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ORIGINAL ARTICLE

Yield capacity and quality of winter wheat seeds and grains depending on pre-sowing seed treatment with MWF of EHF

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We established that the formation of the elements of the winter wheat yield structure and its biological yield capacity were mainly influenced by the agrometeorological conditions of the growing year. Winter wheat yield capacity had a significant-close positive correlation with the number of productive stems (r=0.91) and a close correlation with the total number of stems (r=0.75). The most efficient methods of seed pre-sown treatment that cause an increase in the winter wheat yield capacity compared to seed treatment with Vitavax 200 FF, 2.5 L/t are seed irradiation with EHF MWF in the mode of 0.9 kW/kg, 45 sec. or seed irradiation with EHF MWF in the mode of 1.8 kW/kg, 15 sec with additional treatment with Mars EL growth regulator, 0.2 L/t. At high sowing quality indices of the harvested winter wheat grains of the Astet variety within 96-97% of the naturally determined influence of EHF MWF only or together with the Mars EL growth regulator on the indices of sprouting energy and germinating power have not been established. The baking qualities of winter wheat grains of the Astet variety did not change significantly depending on the method of the pre-sown seed treatment. According to the protein content indices and the amount and quality of fluid gluten, the winter wheat grain is under control and in the standard case with Vitavax 200 FF seed treatment, as well as in the cases of applying EHF MWF and Mars EL growth regulator, corresponding to the third class (III) on average for 2011-2013. We observed the highest fluid gluten content in the wheat grains in the EHF of the seed irradiation with MWF of EHF in the mode of 0.9 kW/kg of seeds and exposure of 45 sec.; it was 22.4-22.5%, while under control, it was 21.2%.

Keywords: Pathogens yield, Quality, Sowing qualities, Pre-sowing treatment, Seeds, Grain, Fungicides, MWF, EHF, Growth regulators, Winter wheat.

Introduction

One of the obligatory elements of the technological process of cultivating cereal crops, which affects the increase in crop yield and quality of crop production, is the pre-sowing treatment of seeds with chemical and biological products of different origins. However, today in Ukraine, the problem of seed sanitation and selection of the most viable biotypes with high productive properties by pre-sowing treatment with ecologically friendly methods has not yet been solved. The search for new alternative methods for seed disinfection to reduce the negative influence of agrochemicals on the environment has recently been carried out in Ukraine and abroad. Physical methods, such as the treatment with ozone, microwave, and ultrasonic radiation, are of great interest (Tuchnyj et al., 2007; Tuchnyj, Karmazin and Levchenko, 2007; Shevchenko et al., 2007; Tuchnyj, Karmazin and Dzigovskij, 2012).

One of the most ecologically friendly and cost-effective methods of pre-sowing seed treatment 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 used to increase plants' resistance to adverse factors and the yield capacity of many crops have become widespread in agricultural practice (Anishin, 2002; Lihochvor, 2003).

Several scientists have studied the dependence of winter wheat yield capacity on agro-meteorological factors in the Ukraine territory (Krenke et al., 1992; Tarariko et al., 2013). We know that something closely related the rate of plant development to the weather of a particular year. Analysis of agricultural crop development characteristics in interaction with meteorological factors is a significant

part of agro-meteorological information. Here, the criterion for evaluating agrometeorological conditions in which the crop is grown, is the value of the grain yield capacity and its quality (Kuperman, 1955).
The following indices were used to characterize the agro-meteorological conditions of winter wheat and spring barley cultivation during the research period: duration of interphase periods, average daily air temperature, a sum of effective temperatures (above five °C), and amount of precipitation in interaction with the elements of crop productivity.

Materials and Methods

A variety of soft winter wheat is the research material-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 is recommended for cultivation in the Forest-Steppe and Steppe Zones of Ukraine (Katalog sortiv i gibridiv polovih kultur NAAN, 2013). Its approbation signs are the erythrospermum variety. The grain is red, of medium size, oval in shape, with a broad pubescent tuft. The stem has a medium wax coating on the upper internode. The spike has a slight spindle-shaped covering 8-9 cm long; it has a medium density. The awns are long (10 cm), jagged, and anthocyanin color after ear formation. The anthers have an anthocyanin color. The weight of 1,000 grains is 39 to 43 g.
The biological characteristics we considered were: the variety is mid-ripening; the ear formation and ripening occur in terms close to the standards; the variety has short stems (the plant height is 79-85 cm), and it is resistant to lodging. The stem is thin, has an excellent tillering capacity, and can form 700 or more productive shoots per 1 m^2. The winter hardiness is relatively high; it is 8.2-8.7 marks. Under 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. Depending on the place and cultivation conditions, the grain contains 12.4-14.5% of protein and 25-29.9% of the gluten; the flour strength is 280-431 alveograph units, and the bread volume is 660 cm^3. The data on the factors regarding the pre-sowing seed treatment are as follows.
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 with protective and therapeutic action. It destroys fungal pathogens on the surface and within seeds; it prevents infection of the crop seedlings 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 pesticides and agrochemicals allowed for Ukraine. The seeds of cereal crops were treated with preparation at a consumption rate recommended by the producer, that is 2.5-3.0 L dissolved in 10 L of water per 1 ton of seeds. We also examined reduced rates in the experimental cases. 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 sortovi ta posivni yakosti. Tehnichni umovi. DSTU 2240-94, 1994; Nasinnya silskogospodarskih kultur sortovi ta posivni yakosti. Metodi viznachennya yakosti. DSTU 4138-2002, 2003). 100 seeds in quadruplicate recurrence were selected for this purpose. We carried germination out on a thermostat at a temperature of +20°C on the moistened filter paper. We calculated the sprouting energy in 4 days and the laboratory germinating power in 7 days. We carried field experiments out in crop rotation at the Seed Production and Seed Science Laboratory. The predecessor of spring barley was peas for grain, and the predecessor of winter wheat was fallow in autumn. The acreage of the examined plot during the experiments was 20 m^2, the quadruple recurrence was used and we placed the plots in a systematic character (Nasinnya silskogospodarskih kultur sortovi ta posivni yakosti. Tehnichni umovi. DSTU 2240-94, 1994).

