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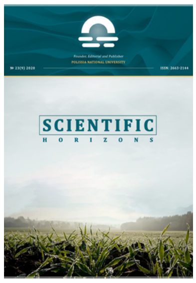

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PHOTOSYNTHETIC POTENTIAL OF SPRING BARLEY PLANTS IN THE STEPPE ZONE

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Abstract. Today, an increase in the real potential of grain crops, including spring barley, is a necessary condition for elements of crop cultivation technologies. Therefore, given the limited resource potential of spring barley crops, their fastidiousness to the soil, considerable attention should be paid to the photosynthetic potential of plants and the standardised application of mineral fertilisers. The aim of the study was to improve the elements of the technology of growing promising varieties of spring barley by establishing the mineral nutrition effect on the photosynthetic activity of plants in the conditions of the Luhanska Oblast. This study provides examples of improving some technologies for growing promising varieties of spring barley and determines the optimal norms for applying mineral nutrition to ensure the high photosynthetic potential of these plants in the climatic conditions of the steppe zone of Ukraine. It was found that the use of ammonium nitrate had a positive effect on the leaf area, increasing it by 1-2.2 thousand m^2/ha compared to the control for all varieties studied. The combined use of diammonium phosphate and ammonium nitrate contributed to an increase in the leaf area by 2-4.4 thousand m^2/ha compared to the control variant. Simultaneous application of ActiBION increased the total leaf area for all samples studied by 3.8-6.4 thousand m^2/ha. The best indicators among the studied varieties were observed on the six-row variety Helios and the double-row variety Stalker. The six-row variety Vakula and the two-row variety Adapt showed slightly lower results. Further research implies the study of the influence of photosynthetic activity of promising varieties of spring barley on crop productivity in the steppe zone of Ukraine. The findings can be recommended for production as one of the elements in the technology of growing spring barley in the climatic conditions of the Luhanska Oblast

Keywords: photosynthetic potential, spring barley, Helios, Vakula, Adapt, Stalker

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INTRODUCTION

The development and improvement of existing technologies for growing grain crops, in particular spring barley, in steppe conditions is currently the main priority area of agricultural production [1; 2]. One of the ways to increase the yield of spring barley is to create conditions under which the crop reaches potential [3]. Spring barley is one of the key grain crops cultivated in Ukraine and is the fourth in the world in terms of production, making the country one of the world leaders (top five) [4].

According to analysts, the export production of barley in Ukraine will be at the level of 9.4 million tonnes. The country can provide 20% of the world's total crop [5; 6]. Therefore, today the Ukrainian farmers must take into account both the rapid market of products and the problems that they directly face in the field. Thus, given the limited resource potential of the plant, changing weather conditions, the fastidiousness of barley to the soil and the crop productivity, it is necessary to pay considerable attention to: establishment of the optimal density of productive stem; phytosanitary condition of the field; the choice of fertiliser systems and retardant protection; development of the root system and photosynthetic potential of plants [6-8]. Many Ukrainian scientists agree with this statement: I.D. Tkalich, E.I. Mamadova, O. V. Bochevar et al., – note the fact that improvement of the nutrition background has a positive effect on the height of plants, the length of the ear, the number of productive shoots, etc. [9; 10].

As a result of the action of trace elements, plants become more resistant to drought, low temperatures, diseases and damage by harmful organisms, so one of the factors in the development of photosynthetic activity of spring barley crops is the norm of mineral nutrition, taking into account the poorly developed root system. The results of experiments conducted in the steppe zone indicate that all structural elements of the crop depend on fertiliser. Therefore, to achieve high yields, a balanced mineral nutrition and full photosynthetic productivity of plants are required [8; 10; 11].

Photosynthetic productivity of spring barley crops is the result of processes that produce energy-rich complex and diverse organic compounds from simple substances and depends on disease damage, resulting in a shortage of crops [9; 11; 12]. Therefore, an effective fertiliser system contributes to the normal course of the physiological state of the plant, its assimilation of nutrients, moisture and their transformation during photosynthesis into spare substances of the grain. Directly, one of the indicators of photosynthetic activity of plants is the area of the leaf surface. Therefore, the intensity of this process and the duration of its operation are crucial factors in the photosynthetic productivity, determining the size and quality of the crop [10; 11].

