1.8			0.9			1.8		
	2009	2010	average	2009	2010	average	2009	2010	average	2009	2010	average	2009	2010	average	2009	2010	average
0	19	17	18	19	17	18	90	89	90	90	89	90	90	91	91	90	91	91
5	21	19	20	25	24	25	89	90	90	88	90	89	90	91	91	92 ¹⁾	91	92
10	22	23	23	29	31	30	86 ¹⁾	90	88	87 ¹⁾	91	89	88	91	90	91	91	91
15	25	24	25	45	39	42	87 ¹⁾	91	89	87 ¹⁾	91	89	88	91	90	91	92	92
20	27	26	27	49	46	48	85 ¹⁾	90	88	91	90	91	88	91	90	92 ¹⁾	91	92
25	29	29	29	52	54	53	86 ¹⁾	90	88	85 ¹⁾	90	88	90	91	91	86 ¹⁾	91	89
30	32	31	32	59	59	59	92 ¹⁾	91	92	86 ¹⁾	90	88	93 ¹⁾	92	93 ¹⁾	88 ¹⁾	92	90
35	36	33	35	62	64	63	89	92 ¹⁾	91	66 ¹⁾	88	77 ¹⁾	90	92	91	82 ¹⁾	91	87 ¹⁾
40	34	34	34	78	70	74	87 ¹⁾	91	89	57 ¹⁾	79 ¹⁾	68 ¹⁾	90	92	91	67 ¹⁾	86 ¹⁾	77 ¹⁾
45	36	35	36	84	76	80	94 ¹⁾	92 ¹⁾	93 ¹⁾	54 ¹⁾	68 ¹⁾	61 ¹⁾	94 ¹⁾	92	93 ¹⁾	60 ¹⁾	83 ¹⁾	72 ¹⁾
50	38	40	39	92	82	87	93 ¹⁾	91	92	42 ¹⁾	48 ¹⁾	45 ¹⁾	94 ¹⁾	92	93 ¹⁾	43 ¹⁾	66 ¹⁾	55 ¹⁾
55	41	41	41	-	-	-	89	90	90	-	-	-	91	90	91	-	-	-
60	45	42	44	-	-	-	89	89	89	-	-	-	90	90	90	-	-	-
65	51	44	48	-	-	-	89	92 ¹⁾	91	-	-	-	90	92	91	-	-	-
70	47	45	46	-	-	-	86 ¹⁾	90	88	-	-	-	87 ¹⁾	92	90	-	-	-
75	57	48	53	-	-	-	89	91	90	-	-	-	92	92	92	-	-	-
80	56	49	53	-	-	-	85 ¹⁾	91	88	-	-	-	88	91	90	-	-	-
85	64	54	59	-	-	-	86 ¹⁾	87	87 ¹⁾	-	-	-	89	90	90	-	-	-
90	66	55	61	-	-	-	84 ¹⁾	88	86 ¹⁾	-	-	-	88	91	90	-	-	-
95	68	56	62	-	-	-	84 ¹⁾	85 ¹⁾	85 ¹⁾	-	-	-	89	89	89	-	-	-
SSD ₀₅							1.9	2.9	2.5	2.8	3.6	3.7	2.0	1.9	1.6	1.5	2.5	3.7

¹⁾ Significant difference

The indices of the sprouting energy and germinating power of the irradiated barley and wheat seeds varied significantly. They were dependent on the irradiation power, exposure, and sowing qualities of the seeds, to which the increased "a rate – an exposure" modes were used, which reduced significantly, and even the germs' death was noted (Table 1, 2).

We determined the variability in the sprouting energy and germinating power of spring barley seeds of the Aspect variety depending on the temperature of seed heating and the irradiation exposure. We noted the slight fluctuations in the sprouting energy and germinating power at 0.9 kW/kg (Table 1, Fig. 2). Thus, at the exposure from 5 to 40 sec, the sprouting energy was 88–92 %, while at the exposure of 45 sec, it was 93 %. The further increase in the seed irradiation exposure up to 50–80 sec led to a decrease in the sprouting energy of 88–92 %. At the same time, the seed germinating power at the exposure from 5 to 40 sec was within the range of 90–93 %, at the exposures of 45–50 sec, it was 93 %. Further increase of seed exposure up to 55–

80 sec led to a decrease in 90–92 % germinating power. Therefore, we observed the highest rates of the sprouting energy and germinating power of seeds (93 % each) at 0.9 kW/kg for 45 sec (Fig. 2).