Agro-meteorological conditions for winter wheat cultivation

We carried winter wheat sowing during the research period out in optimum terms for the Eastern Forest-Steppe Zone, namely in the second decade of September. For this zone, a sharp change in weather according to the seasons of the year influenced the duration of the winter wheat growing season, both over the years and over the interphase periods of plant growth and development. The vegetation period of the Astet variety ranged from 153 days in 2011 to 148 days in 2013, with 115 days in 2012 (Table 1).
The fall period, which conditions the sprouting and tilling of the plants, is an essential stage of developing winter crops. The duration of the sowing period in the interphases-sprouting did not change significantly over the years and was 6 to 7 days. The insignificant fluctuations in the average daily air temperature amounted to 15-17°C and the sum of the effective temperatures was 86-99°C in 2011 and 2012. The distribution of precipitation as a source of water replenishment in the soil during this period was uneven. The maximum amount of precipitation was 25 mm in 2010, and the minimum was 5.3 mm in 2011. The next interphase period of the fall vegetation 'sprouting-tillering' falls in the third decade of September and the first decade of October (Table 1).

Table 1. Phenological phases of Astet variety development of winter wheat crops of Astet variety in 2010-2013.

Sowing	Sprouting	Tillering	Stopping of fall Vegetation	Resumption of Spring Vegetation	Stalk Shooting	Tillering	Full Ripening
15.09.2010.	21.09. 2010	6.10.2010	25.11.2010	02.04.2011	1.05. 2011	19.05.2011	25.06.2011
16.09.2011	23.09.2011	12.10.2011	04.011.2011	18.04.2012	15.05.2012	28.05.2012	22.06.2012
14.09.2012	21.09.2012	5.10.2012	10.11.2012	31.03.2013	16.05.2013	23.05.2013	28.06.2013

The duration of the period varied between 15 and 19 days over the years (Table 2). There was a significant decrease in the average daily temperature to 10.7°C and in the sum of effective temperatures up to 76°C against the background of maximum precipitation of 81 mm, with a long-term rate of 20 mm in 2010. We observed optimal conditions for vegetation only in 2012.
However, the agrometeorological conditions for winter wheat cultivation varied significantly over the research period, leading to different duration of interphase periods of plant growth and development and ultimately to different levels of crop yield capacity over the years. Therefore, in 2010-2011, the vegetation period of the Astet winter wheat variety lasted 156 days (from sowing to full ripeness). During the growing season, the sum of effective temperatures was 1302°C, and the precipitation was 452.6 mm (Table 2).

Table 2. Duration of interphase periods of winter wheat development depending on agro-meteorological conditions during the years of research, 2010-2013.

S.No.	Indices	Interphase period						The Sum of Days Over Vegetation Period	Yield Capacity. t/ha
		Sowing-sprouting	Sowing-tillering	Tillering Stopping of vegetation	RSV-stalk Shooting	Stalk Shooting-ear Formation	Ear Formation Full Ripening		
				2010-2011					
1	Duration of the interphase period (days)	6	15	51	25	18	38	153	4.44
2	Average daily air temperature, °C	15.0	10.7	7.0	11.2	17.5	20.6	12.9	
3	Sum of effective temperatures above 5°C	93.0	76.0	-	174.0	238.0	721.0	1302.0	
4	Amount of precipitation, mm	25.0	80.6	56.0	64.0	20.0	207.0	452.6	
				2011-2012					
1	Duration of the interphase period (days)	7	19	23	27	13	26	115	5.09
2	Average daily air temperature, °C	15.7	12.8	4.9	20.0	19.5	22.0	19.7	
3	Sum of effective temperatures above 5°C	86.0	148.0	-	405	189	408	1236	
4	Amount of precipitation, mm	0.0	12.2	20.0	0.3	25.0	29.0	86.5	
				2012-2013					
1	Duration of the interphase period (days)	7	15	36	46	7	37	148	6.63
2	Average daily air temperature, °C	16.9	15.6	9.4	16.6	22.1	22.7	15.1	
3	Sum of effective temperatures above 5°C	99.0	151.0	180.0	455.0	123.0	631.0	1639	
4	Amount of precipitation, mm	5.3	13.1	115.0	10.3	15.4	75.8	234.9	