Thus, for spring barley crops, taking into account their anatomical and morphological structure during the growing season, it is necessary to create such conditions that optimally contribute to the formation of the leaf apparatus, and therefore effective photosynthetic activity in general.

The aim of the study was to investigate the influence of both conventional and new mineral fertilisers on the photosynthetic activity of spring barley crops, thereby improving the elements of technologies for growing promising spring barley varieties in the steppe zone of Ukraine.

LITERATURE REVIEW

Today, due to sharp climate changes, modern agronomic science faces an important question: an increase in the content of finished organic matter in plants during photosynthesis. According to the researchers, this is possible by changing the mineral nutrition, humidity, and seeding rates. Such measures can significantly increase the total percentage of PAR (photosynthetic active radiation) [7-9]. According to scientists, in the steppe zone the assimilation potential of plants is at the level of 0.5 million m^2/day. However, if proper agricultural techniques are followed, it can be increased to 2 million m^2/day [13]. Therefore, both the fertiliser system and all agricultural equipment should provide for the maximum provision of plants with the necessary root nutrition elements in a timely manner to increase the entire vegetation mass. As it increases, the total area of the leaf will also increase, which will ensure that the plant absorbs solar radiation.

Therefore, in spring barley crops, it is necessary to achieve their optimal density, since the growth of the photosynthetic apparatus can gradually lead to mutual shading of leaves, deterioration of aeration of crops and complicate the process of transferring carbon dioxide to the atmosphere. For its part, this will worsen photosynthetic conditions and reduce the efficiency of increasing fertiliser and water supply levels [14; 15]. According to researchers, this problem can be solved by placing rows from West to East, so the row spacing will be shaded by growing plants. In addition, the moisture capacity of crops will be preserved and the number of weeds will be reduced [14-16].

According to long-term studies by A.A. Nichiporovich, O.G. Andreichenko et al., yield and crop productivity are influenced by three main factors: photosynthetic productivity, respiration and translocation. It is known that photosynthesis and respiration are closely related, the more active the one, the more active is the other [10; 11].

Using the photosynthesis, plants absorb the entire mass of carbon dioxide from the external environment, due to which 42-45% of the mass of organic matter is formed [1]. Photosynthetic activity of a set of plants in grain crops includes a number of very important components: the area of photoactive foliage, the rate of its growth, the duration and intensity of leaf work, the coefficient of use of headlights in specific environmental conditions. The key factor that very often suppresses the development of plants is their insufficient resistance to adverse environmental conditions, which mainly determines the amount of solar energy absorbed, the volume of carbohydrate synthesis, and so on. First of all, such processes are observed when the optimal sowing time is violated, associated with various circumstances, most often with an acute lack of moisture in the soil, violations of the nutrient regime, poor-quality seed material, etc. [10; 13]. Therefore, there is reason to assert that the active introduction of the varieties most adapted to the conditions of the region, as well as the standardised application of mineral fertilisers, will contribute to better growth and development of spring barley crops [12; 14].

According to numerous studies conducted in different countries, it was found that microelement compounds, getting into the plant, are directly involved in the processes of metabolism, affecting all phases of ontogenesis and the timeliness of their course [12; 17; 18].

This study suggests that the issue of applying the optimal rate of conventional and modern mineral fertilisers, according to various predecessors, as well as taking into account the genetic properties of the spring barley plant variety in the steppe zone of Ukraine, remains open.

Thus, taking into account the above-mentioned problems, there is a need to establish changes in the indicators of photosynthetic activity in crops depending on various factors, in particular, the conditions of insufficient moisture in the Luhanska Oblast.

MATERIALS AND METHODS

Experimental studies were carried out in 2018-2020 at the experimental plots of the Department of Biology and Agronomy, in the department of scientific and technical training of the Taras Shevchenko National University of Luhansk (Luhanska Oblast, Starobilsk district) located in an agroclimatic area with insufficient moisture. The soils of the experimental sites were represented by ordinary chernozems on loess rocks with a thickness of humus layer of 65-80 cm. The weather conditions were not the same. In terms of the degree of moisture content, they were close to the long-term average. The average annual precipitation was 474.7 mm. The average air temperature (March – August) over the years of the study was in the range of 15-16°C, which is 1.37°C more than the long-term average [19].

