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Formation of photosynthetic and grain yield of spring barley (*Hordeum vulgare* L.) depend on varietal characteristics and plant growth regulators

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Abstract. The aim of the study was to determine the efficiency of the barley treatment crops with modern retrograde preparations on the background of the mineral fertilizers introduction into the photosynthetic activity of crops and grain yield. The experiments were carried out in 2013 -2017 on the southern black soil in the conditions of the Ukrainian Steppe. On the basis of the study results, it was determined that the introduction of irrigated fertilizer barley in a dose of $N_{30}P_{30}$ (background) under pre-sowing cultivation and the application of extra-root crop supplements at the phases beginning of the barley outflow straw into the tube and the organoleptic fermentation of Organic D2 and natural microbial complex Escort - Bio creates favorable conditions for the formation at the optimal levels of photosynthetic parameters and grain yield. Thus, on average, over the years of research and by factor variety, grain yield on these experimental variants was 3.37–3.41 t ha^{-1}, which exceeded its level on uncontrolled control by 0.71–0.75 t ha^{-1} or 26.7–28.2%. Based on the study results, the use of modern regenerating agents against the background of mineral fertilizers can be recommended as an expedient and effective measure of spring barley raising the productivity.

Key words: spring barley, variety, plant nutrition, leaf area, photosynthetic potential, pure photosynthesis productivity.

INTRODUCTION

Grain crops have a long history of using by people. Cereals are the main food and they are important sources of nutrients in both developed and developing countries. World cereal consumption in 2015–2017 was 2.6 billion tons (FAO). Global consumption of cereals is projected to increase to 2.9 bln tons in 2027, driven mainly by higher feed use (+167 Mt) followed by food use (+151 Mt). Developing countries will account for 84% of projected increase in overall consumption, but contrary to global outlook, the absolute increase in food use (+148 Mt) for developing countries will exceed the growth of feed use (+132 Mt). Conversely, for developed countries, feed use (+36 Mt) will grow more than food use (+3 Mt). Cereal products are the important source of energy, carbohydrates, proteins and fiber, and they also contain a variety of trace elements and vitamins (McKevith, 2004; Ashikari et al., 2005; Hake, 2008; Hirano et al., 2014).

Historically, barley (*Hordeum vulgare* L.) was a common crop grown in far agricultural areas, but it was neglected by breeders of Europe during the period of intensive crop development (Šterna et al., 2017). During in recent years grain barley production has decreased from 65.7 million tons in 2008 to 58.7 million tons in 2017, ie 10.7%. This was primarily due to the low demand for barley and price policy (Eurostat regional yearbook, 2017). The increased interest in barley, as a grain culture which can be used in the food industry, arose after studies run by Wood (2004) and Anonymous (2005). Grain of spring barley is widely used for food, technical and nutritional purposes, including brewing, in the production of pearl barley and cereals, but its main amount is used for feed purposes (Yarchuk et al., 2015).

The growing needs of modern agrarian production determine the need to find new ways and means for increasing of the productivity of agricultural crops and the quality of their products. The formation of yields is influenced by environmental conditions and the availability of resources, the most important of which are nutrients, water and light (Kren et al., 2015; Korchova et al., 2018). Growth regulators are important components of modern plant growing technologies (Komarova, 1998; Henselová et al., 2001).

Interest in this group of compounds is due to a wide range of their effects on plants, the ability to directly regulate specific stages of ontogenesis with the aim of mobilizing the potential of the plant organism and more efficient implementation of the genetic program (Khan & Ansari Samiullah, 1998; Malinauskaitė & Jakienė, 2005). Stimulators-native phytohormones and their synthetic analogues are the most used group of growth regulators (Laichicxi et al., 2002; Gavelienė et al., 2007). With the help of these compounds it can be influenced on the intensity and direction of the physiological processes in the plant organism, including the photosynthetic processes (Xinping et al., 2002; Angela, 2004).

