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ORIGINAL ARTICLE

Influence of pre-sowing seed treatment with MFF and growth regulators on winter wheat and spring barley development

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We registered that seed treatment with MWF of EHF, and in combination with the growth regulator, Mars EL increased the height of the winter wheat plants of the Astet variety from the spring resumption of vegetation on average by 4.0–7.9 cm at 66.6 cm under control. The tillering factor increased by 0.2–0.4 at the index of 2.9 under control; the leaf surface in the phases of tillering, stalk shooting, and ear formation also increased by 12–23, 6–13, and 9–19%, respectively, while under control the leaf surface was 11.7, 29.4, and 37.8 thousand m^2/ha; PSP increased by 9–16% while under control it was 1,21 million m^2 days/ha. The highest and most stable results were provided by applying MWF of EHF in the mode of 0.9 kW/kg, 45 sec only, or additional treatment with the Mars EL preparation. The pre-sowing treatment of Aspect and Vyklyk varieties seeds with MWF of EHF in 0.9 kW/kg, 45 sec or 1.8 kW/kg, 20 sec, and the growth regulators Radostim or Albit increased the height of plants on the average by 3.4–8.0 cm. The plant density increased by 5–10%, the leaf surface in the phases of tillering, stalk shooting, and ear formation increased by 7–16, 6–30, and 10–32% in the Aspect variety. In the Vyklyk variety, these indices were 13–33, 8–36, and 9–37%, respectively. The PSP increased by 8–27% and 11–37% in Aspect and Vylkyl varieties, while in control, these indices were 51.9 and 43.9 cm, 293 and 328 pcs/m^2, 9.9, 19.1, 15.6, 9.9, 19.0, and 15.9 thousand m^2/ha, 0.63 and 0.63 million m^2 days/ha, respectively.
Keywords: disinfection, fungicides, growth regulators, pathogens, seeds, grain, winter wheat, spring barley, microwaves.

Introduction

The world experience shows that in the countries with high levels of agro-technical support, the increase in grain yield reaches a critical limit. The "intensive" technologies in crop production have sharpened the contradictions between the economy and the environment since the 1980s. The intensive application of pesticides and mineral fertilizers in agriculture, including chemicals for the pre-sowing seed treatment, and increasing the productivity of plants cause several undesirable effects of ecological and economic characters. One of the obligatory elements of the technological process of cultivating cereal crops, which affects the increase in the 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, seed sanitation and selection of 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 (Shevchenko et al., 2007; Tuchnyj et al., 2007a, 2007b, 2012). The dependence of winter wheat yield capacity on agro-meteorological factors in the territory of Ukraine has been studied by several scientists (Krenke et al., 1992; Tarariko et al., 2013). It is known that the rate of plant development is closely connected with the weather conditions of a particular year. The analysis of the features of crop development in interaction with the meteorological factors is a significant part of agro-meteorological information. In this case, the criterion for evaluating agrometeorological conditions in which the crop is grown in the grain yield capacity's value and quality (Kuperman, 1955; Krenke et al., 1992).

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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, the sum of the effective temperatures (above 5 °C), and amount of precipitation in interaction with the crop productivity elements.

Material and methods

The research program aimed to determine the influence of the following factors on the yield capacity and quality of spring barley products: Varieties, factor A: 1. Aspect, 2. Vyklyk; Seed treatment, factor B: Experiment No1. To examine the effects of the microwave fields (MWF) of extra high frequencies (EHF) and plant growth regulators on spring barley's sowing qualities and yield capacity. 1. Control, without treatment; 2. Vitavax FF, 2.5 L/t; 3. Radostim, 0,.5 L/t; 4. Albit, 30 ml/t; 5. MWF of EHF 0.9 kW/kg, 45 sec; 6. MWF of EHF 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1.25 L/t; 7. MWF of EHF 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t; 8. MWF of EHF 0.9 kW/kg, 45 sec + Albit, 30 ml/t; 9. MWF of EHF 1.8 kW/kg, 20 sec; 10. MWF of EHF 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t; 11. MWF of EHF 1.8 kW/kg, 20 sec + Radostim, 0.25 L/t; 12. MWF of EHF 1.8 kW/kg, 20 sec + Albit, 30 ml/t; Experiment No 2. To examine the effect of the microwave fields (MWF) of extra high frequencies (EHF) on the sowing qualities and yield capacity of the Astet winter wheat variety. 1. Control, without treatment; 2. Vitavax 200 FF, 2.5 L/t; 3. MWF of EHF 1.8 kW/kg, 15 sec; 4. MWF of EHF 1.8 kW/kg, 15 sec + Mars EL, 0.2 L/t; 5. MWF of EHF 0.9 kW/kg, 45 sec; 6. MWF of EHF 0.9 kW/kg, 45 sec + Mars EL, 0.2 L/t.
The following indices were used to characterize the agrometeorological conditions of winter wheat and spring barley cultivation during the research period: duration of interphase periods, average daily air temperature, the sum of the effective temperatures (above 5 °C), and amount of precipitation in interaction with the crop productivity elements.
Agro-meteorological conditions for winter wheat cultivation
During the research period, the sowing of winter wheat was carried out in the terms optimum for the Eastern Forest-Steppe Zone, namely in the second decade of September. Characteristic for this zone, a sharp change in weather conditions 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 a minimum period of 115 days in 2012 (Table 1). The autumn period, which conditions form the sprouting and tillering of the plants, is an important stage of winter crop development. The duration of the interphase period of sowing – sprouting did not change significantly over the years and was 6–7 days. Insignificant fluctuations in 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 precipitation was 25 mm in 2010, and the minimum one was 5.3 mm in 2011. The next interphase period of the autumn vegetation "sprouting – tillering" falls on the third decade of September and the first decade of October (Table 1). The duration of the period varied within 15–19 days over the years (Table 2). There was a significant fall in average daily temperature to 10.7 °C and sum of effective temperatures up to 76 °C under maximum precipitation of 81 mm with a long-term rate of 20 mm in 2010. The optimum conditions for vegetation were noted only in 2012.

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

Sowing	Sprouting	Tillering	Stopping of autumn 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

However, the agro-meteorological conditions for winter wheat cultivation varied significantly over the research period, which led to different duration of interphase periods of plant growth and development and ultimately to different levels of crop yield capacity over the years.
Thus, in 2010–2011 the vegetation period of the Astet winter wheat variety lasted 156 days (from the sowing date to full ripeness). At the same time, during the growing season, the sum of effective temperatures was 1302 °C, and the amount of precipitation was 452.6 mm (Table 2).
A characteristic feature of winter wheat vegetation in 2010–2011 was the absence of the effective temperatures during the interphase period of "tillering – stopping of autumn 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 174.0 °C respectively. The resumption of vegetation was noted on April 2, 2011. Another feature of 2010–2011 was 46 % (207 mm) of the annual amount of precipitation during the interphase period of "ear formation – full ripening". In such conditions, the winter wheat yield capacity of the Astet variety in 2011 was 4.44 t/ha on average.

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

№	Indices	Interphase period							
		sowing-sprouting	sowing-tillering	tillering stopping of vegetation	RSV–stalk shooting	stalk shooting-ear formation	ear formation full ripening	the sum of days over vegetation period	yield capacity, t/ha
				2010–2011					
1	Duration of 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 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 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	

In 2011–2012 the vegetation period of winter wheat 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 vegetation period of wheat was 86,5 mm. At the same time, 62 % (54 mm) of precipitation has been distributed evenly 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" took place at the high average daily air temperatures; as a result, the sums of the effective temperatures during these periods were 148.0 and 405 °C at the duration of the periods of 19 and 27 days respectively. The resumption of vegetation was observed 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 2011–2012, the agro-meteorological conditions of winter wheat vegetation were more favorable than in the previous period, making it possible to obtain the yield capacity at the level of 5.09 t/ha.

The vegetation period of winter wheat in 2012–2013 should be marked as the most favorable during field research. Its duration was 145 days at the highest sum of the effective temperatures of 639 °C and the precipitation amount of 234.9 mm. The interphase period of "sprouting – tillering" at high average daily air temperatures (15.6 °C on average compared with 10.7 and 12.8 °C in the previous periods) was 15 days. In 2010–2011 and 2011–2012, the duration was 15 and 19 days, and the sum of the effective temperatures was 151.0 °C. It is noteworthy that the tillering of winter wheat took place under favorable conditions and lasted almost until the stopping of autumn vegetation; the average daily air temperature was 9.4 °C, and the sum of effective temperatures was 180 °C. There was 115 mm of precipitation or 49 % of the total precipitation for the crop vegetation period during this period. The period of "resumption of vegetation – stalk shooting" was also favorable for 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). The resumption of vegetation was noted on March 31. The Astet winter wheat variety vegetation from stalk shooting to full ripeness took place at high average daily air temperatures. At the same time, the sum of the effective temperatures was 754 °C, and there was 91.2 mm of precipitation.