The predecessor of spring barley was sunflower. Technological techniques that were not studied were generally accepted for the region. In particular, tillage included peeling stubble with an LDG-15 Husker to a depth of 10-12 cm after harvesting the predecessor, ploughing with a PN-4-35 plough to a depth of 20-22 cm. The main tillage, which was studied in experiments on spring barley, was carried out in autumn with a non-polar (chisel) – deep digger Catros 4000 to a depth of 12-14 cm.

Spring tillage was carried out with an AK-8.5 cultivator to a depth of 6-8 cm. For seed treatment, Vencedor solution (1 l per 100 kg) was used, which is a two-component contact-system fungicide with growth-regulating properties. Sowing of seeds was carried out at the end of March, with a seed-fertiliser seeder SZ-5.4. Seeding rates were 4.0-5.5 million tonnes. seeds per 1 hectare, the optimal depth of seed embedding was 4-5 cm. Mineral fertilisers were applied simultaneously with sowing. The experiment was laid down in three-fold repetition. The sown area of the plot was 25 m^2, the accounting area was 20.6 m^2.

Promising six-row regionalised varieties Helios, Vakula, and two-row – Adapt and Stalker – were sown:

1. Helios. (Originator: CJSC "Selena"; in the State Register of plant varieties of Ukraine since 2006). The weight of 1000 seeds is 47.8-49.9 g. It is recommended for growing in the steppe, forest-steppe and Polesia zones. Intensive-type variety. The average yield is 50.8-55.1 ctr/ha, the potential yield of the variety is 89 ctr/ha [20].
2. Vakula. (Originator: Breeding and Genetic Institute – National Centre for Seed Science and Variety Research of the UAAS; in the State Register of plant varieties of Ukraine since 2006). Weight of 1000 seeds – 44 g. The variety is suitable for growing in conditions of drought and high soil acidity. The average yield is 48.4 ctr/ha, the potential yield is 105 ctr/ha.
3. Adapt. (Originator: Breeding and Genetic Institute – National Centre for Seed Science and Variety Research of the UAAS; in the State Register of plant varieties of Ukraine since 1998). The weight of 1000 seeds – 47-63 g. The variety is bred for severe drought conditions. The yield is 50-75 ctr/ha.
4. Stalker – (originators: Breeding and Genetic Institute – National Centre for Seed Science and Variety Research of the UAAS; in the State Register of plant varieties of Ukraine since 1997). Weight of 1000 grains – 50-55 g. The variety was bred under the breeding programme for increased adaptability to the conditions of the arid steppe. The yield under production conditions – 55-70 ctr/ha [21].

Barley was harvested in the phase of full grain ripeness by a combine. The work started when the grain humidity reached 14%. The study used a modern and more powerful combine harvester NEW HOLLAND CX 60.90.

The scheme of the experiment with spring barley included the following options:

Factor A – variety:
1. Helios
2. Vakula
3. Stalker
4. Adapt

Factor B – fertiliser background:
1. Without fertilisers
2. Ammonium nitrate NH_4: NO_3 1:1 at a rate of 200 kg/ha
3. Diammonium phosphate $(NH_4)_2HPO_4$, N:P 18:46, at the rate of 100 kg/ha + ammonium nitrate NH_4: NO_3 1:1 at a rate of 100 kg /ha
4. ActiBION (N-9, P_2O_5 – 20, K_2O – 12, SO_3 – 15,

CaO – 16, Mg – 2, Mn – 0.01, B – 0.1, Fe – 0.5 at a rate of 100 kg/ha + ammonium nitrate NH_4NO_3 at a rate of 100 kg/ha.

For a comprehensive assessment of technologies, phenological observations, biometric records, etc. were carried out. Records, measurements and related observations were carried out in accordance with the methods of field research, according to the method of state variety testing of agricultural crops [22]. Photosynthetic activity was determined using the method described by A. A.Nichiporovich [10; 11]

The results obtained were processed.

