EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2024, 25(4), 282–291
https://doi.org/10.12912/27197050/183939
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Received: 2023.11.16
Accepted: 2024.02.10
Published: 2024.02.25

Formation of Yield and Grain Quality of Spring Barley Depending on Fertiliser Optimisation

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ABSTRACT

In the current conditions of intensification of grain production, it is important to develop resource-saving cultivation technologies that ensure the maximum realisation of the genetic potential of crop varieties through the use of foliar fertilisation and mineral fertilisers. The article presents the results of research on the optimisation of fertilisation of spring barley plants. During the period of research, the influence of fertilisation and foliar feeding on the germination and preservation of spring barley plants, net photosynthetic productivity, elements of the yield structure, yield and grain quality was assessed. The research was conducted in the experimental field of Vinnytsia National Agrarian University during 2018–2020 on grey forest medium loamy soils. The hydrothermal conditions were quite contrasting and differed from the average perennial conditions both in terms of heat intensity and moisture level, which allowed to study the influence of the studied factors and their interaction on the formation of spring barley yield and grain quality. The maximum indicators of plant preservation, net productivity of photosynthesis, elements of crop structure, yield and grain quality were obtained in the experiment variant with the combined application of mineral fertiliser at a dose of $N_{30}P_{30}K_{30}$ and foliar feeding of plants with Vuksal microfertiliser (BBCH 33-51) and (BBCH 51-54) in Aizhan and Aristey varieties. With the application of mineral fertiliser at a dose of $N_{30}P_{30}K_{30}$, the grain yield of spring barley varieties Aizhan and Aristey increased by 0.99; 0.85 $Mg \cdot ha^{-1}$, and the protein content by 1.9; 2.0% compared to the control variant. With the combined application of mineral fertiliser at a dose of $N_{30}P_{30}K_{30}$ and foliar feeding of plants with Vuksal microfertiliser, grain yield increased by 1.54; 1.23 $Mg \cdot ha^{-1}$ for one-time foliar feeding; by 1.77; 1.42 $Mg \cdot ha^{-1}$ for two-time foliar feeding, and protein content by 2.8; 2.7 and 3.4; 3.3% in Aizhan and Aristey varieties compared to the control variant, respectively.

Keywords: spring barley, fertilizers, foliar nutrition, photosynthesis, field germination rate.

INTRODUCTION

Crops, especially modern intensive varieties, achieve their fullest potential under favorable environmental conditions, especially under optimal nutrition and moisture supply. Under conditions of a favorable combination of these factors, optimal conditions are provided for the growth processes, while deviations from them, especially significant ones, result in the inhibition of the growth processes. Soil is the main source of nutrients for plants, especially soil nutrients as well as physical and physicochemical properties that provide necessary mobility for nutrient assimilation during the main phases of development (Didur et al., 2020; Razanov et al., 2020). Increase in the crop yield and improvement of the product quality largely depend on the level of soil nutrients (Branitskyi et al., 2022).

Identification of mechanisms of the effect of mineral fertilizers on the soil fertility and crop yields is an important task for the development of a science-based system of fertilization. The most favorable conditions for achieving high plant productivity, as well as for maintaining soil fertility at a reasonable level, are created when fully supplying their nutrients. According to (Demydov et al., 2018; Mazur et al., 2021), application of mineral fertilizers, especially nitrogen fertilizers, in moderate doses (N_{23-45}) in combination with phosphorus and potassium ones, allows to significantly improve nutrient regime of the soil. Plants are provided with available nutrients as a result of mineralization of organic compounds by soil microorganisms and transition of dissoluble minerals into soluble ones.

It is established that spring barley absorbs on average 23–30 kg of nitrogen, 10–15 kg of phosphorus and 20–25 kg of potassium to form 1 ton of the main and by-products (Volkodav, 2001; Buriak, 2008). The intensity of its growth and development directly depends on the supply of easily soluble nutrients in the initial stages of organogenesis. It is known that throughout the whole growing season 67% of potassium, 46% of phosphorus and most of the nitrogen from the total need are absorbed by plants before the phase of stem elongation (Razanov et al., 2018; Tkachuk, 2021).

One of the ways to increase the effectiveness of mineral fertilizers under reduced application rates is to apply growth stimulants, which increase plant resistance to adverse weather conditions, pests and diseases. Recently, both abroad and in our country, foliar nutrition with fertilizers has become increasingly important as one of the most economical ways to use them, which has a positive effect on physiological processes of plants, yields and product quality (Tkachuk, Verhelis, 2021; Mostovenko et al., 2022).

MATERIALS AND METHODS

The research was conducted in the research field of Vinnytsia National Agrarian University during 2018-2020. The hydrothermal regime was quite contrasting during the research period. It should be noted that less favorable conditions were formed in 2018, both in terms of precipitation and temperature regimes, the most optimal conditions for moisture supply and temperatures were observed in 2019.