One of the critical vegetation periods of winter cereals is the "tillering" phase. During this period, the lateral shoots and a secondary root system are formed from the underground stem nodes; that is, the setting of organs that determine the crop yield occurs. The indices of productive tillering depend on the conditions of autumn and winter periods. The water reserve is a significant factor under air temperature of 15–18 °C (Ulanova, 1975; Vrkach, 1984; Lihochvor & Petrichenko, 2006). The interphase period of "sprouting –tillering" fell on the third decade of September and the first decade of October. We registered that the duration of the period varied over the years from 15, 19, and 13 days respectively (Table 2). This period was characterized by lowering temperatures in 2010 and 2011; the temperatures were 10.7 and 12.8°C, respectively, whereas, in

2012, the temperature drop was insignificant – 15.6 versus 16.9 °C. In 2010 the sum of the effective temperatures was minimum (76 °C) against a background of maximum precipitation of 81 mm at average long-term precipitation of 20 mm. In 2011 and 2012, the same period was drier; the sum of the effective temperatures amounted to 148–151 °C at a minimum amount of precipitation of 12.2–13.1 mm. Consequently, the sharp fluctuations in the heat and humidity were not optimum for the intensive tillering during the examined vegetation period. It is known that the tillering phase of winter cereals continues until stopping of the vegetation, that is, until a steady rise in the average daily temperature above 5 °C (Lihochvor et al., 2003; Lichhochvor & Petrichenko, 2010).

The duration of the "tillering – stopping of vegetation" period varied significantly depending on the meteorological conditions of the autumn growing season. If the beginning of the "tillering" phase was noted almost simultaneously (the first decade of October), then the date of stopping the autumn vegetation of winter wheat ranged within the limits of 15–20 days. The most extended interphase period of tillering - stopping of vegetation (49 days) was observed in 2010 and was accompanied by a lowering in the average daily air temperature to 7 °C, the sum of the effective temperatures was 96 °C and the precipitation amount was 72 mm. Such weather conditions were 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 the plants. The lowering of air temperature for 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 of vegetation" were observed in 2012; the period lasted up to 36 days with a slower lowering of air temperature up 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 autumn vegetation showed that winter wheat significantly responds to the changes in weather conditions. The corresponding reaction of the plants influenced the field germination and tillering as the main elements of the yield structure. Stopping the autumn vegetation of winter wheat varied from the first to the third decade of November and depended on the temperature regime. In winter wheat, autumn, and winter periods are also important for forming water reserves in the soil in early spring. The well-developed crops are intensively developing, forming the leaf tube and spikelets in the ear using mainly the spring water reserves.

During the research period, the most favorable water supply conditions at the beginning of spring were noted in 2013. The amount of precipitation in November–March was 211 mm, which exceeded the average long-term rate by 15 %. In 2011 and 2012, the precipitation was significantly low and was 149 and 122 mm, respectively, or 81 % and 67 % of the rate. The terms of the 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 leading cause of spring crop losses was the late date of the vegetation resumption when the plants could not adapt quickly to sudden temperature changes. According to our research (Table 1), the earliest date of the 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.

The date of early vegetation of winter wheat (April 2) was registered in 2011. However, the interphase period from the vegetation resumption to the stalk shooting phase was 21 days shorter than in 2013. When the primary biomass is accumulated, the shortening of the active vegetation period influences the shortage of productivity. The critical conditions of the period under consideration were 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 the "vegetation resumption – stalk shooting" up to 27 days was due to the rise in the temperature regime. The sum of the effective temperatures of 405–455°C exceeded the average long-term norm almost twice, and the amount of precipitation was two times lower.

The duration of the interphase period of "stalk shooting – ear formation" (Table 2) varied from 7 to 19 days against the background of the temperature rise. The average daily temperature was within the range of 17–22°C, the sum of the 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 winter wheat yield capacity is the period from ear formation to full ripening. This period was minimal in 2012 – 26 days and maximal up to 37 days in 2011 and 2013 at an optimum temperature of 20–23°C. However, the fluctuation precipitation from 29 mm in 2012 to 207 mm in 2011 led to a yield shortage up to 4.44 and 5.09 t/ha in 2011 and 2012. Moreover, in 2013, the yield capacity was 6.63 t/ha (this was the highest winter wheat yield capacity in our research).

Agro-meteorological conditions for spring barley cultivation

The spring barley crop, by its biological characteristics, is not frugal of heat. The minimum temperature of seed sprouting is +1...2 °C; the seedlings can withstand the short-term light frosts up to –3.... – 4 °C. Such features determine the early terms of barley sowing Cherenkov et al., 2010). In recent years the spring rise in the air temperature above 0 °C during 20–25 days and more has fluctuated sharply. Therefore, the sowing dates of the early ripening spring cereal crops need annual adjustments considering air temperature and water accumulation in the soil (Krenke et al., 1992; Yizhik, 2001). Early sowing dates facilitate more efficient water use accumulated in early spring; diseases and pests less damage the plants. It is essential that early sowing delays the transition to the generative phase of development and has a positive influence on the density of productive stems and the yield capacity (Nasinnya silskogospodarskih kultur...., 1994).

Brewing barley is susceptible to late sowing, which leads to a deterioration of grain quality – the huskiness is increased, the size of grain and the starch content are reduced (Lichhochvor & Petrichenko, 2010). In 2011, the sowing of barley was carried out on April 24. The vegetation period of spring barley, irrespective of a variety, lasted 91 days. The sum of the effective temperatures was 1308 °C, and the average daily temperature was 19,4 °C at an amount of precipitation of 292 mm (Table 3). A characteristic feature of 2011 was 165,3 mm or 57 % of precipitation (mainly heavy showers) during the interphase period of "ear formation – full ripening". In such conditions, there was a significant lodging of spring barley plants on the experimental plots, which worsened the conditions of ripening and harvesting. Another feature of spring barley vegetation in 2011 was the slow development of plants at the beginning of the vegetation period due to a fall in air temperature. For example, the "sowing

– stalk shooting" period lasted 50 days, whereas the "stalk shooting – ear formation" period was shorter for the entire research period and lasted 14 days. In such conditions of 2011, the Aspect variety produced a yield of 2.95 t/ha.
The agrometeorological conditions in 2012 can be generally described as the most favorable for spring barley cultivation during the research period. The sowing was carried out on April 18. The vegetation period of barley, irrespective of a variety, was the shortest and lasted 83 days from the sowing to full ripening. Thus, the interphase periods "sowing – sprouting" and "sprouting – tillering" were the shortest – 8 and 19 days. In general, the development of plants from sowing to stalk shooting lasted 35 days, which is 15 days less than in 2011. The average daily temperature of the vegetation period in 2012 was 21.1 °C, which is 1.7 °C higher than in 2011, and the sum of the effective temperatures was 1335 °C. In 2012 the amount of precipitation was 79 mm, the least during the entire period of the research, while in the interphase period of "sowing – tillering," there was no precipitation.
However, the development of spring barley plants during the period from tillering to full ripening took place under favorable conditions in terms of temperature and moisture, which made it possible to form the highest level of the yield capacity of barley varieties in our researches: Aspect – 4.72 t/ha and Vyklyk – 4.83 t/ha. Early spring was observed in 2013 when the rise of air temperature above 0 and 5 °C took place almost simultaneously and fell in the middle of the third decade of March. Under such conditions, the sowing of spring barley was carried out earlier, namely on April 17.

Table 3. Duration of interphase periods of spring barley development depending on agro-meteorological conditions, 2011-2013

Index	Interphase period					Sum for the vegetation period	Yield capacity, t/ha	
	Sowing-sprouting	Sprouting-tillering	Tillering-stalk shooting	Stalk shooting-ear formation	Ear formation-full ripening		Aspect	Vyklyk
Duration of interphase period (days)	10	20	20	14	27	91	2.95	-
Average daily air temperature, °C	14.4	16.1	21.0	20.7	21.8	19.4		
Sum of effective temperatures above 5 °C	94.0	222.0	320.0	220.0	452.0	1308		
Amount of precipitation, mm	2.0	32.0	15.2	77.2	165.3	292		
2012								
Duration of interphase period (days)	8	8	19	20	28	83	4.72	4.83
Average daily air temperature, °C	15.6	19.4	22.5	19.5	23.3	21.1		
Sum of effective temperatures above 5 °C	85.0	116.0	332.0	289.0	513.0	1335		
Amount of precipitation, mm	0.0	0.0	15.2	32.4	31.0	79.0		
2013								
Duration of interphase period (days)	9	9	12	33	24	87	2.69	2.60
Average daily air temperature, °C	14.1	18.0	21.4	21.8	23.4	20.9		
Sum of effective temperatures above 5 °C	82.0	116.0	197.0	554	441.3	1390		
Amount of precipitation, mm	0.0	0.0	4.0	58.0	33.0	95.0		

In the agrometeorological conditions of 2013, the vegetation period of spring barley lasted 87 days. The sum of the effective temperatures was 1390 °C, and the average daily temperature was 21.8 °C at an amount of precipitation of 95 mm (Table 3). At the same time, the interphase periods "sowing – sprouting" and "sprouting – tillering" were the shortest – 9 and 12 days, respectively. In general, the development of plants from the sowing to stalk shooting lasted 30 days, which is five days less than in 2012. During the mass ear formation of barley, the temperature factor significantly influences the final crop yield. The closest feedback between the yield capacity and average daily air temperature during this development phase is observed in the areas where the temperature exceeds 20 °C (Vrkach, 1984; Nasinnya silskogospodarskih kultur…., 1994).
According to the results of the observations carried out in 2013, the yield capacity of spring barley was influenced by the high average daily temperature in the "ear formation" phase (21.8°C), the uneven distribution of precipitation during the vegetation period, and the lowest sum of the effective temperatures in the "tillering – stalk shooting" phase (197.0 °C) (Table 3).