A characteristic feature of winter wheat vegetation in 2010-2011 was the absence of effective temperatures during the interphase period of 'tillering-stopping of fall vegetation', which lasted 51 days, as well as their lack in the periods of 'sprouting-tillering' and 'spring vegetation resumption-stalk shooting"; the period lasted 25 days, and the total sum of temperature was 76 and 174°C, respectively. We observed the resumption of vegetation on April 2, 2011. Another characteristic of 2010-2011 was 46% (207 mm) of the annual precipitation during the interphase period of "ear formation-full ripening". Under such conditions, the winter wheat yield capacity of the Astet variety in 2011 was 4.44 t/ha on average. In 2011-2012, the winter wheat vegetation period lasted 115 days at the sum of effective temperatures of 1236°C. During the research, this period was the driest; the amount of precipitation during the wheat vegetation period was 86.5 mm. About of 62% (54 mm) of precipitation has been dispersed during the interphase period of 'stalk shooting-full ripening'. It is noteworthy that winter wheat vegetation in the interphase periods of "sprouting-tillering" and "spring resumption of vegetation-stalk shooting" occurred at high average daily air temperatures; as a result, the sums of effective temperatures during these periods were 148.0 and 405°C at the duration of the periods of 19 and 27 days, respectively. We observed the resumption of vegetation on April 18, 2012. The period of 'stalk shooting-ear formation' lasted 13 days under favorable conditions; the average daily air temperature was 19.5°C, the sum of the effective temperatures was 189°C, and the amount of precipitation was 25 mm. Therefore, in the 2011-2012 period, the agro-meteorological conditions of the winter wheat vegetation were more favorable than in the previous period, which allowed the yield capacity to be got at the level of 5.09 t/ha.

The winter wheat vegetation period in 2012-2013 should be noted as the most favorable during field research. Its duration was 145 days at the highest sum of effective temperatures of 639°C and the precipitation amount of 234.9 mm. The duration of the interphase period of 'sprouting-tillering' at high average daily air temperatures (15.6°C on average compared to 10.7 and 12.8°C in the previous periods) was 15 days. In the 2010-2011 and 2011-2012 periods, the duration was 15 and 19 days and the sum of the effective temperatures was 151.0°C. We should note that winter wheat tilling took place under favorable conditions and lasted almost until fall vegetation; the average daily air temperature was 9.4°C and the sum of effective temperatures was 180°C. During this period, there were 115 mm of precipitation or 49% of the total precipitation for the crop vegetation period. The period of 'resumption of vegetation-stalk shooting' was also favorable to the growth, development, and formation of the generative organs of winter wheat. It was comparatively the longest (46 days) and the warmest (the sum of effective temperatures was 455°C). We observed the resumption of vegetation on March 31. The vegetation of the Astet winter wheat variety, from the shooting phase of the stalks to full ripeness, occurred at high average daily air temperatures. The sum of the effective temperatures was 754°, with 91.2 mm of precipitation.

One of the critical vegetation periods of winter cereals is the 'tillering' phase. During this period, they formed the lateral shoots and a secondary root system from the underground stem nodes, the setting of organs that determine the crop yield. The indices of productive tilling depend on the conditions of the fall and winter periods. The water reserve is a major factor when it is quite warm (at an air temperature of 15-18°C) (Ulanova, 1975; Vrkach, 1984; Lihochvor and Petrichenko, 2006).

During the years of research, the interphase period of 'sprouting-tillering' fell in the third decade of September and the first decade of October. According to the data (Table 2), the duration of the period varied over the years from 15, 19, and 13 days, respectively. The lowering of temperatures in 2010 and 2011 characterized that period; the temperatures were 10.7 and 12.8°C respectively, whereas, in 2012, the lowering in temperature compared to the previous period was insignificant-15.6 versus 16.9°C. In 2010, the sum of effective temperatures was minimum (76°C) against a background of maximum precipitation of 81 mm at average long-term precipitation of 20 mm. In the following 2011 and 2012, the same period was drier; the sum of the effective temperatures amounted to 148 to 151°C with minimum precipitation of 12.2-13.1 mm. As a result, the sharp fluctuations in heat and humidity were not optimum for intensive tilling during the examined vegetation period. It is known that the tillering phase of winter cereals continues until the vegetation stops, until a steady increase in the average daily temperature above 5°C (Lichhochvor and Petrichenko, 2010; Lihochvor et al., 2003).

The duration of the "tillering-stoppage of vegetation" period varied significantly depending on the meteorological conditions of the fall growing season. If the beginning of the 'tillery' phase was observed almost simultaneously (the first decade of October), then the date of stopping the fall wheat vegetation ranged within the limits of 15-20 days. The most extended interphase period of tilling-stoppage of vegetation (49 days) was observed in 2010 and was accompanied by a decrease in the average daily air temperature to 7°C, the sum of effective temperatures was 96°C and the amount of precipitation were 72 mm. Such weather was following the climatic norm. The minimum duration of this period (24 days) was observed in 2011. The temperature factor was crucial for the intensive growth and development of plants. The lowering of the air temperature to 5°C and below in the absence of effective temperatures and at minimum precipitation of 20 mm (60% of the average long-term rate) influenced the shortening of the vegetation period. The most favorable conditions during the period of 'tillering-stopping vegetation' were observed in 2012; the period lasted up to 36 days with a slower decrease in air temperature to 9.4°C and the maximum sum of the effective temperatures of 180°C, which is 20% higher than in the previous period of 'sprouting-tillering'. The amount of precipitation was also above the long-term rate.

The considered periods of fall vegetation showed that winter wheat responds significantly to changes in weather. The plants' corresponding reaction influenced the field's germination and tilling as the major elements of the yield structure. The stopping of winter wheat fall vegetation varied from the first to the third decade of November and depended on the temperature regime. With winter wheat, the role of fall and winter periods is also important for forming water reserves in the soil in early spring. Well-developed crops develop intensively, forming the leaf tube and spikelets in the ear using mainly spring water reserves.