Photosynthesis is a major source of dry matter and crop yields. Improvement of photosynthesis of leaves occurred with the withdrawal of high-yielding crop varieties (Jiang et al., 2002).

Numerous studies of scientists in the world found that the use of complex organo-mineral fertilizers, composite growth bioregulators, inoculants, nanoparticles, biogenic elements contributes to the regulation of growth and development processes of plants, their resistance to stress through increased plant immunity, activation of biological processes, synthesis of organic substances, increasing the area of the leaf surface, improving the net productivity of photosynthesis and yields of crops (Wakchaure et al., 2016; Pestovsky & Martinez-Antonio, 2017; Piskaeva et al., 2017; Klein & Guimarães, 2018; Singh et al., 2018). However, today, the market presents a very wide range of preparations, which complicates the choice, and scientific evidence of the impact of those preparations on the productivity of spring barley remains unimportant in the world scientific literature.

Taking into account the acuteness of the problem, the aim of the study was to determine the impact of modern certified drugs, in particular organo-mineral fertilizers Organic D2 and natural microbial complex Escort-bio, on the productivity of barley of spring varieties Adapt, Stalker and Aeneas, which involves the partial replacement of mineral fertilizers and chemical pesticides in order to increase the net productivity of photosynthesis, the yield and quality of the grain and the creation of the most favourable conditions for the restoration of soil fertility. The relevance of this study increases with the globalization of the influence of anthropo-technological load on the natural environment and the growth of the rate of depletion of natural ecosystems.

MATERIALS AND METHODS

Experimental researches were carried out during 2013–2017 years in the conditions of the educational-scientific-practical center of the Mykolaiv National Agrarian University.

The soil of experimental sites was represented by the southern, resiliently weakly sunny, heavy-sooty black soilon the loesses. The reaction of the soil solution was neutral (pH 6.8–7.2). The content of humus in the 0–30 cm layer was 123–125 g kg^{-1}. The arable layer of soil contained moving forms of nutrients on average: nitrates (by Grandval Liagou - this method is based on interactions between nitrates and disulpfo-phenolic acid from which trinitrophenol (picric acid) is formed. In alkaline environment it gives us yellow coloring due to formation of potassium trinitrophenolate (or natrium, depending from alkali used) in quantity equivalent to nitrates content) as 15–25 mg kg^{-1}, mobile phosphorus (by Machigin - this method is based on extraction of mobile phosphorus and potassium compounds from the soils with 1% ammonium carbonate solution, pH 9.0, at 25 ± 2 °C) as 41–46 mg kg^{-1}, exchangeable potassium (on a flame photometer) as 389–425 mg $kg^{-1}$of soil.

The territory of the farm locates in the third agro-climatic region and belongs to the subzone of the southern steppe of Ukraine. The climate here is temperate-continental, warm, dry, with unstable snow cover. Weather conditions by hydrothermal indices during the research years varied, which gave an opportunity to obtain objective results (Fig. 1).