Results

The formation of plant density is continuing throughout the whole vegetation period and is accompanied by the death of some of them before the harvesting period. Many factors, in particular weather conditions, sowing time, seeding rates, and agrotechnical measures, especially in the period of tillering and ear formation, influence the formation of the plant density (Nichiporovich, 1956; Nichiporovich, 1961; Ulanova, 1975; Lepajye, 1993; Shmorgun, 1999; Fatyhov, 2001; Skidan, 2006; Popov et al., 2007; Glupak & Radchenko, 2014). The pre-sowing methods of treating the seeds with MWF of EHF on the formation of plant density and winter wheat and spring barley tillering depending on the agro-meteorological conditions of the growing year were examined during the researches of 2010–2013.

We found out that the increase in the field germination of winter wheat and spring barley seed due to its pre-sowing treatment with MWF of EHF provides the preservation of higher plant density throughout the vegetation period. Thus, during winter wheat autumn tillering in the cases when the seeds were treated with MWF of EHF in the modes of 1.8 kW/kg, 15 sec or 0.9 kW/kg, 45 sec, the plant density was 416 and 425 pieces/m^2 on the average for three years, that is 4 and 7 % more than under control (Table 4). In similar cases with the additional treatment of seeds with the growth regulator Mars EL, the plant density was significantly higher – 436 and 424 pieces/m^2 or 9.5 and 6.5 % more than under the control where it was 398 pieces/m^2. When the record of plant density and the calculation of the formed shoots of winter wheat were carried out simultaneously, it was found out that the tillering factor in the control case amounted to 3.2 on the average for three years, whereas in most cases of the pre-sowing seed treatment it was 3.3. The highest tillering factor (3.4) was observed while treating the seeds with MWF of EHF, 0.9 kW/kg, 45 sec. As a result, on the average for three years, the number of shoots per 1 m^2 under different methods of MWF of EHF application significantly exceeded the control value by 122, 181, 162, and 142 respectively, and also tended to increase by 76, 135, 116 and 96 pieces respectively in comparison with treating the seeds with Vitavax 200 FF.

Table 4. The density of winter wheat plants of Astet variety depending on the method of pre-sowing seed treatment and phase of plant development, 2010–2013

Cases of seed treatment	Autumn tillering			Stalk shooting		
	number, pcs/m^2		tillering factor	number, pcs/m^2		tillering factor
	plants	shoots		plants	stems	
Control	398	1258	3.2	365	1075	2.9
Vitavax 200 FF, 2.5 L/t	400	1304	3.3	392	1222[1)]	3.1
MWF of EHF 1.8 kW/kg, 15 sec	416	1380[1)]	3.2	410[1)]	1306[1)]	3.2
MWF of EHF 1.8 kW/kg,15 sec + Mars EL	436[1)]	1439[1)]	3.3	420[1)]	1288[1)]	3.1
MWF of EHF 0.9kW/kg, 45 sec	425[1)]	1420[1)]	3.4	416[1)]	1378[1)]	3.3
MWF of EHF 0.9kW/kg, 45 sec + Mars EL	424[1)]	1400[1)]	3.3	401[1)]	1295[1)]	3.2
SSD $_{05}$	20,7	95,9	–	29.2	99.8	–

Note [1)] – Significant difference

The significant fluctuations of the plant density indices in the autumn, which were observed during the years of the research regardless of the seed treatment method, are connected with different water content in the period of "germination – stopping of autumn vegetation" (Table 5). The maximum tillering factor were 4.1 and 3.6 in control, the number of stems was 1686 pieces/m^2, and 1400 pieces/m^2 in control were observed in the most humid autumn of 2010. The minimum values of the tillering factor of 2.4–2.6 and the number of stems 980–1028 pieces/m^2 were observed during the dry period of autumn tillering in 2011.

Table 5. Plant density of Astet winter wheat variety depending on MWF of EHF and plant growth regulators application, 2010–2012 (autumn tillering)

Cases of seed treatment	Number of plants, pcs/m^2				Number of stems, pcs/m^2				Tillering factor			
	2010	2011	2012	average	2010	2011	2012	average	2010	2011	2012	average
Control	390	412	391	398	1400	980	1393	1258	3.6	2.4	3.6	3.2
Vitavax 200 FF, 2.5 L/t (standard)	388	395	418	400	1512[1)]	1028	1373	1304	3.9[1)]	2.6[1)]	3.3	3.3
MWF of EHF, 1.8 kW/kg, 15 sec	421[1)]	430	429[1)]	416	1571[1)]	990	1580[1)]	1380[1)]	3.7	2.3	3.7	3.2
MWF of EHF, 1.8 kW/kg,15 sec + Mars EL, 0.2 L/t	430[1)]	437[1)]	440[1)]	436[1)]	1638[1)]	992	1687[1)]	1439[1)]	3.8[1)]	2.3	3.8[1)]	3.3
MWF of EHF, 0.9kW/kg, 45 sec	413	428	433[1)]	425[1)]	1686[1)]	990	1584[1)]	1420[1)]	4.1[1)]	2.3	3.7	3.4[1)]
MWF of EHF, 0.9kW/kg, 45 sec+ Mars EL, 0.2 L/t	427[1)]	413	431[1)]	424[1)]	1554[1)]	1005	1640[1)]	1400[1)]	3.6	2.4	3.8[1)]	3.3
SSD $_{05}$	23.2	24.6	29.6	20.7	89.1	78.4	93.8	95.9	0.20	0.18	0.19	0.15

Note [1)] – Significant difference

We found a total decrease in the number of plants in all cases of the experiment after overwintering. The regularities of these indices varied, depending on the case of the pre-sowing treatment in the whole, have remained the same. Thus, under different methods of applying MWF of EHF, the plant density in the stalk shooting phase exceeded the control indices by 45, 55, 51, and 36 pieces/m^2 on the average for three years, and the number of stems was exceeded by 231, 213, 303 and 220 pieces/m^2 while under control these indices were 365 and 1075 pieces/m^2 respectively. In this case, the tillering factor of winter wheat in the control case was 2.9, and when irradiated the seeds with MWF of EHF separately or with the additional treatment with Mars EL, the tillering factor was 3.1–3.3. This index was maximum when using MWF of EHF in the mode of 0.9 kW/kg, 45 sec (Table 6).

Table 6. Plant density of Astet winter wheat variety depending on MWF of EHF and plant growth regulators application, 2011–2013 (stalk shooting phase)

Cases of treatment	Number of plants, pcs/m^2				Number of stems, pcs/m^2				Tillering factor			
	2011	2012	2013	average	2011	2012	2013	average	2011	2012	2013	average
Control	293	412	390	365	910	1559	756	1075	3.1	3.8	1.9	2.9
Vitavax 200 FF, 2.5 L/t (standard)	377[1)]	395	404[1)]	392	1373[1)]	1653	893[1)]	1306[1)]	3.6[1)]	4.2[1)]	2.2[1)]	3.3[1)]
MWF of EHF, 1.8 kW/kg, 15 sec	420[1)]	420	421[1)]	420[1)]	1290[1)]	1548	827	1222[1)]	3.1	3.7	2.0	2.9
MWF of EHF, 1.8 kW/kg,15 sec + Mars EL, 0.2 L/t	403[1)]	430	427[1)]	420[1)]	1280[1)]	1709[1)]	876[1)]	1288[1)]	3.2	4.0	2.1[1)]	3.1[1)]
MWF of EHF, 0.9kW/kg, 45 sec	420[1)]	425	433[1)]	426[1)]	1180[1)]	1702[1)]	893[1)]	1258[1)]	2.8[1)]	4.0	2.1[1)]	3.0
MWF of EHF, 0.9kW/kg, 45 sec+ Mars EL, 0.2 L/t	337[1)]	412	423[1)]	391	1043[1)]	1663[1)]	909[1)]	1205[1)]	3.1	4.0	2.1[1)]	3.1[1)]
SSD $_{05}$	47.4	26.2	30.7	29.2	129.2	97.2	96.4	99.8	0.19	0.21	0.18	0.17