During the research period, we observed the most favorable conditions for water supply at the beginning of spring in 2013. From November to March, precipitation was 211 mm, which exceeded the average long-term rate by 15%. In 2011 and 2012, the amount of precipitation was significantly low and was 149 and 122 mm, respectively, or 81% and 67% of the rate. The terms of spring vegetation resumption (SVR) of winter wheat, especially their extreme values, significantly influence the further development of plants up to the ear formation phase (Lihochvor et al., 2003). The primary cause of spring crop losses is the late date of vegetation resumption, when plants cannot adapt quickly to sudden temperature changes. According to our research (Table 1), the first date of vegetation resumption was observed on March 31, 2013, with a further maximum duration of the interphase period of 'vegetation resumption-stalk shooting' of 46 days. Early winter wheat vegetation (April 2) was also observed in 2011. However, the duration of the interphase period from vegetation resumption to stalk shooting phase was 21 days shorter than in 2013. The shortening of the active vegetation period, when the main biomass is accumulated, influences the shortage of productivity.

We observed the critical conditions of the period under consideration in 2012, the date of the vegetation resumption fell on April 18, i.e., 15 days later than the earlier terms. The shortening of the interphase period of 'vegetation resumption-stalk shooting' up to 27 days was because of the increase in the temperature regime. The sum of the effective temperatures of 405-455°C exceeded the average long-term norm almost twice, and the precipitation was twice as low. The duration of the interphase period of 'stalk shooting-ear formation' (Table 2) ranged from 7 to 19 days despite the temperature increase. The average daily temperature was within the range of 17-22°C, the sum of effective temperatures was 120-240°C, and the amount of precipitation was 15-25 mm, which corresponded to the average long-term rate. A significant factor in the winter's formation wheat yield capacity is the duration of the period from ear formation to full ripening. During the years of research, this period was minimum in 2012-26 days and maximum up to 37 days in 2011 and 2013 at an optimal temperature of 20-23°C. However, an uneven distribution of precipitation from 29 mm in 2012 to 207 mm in 2011 and its intensity led to a shortage in yields of up to 4.44 and 5.09 t/ha in 2011 and 2012, while in 2013, the yield capacity was 6.63 t/ha. Such agrometeorological conditions during the vegetation period provided the highest winter wheat yield capacity in our research, it was 6.63 t/ha in 2013.

Results

Influence of pre-sowing seed treatment with MWF of EHF on the formation of structural elements of the yield and yield capacity of winter wheat depending on the method of application

As is known, the level of the yield capacity comprises many interrelated factors; each of them has some influence on the growth and development of the plant. Increasing the yield capacity of grain crops is one of the primary tasks of the agricultural science and production (Sozinov and Obod, 1970; Krenke, Demyanchuk and Emelyanova, 1992; Sajko, Lobas, and Yashovskij, 1994; Nasinnya silskogospodarskih kultur sortovi ta posivni yakosti. Metodi viznachennya yakosti, 2003; Sokolov, Starodvorov and Mostovoj, 2006; Adamenko, 2008; Kirichenko, 2011). The study of the yield structure allows determining the peculiarities of the formation of the yield capacity and quality of the grain under the specific agrometeorological conditions during the period of the field research depending on the influence of the developed elements of the crop growing technology. Therefore, a part of our research was to study the influence of the pre-sowing seed treatment with EHF MWF depending on the irradiation mode and the application of Mars EL growth regulator on the formation of the elements of the crop structure and the biological yield capacity of winter wheat grain of the Astet variety.

Table 3. Structure of the winter wheat yield of Astet variety depending on the application of MWF of EHF.

S.No	Cases of Seed Pre-sowing Seed Treatment	Number, pes m^2			The Factor of Productive Tillering	Grain Content in the Ear, pes	Weight of 1000 Grains, g	Biological Yield Capacity, t/ha
		Plants	Stems					
			Total	Including Productive				
1	Vitavax 200 FF, 2.5 L/t (standard)	344	619	496	1.44	29.4	37.3	5.42
2	MWF of EHF, 1.8 kW/kg, 15 sec.	351	655	531[1)]	1.48	28.7	37.0	5.58
3	MWF of EHF, 1.8 kW/kg,15 sec.+Mars EL, 0.2 L/t	369[1)]	715[1)]	552[1)]	1.45	28.9	36.6	5.74[1)]
4	MWF of EHF, 0.9kW/kg, 45 sec.	345	680[1)]	542[1)]	1.55[1)]	29.0	37.8	5.80[1)]
5	MWF of EHF, 0.9kW/kg, 45 sec.+Mars EL, 0.2 L/t	380[1)]	675[1)])	535[1)]	1.44	29.8	36.6	5.76[1)]
6	Vitavax 200 FF, 2.5 L/t (standard)	359[1)]	654	536[1)]	1.51[1)]	29.4	37.2	5.77[1)]
correlation coefficient with yield capacity		0.51	0.75	0.91[1)]	0.50	0.01	-0.09	-
SSD $_{05}$		14.0	51.0	22.2	0.05	0.7	0.8	0.27

Note: [1)]-Significant difference.

Table 4. Yield structure of Astet winter wheat variety according to the application of EHF MWF and the Mars EL plant growth regulator, 2011.