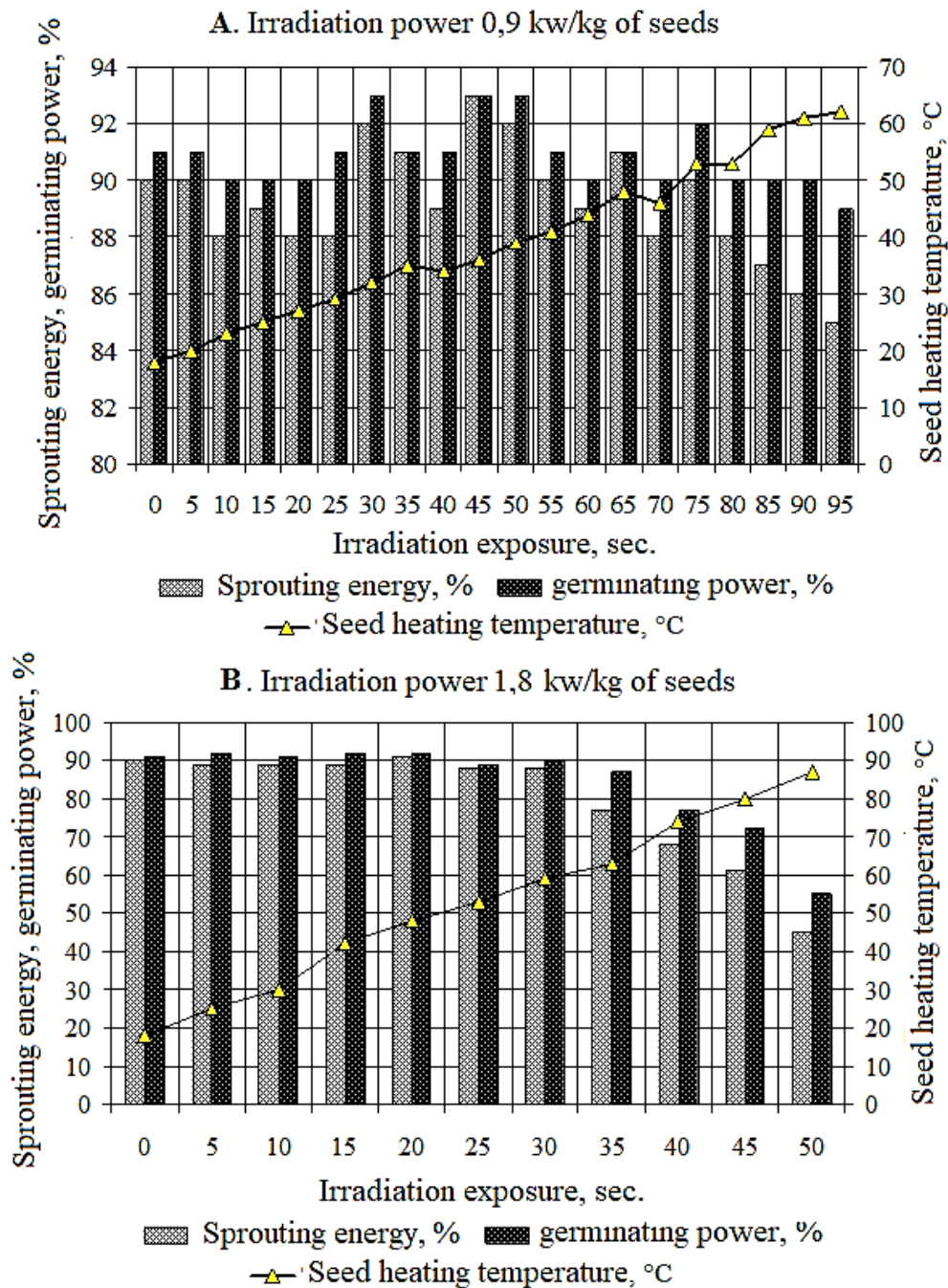


Fig. 2. Sprouting energy and germinating power of spring barley seeds of Aspect variety after irradiation with MWF of EHF at different power and exposure modes, the average for 2009, 2011 (A – 0.9 kW/kg, B – 1.8 kW/kg)