RESULTS AND DISCUSSION

During the study, it was found that the use of the proposed options for background nutrition of spring barley affected the total area of the leaf surface of plants. Active growth of vegetative mass was observed before and during the earing phase, after passing this stage of ontogenesis, they had some downward tendencies. It was at this time that the required leaf area was formed, as the main photosynthetic organ of plants, accumulating a sufficient amount of carbohydrates and dry vegetative mass and, accordingly, net photosynthetic productivity. Thus, the two-row Stalker variety under control had a leaf surface area of 47.8 thousand m²/ha, which is 1.0 thousand m²/ha more than the Adapt variety. The introduction of ammonium nitrate led to an increase in the area of both varieties from 0.8 to 1.0 thousand m²/ha, respectively, the combined introduction of diammonium phosphate and ammonium nitrate increased the leaf surface from 1.6 to 2.0 thousand m²/ha. The complex use of ActiBION at a rate of 100 kg/ha and ammonium nitrate at a rate of 100 kg/ha contributed to an increase in the leaf area from 2.2 to 2.8 thousand m²/ha, respectively, compared to the control.

Studies have shown that six-row varieties in comparison with two-row varieties had a tendency to increase the leaf surface area. Among them, the Helios variety showed 48.8 thousand m²/ha, and the Vakula variety – 47.8 thousand m²/ha. When fertilised only with ammonium nitrate, the area increased from 0.4 in the Vakula variety to 1.8 thousand m²/ha in the Helios variety. The combined use of diammonium phosphate and ammonium nitrate positively changed the area from 1.6 thousand m²/ha (Vakula variety) to 1.8-1.8 thousand m²/ha (Helios variety). The maximum increase in leaf area was observed in the Helios variety when using ActiBION and ammonium nitrate, which is 0.4 more than in the Vakula variety compared to the control (Table 1, Figure 1).

Table 1. *Leaf surface area of spring barley crops depending on the varietal characteristics and mineral nutrition in the earing phase (average for 2018-2020), thousand m²/ha*

Varieties	Mineral nutrition background	Ontogenesis phase (earing)
Helios	Without fertilisers (control)	48.8
	Ammonium nitrate 200 kg/ha	50.6
	Diammonium phosphate 100 kg/ha + ammonium nitrate 100 kg/ha	52.4
	ActiBION 100 kg/ha + ammonium nitrate 100 kg/ha	54.2
Vakula	Without fertilisers (control)	47.8
	Ammonium nitrate 200 kg/ha	48.2
	Diammonium phosphate 100 kg/ha + ammonium nitrate 100 kg/ha	49.8
	ActiBION 100 kg/ha + ammonium nitrate 100 kg/ha	51.2
Stalker	Without fertilisers (control)	47.8
	Ammonium nitrate 200 kg/ha	48.8
	Diammonium phosphate 100 kg/ha + ammonium nitrate 100 kg/ha	50.8
	ActiBION 100 kg/ha + ammonium nitrate 100 kg/ha	53.6
Adapt	Without fertilisers (control)	46.8
	Ammonium nitrate 200 kg/ha	47.6
	Diammonium phosphate 100 kg/ha + ammonium nitrate 100 kg/ha	49.2
	ActiBION 100 kg/ha + ammonium nitrate 100 kg/ha	51.4