S.No.	Cases of seed pre-sowing seed treatment	Number, pcs/m^2			The factor of productive tillering	Grain content in the ear, pcs/ear	Weight of 1000 grains, g	Biological yield capacity, t/ha
		plants	stems in total	productive stems				
1	Control, without treatment	292	545	407	1.39	34.8	31.4	4.45
2	Vitavax 200 FF, 2.5 L/t	314	617[1)]	468[1)]	1.54[1)]	32.3	31.9	4.82[1)]
3	EHF 1.8 kW/kg, 15 sec.	313	643[1)]	467[1)]	1.49[1)]	33.1	31.7	4.90[1)]
4	EHF 1.8 kW/kg, 15 sec.+Mars EL, 0.2 L/t	296	596	456	1.55[1)]	34.2	32.6[1)]	5.08[1)]
5	EHF 0.9 kW/kg, 45 sec.	335[1)]	663[1)]	471[1)]	1.43[1)]	34.7	31.7	5.18[1)]
6	EHF 0.9 kW/kg, 45 sec.+Mars EL, 0.2 L/t	314	600[1)]	464[1)]	1.48[1)]	34.4	32.8[1)]	5.24[1)]
correlation coefficient with yield capacity		0.60	0.63	0.80	0.38	0.12	0.70	-
SSD $_{05}$		25.2	52.1	50.8	0.12	0.8	0.9	0.35

Note: [1)]-Significant difference.

We primarily influenced the formation of the structural elements of the winter wheat crop and its biological yield capacity by the agrometeorological conditions of the growing year. Thus, in 2011, the biological yield capacity of the Astet winter wheat variety according to the research was 4.94 t/ha on average, in 2012, it was 5.14 t/ha, and in 2013-6.91 t/ha (Table 3-6).

Table 5. Yield structure of Astet winter wheat variety according to the application of EHF MWF and the Mars EL plant growth regulator, 2012.

S.No.	Cases of Seed Pre-sowing Seed Treatment	Number, pcs/m^2			The Factor of Productive Tillering	Grain Content in the Ear, pcs/ear	Weight of 1000 grains, g	Biological Yield Capacity, t/ha
		Plants	Stems in total	Productive Stems				
1	Control without treatment	388	709	571	1.47	22.7	38.7	5.02
2	Vitavax 200 FF, 2.5 L/t	380	734	598	1.45	22.5	37.3	5.02
3	EHF 1.8 kW/kg, 15 sec.	415[1)]	864[1)]	643[1)]	1.41	22.2	36.8	5.25[1)]
4	EHF 1.8 kW/kg, 15 sec.+Mars EL, 0.2 L/t	394	752	626[1)]	1.58	22.0	38.3	5.27[1)]
5	EHF 0.9 kW/kg, 45 sec.	430[1)]	756	603[1)]	1.40	23.7[1)]	36.7	5.24[1)]
6	EHF 0.9 kW/kg, 45 sec.+Mars EL, 0.2 L/t	393	735	603[1)]	1.54	23.1	36.3	5.06
	correlation coefficient with yield capacity	0.73	0.64	0.78	-0.06	0.14	-0.13	-
	SSD $_{05}$	25.9	75.2	31.1	0.11	0.8	2.5	0.21

Note: [1)]-Significant difference.

Table 6. Yield structure of Astet winter wheat variety according to the application of EHF MWF and the Mars EL plant growth regulator, 2013.

S.No.	Cases of Seed Pre-sowing Seed Treatment	Number, pcs/m^2			The Factor of Productive Tillering	Grain Content in the Ear,	Weight of 1000 Grains, g	Biological Yield Capacity, t/ha
		Plants	Stems in Total	Productive Stems				
1	Control without treatment	353	604	511	1.45	30.6	41.7	6,52
2	Vitavax 200 FF, 2.5 L/t	358	613	527	1.46	31.3[1)]	41.9	6,91[1)]
3	EHF 1.8 kW/kg, 15 sec.	379[1)]	638	546[1)]	1.45	31.4[1)]	41.3	7,08[1)]
4	EHF 1.8 kW/kg, 15 sec.+Mars EL, 0.2 L/t	344	593	544[1)]	1.53	30.6	42.5	7,07[1)]
5	EHF 0.9 kW/kg, 45 sec.	376	607	532	1.50	31.1	41.5	6,87[1)]
6	EHF 0.9 kW/kg, 45 sec.+Mars EL, 0.2 L/t	371	626	540[1)]	1.52	30.6	42.5	7,02[1)]
	correlation coefficient with yield capacity	0.27	0.37	0.97[1)]	0.48	0.28	0.29	-
	SSD $_{05}$	24.2	45.4	23.2	0.10	0.6	1.2	0.31

Note: [1)]-Significant difference.

Pre-sowing seed irradiation with MWF of EHF in the modes of 1.8 kW/kg, 15 s or 0.9 kW/kg, 45 sec. only or with additional seed treatment with the Mars EL growth regulator, 0.2 L/t, positively affecting field germination, growth and plant development processes, and increasing the resistance of plants to root rots, caused the formation of a larger number of elements of the yield structure and increased the biological yield capacity of winter wheat. On average for 2011-2013, according to the structural analysis of the results of the yield capacity structural analysis, it has been established that, depending on the method of seed preparation, the high density of the plant and the total number of stems, including the productive ones, remained until the harvest period and were 1 to 56, 37 to 96 and 35 to 56 pieces/m^2, respectively, while under control these indices were 344, 619 and 496 pieces/m^2, respectively. The correlation coefficient of these indices with biological productivity made up 0.51, 0.75, and 0.91, respectively. Depending on the method of pre-sown seed treatment, the grain content in the ear and the weight of 1000 grains did not change significantly, and these indices practically did not influence the level of winter wheat yield capacity; the correlation coefficients made up 0.01 and 0.09.