The seed sprouting energy of 89% and the germinating power of 91–92 % have been obtained when irradiating the seeds in the mode at a power of 1.8 kW per 1 kg of seeds and the exposure of 5 to 15 sec. The highest sprouting energy and germinating power have been obtained at the exposure of 20 sec. They were 91 and 92 % respectively. The increase in the irradiation exposure from 25 to 50 sec was accompanied by a sharp decrease in the sprouting energy and germinating power of the seeds – 88–45 % and 89–55 %, respectively. Therefore, the exposure of 20 sec has been chosen for the field researches under the irradiation of seeds in the mode with the power of 1.8 kW per 1 kg.

According to our research, the regularity inherent in each variety has been revealed; at a specific irradiation exposure, before the "threshold" of a significant decrease in the germination, its maximum increase occurred, which in many cases exceeded the index of the control case (Manzhos, 1971; Dindorogo et al., 2009).

The pre-sowing seed treatment with MWF of EHF increased the laboratory germinating power by 2 % under the irradiation mode of 1.8 kW per 1 kg of seeds and 20 sec, and it increased the power by 4% under the mode of 0.9 kW per 1 kg of seeds and 45 sec.

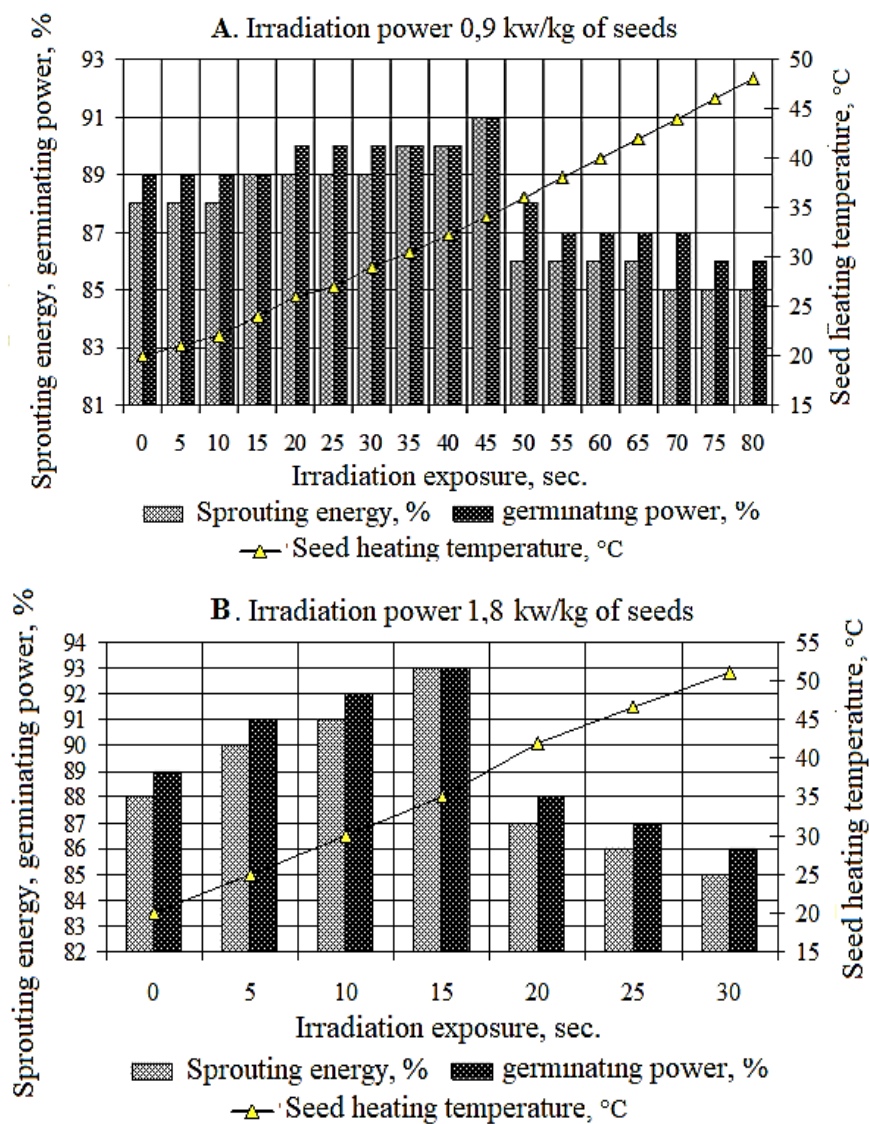


Fig. 3. Sprouting energy and germinating power of winter wheat seeds of Astet variety after irradiation with MWF of EHF at different power and exposure modes, the average for 2009, 2011 (A – 0.9 kW/kg, B – 1.8 kW/kg)

Thus, at the exposure from 0 to 30 sec, the sprouting energy was 88–89 %; at the exposure of 35–40 sec, it was 90 %, and at the exposure of 45 sec, it was 91 %. Further increase in the seed irradiation exposure to 50–80 sec resulted in a significant decrease in the sprouting energy of 85–86 %. Simultaneously, the seed germinating power at the exposure from 0 to 15 sec was within the limits of 89 %, at the exposure from 20 to 40 sec – 90 %, at 45 sec – 91 %. Further increase in the seed irradiation exposure to 50–80 sec led to a significant decrease in the germinating power of 86–88 %. Therefore, the highest indices of the sprouting energy and germinating power of the seeds (91 %) at 0.9 kW/kg have been observed at 45 sec.