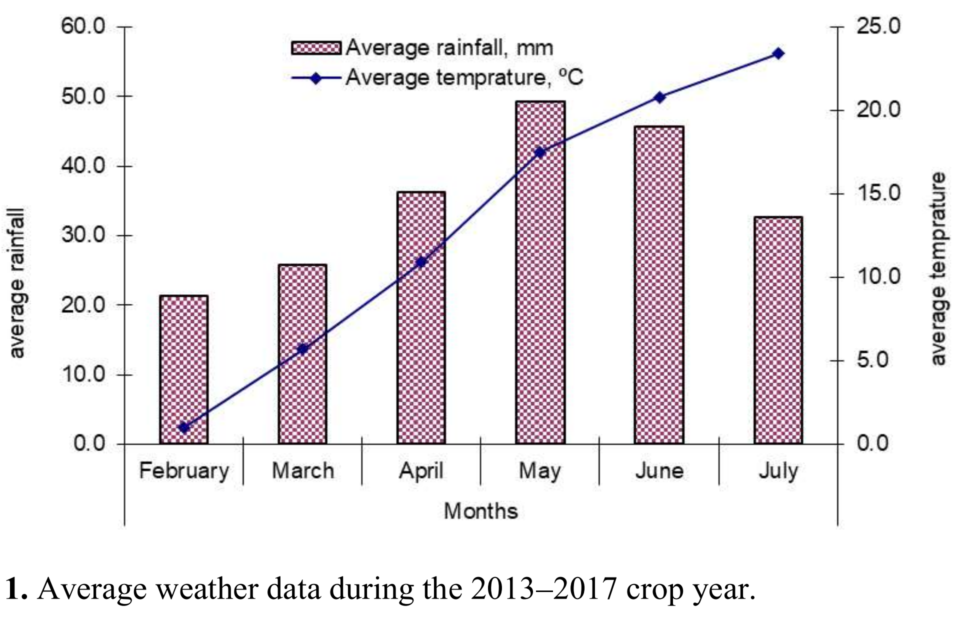

Figure 1. Average weather data during the 2013–2017 crop year.

The amount of precipitation for the vegetation period of spring barley on the average over the years of research (2013–2017) is 210.9 mm, which is within the normal range, but the average monthly rates have significant deviations from the norm. Thus, the smallest amount of precipitation (21.4 mm) fell in February, which is 31.6% less than the norm (31.3 mm). The farthest from the norm for the years of research was April, with the average rainfall of 36.3 mm, which is 72.9% more than the average yearly norm (21.0 mm). The largest amount of precipitation (49.2 mm) dropped in May, representing 23.3% of the total for the entire period of vegetation of barley.

The temperature conditions for the growing season of barley in 2013–2017 were within the normal range, except for the average monthly temperature of March, which for the average in 5 years was 15.8% higher than the norm (4.8 °C).

The object of research was spring barley – varieties Adapt, Stalker and Aeneas. The technology of their cultivation, with the exception of the investigated factors, was generally accepted to the existing zonal recommendations for the Southern Steppe of Ukraine. Weather conditions in the years of research varied, in particular, in 2015 and 2016 during the vegetation the considerably more rainfall dropped. In general, they were typical for the southern steppe region of Ukraine.

The total area of the experimental plot was 80 m^2, the accounting one was 36 m^2, the repetition was three times. Scheme of the experiment included the following options:

Factor A – variety: 1. Adapt; 2. Stalker; 3. Aeneas.

Factor B – plantnutrition: 1. Control (without fertilizers); 2. $N_{30}P_{30}$ – under pre-sowing cultivation – background; 3. Background + Urea K1 (1 L ha^{-1}); 4. Background + Urea K2 (1 L ha^{-1}); 5. Background + Escort-bio (0.5 L ha^{-1}); 6. Background + Urea K1 + Urea K2 (0.5 L ha^{-1}); 7. Background + Organic D2 (1 L ha^{-1}). The standard working solution was 200 L ha^{-1}. The fertilization of crops by fertilizers was carried out at the beginning of the phases of the spring barley stooling and earing.

Preparations to be used for foliar application of barley crops were listed in the listof pesticides and agrochemicals authorized for use in Ukraine. Preparations of Urea K1 and Urea K2 are registered as fertilizers containing respectively N as 11–13%, P_2O_5 as 0.1–0.3%, K_2O as 0.05–0.15%, micronutrients as 0.1%, succinic acid as 0.1% and N as 9–11%, P_2O_5 as 0.5–0.7%, K_2O as 0.05–0.15%, sodium humate as 3 g L^{-1}, potassium humate as 1 g L^{-1}, trace elements as 1 g L^{-1}. Organic D2 is organo-mineral fertilizer containing N as 2.0–3.0%, P_2O_5 as 1.7–2.8%, K_2O as 1.3–2.0%, total calcium as 2.0–6.0%, organic matter as 65–70% (in terms of carbon). Escort-bio is a natural microbial complex that contains strains of microorganisms of genera Azotobacter, Pseudomonas, Rhizobium, Lactobacillus, Bacillus, and biologically active substances produced by them.