On average for 2011-2013 in the cases of pre-sowing seed treatment with EHF MWF, 1.8 kW/kg, 15 sec and EHF MWF, 1.8 kW/kg, 15 sec+Mars EL, 0.2 L/t, the biological yield capacity of winter wheat increased by 6% and 7%, respectively; the yield capacity under control was 5.42 t/ha. In similar cases of irradiation with EHF MWF in the mode 0.9 kW/kg, 45 s, the biological yield capacity was almost the same and was 5.76 and 5.77 t/ha, respectively, which is on average 6% higher than the control. With traditional seed treatment with Vitavax 200 FF at the recommended consumption rate of 2.5 L/t, the biological yield capacity was 5.58 t/ha on average for three years, 3% higher than the control. The harvesting and recording of the yield on the experimental plots confirmed the tendencies as to the variability of this index depending on the method of the pre-sowing seed treatment revealed under the structural analysis of the winter wheat yield capacity of the Astet variety. We determined that the pre-sowing seed irradiation with EHF MWF in the mode of 1.8 kW/kg of seeds and exposure of 15 seconds, as well as in the mode of 0.9 kW/kg of seeds and exposure of 45 sec. allows for increasing the winter wheat yield capacity significantly; on average, for 2011-2013, it increased by 0.19 and 0.24 t/ha, or by 3.5 and 4.5% respectively, the yield under control amounted to 5.39 t/ha (Table 7).

Table 7. Yield capacity of Astet winter wheat variety depending on the method of pre-sowing seed treatment, t/ha.

S.No.	Seed Treatment Methods	Years			Average	+/- Before Control	
		2011	2012	2013		t/ha	%
1	Control without treatment	4.44	5.09	6.63	5.39	-	-
2	Vitavax 200 FF, 2.5 L/t (standard)	4.66	5.09	6.72	5.49	0.10	1,9
3	MWF of EHF, 1.8 kW/kg, 15 sec.	4.73[1)]	5.21[1)]	6.79[1)]	5.58[1)]	0.19	3,5
4	MWF of EHF, 1.8 kW/kg,15 sec.+Mars EL, 0.2 L/t	4.88[1)]	5.18	6.82[1)]	5.63[1)]	0.24	4,5
5	MWF of EHF, 0.9kW/kg, 45 sec.	4.99[1)]	5.26[1)]	6.65	5.63[1)]	0.24	4,5
6	MWF of EHF, 0.9kW/kg, 45 sec.+Mars EL, 0.2 L/t	4.64	5.09	6.69	5.47	0.08	1,5
	SSD $_{05}$	0,22	0.12	0.11	0.18	-	-

Note: [1)]-Significant difference.

However, it should be noted that the efficiency of such seed treatment has varied significantly over the years. For example, in 2011, when the agro-meteorological conditions were the least favorable for the growth and development of winter wheat, which led to the lowest level of yield during the research period, the positive effect of the application of MWF of EHF was the increase in highest-the yield increase was the largest. It amounted to 7 and 12% according to irradiation mode, with a yield under the control of 4.44 t/ha. When treating the seeds with Vitavax 200 FF at the recommended rate of 2.5 L/ha, the yield capacity of the Astet winter wheat variety was increased by 0.1 t/ha on average for three years. Moreover, we also observed the largest significant effect of this method in 2011, the increase was 0.22 t/ha. The efficiency of the additional presowing treatment of the seeds irradiated with EHF MWF and treated with Mars EL growth regulator at a consumption rate of 0.2 L/t depended on the irradiation mode and the conditions of the research year. Therefore, on average for 2011-2013, with EHF MWF irradiation, 1.8 kW/kg, 15 sec.+Mars EL, 0.2 L/t, the winter wheat yield was 5.63 t/ha, while with EHF MWF, 1.8 kW/kg, 15 sec. It was 5.58 t/ha.

The efficiency of the pre-sown seed treatment with MWF of EHF in 0.9 kW/kg mode, 45 sec. because of the additional treatment of Mars EL has decreased. Thus, on average for three years, the winter wheat yield capacity in this case was 5.47 t/ha, which is 0.16 t/ha less than in the cases with EHF MWF, 0.9 kW/kg, 45 sec. Only in 2013 was the yield capacity of winter wheat under double treatment relatively higher and amounted to 6.65 and 6.69 t/ha, respectively. Thus, the most effective methods of pre-sowing seed treatment that cause an increase in winter wheat yield capacity compared to Vitavax 200 FF seed treatment, 2.5 L/t are EHF seed irradiation with MWF in the mode of 0.9 kW/kg, 45 sec. or EHF seed irradiation with MWF in the mode of 1.8 kW/kg, 15 sec. with additional treatment with Mars EL growth regulator, 0.2 L/t.