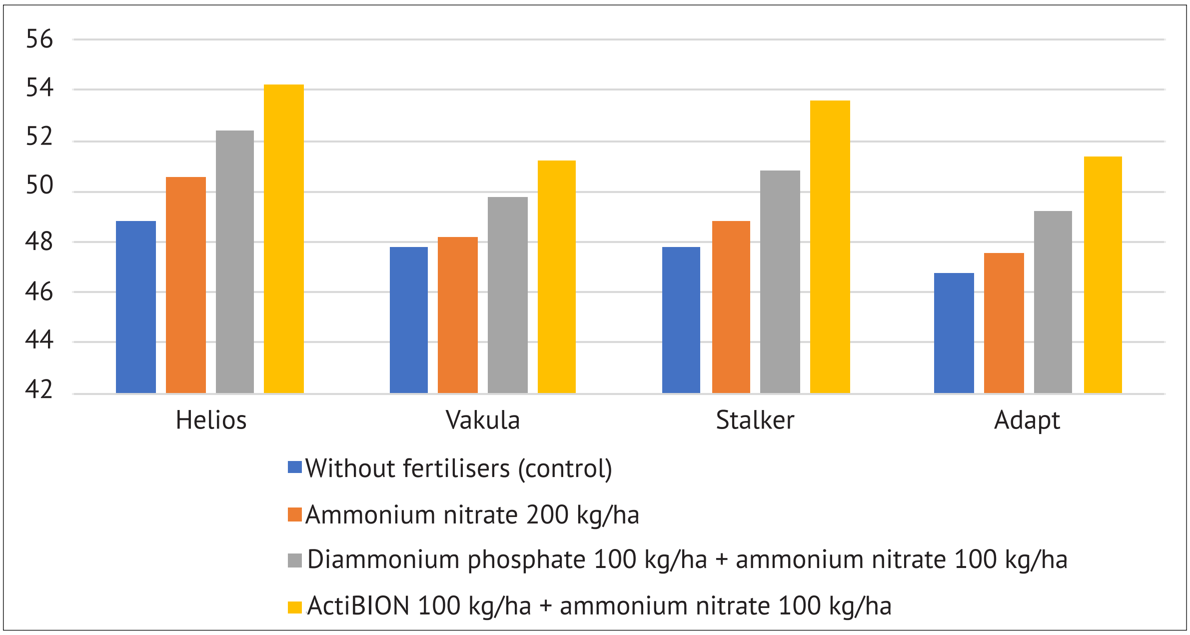

Figure 1. *Dynamics of changes in the leaf surface area of spring barley crops depending on the varietal characteristics and mineral nutrition in the earing phase (average for 2018-2020), thousand m²/ha*

Analysing the data obtained, it can be argued that the development of the leaf surface of spring barley was positively influenced by both varietal characteristics of crops and the introduction of mineral fertilisers. The best indicators were obtained with the combined use of ActiBION at a rate of 100 kg/ha and ammonium nitrate at a rate of 100 kg/ha on Helios and Stalker varieties.

Notably, before the onset of the earing phase, the lower leaves of spring barley plants, in all the proposed variants of the experiment, dried up. Thus the main role in the process of photosynthesis, and therefore photosynthetic activity in general, was assumed by the upper leaves. Therefore, it can be argued that the introduction of mineral fertilisers has become a necessary factor in the full supply of the plant with the necessary elements that play an important role in the metabolic processes in the plant (Fig. 2).

Figure 2. *Helios spring barley plants in the earing phase (2020)*

Source*: author's research*

Based on the findings and taking into account the varietal characteristics of spring barley plants, the authors investigated the photosynthetic potential of crops using the method of A.A. Nichiporovic [10; 11]. Taking into account that the growing season of the studied varieties depended more on their varietal characteristics and hydrothermal conditions in the studied years than on the factors studied, data on the growing season were taken on average for the years of the study (Table 2).

Table 2. *Photosynthetic potential of spring barley crops depending on the varietal characteristics and mineral nutrition in the earing phase (average for 2018-2020), thousand m²/ha*

Varieties	Mineral nutrition background	Ontogenesis phase (earing)
Helios	Without fertilisers (control)	2.93
	Ammonium nitrate 200 kg/ha	3.04
	Diammonium phosphate 100 kg/ha + ammonium nitrate 100 kg/ha	3.15
	ActiBION 100 kg/ha + ammonium nitrate 100 kg/ha	3.25
Vakula	Without fertilisers (control)	2.87
	Ammonium nitrate 200 kg/ha	2.90
	Diammonium phosphate 100 kg/ha + ammonium nitrate 100 kg/ha	2.99
	ActiBION 100 kg/ha + ammonium nitrate 100 kg/ha	3.07
Stalker	Without fertilisers (control)	2.39
	Ammonium nitrate 200 kg/ha	2.44
	Diammonium phosphate 100 kg/ha + ammonium nitrate 100 kg/ha	2.54
	ActiBION 100 kg/ha + ammonium nitrate 100 kg/ha	2.68
Adapt	Without fertilisers (control)	2.34
	Ammonium nitrate 200 kg/ha	2.38
	Diammonium phosphate 100 kg/ha + ammonium nitrate 100 kg/ha	2.46
	ActiBION 100 kg/ha + ammonium nitrate 100 kg/ha	2.57