The hydrothermal regime during the study period was quite contrasting. It should be noted that less favourable conditions were formed in 2018, with an average monthly air temperature of 17.5 °C and precipitation of 302 mm during the growing season, while the most optimal conditions were in 2019, with moisture availability of 309 mm and temperatures of 16.4 °C. In 2020, the conditions were marked by a moisture deficit of 261 mm and a favourable average monthly air temperature of 15.4 °C. The sown area of each variant, on which experimental sowing was carried out, was 40 m^2. Within this area, an accounting area of 25 m^2 was allocated, within which observations and records were carried out. Each sowing and accounting area was planted four times. Phenological observations establishing occurrence of the microstages were conducted according to the methodology (Meier, 2001; Volkodav, 2001).

The trial scheme included the study of the following variants (Table 1): Factor A – varieties: 1 – Aizhan and 2 – Aristei; Factor B – fertilization: 1. without fertilizers (control); 2. background – $N_{30}P_{30}K_{30}$; 3. foliar nutrition in the phase of stem elongation on the background of $N_{30}P_{30}K_{30}$; 4. double foliar nutrition (in the phase of stem elongation and in the earing phase) on the background of $N_{30}P_{30}K_{30}$.

Processing of experimental data and statistical analysis of the results were performed on a PC using MS Excel 2019 software (Microsoft, USA) and Statistica 12.6 (Dell Technologies, USA) using built-in statistical functions. The small sample method was used. The method of small samples provided for the determination of the arithmetic mean values (AM) and the deviation of the arithmetic mean values (±MAE) (Rudenko, 2012). The results of crop accounting were subjected to analysis of variance (Moiseichenko et al., 1996).

RESULTS AND DISCUSSION

Field germination rate and friendship of seedlings are the main components of the intensive technology of growing grain crops with large reserves for the yield increase (Kaminska et al., 2012). According to long-term data, it has been noted that germination of grain crops does not exceed 70% (Razanov et al., 2020). Due to low field germination rate, it is impossible to obtain the required number of plants as well as ensure their uniform distribution by the nutrition area. There

Table 1. Experimental design

Variety (A)	Fertilizers (B)
Aizhan Aristei	Without fertilizers (control)
	$N_{30}P_{30}K_{30}$ (background)
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R
	$N_{30}P_{30}K_{30}$ (background) + Vuksal

is a differentiation of sowings by the degree of development, nature of interaction and competition for the factors of growth and development, there appear greater differences in the individual development of morphological processes of plants (Zakharchenko, 2007).

A significant impact on the field germination is made by the seed infestation with fungal diseases, damage by wireworms (*Elateridae*) and false wireworms (*Tenebrionidae*) due to deep seeding depth or sowing in over-dried soil, as a result of which plants lose germinating power (Lisovyi, 1991). The effect of mineral fertilizers on field germination has been insufficiently studied. According to some research results, the dependence of field germination of spring barley (*Hordeum vulgare* L.) seeds on the seeding rates and fertilization has been established. At the same time, some authors explain the decrease in field germination of seeds under the increase in sowing rates by the fact that seeds of all crops contain specific compounds that delay germination of neighboring seeds under conditions of too dense sowing and thus reduce field germination. When the sowing density is lower, these compounds are absorbed directly by the soil (Babych, 1994).

In some experiments conducted on sod-podzolic soils, after the occupied fallow and late harvested predecessors, complex fertilizers increase field germination rate by 7–9% (Mazur et al., 2023). According to research results, field germination rate was influenced by the soil temperature and humidity during seed germination and the system of fertilization. The highest field germination rate in Aizhan (84.1%) and Aristei (83.3%) varieties was observed in the trial variants where mineral fertilizers were applied at a dose of $N_{30}P_{30}K_{30}$, which was 1.2% more, respectively (Table 2).

Depending on the variety, plant density in the phase of full germination, varied within 328.4±3.2 to 337.2±3.4 plants per m^2 and differed insignificantly according to the variants of the experiment. Mineral fertilizers ensure seed germination and acceleration of the growth process in plants, facilitate improvement of the root system development, which in general increases moisture supply of plants as well as provision with macro- and microelements. Thus, the highest plant density of barley was obtained in the trial variant, where there were applied mineral fertilizers in a dose of $N_{30}P_{30}K_{30}$ – 336.4±3.4; 333.2±3.3 plants per m^2, which was 4.8 plants per м^2 more than in the control variant. The first foliar nutrition with microfertilizers Yara Vita, Vuksal and Avanhard R was conducted in the phase of stem elongation, so that this technological practice did not influence plant density in the phase of full germination.