Winter wheat seed sowing qualities depending on the method of pre-sowing treatment with MWF of EHF

In our research, we performed a laboratory analysis of the seeds' sowing qualities after harvesting the Astet variety's winter wheat. According to the data of V.V. Malynovskyi, the MWF of EHF irradiation of winter wheat seeds of the Soiuz and Viktoriia varieties with low germinating power in the agricultural firm APF 'Aleks' (Zaporizhzhia Oblast) increased the germinating power from 82 to 84%, 92 and 95%, respectively (Antonov, 2009). The germinating power of the winter wheat seeds harvested on average for 2011-2013 was mainly high, within 96-97%, so we did not establish a significant difference between the research cases (Table 8). This confirms the results of our laboratory research carried out after the presowing seed treatment with MWF of EHF and Mars EL growth regulator before sowing).

Table 8. Sowing qualities of the Astet winter wheat variety depending on the MWF of the EHF application (after harvest in 2011-2013).

S.No.	Seed treatment case	Sprouting energy,%			Average	Germinating power,%			Average
		2011	2012	2013		2011	2012	2013	
1	Control without treatment	98	95	94	96.6	98	95	96	96.3
2	Vitavax 200 FF, 2.5 L/t	95[1)]	97	96[1)]	96.0	96	97	97	96.6
3	MWF of EHF, 1.8 kW/kg, 15 sec.	99	95	95	96.0	99	96	97	97.3
4	MWF of EHF, 1.8 kW/kg,15 sec.+Mars EL	98	93	96[1)]	96.6	98	94	97	96.3
5	MWF of EHF, 0.9kW/kg, 45 sec.	97	95	95	96.0	98	95	96	96.3
6	MWF of EHF, 0.9kW/kg, 45 sec.+Mars EL	98	95	95	96.6	99	96	96	97.0
	SSD $_{05}$	1.5	2.5	1.8	1.5	1.4	2.1	1.5	1.3

Note: 1)-Significant difference.

Winter wheat grain quality indices depending on the method of pre-sowing seed treatment with MWF of EHF

Among the techniques aimed at obtaining high-quality wheat grain, the shortest possible terms of grain harvest play an important role. A delay in the harvesting terms and being in the swaths over a long period increases the grain falling and decreases the grain glassiness. The yield losses 20 days after full ripening are 0.25-0.64 t/ha, depending on the variety. The protein content is reduced by 1.2-1.4% compared to the control, and the gluten content is reduced by 2-4% (Gasanova et al., 2010; Dencic et al., 2011; Soloshenko et al., 2014). Several factors influence the formation and quality of winter wheat grain, among which the genetic potential of the variety, agroclimatic conditions, and agrotechnical measures or elements of the crop growing technology are the main factors ones.

There is feedback between the yield value and the protein content in the wheat grain. It formed high yields under optimal weather, but protein accumulation in the grain is decreasing (Medinec, 2009; Mladenov and Kobiljski, 2011). According to the data of M.H. Tsekhmeistruk, N.V. Kuzmenko, and A.E. Lytvinov, the sun pest bug and weather conditions have a significant influence on the formation of the yield and quality of winter wheat grain. Thus, in 2011, the damage of winter wheat shoots caused by the sun pest at the end of the spring tillering phase was the largest and amounted to 5.5%, and the damage caused by the intra-stem pests was 20,0% (Bublik and Vasechko, 2011). During the winter wheat vegetation period, the epidemiological threshold of the harmfulness of root rot was 5% as for damaged plants; the seeds were damaged by 10-15%. 5% of spring barley plants and 12% of seeds were damaged during the arid years and 34% of seeds were damaged during the wet years.

In 2012 and 2013, the damage of the shoots caused by the sun pest bug was significantly lower-2.2 and 0.4% respectively, though the damage caused by the intrastem pests was, on the contrary, higher-26.2 and 31.1%. In 2011, the damage to the winter wheat grain of the Astet variety caused by the sun pest bug was the highest and amounted to 4.5%, in 2012, the damage was 1.1%. The quality of wheat grain depends not only on the quantity and quality of gluten, but also on the state of the hydrate and amylose complex of the grain, which is determined by the index of falling number, which can range from 60 to 600 sec. or more. The bread meets the standard when the falling number is not less than 150 sec. (Podpryatov et al., 2004; Medinec, 2009; Glupak and Radchenko, 2014). The results of the research testify that the quality indices of the Astet winter wheat grain, namely the specific weight of protein, fluid gluten content, and its quality, and falling number varied depending on the year conditions and on pre-sown seed treatment method. However, the changes were mostly insignificant. The grain quality under control and in the standard case of treating seeds with Vitavax 200 FF and the cases of MWF of EHF application corresponding to the third class (III) on average for 2011-2013 (Table 9). However, in different years of research, some quality indices could be referred to as higher classes. Thus, the falling number ranged from 352 to 390 units, corresponding to high grain quality indices.

In 2011, the fluid gluten and protein content in the grains of the Astet winter wheat variety under seed irradiation with MWF of EHF in the mode of 1.8 kW/kg of seeds and exposure of 15 sec. The gluten quality in the grains of the Astet variety was from 43 units of gluten deformation measurement (GDM) (corresponding to the second group) under control up to 58 units of gluten deformation measurement (corresponding to the first group) with EHF seed irradiation in the mode of 0.9 kW/kg of seeds, 45 sec. Reduced to 20.4-21.2% and 12.0-12.1%, respectively, these indices were 22.4% and 12.3% under control. The irradiation of the seeds in the mode of 0.9 kW/kg and the exposure of 45 sec, on the contrary, contributed to the increase in fluid gluten up to 22.8-24.8% (Table 7). Only the winter wheat grain irradiated with EHF MWF in the mode of 0.9 kW/kg of EHF, 45 sec. can be referred to the second class according to the content of fluid gluten in it, and the grains treated with other methods belong to the third class. In our researches in 2011, the case with EHF MWF of 45 sec. and the gluten content (should note 0.9 kW/kg24.8%), it can be referred to as the 2nd class, at 22.4% under control.