Note [1)] – Significant difference

It should be noted that the indices of plant density and the number of stems in the stalk shooting phase varied significantly over the years, depending on the conditions of wintering and spring resumption of vegetation. Thus, the maximum values of the tillering factor and stems number were observed in 2012 and amounted to 3.7–4.2 and 1559–1709 pieces/m^{2,} respectively (the control indices were 3.8 and 1559 pieces/m^2), and the minimum ones were in 2013 when the tillering factor for different seed treatments was 1.9–2.2, and the number of stems was 756–909 pieces/m^2 (the control indices were 1.9 and 756 pieces/m^2). The biometric records have established that the pre-sowing treatment of winter wheat seeds with MWF of EHF, depending on the mode and method of application, causes an increase in the height of winter wheat plants. It is noteworthy that when recorded at the beginning of the growing season of wheat – in the phase of autumn tillering – the height of plants in the experimental cases was almost indistinguishable from the control one and amounted to 23.3–24.3 cm at 23.1 cm under control on the average for 2010–2012 (Table 7). However, in the spring, in the stalk shooting phase, the height of plants in the cases of seed treatment with MWF of EHF, 1.8 kW/kg, 15 sec + Mars EL; MWF of EHF, 0.9 kW/kg, 45 sec, and MWF of EHF, 0.9 kW/kg, 45 sec + Mars EL significantly exceeded the control (53,2 cm) by 3.4, 2.2, and 2.7 cm.

Table 7. Height of winter wheat plants of Astet variety depending on pre-sowing seed treatment with MWF of EHF and plant growth regulator, cm

Cases of treatment	Plant development phase											
	autumn tillering				stalk shooting				full ripening			
	2010	2011	2012	average	2011	2012	2013	average	2011	2012	2013	average
Control	16.3	21.7	31.3	23.1	45.0	51.5	63.1	53.2	61.2	71.4	67.2	66.6
Vitavax 200 FF, 2.5 L/t	17.3[1)]	22.2	30.9	23.5	46.1	51.1	64.7	54.0	63.3	75.6[1)]	69.4	69.4
MWF of EHF, 1.8 kW/kg, 15sec	16.6	21.7	31.7	23.3	46.1	52.0	64.5	54.2	67.3[1)]	73.0	71.5	70.6[1)]
MWF of EHF, 1.8 kW/kg, 15 sec + Mars EL	17.2[1)]	22.2	32.2[1)]	23.9[1)]	46.7	55.5[1)]	68.3[1)]	56.8[1)]	71.0[1)]	73.6	74.1[1)]	72.9[1)]
MWF of EHF, 0.9 kW/kg, 45 sec	16.4	21.7	31.8	23.3	47.2	53.3	65.6[1)]	55.4[1)]	66.6[1)]	76.3[1)]	75.7[1)]	72.9[1)]
MWF of EHF 0.9 kW/kg, 45 sec + Mars EL	17.8[1)]	22.6[1)]	32.4[1)]	24.3[1)]	48.2[1)]	53.6	66.0[1)]	55.9[1)]	68.7[1)]	76.7[1)]	78.1[1)]	74.5[1)]
SSD $_{05}$	0.7	0.6	0.7	0.63	3.0	2.7	2.4	1.52	3.1	3.4	5.3	3.9

Note [1)] – Significant difference

In the phase of the full ripening, the height of the plants under all methods of applying MWF of EHF, on average for three years, significantly exceeded the control (66.6 cm) by 4.0, 6.3, 6.3, and 7.9 cm, respectively (Table 8).

Table 8. Plant density of Astet winter wheat variety depending on MWF of EHF and plant growth regulators application, 2011–2013, full ripen

Cases of treatment	Number of plants, pcs/m^2				Number of stems, pcs/m^2				Tillering factor			
	2011	2012	2013	average	2011	2012	2013	average	2011	2012	2013	average
Control	292	388	353	344	545	709	604	619	1.9	1.8	1.7	1.8
Vitavax 200 FF, 2.5 L/t (standard)	314	380	358	351	701[1)]	734	613	683[1)]	2.2[1)]	1.9	1.7	2.0[1)]
MWF of EHF, 1.8 kW/kg, 15 sec	313	415[1)]	379[1)]	369[1)]	578[1)]	864[1)]	638	693[1)]	1.8	2.1[1)]	1.7	1.9
MWF of EHF, 1.8 kW/kg,15 sec + Mars EL, 0.2 L/t	296	394	344	345	543	752	593	629	1.8	1.9	1.7	1.8
MWF of EHF, 0.9kW/kg, 45 sec	335[1)]	430[1)]	376	380[1)]	663[1)]	756	637	685[1)]	2.0	1.8	1.7	1.8
MWF of EHF, 0.9kW/kg, 45 sec+ Mars EL, 0.2 L/t	314	393	371	359[1)]	616[1)]	735	664[1)]	672[1)]	2.0	1.9	1.8	1.9
SSD $_{05}$	25.2	25.9	24.2	14.0	52.1	75.02	45.4	51.0	0.14	0.13	0.12	0.11

Note [1)] – Significant difference

Due to the researches carried out with spring barley, it has been found out that the pre-sowing seed treatment with MWF of EHF in the mode of 0.9 kW/kg, 45 sec or 1.8 kW/kg, 20 sec, and Radostim or Albit growth regulators, as well as their combination in most cases, causes an increase in the field germination and stimulation of vegetative development of plants (Tables 9, 10).

Table 9. Biometric indices of spring barley varieties in full ripen depending on pre-sowing seed treatment with MWF of EHF and plant growth regulators

Cases of treatment	Aspect, the average for 2011-2013				Vyclyc, the average for 2012-2013			
	number, pcs/m^2		tillering factor	plants height, cm	number, pcs/m^2		tillering factor	plants height, cm
	plants	stems			plants	stems		
Control	293	564	1.9	51.9	328	665	2.0	43.9
Vitavax 200 FF, 2.5 L/t (standard)	307	570	1.9	54.5[1)]	333	678	2.0	45.9
Radostim, 0.25 L/t	301	587	1.9	57.4[1)]	336	697[1)]	2.1	47.4[1)]
Albit, 30 ml/t	321	607[1)]	1.9	58.0[1)]	326	663	2.1	48.6[1)]
MWF of EHF, 0.9 kW/kg, 45 sec	318[1)]	634[1)]	2.0	58.6[1)]	347[1)]	701[1)]	2.0	47.9[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	313	593	1.9	58.0[1)]	325	684	2.2	47.3[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	307	590	1.9	58.0[1)]	350[1)]	718[1)]	2.1	48.0[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	320[1)]	597[1)]	1.9	59.9[1)]	346[1)]	717[1)]	2.1	47.6[1)]
MWF of EHF, 1.8 kW/kg, 20 sec	311	586	1.9	58.3[1)]	329	713[1)]	2.2	49.2[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	322[1)]	617[1)]	1.9	56.3[1)]	343	673	2.0	51.1[1)]
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	318[1)]	596	1.9	56.6[1)]	343	710[1)]	2.1	48.7[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	318[1)]	613[1)]	1.9	56.7[1)]	331	691	2.1	48.6[1)]
SSD 05	23	33		22	18	31		2.2

Note [1)] – Significant difference

Table 10. Plant density of Aspect spring barley variety depending on MWF of EHF and plant growth regulators application, 2011–2013 (tillering phase)

Cases of treatment	Number of plants, pcs/m²				Number of stems, pcs/m²				Tillering factor			
	2011	2012	2013	average	2011	2012	2013	average	2011	2012	2013	average
Control	284	296	356	312	296	764	452	504	1.8	2.6	1.1	1.8
Vitavax 200 FF, 2.5 L/t (standard)	196[1)]	284	404[1)]	294	392[1)]	664[1)]	520[1)]	523	2.3[1)]	2.6	1.4[1)]	2.1[1)]
Radostim, 0.25 L/t	303[1)]	268	372	314	480[1)]	696[1)]	540[1)]	572[1)]	1.6[1)]	2.7	1.5[1)]	1.9
Albit, 30 ml/t	328[1)]	300	428[1)]	323	524[1)]	620[1)]	552[1)]	565[1)]	1.6[1)]	3.5[1)]	1.3[1)]	1.9
MWF of EHF, 0.9 kW/kg, 45 sec	280	240	420[1)]	313	436[1)]	628[1)]	536[1)]	533	1.6[1)]	2.6	1.3[1)]	1.8
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	224	390[1)]	436[1)]	363[1)]	492[1)]	664[1)]	564[1)]	573[1)]	2.2[1)]	3.4[1)]	1.3[1)]	2.2[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	256	296	404[1)]	319	412[1)]	692[1)]	484	529	1.6[1)]	2.6	1.2	1.8
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	348[1)]	260	430[1)]	356[1)]	568[1)]	600[1)]	516[1)]	561[1)]	1.6[1)]	2.9[1)]	1.2	1.9
MWF of EHF, 1.8 kW/kg, 20 sec	240	276	356	291	360[1)]	720[1)]	472	517	1.6[1)]	2.9[1)]	1.3[1)]	1.9
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	248	304	432[1)]	335[1)]	388[1)]	844[1)]	512[1)]	581[1)]	1.6[1)]	2.8[1)]	1.2	1.8
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	312[1)]	244	384	313	556[1)]	654[1)]	520[1)]	576[1)]	1.8	2.7	1.4[1)]	2.0[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	244	272	416[1)]	311	576[1)]	744	460	593[1)]	1.9	2.8[1)]	1.1	1.9
SSD_{05}	21.0	24.0	39.6	21.1	25.1	40.0	39.8	33.2	0.13	0.14	0.12	0.11

Note [1)] – Significant difference

For example, in the cases of the pre-sowing seed treatment of spring barley of the Aspect variety with the Albit preparation, 30 ml/t; MWF of EHF, 0.9 kW/kg, 45 sec; MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t; MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t; MWF of EHF, 1.8 kW/kg, 20 sec + Radostim, 0.25 L/t and MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t, on the average for three years the plant density exceeded the control indices by 25–29 pieces/m², and the number of stems exceeded the control indices by 33–70 pieces/m². The tillering factor of the Aspect spring barley variety did not change significantly and, in most cases, was 1.9 (Table 11).