During the growing season plant density was reducing, which was caused by plant lodging that in its turn influenced plant resistance to abiotic and biotic factors, which was confirmed by the research results of others scientists who argued that when observing the dynamics of spring barley plant density during the growing season it was

Table 2. Influence of fertilizers and microfertilizers on the field germination and plant density of spring barley plants in the phase of full germination (average of 2018–2020), AM + MAE

Variety (A)	Fertilizers (B)	Plant density, plants per m^2	Field germination rate, %
Aizhan	Without fertilizers (control)	331.6±3.5	82.9
	$N_{30}P_{30}K_{30}$ (background)	336.4±3.4	84.1
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	336.0±3.2 336.4±3.3	84.0 84.1
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	336.8±3,6 337.2±3.4	84.2 84.3
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	336.4±3.2 336.8±3.5	84.1 84.2
Aristei	Without fertilizers (control)	328.4±3.2	82.1
	$N_{30}P_{30}K_{30}$ (background)	333.2±3.3	83.3
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	333.2±3,5 333.2±3.1	83.3 83.3
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	334.0±3.2 334.4±3.1	83.5 83.6
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	333.2±3.3 333.2±3.2	83.3 83.3

Note: in the numerator – nutrition in the phase of "stem elongation"; in the denominator – double foliar nutrition in the phase of "stem elongation" and "beginning of earing".

found that this indicator was reducing while the plants were growing and developing as a result of lodging. This phenomenon was caused by a group of biotic and abiotic factors of the environment (Kalenska, Suddenko, 2016; Myronova et al., 2023). Thus, during the period of ripening plant density was reducing and was 254.1±2.6 to 275.0±2.7 plants per m^2 by the trial variants.

According to research results, it was found that mineral fertilizers had a positive effect on field germination, while foliar nutrition of plants with microfertilizers Yara Vita, Vuksal and Avanhard R together with mineral fertilizers increased plant survival (Table 3). Survival of spring barley plants, depending on the trial variant, varied from 77.4 to 81.7%. In the trial when mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ was applied, survival of plants was 79.8% in Aizhan variety and 79.0% in Aristei variety, which was higher compared to the control by 1.9; 1.6% or 10.1; 9.2 plants per m^2. This is confirmed by the results of research: with the correct application of fertilisers, the yield of intensive spring barley varieties increases significantly, with insufficient moisture, water is used by plants to form a unit of yield by 15–20% more economically, plant resistance to drought, diseases and pests increases, grain quality and potassium significantly improve, in particular, resistance to lodging (Len, 2010).

Under combined application of mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ and foliar nutrition of plants with biogent Yara Vita in the phase of stem elongation and in the phase of earing in Aristei and Aizhan varieties, plant survival was 81.4; 81.5% and 81.3; 81.3%, which was higher compared to the control by 3.5; 3.6% and 3.9; 3.9%. Under combined application of mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ and foliar nutrition of plants with Avanhard R microfertilizer in the phase om elongation and in the phase of earing in Aizhan and Aristei varieties, plant survival was 80.6; 81.1% and 80.2; 80.8%, which was higher compared to the control by 2.7; 3.2 and 2.8; 3.4%.

Under combined application of mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ and foliar nutrition of plants with Vuksal microfertilizer in the phase of stem elongation and in the phase of earing in Aristei and Aizhan varieties, plant survival amounted to 81.6; 81.7% and 81.4; 81.5%, which was higher compared to the control by 3.7; 3.8 and 4.0; 4.1% or 16.2; 16.7 and 17.1; 17.5 plants per m^2. In addition, it was found that plant survival in Aizhan variety was higher (by 0.1–0.5%) compared to Aristei variety.

Combined application of foliar nutrition and mineral fertilizers increased survival of spring barley plants by 3.5–3.9% when Yara Vita was applied and by 3.7–4.1% when Vuksal was applied. This is determined by the positive impact on the establishment and formation of generative organs, improvement of the vegetative growth and development of plants, prevention of chlorosis, increase in the duration of active activity of the leaf apparatus, improvement of the photosynthesis intensity (Panasyk, 2005). There was observed a tendency toward the increase in the

Table 3. Influence of fertilizer on the survival of spring barley plants (average of 2018-2020), AM + MAE

Variety (A)	Fertilizer (B)	Plant density, plants per m^2	Survival during harvesting, %
Aizhan	Without fertilizers (control)	258.3±2.6	77.9
	$N_{30}P_{30}K_{30}$ (background)	268.4±2.5	79.8
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	273.8±2.4 274.2±2.5	81.4 81.5
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	271.5±2.6 273.5±2.4	80.6 81.1
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	274.5±2.5 275.0±2.7	81.6 81.7
Aristei	Without fertilizers (control)	254.1±2.6	77.4
	$N_{30}P_{30}K_{30}$ (background)	263.3±2.2	79.0
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	270.9±2.4 271.0±2.3	81.3 81.3
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	267.9±2.5 270.2±2.6	80 .2 80 8
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	271.2±2.7 271.6±2.9	81.4 81.5

Note: in the numerator – nutrition in the phase of “stem elongation”; in the denominator – double foliar nutrition in the phase of “stem elongation” and “beginning of earing”.

level of plant survival in the variants where mineral fertilizers were applied. This was caused by the improvement of nutrient supply, formation of a stronger root system, vegetative mass and increased resistance to adverse abiotic and biotic conditions. Thus, the best conditions for maintaining the number of plants when achieving maturity was observed in the trial variants, where mineral fertilizers were applied at a dose of $N_{30}P_{30}K_{30}$ and double foliar nutrition with Yara Vita and Vuksal microelements in the phase of stem elongation and in the phase of earing (Baliuk et al., 2019).