The most optimum irradiation exposure of winter wheat seeds of the Astet variety with MWF of EHF in the mode at the power of 1.8 kW/kg of seeds is 15 sec. At this exposure, the maximum indices of the sprouting energy and germinating power at the level of 93 % were noted; under control, without any treatment, these indices were 88 % and 89 %, respectively. At the irradiation exposure of 5 to 10 sec, the sprouting energy and germinating power were lower than 90–91 % and 91–92 %, respectively. The increase in the irradiation exposure from 20 to 30 sec. was accompanied by a sharp decrease in the sprouting energy and germinating power of the seeds of 85–87 % and 86–88 %, respectively (Fig. 3, Table 2).

Increasing the efficiency of pre-sowing treatment of winter wheat and spring barley seeds with MWF of EHF by subsequent treatment and application of growth regulators

The preparation of seeds for sowing is a compulsory component in agricultural crop cultivation's complex technological methods. Usually, the pre-sowing preparation consists of seed disinfection with the treatment agents, as well as treating with the synthetic preparations of different origin, which stimulate the sowing and yielding qualities of the seeds (Strona, 1984, Homenko et al., 2009; Retman, 2009; Kirpa, 2011; Petrovskij, Volkov, & Kalinichenko, 2011).

Simultaneously, the research to study the efficiency of the nontraditional ecologically friendly methods of the pre-sowing seed treatment is being carried out in Ukraine and other countries. One of such methods is the microwave irradiation of extra high frequencies. Buriak Yu.L, Ohurtsov Yu.Ye., Klimenko I.I., Krupchenko L.V., Bezpalko V.V., Soloshenko O.V., Khomenko H.V., Volkohon V.V., Shevchenko E.P., Levchenko Ye.A., and other authors think that the use of microwave technology does not

exclude the possibility of its combination with the seeds treatment with the biological and chemical preparations (Buryak et al., 2011; Bospalko & Buryak, 2014; Perelik pesticidiv, 2018). Therefore, the next stage of the laboratory research was to study the influence of the additional pre-sowing treatment of barley and wheat seeds irradiated with MWF of EHF, the treatment agent and plant growth regulators sprouting energy, and germinating power indices. For this purpose, after the irradiation with MWF of EHF, the pre-sowing treatment of spring barley seeds of the Aspect and Vyklyk varieties with the growth regulators Radostim and Albit, and Vitavax 200 FF treatment agent has been conducted. The recommended consumption rates of the preparations and the rates reduced by half have been tested during the research (Dmitrenko, 1980).