Table 11. Plant density of Aspect spring barley variety depending on MWF of EHF and plant growth regulators application, 2011–2013, full ripen

Cases of treatment	Number of plants, pcs/m²				Number of stems, pcs/m²				Tillering factor			
	2011	2012	2013	average	2011	2012	2013	average	2011	2012	2013	average
Control	279	300	300	293	541	687	493	574	1.9	2.3	1.6	2.0
Vitavax 200 FF, 2.5 L/t (standard)	294	307	319	307	558	677	476	570	1.9	2.2	1.5	1.9
Radostim, 0.25 L/t	298	323	281	301	547	753[1)]	461	587	1.8	2.3	1.6	1.9
Albit, 30 ml/t	281	332[1)]	350[1)]	321[1)]	541	775[1)]	506	607[1)]	1.9	2.3	1.4[1)]	1.9
MWF of EHF, 0.9 kW/kg, 45 sec	287	312	356[1)]	318[1)]	561	791[1)]	549[1)]	634[1)]	2.0[1)]	2.5[1)]	1.5	2.0
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	281	299	360[1)]	313	536	740[1)]	503	593	1.9	2.5[1)]	1.4[1)]	1.9
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	282	308	330	307	567[1)]	708	495	590	2.0[1)]	2.3	1.5	1.9
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	276	305	378[1)]	320[1)]	551	690	550[1)]	597	2.0[1)]	2.3	1.5	1.9
MWF of EHF, 1.8 kW/kg, 20 sec	312[1)]	329[1)]	292	311	579[1)]	713	466	586	1.9	2.2	1.6	1.9
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	284	314	367[1)]	322[1)]	563	705	582[1)]	617[1)]	2.0[1)]	2.2	1.6	1.9
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	309[1)]	331[1)]	315	318[1)]	583[1)]	732[1)]	473	596	1.9	2.2	1.5	1.9
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	287	315	351[1)]	318[1)]	572[1)]	725	542[1)]	613[1)]	2.0[1)]	2.3	1.5	1.9
SSD_{05}	20.7	23.9	39.1	22.7	24.7	39.7	38.9	32.8	0.14	0.14	0.12	0.11

Note [1)] – Significant difference

At the same time, the height of the Aspect barley plants variety in the phase of full ripening in the cases of MWF of EHF seed treatment and plant growth regulators exceeded the control index (51.9 cm) b 4.4–8.0 cm (Table 12).

Table 12. Height of plants of spring barley varieties depending on pre-sowing seed treatment with MWF of EHF and plant growth regulators, cm

Cases of treatment	Aspect								Vyklyk					
	stalk shooting				full ripening				stalk shooting			full ripening		
	2011	2012	2013	average	2011	2012	2013	average	2012	2013	average	2012	2013	average
Control	46.6	43.7	27.4	39.2	62.7	46.5	50.3	53.2	37.6	28.3	33.0	45.2	44.7	45.0
Vitavax 200 FF, 2.5 L/t (standard)	46.4	41.8	31.5[1)]	39.9	64.2	47.0	57.4[1)]	56.2[1)]	39.4	27.3	33.4	45.5	44.9	45.2
Radostim, 0.25 L/t	53.6[1)]	44.3	30.6[1)]	42.8[1)]	66.2[1)]	48.2	57.7[l)]	57.4[1)]	38.9	30.5	34.7[1)]	46.5	46.7	46.6
Albit, 30 ml/t	48.1	46.8[1)]	33.3[1)]	42.7[1)]	66.I[1)]	51.4[1)]	56.5[1)]	58.0[1)]	38.4	31.9[1)]	35.2[1)]	48.3[1)]	45.6	47.0
MWF of EHF, 0.9 kW/kg, 45 sec	46.8	44.7	30.9[1)]	40.8	69.2[1)]	49.2	59.2[1)]	59.2[1)]	38.1	27.0	32.6	47.8	46.9	47.4[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	47.6	43.7	33.4[1)]	41.6[1)]	67.7[1)]	48.2	56.7[l)]	57.5[1)]	41.4[1)]	28.1	34.8[1)]	46.9	45.7	46.3
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	47.4	44.7	32.4[1)]	41.5[1)]	69.5[1)]	49.7	58.5[1)]	59.2[1)]	39.3	25.4	32.4	48.5[1)]	48.4[1)]	48.5
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	50.1	43.6	33.0[1)]	42.2[1)]	65.5	49.2	57.8[1)]	58.0[1)]	39.5	29.2	34.4	47.1	48.4[1)]	47.8[1)]
MWF of EHF, 1.8 kW/kg, 20 sec	46.9	43.7	30.6[1)]	40.4	65.4	51.8[1)]	57.2[1)]	58.1[1)]	38.9	28.8	33.9	47.2	48.2[1)]	47.0[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	51.70	43.7	28.0	41.1	65.5	51.3[1)]	50.6	55.8[1)]	38.7	28.0	33.4	48.7[1)]	53.3[1)]	51.0[1)]
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	50.3	43.8	29.9	41.3[1)]	63.7	51.0[1)]	53.9	56.2[1)]	39.4	28.4	33.9	47.8[1)]	46.0	46.9
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	52.7[1)]	45.8	32.5[1)]	43.7[1)]	62.8	51.7[1)]	56.3[1)]	56.9[1)]	40.2[1)]	30.2	35.2[1)]	47.4	53.4[1)]	50.4[1)]
SSD 05	3.9	3.0	2.7	2.0	3.1	3.3	4.5	2.2	2.4	3.4	1.7	2.6	3.0	2.2

Table 13. Plant density of Vyklyk spring barley variety depending on MWF of EHF and plant growth regulators application, 2012–2013 (tillering phase)

Cases of treatment	Number of plants, pcs/m^2			Number of stems, pcs/m^2			Tillering factor		
	2012	2013	average	2012	2013	average	2012	2013	average
Control	248	372	310	708	640	674	2.9	1.7	2.3
Vitavax 200 FF, 2.5 L/t (standard)	216	476[1)]	346[1)]	672	612	642	3.2[1)]	1.3[1)]	2.2
Radostim, 0.25 L/t	260	388	324	644[1)]	672	658	2.7	1.7	2.2
Albit, 30 ml/t	220	548[1)]	384[1)]	552[1)]	780[1)]	666	2.9	1.4[1)]	2.2
MWF of EHF, 0.9 kW/kg, 45 sec	288[1)]	528[1)]	408[1)]	684	724	648	2.8	1.4[1)]	2.1[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	188[1)]	428[1)]	308	660	636	648	3.5[1)]	1.5[1)]	2.5[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	212	520[1)]	366[1)]	660	652	656	3.1[1)]	1.3[1)]	2.2
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	260	452[1)]	356[1)]	644	724	684	2.4	1.6	2.0[1)]
MWF of EHF, 1.8 kW/kg, 20 sec	260	456[1)]	320	728	660	694	2.8	1.4[1)]	2.1[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	260	380	320	692	688	690	2.7[1)]	1.8	2.3
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	280[1)]	468[1)]	374[1)]	676	632	654	2.5[1)]	1.4[1)]	2.0[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	208	460[1)]	334[1)]	628	664	646	3.0	1.4[1)]	2.2
SSD $_{05}$	25.6	27.0	18.9	38.6	33.9	31.7	0.16	0.15	0.15

Note [1)] – Significant difference

Depending on the seed treatment methods, the density of spring barley plants of the Vyklyk variety varied less naturally. So, only in the cases of the pre-sowing seed treatment with MWF of EHF, 0.9 kW/kg, 45 sec; MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t; MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t, on the average for two years the plant density significantly exceeded the control by 18–22 pieces/m^2, and in the rest of the cases the tendency to this index increasing has been noted. However, a typical varietal reaction of the Vyklyk variety to the application of MWF of EHF and plant growth regulators as a tendency to increase productive tillering to 2.1–2.2 has been identified in the research. In contrast, under control and in the standard case with seed treatment with Vitavax 200 FF, it was 2.0 (Tables 13, 14).