In the process of research, the method of the State Variety Testing of Agricultural Cultures was used (Volkodav et al., 2001). To determine phytometric indices (mass of dry and raw matter of plants, leaf area), plants were taken by frame method from 1 m^2 in three non-adjoining repeats in stages of growth and development. During the growing season, the area of the leaf surface of the plants was determined by the method of carving, the net productivity of photosynthesis (NFP) as the growth of the mass of dry matter per unit time per unit leaf area, the index of the leaf surface (PI) – as the ratio of the total leaf area to unit area of plantings. The crop structure was analyzed by the sheaves, which were taken before harvesting from the sites of 1 m^2. The yield was determined by the method of continuous harvesting of each registration area (Sampo – 130 combine harvester).

Variant placing in the experiments was random; repetition was three times. The results of the research were processed using the method of multivariate disperse analysis.

RESULTS AND DISCUSSION

The overground mass plays an important role in the life of plants as it mobilizes carbohydrates and nitrogen-containing substances to form the productive part of the crop. Particularly important role of the overground mass of plants is diverted to the south of Ukraine, where until the period of grain filling a significant part of the leaf apparatus (Panfilova et al., 2019).

Mineral fertilizers, including increasing doses of nitrogen fertilizers, contribute to the growth of the overground mass of plants and the increase in grain yield (Novotna et al., 2015; Povilaitis et al., 2018). One of the ways to increase the effectiveness of using mineral fertilizers for reducing their norms is the use of growth-stimulating preparations. The use of growth-stimulating preparations causes changes in the leaf apparatus of crops, in particular, it leads to a significant increasing in the number of leaves per plant, the mass of raw and dry matter of leaves, which is a typical reaction of the plant organism to the action of growth-stimulating preparations and it is confirmed in literary sources (Khan & Ansari, 1998; Fauate et al., 2007). On average, over the years of research, somewhat larger amounts of crude and dry earth masses have accumulated by plants of the Aeneas variety (Table 1).

Thus, on the control version of the experiment of the plants raw biomass of the Aeneas variety, in the stooling phase it was accumulated 896 g m^{-2}, and in the earing phase it was accumulated 1,692 g m^{-2}, which was at 28–57 g m^{-2}or 1.7–6.8% more compared to the raw mass of plants of the Adapt variety and at 15–48 g m^{-2}or 0.9–5.7% more than the Stalker variety. The same trend was observed in other variants of the experiment.

It should be noted that the application of foliar nutrition of plants during the period of vegetation with modern growth-regulating preparations Organic D2 and Escort - bio in the background of the application of a moderate dose of mineral fertilizers contributed to the accumulation of somewhat larger amounts of crude overground mass of plants of the studied varieties of spring barley. Thus, on average, over the years of research and by variety factor, at the end of the stooling phase it was formed 1,799–1,851 g m^{-2}, and in the earing phase it was formed 2,665–2,706 g m^{-2}, which respectively 938–990 and 987–1,028 g m^{-2}, or 52.1–53.5 and 37.0–38.0% exceeded the parameters of the control variant.

The dynamics of accumulation of dry matter during the growing of spring barley in our studies had practically the same tendencies that were found during the formation of the crude overground mass. In the tillering phase, the process of accumulation of dry matter by plants was slow, and the difference between the studied variants was only 9–11 g m^{-2}depending on the type of studied variety. However, already from the stooling phase it was seen a significant difference depending on the nutrition of plants and varieties by 40.6–59.8; 43.3–62.2 and 35.4–55.5% with the advantage of the background + Escort - bio.

And in the research of other scientists application of fertilizers in different ways influenced on the accumulation of dry mass of plants. Thus, an increase in the fertilizer dose up to 300 mg N per pot contributed to a decrease in the specified index in spring barley plants (Kostadinova et al., 2016).