We established that treating the seeds with Vitavax 200 FF at a rate reduced by half from the recommended one has led to a 2 % increase in the sprouting energy and laboratory germinating power, whereas the total rate of the treatment agent did not provide the improvement in the sowing qualities (Table 3). The application of the reduced rates of the plant growth regulators Radostim and Albit proved to be less effective; the germinating power increased by 1–3 % compared to 2–4 % when applied the total rate. Therefore, for further laboratory and field research of the pre-sowing treatment of seeds irradiated with MWF of EHF, the treatment agent Vitavax 200 FF at the rate reduced by half, that is 1.25 L/t, and the plant growth regulators Radostim and Albit at the total rates of 0.25 L/t and 30 ml/t respectively have been used. Our research examined the Mars EL plant growth regulator for treating winter wheat seeds at the rate recommended by the producer of 0.2 L/t.

Table 3. Sowing qualities of spring barley seeds of Aspect variety depending on the application of MWF of EHF, different rates of treatment agents, and plant growth regulators

Case of seed treatment		Sprouting energy, %			Germinating power, %		
seed treatment mode with MWF of EHF	preparations, rates of application	2009	2010	average	2009	2010	average
	Control, without treatment	90	89	90	90	91	91
0.9 kW/kg, 45 sec	Vitavax 200 FF, 2.5 L/t	92 ¹⁾	90	91	92 ¹⁾	90	91
	Vitavax 200 FF, 1.25 L/t	94 ¹⁾	92 ¹⁾	93 ¹⁾	94 ¹⁾	92	93 ¹⁾
1.8 kW/kg, 20 sec	Vitavax 200 FF, 2.5 L/t	89	88	89	90	89	90
	Vitavax 200 FF, 1.25 L/t	91	90	91	92 ¹⁾	91	92
0.9 kW/kg, 45 sec	Radostim, 0.25 L/t	95 ¹⁾	93 ¹⁾	94 ¹⁾	95 ¹⁾	93 ¹⁾	94 ¹⁾
	Radostim, 0.12 L/t	94 ¹⁾	92 ¹⁾	93 ¹⁾	94 ¹⁾	92	93 ¹⁾
1.8 kW/kg, 20 sec	Radostim, 0.25 L/t	92 ¹⁾	91 ¹⁾	92 ¹⁾	93 ¹⁾	92	93 ¹⁾
	Radostim, 0.12 L/t	91	90	91	92 ¹⁾	91	92
0.9 kW/kg, 45 sec	Albit, 30 mL/t	96 ¹⁾	94 ¹⁾	95 ¹⁾	96 ¹⁾	94 ¹⁾	95 ¹⁾
	Albit, 15 mL/t	95 ¹⁾	93 ¹⁾	94 ¹⁾	95 ¹⁾	93 ¹⁾	94 ¹⁾
1.8 kW/kg, 20 sec	Albit, 30 mL/t	93 ¹⁾	92 ¹⁾	93 ¹⁾	94 ¹⁾	93 ¹⁾	94 ¹⁾
	Albit, 15 mL/t	92 ¹⁾	91	92 ¹⁾	93 ¹⁾	92	93 ¹⁾
	SSD ₀₅	1.7	1.6	1.6	1.6	1.5	1.4