Table 14. Plant density of Vyklyk spring barley variety depending on MWF of EHF and plant growth regulators application, 2012–2013, full ripen

Cases of treatment	Number of plants, pcs/m^2			Number of stems, pcs/m^2			Tillering factor		
	2012	2013	average	2012	2013	average	2012	2013	average
Control	324	332	328	826	503	665	2.5	1.5	2.0
Vitavax 200 FF, 2.5 L/t (standard)	335	371[1)]	353	849	547[1)]	698[1)]	2.5	1.5	2.0
Radostim, 0.25 L/t	330	341	336	849	544[1)]	697[1)]	2.6	1.6	2.1
Albit, 30 ml/t	300	352	326	827	499	663	2.8[1)]	1.4	2.1
MWF of EHF, 0.9 kW/kg, 45 sec	333	360[1)]	347[1)]	892[1)]	509	701[1)]	2.7[1)]	1.4	2.0
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	300	350	325	848	520	684	2.8[1)]	1.5	2.2[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	322	378[1)]	350[1)]	837	599[1)]	718[1)]	2.6	1.6	2.1
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	304	388[1)]	346	826	607[1)]	717[1)]	2.7[1)]	1.6	2.1
MWF of EHF, 1.8 kW/kg, 20 sec	309	348	329	831	595[1)]	713[1)]	2.7[1)]	1.7	2.2[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	335	351	343	830	496	663	2.5	1.4	1.9
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	316	370[1)]	343	899[1)]	520	710[1)]	2.8[1)]	1.4	2.1
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	315	347	331	852	530	691	2.7[1)]	1.5	2.1
SSD_{05}	25.1	26.7	18.6	38.1	33.6	31.0	0.16	0.14	0.14

Note [1)] – Significant difference

The height of plants of the Vyklyk spring barley variety during the full ripen in the cases of the seed treatment with MWF of EHF and plant growth regulators, on the average for 2012–2013, significantly exceeded the control index (43.9 cm) by 3.4–7.2 cm (Table 12). The leaf surface, which is connected with the height, plays an essential role in increasing the crop yield capacity (Nichiporovich, 1956; Fadeev et al., 1986). E.A. Kalinina and E.A. Shevchenko believe that the use of phytoregulators – the synthetic analogs of natural phytohormones is one of the effective methods of controlling the physiological and biochemical processes in the plants. Thus, the triple treatment of the surface part of the plants during the ontogenesis leads to stems thickening by 15–20% and to an increase in the number of cells in the leaf 1.4 times. As a result, there is an increase in the leaves' surface and a 1.6 times increase in the intensity of plants' photosynthesis (Kalinin et al., 2000). In the researches of the Plant Production Institute in 2006–2010, it was found out that an essential consequence of the action of plant growth regulators (Endophyte L1, Biolan, Biosil, Reacom-CP-Zerno and Reastim-Zerno) under various ways of application is the increase in the leaf surface of spring wheat and barley by 12–23% on the average (Pyatygin, 2008; Gadzalo, 2009).

According to the researches of A.A. Nychyporovych (1956) and Fadeev et al. (1986), the leaf surface must enlarge rapidly and exceed 40 thousand m²/ha in order to form the high-productive crops. In our research, winter wheat and spring barley leaf surface were determined in the tillering, stalk shooting, and ear formation phases. A positive effect of the pre-sowing seed treatment with MWF of EHF on this index compared with the case without seed treatment and the traditional seed treatment with Vitavax 200 FF has been established. Thus, as a result of the pre-sowing seed treatment with MWF of EHF in the modes of 1.8 kW/kg, 15 sec and 0.9 kW/kg, 45 sec on the average for 2011–2013, the surface of winter wheat leaves has enlarged in the phases of tillering, stalk shooting and ear formation by 1.6 and 2.7 thousand m^2/ha, 1.9 and 3,5 thousand m^2/ha and 4,6 and 7,0 thousand m^2/ha respectively in comparison with the control, where it was 11.7, 29.4 and 37.8 thousand m^2/ha (Tables 15-18).

Table 15. Leaf surface of Astet winter wheat variety in tillering phase depending on the method of pre-sowing seed treatment, thousand m^2/ha, 2011-2013

Seed treatment cases	Plant development phases		
	tillering	stalk shooting	ear formation
Control	11.7	29.4	37.8
Vitavax 200 FF, 2.5 L/t	12.7	30.1	39.7
MWF of EHF 1.8 kW/kg,15 sec	13.3[1)]	31.3	42.4[1)]
MWF of EHF 1.8 kW/kg,15 sec + Mars EL	13.8[1)]	33.2[1)]	42.8[1)]
MWF of EHF 0.9kW/kg, 45 sec	14.4[1)]	32.9[1)]	44.8[1)]
MWF of EHF 0.9kW/kg, 45 sec + Mars EL	13.6[1)]	32.7[1)]	41.3[1)]
$SSD_{0.5}$	1.1	1.9	2.1

Note [1)] – Significant difference

Table 16. Leaf surface of Astet winter wheat variety in tillering phase depending on the method of pre-sowing seed treatment, thousand m^2/ha

Cases of seed treatment	Years			Average
	2011	2012	2013	
Control	9.7	12.3	13.2	11.7
Vitavax 200 FF, 2.5 L/t	10.5	12.7	14.8	12.7
MWF of EHF 1.8 kW/kg,15 sec	11.0	13.7	15.1[1)]	13.3[1)]
MWF of EHF 1.8 kW/kg,15 sec + Mars EL	11.8[1)]	13.2	16.3[1)]	13.8[1)]
MWF of EHF 0.9kW/kg, 45 sec	11.9[1)]	14.6[1)]	16.6[1)]	14.4[1)]
MWF of EHF 0.9kW/kg, 45 sec + Mars EL	11.5[1)]	12.6	16.7[1)]	13.6[1)]
$SSD_{0.5}$	1.3	1.5	1.6	1.1

Note [1)] – Significant difference

Table 17. Leaf surface of Astet winter wheat variety in tillering phase depending on the method of pre-sowing seed treatment, thousand m^2/ha

Cases of seed treatment	Years			Average
	2011	2012	2013	
Control	28.0	29.1	31.2	29.4
Vitavax 200 FF, 2.5 L/t	28.8	30.0	31.4	30.1
MWF of EHF 1.8 kW/kg,15 sec	29.5	31.9[1)]	32.4	31.3
MWF of EHF 1.8 kW/kg,15 sec + Mars EL	30.9[1)]	31.8	36.9[1)]	33.2[1)]
MWF of EHF 0.9kW/kg, 45 sec	30.3[1)]	32.3[1)]	36.2[1)]	32.9[1)]
MWF of EHF 0.9kW/kg, 45 sec + Mars EL	30.1	32.0[1)]	36.1[1)]	32.7[1)]
$SSD_{0.5}$	2.1	2.7	2.8	1.9

Note [1)] – Significant difference

Table 18. Leaf surface of Astet winter wheat variety in ear-formation phase depending on the method of pre-sowing seed treatment, thousand m^2/h

Cases of seed treatment	Years			Average
	2011	2012	2013	
Control	31.2	39.6	42.5	37.8
Vitavax 200 FF, 2.5 L/t	33.8[1)]	40.9	44.4	39.7
MWF of EHF 1.8 kW/kg,15 sec	35.5[1)]	44.2[1)]	47.6[1)]	42.4[1)]
MWF of EHF 1.8 kW/kg,15 sec + Mars EL	37.9[1)]	42.5[1)]	48.0[1)]	42.8[1)]
MWF of EHF 0.9kW/kg, 45 sec	38.3[1)]	46.9[1)]	49.3[1)]	44.8[1)]
MWF of EHF 0.9kW/kg, 45 sec + Mars EL	37.1[1)]	40.7[1)]	46.1[1)]	41.3[1)]
$SSD_{0.5}$	2.5	2.9	3.1	2.1

Note [1)] – Significant difference

The additional treatment of the irradiated seeds with MWF of EHF and with the growth regulator Mars EL provided the further growth of the leaf surface only in the mode of 1.8 kW/kg, 15 sec by 2.1, 3.8, and 5.0 thousand m^2/ha, respectively on the average for three years. The additional treatment of the irradiated seeds with MWF of EHF with the growth regulator Mars EL in the mode of 0.9 kW/kg, 45 sec did not lead to the additional enlargement of the leaf surface compared to treatment only with MWF of EHF. The photosynthetic sowing potential (PSP) and leaf surface were closely related. It was found out that the seed treatment methods influenced the value of the photosynthetic sowing potential, which characterizes the duration of the leaf surface work. Thus, the highest PSP indices of 1.37 and 1.40 million m^2 days/ha have also been observed in the cases of the pre-sowing seed treatment with MWF of EHF in the mode of 1.8 kW/kg, 15 sec with the additional treatment of the irradiated seeds with Mars EL growth regulator and MWF of EHF in the mode of 0.9 kW/kg, 45 sec (Table 19).