Table 1. The growth of crude and dry overground mass of spring barley plants depending on the variety features and nutrition optimization (average for 2013–2017), g m^{-2}

Nutrition variant	Crude overground mass			Dry mass of plants		
	Phase of plant development					
	tillering	plant stooling	earing	tillering	plant stooling	earing
variety Adapt						
Control	307	839	1,664	65	177	566
$N_{30}P_{30}$ (background)	344	1,383	2,040	74	298	706
Background + Urea K1		1,607	2,475		360	867
Background + Urea K2		1,655	2,517		371	890
Background + Escort-bio		1,816	2,678		440	971
Background + Urea K1 + Urea K2		1,722	2,584		403	929
Background + Organic D2		1,773	2,639		413	953
variety Stalker						
Control	313	848	1,677	64	160	575
$N_{30}P_{30}$ (background)	351	1,436	2,057	75	282	717
Background + Urea K1		1,644	2,506		333	896
Background + Urea K2		1,679	2,548		344	916
Background + Escort-bio		1,847	2,704		423	1,002
Background + Urea K1 + Urea K2		1,761	2,601		367	945
Background + Organic D2		1,799	2,662		406	979
variety Aeneas						
Control	304	896	1,692	62	210	553
$N_{30}P_{30}$ (background)	342	1,360	2,086	71	325	727
Background + Urea K1		1,630	2,530		400	924
Background + Urea K2		1,651	2,574		420	947
Background + Escort-bio		1,889	2,737		472	1,045
Background + Urea K1 + Urea K2		1,768	2,633		437	982
Background + Organic D2		1,824	2,695		456	1,011
$LSD_{0.5}$ 2013: A		12	13		13	7
B		8	7		9	10
2014: A		5	5		16	16
B		3	7		9	9
2015: A		10	11		10	15
B		7	8		9	11
2016: A		15	13		21	9
B		11	12		17	10
2017: A		2	6		24	19
B		7	7		9	13

Photosynthesis is the basis of production and, at least, 90% of the grain crop is determined by it (Shao et al., 2005; Makino, 2011). In the process of photosynthesis the simple substances are formed into energy–rich complex and diverse in chemical composition organic compounds. The intensity of the accumulation of organic matter depends on the size of the leaf surface, which is determined by the biometric parameters of the plants and it significantly depends on the mode of their nutrition, as well as the duration of the leaves activity (Malkina & Eremenko, 2016). The area of the leaf surface plays an important role in the analysis of plant growth processes and the formation of grain productivity (Sharma et al., 2003; Guendouz et al., 2016).

In modern agriculture, various plant growth regulators have been widely used, which influence on the intensity of photosynthetic processes. So, in studies of Ukrainian scientists (Gritsaenko et al., 2008) it was established that the treatment of plants with growth regulators increased the net productivity of photosynthesis, it increased the content of photosynthetic pigments in the chloroplasts.

Our research found that the use of foliar fertilization of spring barley crops contributed to an increase in the area of the plants leaf surface from the tillering phase to earing phase, after which in all years of the research a significant decrease was observed in this indicator related to the culture biology, namely, the fading of the leaf apparatus and the outflow of nutrients from the leaves to the generative organs, although the processes of plant development were still ongoing. Thus, on average, over the years of research, during the entire vegetation season in fertilized plants, the area of the leaf surface was greater than the area of untreated ones (Table 2).

So, for the growth of spring barley of the variety Adapt from the tillering phase and to the earing phase in the variants with a moderate dose of mineral fertilizers the index area of the leaf surface increased up to 3.29 m^2 m^{-2}, and for cultivating varieties Stalker and Aeneas it increased up to 3.49–3.71 m^2 m^{-2}.

Foliar nutrition of crops in the main periods of vegetation of spring barley plants with modern growth-regulating drugs in combination with the main application of $N_{30}P_{30}$ provided growth of the index of the leaf surface of plants of the Adapt in the earing phase up to 18.5–28.8%, while the specified index of Stalker and Aeneas varieties increased respectively up to 20.8–30.1 and 20.6–28.1% depending on the plant nutrition.