Conclusions

1. According to the results of the research, the pre-sowing irradiation with MWF of EHF influences the sowing qualities of spring barley and winter wheat seeds in a different manner. This influence depends on the irradiation power and its exposure and the seeds' associated heating temperature.
2. The irradiation of spring barley seeds with MWF of EHF at 0.9 kW/kg from 5 to 50 sec is accompanied by heating of seeds from 20 to 39 °C. However, sprouting energy and germinating power do not change significantly.
3. The irradiation of spring barley seeds with MWF of EHF at 1.8 kW/kg from 5 to 50 sec is accompanied by heating of seeds from 20 to 87 °C. When the seeds are heated at 53–87 °C, the sprouting energy, and germinating power are reduced by 3–45 and 3–36 %, respectively, compared to the control case.
4. The irradiation of winter wheat seeds with MWF of EHF at 0.9 kW/kg from 5 to 45 sec is accompanied by heating of seeds from 20 to 34 °C. However, sprouting energy and germinating power do not change significantly.

5. The irradiation of winter wheat seeds with MWF of EHF at 1.8 kW/kg from 5 to 30 sec is accompanied by heating of seeds from 20 to 51 °C. Simultaneously, the sprouting energy and germinating power are reduced by 1–3 % when the seeds are heated from 42 to 51 °C, compared to the control case.
6. The positive influence on sprouting energy and germinating power of spring barley seeds has been noted when irradiated with MWF of EHF at 1.8 kW/kg for 20 sec and 0.9 kW/kg for 45 sec. The positive influence was noted for the winter wheat seeds at 1.8 kW/kg for 15 sec and 0.9 kW/kg for 45 sec. That is why precisely these irradiation modes have been assumed as the basis for further research.
7. Treatment of the irradiated spring barley and winter wheat seeds with MWF of EHF or treatment with the growth regulators contribute to an additional increase in the sowing quality of seeds depending on the preparation and the rate of its consumption.