Table 19. Photosynthetic sowing potential (PSP) of Astet winter wheat variety depending on the method of pre-sowing seed treatment, million m^2 days/ha

Seed treatment cases	Years			Average
	2011	2012	2013	
Control	1.08	1.23	1.32	1.21
Vitavax 200 FF, 2.5 L/t	1.13	1.27	1.37	1.26
MWF of EHF 1.8 kW/kg, 15 sec	1.17[1)]	1.36[1)]	1.43[1)]	1.32[1)]
MWF of EHF 1.8 kW/kg, 15 sec + Mars EL	1.24[1)]	1.33[1)]	1.55[1)]	1.37[1)]
MWF of EHF 0.9 kW/kg, 45 sec	1.23[1)]	1.41[1)]	1.55[1)]	1.40[1)]
MWF of EHF 0.9 kW/kg, 45 sec + Mars EL	1.21[1)]	1.31[1)]	1.53[1)]	1.35[1)]
$SSD_{0.5}$	0.07	0.08	0.10	0.06

The enlargement of the leaf surface depended on the method of MWF of EHF application in the research with the spring barley varieties. Thus, the pre-sowing seed treatment with MWF of EHF in 0.9 kW/kg, 45 sec, and 1.8 kW/kg, 20 sec increased the leaves surface of the Aspect spring barley variety in the phases of tillering, stalk shooting, and ear formation by 1.0 and 1.4 thousand m^2/ha, 1.2 and 1.9 thousand m^2/ha and 1.6 and 2.1 thousand m^2/ha respectively on the average for 2011–2013. When treating with the growth regulators Radostim and Albit, the leaf surface was enlarged by 0.9 and 0.6 thousand m^2/ha, 2.20 and 3.50 thousand m^2/ha, and 1.9 and 2.6 thousand m^2/ha, respectively, compared to the control where it was 9.9, 19.1 and 15.6 thousand m^2/ha respectively (Tables 20-23). At the same time, the leaf surface in the case of Vitavax 200 FF was 10.4, 19.5, and 16.0 thousand m^2/ha, respectively.

Table 20. Leaf surface of spring barley varieties in the ear formation phase depending on the method of the pre-sowing seed treatment with MWF of EHF and plant growth regulators, thousand m^2/ha

Methods of pre-sowing seed treatment	Aspect			Vyklyk		
	plant development phases					
	tillering	stalk shooting	ear formation	tillering	stalk shooting	ear formation
Control	9.86	19.1	15.6	9.89	19.0	15.9
Vitavax 200 FF, 2.5 L/t (standard)	10.4	19.5	16.0	10.5	19.6	16.4
Radostim, 0.25 L/t	10.7[1)]	21.3[1)]	17.5[1)]	11.2[1)]	21.6[1)]	18.2[1)]
Albit, 30 ml/t	10.5	22.6[1)]	18.2[1)]	10.7	23.2[1)]	19.6[1)]
MWF of EHF, 0.9 kW/kg, 45 sec	10.9[1)]	20.3	17.2[1)]	11.2[1)]	20.6	17.4
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	11.0[1)]	20.7	17.2[1)]	11.6[1)]	22.3[1)]	18.7[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	10.6	21.3[1)]	17.5[1)]	11.4[1)]	22.9[1)]	19.3[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	11.4[1)]	23.0[1)]	19.0[1)]	11.7[1)]	22.1[1)]	18.7[1)]
MWF of EHF, 1.8 kW/kg, 20 sec	11.3[1)]	21.0[1)]	17.7[1)]	12.0[1)]	21.2[1)]	17.8[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	10.5	20.3	17.0	11.9[1)]	20.7	17.4
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	10.9[1)]	21.5[1)]	18.0[1)]	11.7[1)]	23.1[1)]	19.6[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	11.5[1)]	24.9[1)]	20.6[1)]	13.2[1)]	25.9[1)]	21.8[1)]
SSD_{05}	0.83	1.75	1.52	1.10	2.14	1.85

Note [1)] – Significant difference

Table 21. Leaf surface of spring barley varieties in the tillering phase depending on the method of pre-sowing seed treatment with MWF of EHF and plant growth regulators, thousand m^2/ha

Methods of pre-sowing seed treatment	Aspect				Vyklyk		
	2011	2012	2013	average	2012	2013	average
Control	9.18	12.95	7.45	9.86	12.55	7.24	9.89
Vitavax 200 FF, 2.5 L/t (standard)	9.69	12.85	8.67[1)]	10.40	13.46	7.45	10.46
Radostim, 0.25 L/t	9.37	14.69[1)]	8.06	10.71[1)]	14.37[1)]	8.03	11.20[1)]
Albit, 30 ml/t	9.27	14.21[1)]	8.03	10.50	13.95[1)]	7.52	10.73
MWF of EHF, 0.9 kW/kg, 45 sec	9.99	13.85	8.76[1)]	10.87[1)]	14.18[1)]	8.24	11.21[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	10.51[1)]	13.98	8.45[1)]	10.98[1)]	15.12[1)]	8.03	11.58[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	9.57	13.93	8.32[1)]	10.61	14.08[1)]	8.74[1)]	11.41[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	10.09	15.81[1)]	8.42[1)]	11.44[1)]	14.95[1)]	8.53[1)]	11.74[1)]
MWF of EHF, 1.8 kW/kg, 20 sec	10.50[1)]	15.10[1)]	8.22	11.27[1)]	15.32[1)]	8.63[1)]	11.98[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	9.88	13.87	7.80	10.52	14.79[1)]	9.03[1)]	11.91[1)]
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	9.77	14.48[1)]	8.30[1)]	10.85[1)]	15.20[1)]	8.19	11.69[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	10.40[1)]	14.89[1)]	9.14[1)]	11.47[1)]	17.78[1)]	8.61[1)]	13.20[1)]
SSD_{05}	1.0	1.2	0.9	0.83	1.4	1.2	1.10

Note [1)] – Significant difference

Table 22. Leaf surface of spring barley varieties in the stalk shooting phase depending on the method of pre-sowing seed treatment with MWF of EHF and plant growth regulators, thousand m^2/ha

Methods of pre-sowing seed treatment	Aspect				Vyklyk		
	2011	2012	2013	average	2012	2013	average
Control	18.40	22.44	16.6	19.1	21.89	16.1	19.0
Vitavax 200 FF, 2.5 L/t (standard)	18.86	22.22	17.5	19.5	22.55	16.7	19.6
Radostim, 0.25 L/t	19.78	24.53[1)]	19.6[1)]	21.3[1)]	23.87[1)]	19.4[1)]	21.6[1)]
Albit, 30 ml/t	21.74[1)]	24.97[1)]	21.2[1)]	22.6[1)]	24.42[1)]	22.0[1)]	23.2[1)]
MWF of EHF, 0.9 kW/kg, 45 sec	18.98	22.55	19.5[1)]	20.3	22.00	19.2[1)]	20.6
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	20.24[1)]	22.88	18.9	20.7	26.29[1)]	18.4[1)]	22.3[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	20.70[1)]	21.56	21.6[1)]	21.3[1)]	24.20[1)]	21.6[1)]	22.9[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	20.59[1)]	26.07[1)]	22.3[1)]	23.0[1)]	21.67	22.6[1)]	22.1[1)]
MWF of EHF, 1.8 kW/kg, 20 sec	19.55	24.42[1)]	19.1[1)]	21.0[1)]	22.44	19.9[1)]	21.2[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	19.21	22.88	18.7	20.3	22.66	18.8[1)]	20.7
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	20.24[1)]	22.77	21.6[1)]	21.5[1)]	22.77	23.4[1)]	23.1[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	22.43[1)]	28.60[1)]	23.8[1)]	24.9[1)]	28.38[1)]	23.5[1)]	25.9[1)]
SSD_{05}	1.7	1.9	2.3	1.75	1.8	2.2	2.14

Note [1)] – Significant difference

Table 23. Leaf surface of spring barley varieties in the ear formation phase depending on the method of pre-sowing seed treatment with MWF of EHF and plant growth regulators, thousand m^2/ha