It should be noted that on average, over the years of research and in terms of nutrition, the index of the leaf surface of plants of spring barley of the variety Aeneas was slightly higher compared to other studied varieties: in the stooling phase it was higher at 3.3–7.1%, and in the earing phase it was higher at 5.3–10.0%.

According to the results of our researches, the work of the plant apparatus during vegetation was determined by the net productivity of photosynthesis (CRF). We determined that this index depended on the studied factors such as biological characteristics of the studied varieties of spring barley, the background of nutrition, and on the phases of plant growth and development. Thus, on average, over the years of research, in the experimental variants, where only the background fertilizer $N_{30}P_{30}$, in the Adapt and Stalker varieties was introduced in the interphase period of tillering - stooling it was 5.19–5.82 g m^{-2} per day, in the interphase period of stooling - earing it was 12.24–12.27 g m^{-2} per day. For the growing of spring barley of the variety Aeneas the specified values were slightly higher compared to other studied varieties, respectively, 6.16 and 13.14 g m^{-2}per day.

The largest net photosynthesis performance was determined in the background application of $N_{30}P_{30}$ and subsequent fertilization of the crops by Escort Bio. Thus, on average, over the years of research, in the interphase period of tilerring - earing, the net productivity of photosynthesis of the Adapt variety was 12.00 g m^{-2}per day, while the

Stalker and Aeneas varieties it was respectively 11.93 and 12.15 g m^{-2}per day, which exceeded control by 25.9; 26.2 and 34.1% respectively.

Table 2. Photosynthetic activity of spring barley crops depending on varietal characteristics and optimization of nutrition (average for 2013–2017)

Nutrition variant	Leaf index, m^2 m^{-2}			The net productivity of photosynthesis, G m^{-2}per day		
	Phase of plant development			Interphase periods		
	tillering	plant stooling	earing	tillering - stooling	stooling - earing	tillering -earing
variety Adapt						
Control	1.10	2.44	2.72	3.48	11.06	8.89
$N_{30}P_{30}$ (background)	1.21	3.01	3.29	5.82	12.27	9.60
Background + Urea K1		3.07	3.34	7.39	14.54	11.79
Background + Urea K2		3.12	3.40	7.54	14.68	12.01
Background + Escort-bio		3.51	3.82	8.52	13.11	12.00
Background + Urea K1 + Urea K2		3.30	3.62	8.01	13.81	11.96
Background + Organic D2		3.44	3.73	8.07	13.69	11,98
variety Stalker						
Control	1.14	2.59	2.81	2.89	11.31	8.80
$N_{30}P_{30}$ (background)	1.26	3.16	3.49	5.19	12.24	9.65
Background + Urea K1		3.22	3.55	6.37	15.15	11.54
Background + Urea K2		3.27	3.61	6.56	15.23	11.69
Background + Escort-bio		3.62	4.02	7.90	14.11	11.93
Background + Urea K1 + Urea K2		3.43	3.79	6.92	14.45	11.62
Background + Organic D2		3.55	3.92	7.59	14.24	11.80
variety Aeneas						
Control	1.17	2.69	3.00	4.27	11.07	8.01
$N_{30}P_{30}$ (background)	1.31	3.26	3.71	6.16	13.14	8.98
Background + Urea K1		3.32	3.78	7.82	13.78	10.74
Background + Urea K2		3.36	3.83	8.21	13.68	11.63
Background + Escort-bio		3.74	4.17	8.68	13.64	12.15
Background + Urea K1 + Urea K2		3.55	3.98	8.27	13.39	11.77
Background + Organic D2		3.67	4.11	8.50	13.42	11.87

It should be noted that on average, over the years of research and on the factor of plant nutrition, somewhat higher indicators of pure productivity of photosynthesis were for the cultivation of the Adapt variety. Thus, in the inter-phase period of tillering - earing, the net productivity of the photosynthesis of this variety exceeded this indicator in the varieties Stalker and Aeneas at 0.18–0.48 g m^{-2} per day or 1.6–4.5%.