On average, over the years of the study, against the background of no fertiliser in all varieties studied, the indicator ranged from 2.34 to 2.93 million m^2/ha×day. The introduction of ammonium nitrate provided an increase in this indicator for all varieties from 2.38 to 3.04 million m^2/ha×day. Diammonium phosphate and ammonium nitrate provided a tendency to increase the photosynthetic potential from 2.46 to 3.15 million m^2/ha×day, depending on the variety.

The greatest photosynthetic potential of crops was observed with the complex application of ActiBION at a rate of 100 kg/ha and ammonium nitrate at a rate of 100 kg/ha. Thus, on average, it was 2.57 million m^2/ha×days for the Adapt variety, 2.68 million m^2/ha×days for the Stalker variety, 3.07 million m^2/ha×days for the Vakula variety, and 3.25 million m^2/ha×days for the Helios variety compared to the control (Table 2).

CONCLUSIONS

Taking into account the peculiarities of the growth and development of the spring barley crop and constant changes in zonal conditions, elements of the technology for growing promising varieties of spring barley were improved by studying the effect of mineral nutrition on the photosynthetic activity of plants. The study shows that the value of the photosynthetic potential largely dependeds on the varietal characteristics of the crop, on the type and rate of fertiliser, which create conditions for normal growth and development. Therefore, the introduction of mineral fertilisers in all the investigated samples improved the nutritional conditions of spring barley and, accordingly, increased the leaf surface. Studies have established that the complex application of ActiBION and ammonium nitrate maximised the photosynthetic potential of spring barley crops. The best performance was observed in the six-row Helios variety and the two-row Stalker variety.

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ФОТОСИНТЕТИЧНИЙ ПОТЕНЦІАЛ РОСЛИН ЯЧМЕНЮ ЯРОГО В УМОВАХ ЗОНИ СТЕПУ

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Анотація. На сьогодні підвищення реального потенціалу зернових культур, зокрема і ячменю ярого є необхідною умовою елементів технологій вирощування сільськогосподарських культур. Тому, враховуючи обмежений ресурсний потенціал рослин ячменю ярого, вибагливість його до ґрунту, потрібно чималу увагу приділяти фотосинтетичному потенціалу рослин і нормованому внесенню мінеральних добрив. Метою досліджень було вдосконалення елементів технології вирощування перспективних сортів ячменю ярого шляхом встановлення впливу мінерального живлення на фотосинтетичну діяльність рослин в умовах Луганської області. У представленій статті наведені приклади вдосконалення деяких елементів технологій вирощування перспективних сортів ячменю ярого та визначено оптимальні норми внесення мінерального живлення для забезпечення високого фотосинтетичного потенціалу цих рослин у кліматичних умовах зони Степу України. Встановлено, що застосування аміачної селітри позитивно впливало на площу листа, збільшуючи її на 1-2,2 тис. м^2/га у порівнянні з контролем по всіх сортах, що вивчалися. Сумісне використання діамонію фосфату та аміачної селітри посприяло збільшенню площі листка на 2-4,4 тис. м^2/га порівняно з контрольним варіантом. Одночасне внесення препарату ActiBION збільшили загальну площу листків по всіх зразках, що вивчалися на 3,8-6,4 тис. м^2/га. Найкращі показники серед сортів, що досліджувалися, спостерігали на шестирядному сорті Геліос і дворядному сорті Сталкер. Шестирядний сорт Вакула та дворядний сорт Адапт показали дещо менші результати. Подальші результати полягають у вивченні впливу фотосинтетичної діяльності посівів перспективних сортів ячменю ярого на його продуктивність у зоні Степу України. Результати дослідження можуть бути рекомендовані у виробництво як один із елементів у технології вирощування ячменю ярого в кліматичних умовах Луганської області

Ключові слова: фотосинтетичний потенціал, ячмінь ярий, Геліос, Вакула, Адапт, Сталкер