Methods of pre-sowing seed treatment	Aspect				Vyklyk		
	2011	2012	2013	average	2012	2013	average
Control	15.0	17.7	14.1	15.6	17.3	14.5	15.9
Vitavax 200 FF, 2.5 L/t (standard)	15.6	17.6	14.9	16.0	17.8	15.0	16.4
Radostim, 0.25 L/t	16.4	19.4	16.7[1)]	17.5[1)]	18.9	17.5[1)]	18.2[1)]
Albit, 30 ml/t	16.9[1)]	19.7	18.0[1)]	18.2[1)]	19.3	19.8[1)]	19.6[1)]
MWF of EHF, 0.9 kW/kg, 45 sec	17.2[1)]	17.8	16.6[1)]	17.2[1)]	17.4	17.3[1)]	17.4
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1,25 L/t	17.5[1)]	18.1	16.1[1)]	17.2[1)]	20.8[1)]	16.6	18.7[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	17.1[1)]	17.0	18.4[1)]	17.5[1)]	19.1	19.4[1)]	19.3[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	17.5[1)]	20.6[1)]	19.0[1)]	19.0[1)]	17.1	20.3[1)]	18.7[1)]
MWF of EHF, 1.8 kW/kg, 20 sec	17.6[1)]	19.3	16.2[1)]	17.7[1)]	17.7	17.9[1)]	17.8[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	16.9[1)]	18.1	15.9	17.0	17.9	16.9	17.4
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	17.6[1)]	18.0	18.4[1)]	18.0[1)]	18.0	21.1[1)]	19.6[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	19.1[1)]	22.6[1)]	20.2[1)]	20.6[1)]	22.4[1)]	21.2[1)]	21.8[1)]
SSD_{05}	1.6	2.1	2.0	1.52	2.2	2.8	1.85

Note [1)] – Significant difference

The pre-sowing seed treatment with MWF of EHF in 0.9 kW/kg, 45 sec and 1.8 kW/kg, 20 sec, increased the leaves surface of the Vyklyk spring barley variety in the tillering, stalk shooting, and ear formation phases by 1.3 and 2.1 thousand m^2/ha, 1.6 and 2.2 thousand m^2/ha, and 1.5 and 1.9 thousand m^2/ha, respectively, in 2012–2013. In application with the growth regulators Radostim and Albit, these values were by 1.3 and 0.84 thousand m^2/ha, 2.6 and 4.2 thousand m^2/ha and 2.3 and 3.7 thousand m^2/ha, respectively, compared to control, where it was 9.9, 19.0 and 15.9 thousand m^2/ha, respectively. At the same time, the leaf surface in the case with Vitavax 200 FF was 10.5, 19.6, and 16.4 thousand m^2/ha.

The research results are given in Table 20 clearly show that when combined the pre-sowing irradiation with MWF of EHF of different modes with the other seeds treatment with the plant growth regulators, the leaf surface of barley varieties increases to a greater extent in comparison with other methods. For example, the leaf surface of the Aspect barley varieties in the cases with MWF of EHF 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t and MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t in the phases of tillering, stalk shooting and ear formation amounted to 10.6 and 11.4 thousand m^2/ha, 21.3 and 23.0 thousand m^2/ha, and 17.5 and 19.0 thousand m^2/ha respectively on the average for three years while in the case with MWF of EHF, 0.9 kW/kg, 45 sec it was 10.9, 20.3 and 17.2 thousand m^2/ha. The leaf surface in the cases of MWF of EHF, 1.8 kW/kg, 20 sec + Radostim, 0.25 L/t and MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t in the phases of tillering, stalk shooting, and ear formation amounted to 10.9 and 11.5 thousand m^2/ha, 21.5 and 24.9 thousand m^2/ha and 18.0 and 20.6 thousand m^2/ha, respectively on the average for three years, while in the cases with the growth regulators Radostim and Albit it was 10.7 and 10.5 thousand m^2/ha, 21.3 and 22.6 thousand m^2/ha, and 17.5 and 18.2 thousand m^2/ha respectively.

Similar tendencies to leaf surface variability have also been found with the Vyklyk spring barley variety. On the average for 2012–2013, the maximum values of this index in the phases of tillering, stalk shooting, and ear formation of 11.4 and 13.2 thousand m^2/ha, 22.9 and 25.9 thousand m^2/ha, and 19.3 and 21.8 thousand the double pre-sowing seed treatment has caused m2/ha according to the following methods: treatment with MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t and MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t, while under control and in the case with Vitavax 200 FF the leaf surface was respectively 9.9 and 10.5 thousand m^2/ha, 19.0 and 19.6 thousand m^2/ha and 15.9 and 16.4 thousand m^2/ha. When calculating the photosynthetic sowing potential, the relatively high values of the sowing index have been formed in the cases with the largest leaf surface (Table 24). Thus, as for the Aspect variety, the maximum index of PSP on the average for the years 2011–2013 of 0.75 and 0.80 million m^2 days/ha has resulted in the double pre-sowing seed treatment according to the following methods: MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t and MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t, while under control and in the case with Vitavax 200 FF, PSP was 0.63 and 0.65 million m^2 days/ha respectively.

The highest index of PSP on the average for the years 2012–2013 as for the Vyklyk variety of 0.76 and 0.86 million m^2 days/ha was noted in the cases of the pre-sowing seed treatment according to the following methods: MWF of EHF, 1.8 kW/kg, 20 sec + Radostim, 0.25 L/t and MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t, while under control and in the case with Vitavax 200 FF, PSP was 0.63 and 0.66 million m^2 days/ha respectively.

Table 24. Photosynthetic sowing potential (PSP) of spring barley depending on the method of pre-sowing seed treatment, million m[2] days/ha

Methods of pre-sowing seed treatment	Aspect				Vyklyk		
	2011	2012	2013	average	2012	2013	average
Control	0.60	0.76	0.53	0.63	0.74	0.52	0.63
Vitavax 200 FF, 2.5 L/t (standard)	0.62	0.76	0.58	0.65	0.78	0.54	0.66
Radostim, 0.25 L/t	0.64	0.85[1)]	0.61[1)]	0.70[1)]	0.83[1)]	0.61[1)]	0.72[1)]
Albit, 30 ml/t	0.67[1)]	0.85[1)]	0.65[1)]	0.72[1)]	0.83[1)]	0.66[1)]	0.75[1)]
MWF of EHF, 0.9 kW/kg, 45 sec	0.64	0.78	0.62[1)]	0.68[1)]	0.78	0.61[1)]	0.70[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Vitavax 200 FF, 1.25 L/t	0.68[1)]	0.80	0.60[1)]	0.69[1)]	0.89[1)]	0.59	0.74[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Radostim, 0.25 L/t	0.66[1)]	0.76	0.66[1)]	0.70[1)]	0.83[1)]	0.68[1)]	0.75[1)]
MWF of EHF, 0.9 kW/kg, 45 sec + Albit, 30 ml/t	0.67[1)]	0.90[1)]	0.68[1)]	0.75[1)]	0.79	0.70[1)]	0.74[1)]
MWF of EHF, 1.8 kW/kg, 20 sec	0.67[1)]	0.85[1)]	0.60[1)]	0.71[1)]	0.81[1)]	0.64[1)]	0.72[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Vitavax 200 FF, 1.25 L/t	0.64	0.79	0.59[1)]	0.67	0.81[1)]	0.62[1)]	0.71[1)]
MWF of EHF,1.8 kW/kg, 20 sec + Radostim, 0.25 L/t	0.66[1)]	0.80	0.66[1)]	0.71[1)]	0.82[1)]	0.71[1)]	0.76[1)]
MWF of EHF, 1.8 kW/kg, 20 sec + Albit, 30 ml/t	0.72[1)]	0.94[1)]	0.73[1)]	0.80[1)]	0.99[1)]	0.72[1)]	0.86[1)]
SSD_{05}	0.05	0.06	0.06	0.05	0.06	0.08	0.06

Note [1)] – Significant difference

Conclusions

Seed treatment with MWF of EHF or in combination with the growth regulator Mars EL increased the height of the Astet plants from spring resumption of vegetation by 4.0–7.9 cm towards 66.6 cm in control. The tillering factor increased by 0.2–0.4 at the index of 2.9 under control; the leaf surface in the phases of tillering, stalk shooting, and ear formation also increased by 12–23, 6–13, and 9–19%, respectively, while under control the leaf surface was 11.7, 29.4, and 37.8 thousand m^2/ha; PSP increased by 9–16% while under control it was 1.21 million m^2 days/ha. The highest and most stable results were provided by applying MWF of EHF in the mode of 0.9 kW/kg, 45 sec only, or additional treatment with the Mars EL preparation.

The pre-sowing seed treatment of Aspect and Vyklyk varieties with MWF of EHF in 0.9 kW/kg and 45 sec or 1.8 kW/kg and 20 sec with the growth regulators Radostim or Albit increased the plant heights 3.4–8.0 cm. The plant density increased by 5–10%, the leaf surface at tillering, stalk shooting, and ear formation in the Aspect variety increased by 7–16, 6–30, and 10–32%, respectively. In the Vyklyk variety, these indices were 13–33, 8–36, and 9–37%. The PSP increased by 8–27% and 11–37% in Aspect and Vyklyk varieties, respectively, whereas these indices were 51.9 and 43.9 cm, 293 and 328 pcs/m^2, 9.9, 19.1, and 15.6, 9.9, 19.0, and 15.9 thousand m^2/ha, 0.63 and 0.63 million m^2 days/ha, respectively, in control.

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