Consequently, the increasing of growth processes in spring barley plants caused by the influence of modern organo-mineral and mineral fertilizers was resulted in the formation of a larger overground mass of plants, a more powerful leaf apparatus and increased the net productivity of photosynthesis. Such anatomical and morphological changes had a positive effect on the productivity of spring barley varieties (Table 3).

Table 3. Performance of spring barley, depending on varietal characteristics and optimization of nutrition, average for 2013–2017

Variety	Nutrition variant	Number of grains in the ear, pc.	Weight of corn grain, g	Grain yield, t ha^{-1}
Adapt	Control	20.0	0.915	2.56
	$N_{30}P_{30}$ (background)	20.7	1.001	2.91
	Background + Urea K1	20.9	1.024	3.05
	Background + Urea K2	21.0	1.033	3.11
	Background + Escort-bio	21.6	1.077	3.25
	Background + Urea K1 + Urea K2	21.2	1.046	3.17
	Background + Organic D2	21.4	1.061	3.22
Stalker	Control	20.5	0.950	2.63
	$N_{30}P_{30}$ (background)	21.4	1.026	3.02
	Background + Urea K1	21.6	1.051	3.19
	Background + Urea K2	21.8	1.060	3.23
	Background + Escort-bio	22.3	1.097	3.37
	Background + Urea K1 + Urea K2	21.9	1.074	3.29
	Background + Organic D2	22.1	1.084	3.33
Aeneas	Control	21.0	0.970	2.80
	$N_{30}P_{30}$ (background)	21.8	1.047	3.24
	Background + Urea K1	22.0	1.069	3.38
	Background + Urea K2	22.2	1.078	3.44
	Background + Escort-bio	22.6	1.113	3.61
	Background + Urea K1 + Urea K2	22.3	1.091	3.52
	Background + Organic D2	22.4	1.098	3.56
$LSD_{0.5}$ 2013: A		2	0.010	0.08
B		1	0.008	0.11
2014: A		4	0.017	0.10
B		2	0.013	0.13
2015: A		8	0.023	0.09
B		2	0.019	0.14
2016: A		7	0.36	0.08
B		4	0.032	0.10
2017: A		2	0.002	0.11
B		1	0.003	0.13

It is known that the structural elements such as the amount of grains in the ear and the mass of grains from the ear are the main components of grain crops. Formation of their level and variability on a huge selection of varieties and breeding lines, for many years, in a controlled environment is of great interest to the technology of breeding process. First of all, genotypes that stably form high structural elements of the crop, which in the future are used to create new varieties (Gusenkova & Tishchenko, 2018) can be chosen in the huge biological diversity of the investigated material. The variety combines in the genotype the maximum number of features and properties that contribute to obtaining a high level of harvest of appropriate quality. The list of these features was determined by the agroecological conditions and factors affecting agroecenos during the vegetation (Hudzenko et al., 2017). On average, over the years of our research, the nutrition variants to some extent affected on the number of grains in the ear of spring barley. Thus, introduction of pre-sowing cultivation of mineral fertilizers in a dose of $N_{30}P_{30}$ contributed to the increase of the specified figure by 3.4–4.2% depending on the type of variety. The application of mineral fertilizers of extra-root nutritions during the growing season with modern preparations Organic D2 and Escort - bio contributed to an increase in the number of grains in the ear from 6.5 to 7.4% in the Adapt variety, it was from 7.2 to 8.1% in the Stalker variety and it was from 6.3 to 7.1% for the Aeneas variety.