References

- Adamenko, T.I. (2008). Perspektivy ukrainskogo zernovogo rynku v kontekste globalnogo potepleniya. Hranenie i pererabotka zerna, 6 (108), 28–32 (in Russian).
- Anishin, L. (2002). Regulyatori rostu roslin: sumnivi i fakti. Propoziciya, 5, 64–65. (in Ukrainian).
- Babich, A.O., Himich, V.V. & Poberezhna, A.A. (1994). Svitove virobnytvo zerna prodovolchih i furazhnikh kultur. Kormi i kormovij bilok: materiali pershoyi vseukrayinskoyi mizhnarodnoyi konferenciyi (16–17.11), Vinnicya, 74–75 (in Ukrainian).
- Bespalko, V.V. & Buryak, Yu.I. (2014). Vliyanie predposevnoy obrabotki semyan mikrovolnovym polem v sochetanii s regulyatorom rosta i biopreparatom na posevnye kachestva i urozhajne svojstva yachmenya yarovogo. Zernobobovye i krupyanye kultury: nauchno-proizvodstvennyy zhurnal, 4, 133–139 (in Russian).
- Bezpal'ko, V.V., Stankevych, S.V., Zhukova, L.V., Zabrodina, I.V., Turenko, V.P., Horyainova, V.V., Poedinceva, A.A., Batova, O.M., Zayarna, O.Yu., Bondarenko, S.V., Dolya, M.M., Mamchur, R.M., Drozd, P.Yu., Sakhnenko, V.V., Matsyura, A.V. (2020). Pre-sowing seed treatment in winter wheat and spring barley cultivation. Ukrainian Journal of Ecology, 10(6), 255–268.
- Bezpal'ko, V.V., Zhukova, L.V., Stankevych, S.V. & Zabrodina I.V. (2020). Ways to increase the yield capacity of winter wheat and spring barley on the basis of applying pre-sowing seed irradiation with extra high frequencies microwave field in the conditions of eastern forest-steppe of Ukraine: monograph. Kharkiv, Publishing House I. Ivanchenko.
- Bezpal'ko, V.V., Zhukova, L.V., Stankevych, S.V., Ogurtsov, Yu.H., Klymenko, I.I., Hutians'kyi, R.A., Fesenko, A.M., Turenko, V.P., Zabrodina, I.V., Bondarenko, S.V., Batova, O.M., Golovan, L.V., Klymenko, I.V., Poedinceva, A.A., Melenti, V.O. (2019). Ecologically safe methods for presowing treatment of cereal seeds. Ukrainian Journal of Ecology, 9(3), 189–197.
- Buryak, Yu.I. (2011). Vpliv ristregulyuyuchih preparativ i mikrohvilovogo oprominennya posivnogo materialu na vrozhajnist ta posivni yakosti nasinnya yachmenya yarogo. Osnovi biologichnogo roslinnictva v suchasnomu zemlerobstvi: zbirnik materialiv mizhnarodnoyi konferenciyi, 303–309. (in Ukrainian).
- Dindorogo, V.G. (2009). Vpliv MH-stimulyaciyi nasinnya zernovih kolosovih kultur na pidvishennya posivnih yakostej ta vrozhajnih vlastivostej nasinnya. Mikrovolnovye tehnologii v narodnom hozyajstve, 7/8, 82–85. (in Ukrainian).
- Dmitrenko, V.K. (1980). Zalezhnist vrozhayu zerna pshenici vid poperednikiv ta meteorologichnih faktoriv. Visnik silskogospodarskoyi nauki, 2/3, 15–19. (in Ukrainian).
- Gentosh, D.T., Kyryk, M.M., Gentosh, I.D., Pikovskiy, MY., Polozhenets, V.M., Stankevych, S.V., Nemerytska, L.V., Zhuravska, I.A., Zabrodina, I.V., Zhukova, L.V. (2020). Species compositions of root rot agents of spring barley. Ukrainian Journal of Ecology, 10 (3), 106–109.
- Homenko, G.V. et al. (2009). Sovmestnoe primenenie mikrovolnovoy obrabotki i biopreparatov protiv korneyih gnilej i drugih zabolevanij rastenij. Mikrovolnovye tehnologii v narodnom hozyajstve, 6, 67–68. (in Russian).
- Horiainova, V.V., Turenko, V.P., Bilyk, M.O., Stankevych, S.V., Zhukova, L.V., Batova, O.M., Martynenko, V.I., Kucherenko, Ye.Yu., Zviahintseva, A.M. (2020). Species composition, morphological and biological peculiarities of leaf pathogens of spring wheat. Ukrainian Journal of Ecology, 10(3), 115–120.
- Izhik, N.K. (1976). Polevaya vshozhest semyan (biologiya, ekologiya, agrotehnika). Instit. agroh. i pochvoved. UAAN. Kiev, Urozhaj (in Russian).
- Katalog sortiv i gibridiv polovih kultur (2013). NAAN, Institut roslinnictva im. V.Ya. Yur'yeva, Harkiv (in Ukrainian).
- Kirpa, N.Ya. (2011). Za mig do poseva (pro kachestvo semyan). Zerno, 3. (in Russian).
- Lyhochvor, V. (2003). Zastosuvannya regulyatoriv rostu roslin (morfo regulyatoriv, retardantiv) na posivah zernovih kultur. Propoziciya, 3-4, 56–57. (in Ukrainian).
- Manzhos, D.M. (1971). Nasinnyeznavstvo pshenici, Kiyiv, Urozhaj (in Ukrainian).
- Nasinnya silskogospodarskih kultur sortovi ta posivni yakosti. Tehnichni umovi. DSTU 2240–93. (1994). Kiyiv, Derzhstandart (in Ukrainian).
- Nasinnya silskogospodarskih kultur. Metodi viznachennya yakosti. DSTU 4138–2002. (2003). Kiyiv, Derzhstandart (in Ukrainian).
- Perelik pesticidiv i agrohimikativ, dozvolenih do vikoristannya v Ukrayini (2018). Kiyiv, Yuninvest Media (in Ukrainian).
- Petrovskij, O.M., Volkov, S.I. & Kalinichenko, M.I. (2011). Temperaturnij rezhim UVCh oprominennya, yak faktor vplivu na shozhist nasinnya pshenici. Zbirnik naukovih prac Vinnickogo agrarnogo universitetu. Ser. "Tehnichni nauki", 7, 24–28. (in Ukrainian).
- Retman, S.A. (2009). Mikrohvilova tehnologiya v kompleksnij sistemi zahistu roslin. Mikrovolnovye tehnologii v narodnom hozyajstve, 6, 62–63. (in Ukrainian).
- Sajko, V.F. (1997). Perspektiva virobnytva zerna v Ukrayini. Visnik agrarnoyi nauki, 9, 27–32 (in Ukrainian).