Table 9. Winter wheat grain quality indices depending on pre-sown seed treatment with MWF of EHF and growth regulator Mars EL.

S.No.	Case	Years	The Specific Weight of Protein,%	Fluid Gluten		Falling Number, sec.	Class
				Specific Weight,%	GDM Units/group		
1.	Control, without treatment	2011	12.3	22.4	55/I	376	III
		2012	11.5	21.2	45/I	396	III
		2013	12.9	20.0	30/II	399	III
		average	12.2	21.2	43/II	390	III
2.	Vitavax 200 FF, 2.5 L/t	2011	12.4	22.4	50/I	336	III
		2012	12.0	23.2	60/I	383	III
		2013	12.0	18.4	25/II	407	III
		average	12.1	21.3	45/I	375	III
3.	MWF of EHF, 1.8 kW/kg, 15 sec.	2011	12.1	20.4	40/II	336	III

		2012	11.9	22.8	65/I	336	III
		2013	12.0	19.2	40/II	385	III
		average	12.0	20.8	48/I	352	III
4.	MWF of EHF, 1.8 kW/kg,15 sec.+Mars EL	2011	12.0	21.2	40/II	377	III
		2012	11.7	23.6	75/I	406	III
		2013	12.2	18.8	20/II	387	III
		average	12.0	21.0	45/I	390	III
5.	MWF of EHF, 0.9 kW/kg, 45 sec.	2011	12.4	24.8	60/I	306	III
		2012	12.1	24.4	85/II	409	III
		2013	12.4	18.4	30/II	389	III
		average	12.3	22.5	58/I	368	III
6.	MWF of EHF, 0.9kW/kg, 45 sec.+Mars EL	2011	12.3	22.8	40/II	347	III
		2012	11.4	23.6	75/I	385	III
		2013	12.6	20.8	25/II	377	III
		average	12.1	22.4	47/I	370	III

In 2012, we also observed the best grain quality indices under EHF seed irradiation with MWF in the mode of 0.9 kW/kg of seeds and exposure of 45 sec; the fluid gluten content made up 24.4% and protein-12.1%. In the case with EHF the irradiation with MWF of EHF in the mode of 1.8 kW/kg of seeds and exposure of 15 sec. The content of fluid gluten made up 22.8%, and protein-11.9%, and with additional treatment with Mars EL growth regulator, the content of fluid gluten was 23.6% and 11.7%, respectively, under control; these indices were 21.2% and 11.5%.

In 2013, we observed the lowest grain quality. The fluid gluten content ranged from 18,4 to 20,8%, and the protein content ranged from 12.0 to 12.9%. We observed the highest amount of fluid gluten under EHF MWF irradiation in the mode of 0.9 kW/kg of seeds and exposure of 45 sec; in the case with the additional application of the Mars EL growth regulator, it was 20.8%, the protein content was 12.6%, while under control they were 20.0% and 12.9%. According to grain quality indices, the rest did not exceed the control.

On average, for 2011-2013, the content of fluid gluten in the grain was irradiated with EHF MWF in the mode of 0.9 kW/kg of seeds and exposure of 45 sec. increased to 22.4-22.5%, while these indices were 21.2% under control. The protein content in the grain did not change significantly. Considering the conditions of elements of the formation of the winter wheat grain during research, it should be noted that at the beginning terms of the resumption of spring vegetation in 2013, 2011 (March 31 and April 2), the protein content in the grain made up 12.9 and 12.3%, and later in 2012 (April 18), it was 11.5%. The fluid gluten content was 20.0, 22.4, and 21.2%, respectively.

Conclusion

The formation of the elements of the winter wheat yield structure and its biological yield capacity was in the first turn influenced by the agro-meteorological conditions of the growing year. Winter wheat yield capacity had a significant positive correlation with the number of productive stems (r=0.91) and a close correlation with the total number of stems (r=0.75).

The most efficient methods of a pre-sowing seed treatment that cause an increase in the winter wheat yield capacity compared to the seed treatment with Vitavax 200 FF, 2.5 L/t are the seed irradiation with EHF MWF in the mode of 0.9 kW/kg, 45 sec. or the seed irradiation with EHF MWF in the mode of 1.8 kW/kg, 15 sec. with the additional treatment of the Mars EL growth regulator, 0.2 L/t. At high sowing quality indices of the harvested winter wheat grains of the Astet variety within 96-97% of the naturally determined influence of EHF MWF only or together with the Mars EL growth regulator on the indices of sprouting energy and germinating power have not been established. The baking qualities of winter wheat grains of the Astet variety did not change significantly depending on the method of the pre-sown seed treatment. According to the protein content indices and the amount and quality of fluid gluten, the winter wheat grain under control and in the standard case with Vitavax 200 FF seed treatment, as well as in the cases of applying EHF MWF and Mars EL growth regulator, corresponding to the third class (III) on average for 2011-2013.

We observed the highest fluid gluten content in the wheat grains in EHF case of the seed irradiation with MWF of EHF in the mode of 0.9 kW/kg of seeds and exposure of 45 sec; it was 22.4-22.5%, while under control, it was 21.2%.

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