Immediately after the transition of plants from vegetative development to generative one, a gradual implementation of the biopotential of an important element of yield is started as the number of grains in the ear, on which the varietal features have a significant impact (Solonechnuy, 2018). In our studies, somewhat larger amounts of grains in the ear were created during the years of research of the plants of the Aeneas variety. So, on average, over the years of research on the nutrition factor, they formed 22.0 pcs., which exceeded other studied varieties by 1.4–4.8%.

We found that on average over the years of research, varieties and variants of nutrition have affected on the mass of grain from one ear. So, for the introduction of the background recommended dose of mineral fertilizers for spring barley of the variety Adapt the weight of grain from the ear in comparison with unfertilized control increased by 9.4%, while in the Stalker variety it was increased by 8.00%, and in the Aeneas variety it was increased by 7.9%. Conducting of foliar nutrition on the background of mineral fertilizers increased the specified index of yield structure, respectively, by 11.9–17.7; 10.6–15.5 and 10.2–14.7% for control.

Yield is a major parameter of research in agriculture and the environment (Iizumi et al., 2014). Resource-saving technologies, which increase the yield of grain crops up to 10–15%, can contribute to the increase in yields (Dwyer et al., 1995; Markov et al., 2011). Combined use of organic and mineral fertilizers in combination with humic substances in studies by Indian scientists increased grain yield of wheat by 27% and it had beneficial effect on the nutrients and organic carbon content in the soil (Manzoor et al., 2014; Bharali et al., 2017).

In our studies, the growth of grain yield of spring barley of varieties Adapt and Stalker for the introduction of $N_{30}P_{30}$ to control was 0.35–0.39 t ha^{-1} or 13.7–14.8%. The application of growth-regulating drugs on the background of the application of $N_{30}P_{30}$ provided for an increase in the grain yield of spring barley, respectively, from 0.49 to 0.69 and 0.56 to 0.74 t ha^{-1} or 19.1 to 27.0 and 21.3 to 28.1% depending on the drug.

Extra-root fertilization of Aeneas spring barley crops also positively affected on grain yields. Thus, on average, over the years of research, specified agricultural method contributed to an increase in yields by 0.58–0.81 t ha^{-1} or by 20.7–28.9% compared to the control.

The yields of the studied varieties naturally grew on the variants of extra-root nutrition against the background of mineral fertilizers. At the same time, more significant increments of grain were formed in the variants of carrying on their background the fertilization of crops with the preparations Organic D2 and Escort - bio. Their application contributed to the growth of grain yield of spring barley of the variety Adapt at 0.66–0.69 t ha^{-1} or 25.8–27.0%, the growth of yield of the Stalker variety was at 0.70–0.74 t ha^{-1} or 26, 6 to 28.1%, while the growth of yield of the Aeneas variety was 0.76–0.81 t ha^{-1} or 27.1–29.9% respectively.

Grain yields are the result of the interaction of genetic features of plants, agrotechnological and climatic conditions of cultivation (Diacono et al., 2012). On average, over the years of research, the Aeneas variety was superior to the Adapt and Stalker varieties, with the best indicators of the structure of spring barley and grain yield. Thus, on average, over the years of research and on the factor of nutrition, the grain yield of spring barley of the variety Aeneas compared to other studied varieties was formed higher by 0.21–0.32 t ha^{-1} or 6.3–9.5%.

CONCLUSION

In the conditions of southern Ukraine, on the average, during years of research, the application of mineral fertilizers at a dose of $N_{30}P_{30}$ under pre-sowing cultivation and the application of extra-root crop cultivation at the beginning of the stooling and earing phases with fertilizers Organic D2 and Escort-bio contributed to the accumulation of somewhat more crude and dry overground mass of the studied varieties plants of spring barley and the formation of their higher photosynthetic rates.

Nutrition with Escort-Bio and Organic D2 supplies the highest indicators of yield structure, at the same time, the essential influence of the investigated factor was on the mass of grain from one ear. It has been established that significantly higher yield of barley grain for these varieties of food provides the cultivation of the Aeneas variety - 3.56–3.61 t ha^{-1}.

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