- Sajko, V.F. (2008). Naukovi osnovi zemlerobstva v konteksti zmin klimatu. *Visnik agrarnoyi nauki*, 11, 5–10. (in Ukrainian).
- Sajko, V.F., Gricaj, A.D. & Gordecka, S.P. (1994). Ozimi zernovi kulturi. *Naukovi osnovi vedennya zernovogo gospodarstva*, Kiyiv, Urozhaj (in Ukrainian).
- Shevchenko, A.M. (2007). Znachenie mikrovolnovoj tehnologii v narodnom hozyajstve. *Mikrovolnovye tehnologii v narodnom hozyajstve*, Odessa (in Russian).
- Strona, I.G. (1984). Doposevnaya i predposevnaya obrabotka semyan selskohozyajstvennyh kultur. *Teoriya i praktika predposevnoj obrabotki semyan*. YuO VASHNIL. Kiev (in Russian).
- Sytnyk, V.P. (2002). Ekologichni aspekti agropromislovogo kompleksu. *Visnik agrarnoyi nauki*, 9, 55–57. (in Ukrainian).
- Tuchnyj, V.P. (2007). Tehnologiya zavtrashnego polya. *Mikrovolnovye tehnologii v narodnom hozyajstve*, 6, 9–15. (in Russian).
- Tuchnyj, V.P., Karmazin A.I. & Dzigovskij, Yu.A. (2012). Tehnologiya, kotoruyu zhdut agrarii. *Hranenie i pererabotka zerna*, 1(151), 21–24. (in Russian).
- Tuchnyj, V.P., Karmazin Yu.A. & Levchenko Ye.A. (2007). Proryv s pomoshyu novoj tehnologii. *Hranenie i pererabotka zerna*, 4(94), 11–13. (in Russian).
- Turenko, V.P., Bilyk, M.O., Zhukova, L.V., Stankevych, S.V., Zayarna, O.Yu., Lukhanin, I.V., Oleynikov, Ye.S., Batova, O.M., Goryainova, V.V., Poedinceva, A.A. (2019). Dependence of species composition and development of root rots pathogens of spring barley on abiotic factors in the Eastern Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology*, 9(2), 179–188.
- Zakharchuk, N.A., Dolya, M.M., Polozhenets, V.M., Zhuravska, I.A., Tsuman, N.V., Stankevych, S.V., Nemerytska, L.V., Rozhkova, T.O., Chayka, O.V., Popova, L.V. (2020). Producing of potato varieties resistant to fusarial wilt by cell selection. *Ukrainian Journal of Ecology*, 10(1), 289–291.
- Zhukova, L.V., Stankevych, S.V., Turenko, V.P., Bezpal'ko, V.V., Zabrodina, I.V., Bondarenko, S.V., Poedinceva, A.A., Golovan, L.V., Klymenko, I.V., Melenti, V.O. (2019). Root rots of spring barley, their harmfulness and the basic effective protection measures. *Ukrainian Journal of Ecology*, 9(2), 232–238.

Citation:

Bezpal'ko, V.V., Stankevych, S.V., Zhukova, L.V., Matsyura, A.V., Zabrodina, I.V., Turenko, V.P., Horyainova, V.V., Poedinceva, A.A., Zayarna, O.Yu., Lazariyeva, O.V., Tsekhmeistruk, M.H., Pankova, O.V., Chygryna, S.A., Ogurtsov, Yu.Ye., Klymenko, I.I. (2021). Pre-sowing treatment of winter wheat and spring barley seeds with the extremely high frequencies electromagnetic field. *Ukrainian Journal of Ecology*, 11(1), 62-71.



This work is licensed under a Creative Commons Attribution 4.0. License