Plant yields are primarily determined by the size and productivity of the photosynthetic apparatus, which should reach optimal value as soon as possible in the process of plant growth and development. Plant nutrition is one of the factors regulating the area of the assimilation surface. Therefore, during the growing season it is necessary to provide the most favorable nutritional conditions for plants to form the optimal area of the leaf apparatus and effective photosynthetic activity, i.e. one of the ways to increase crop productivity is to improve agro-technological measures, including conditions for plant nutrition (Shadchyna et al., 2006).

Under conditions of insufficient resource provision of agriculture and ecological crises, there is an urgent need to develop technological solutions that would mobilize the possibilities of natural processes affecting plant development, ensure the stability of agricultural systems, reduce chemical load on agrocenoses to increase their productive potential. In this regard, it is important to substantiate the system of fertilization, which will, on the one hand, ensure a sufficient level of productivity of agrocenoses and fulfil a bioproductive potential of crops, and on the other will help to increase its environmental sustainability, biologically valuable crops and environment. The solution of these problems is possible through the use of the latest biostimulating and growth-regulating agents in combination with moderate doses of mineral fertilizers. One of the features of most biostimulants is the selectivity of their action on various tissues and organs of the plant organism. Therefore, the agents that can stimulate the photosynthetic apparatus and plant immunity, increase plant resistance to adverse environmental conditions are becoming more necessary (Zaiets, Kysil, 2019).

According to research results, net productivity of photosynthesis of spring barley plants during the growing season during the period of stem elongation-earing is shown in Figure 1. It should be noted that net productivity of photosynthesis increased in some interphase periods, namely from the period of tillering to earing under the influence of trial variants. In the trial variant the lowest values of net productivity of photosynthesis were obtained in Aizhan variety – 2.8 and Aristei variety – 2.7 g/m^2 per day. However, net productivity of photosynthesis increased depending on fertilization and foliar nutrition with microfertilizers. When applying mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$, net productivity of photosynthesis in the period of stem elongation-earing was in 4.1 g/m^2 per day in Aizhan variety, and 3.8 g/m^2

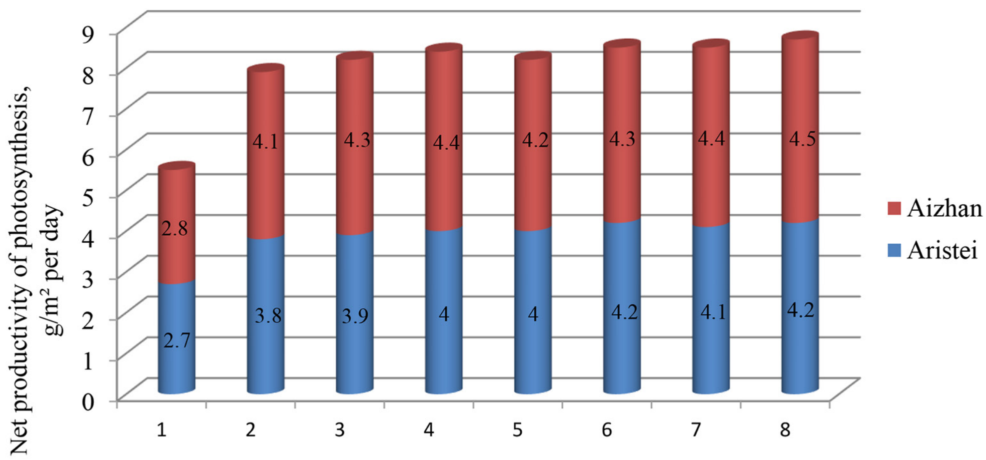

Figure 1. Net productivity of photosynthesis of spring barley varieties in the period of stem elongation-earing depending on fertilization and foliar nutrition. 1 – Control (without fertilization); 2 – $N_{30}P_{30}K_{30}$ (background); 3 – $N_{30}P_{30}K_{30}$ (background)+Yara Vita; 4 – $N_{30}P_{30}K_{30}$ (background)+2 - single application Yara Vita; 5 – $N_{30}P_{30}K_{30}$ (background)+Avanhard R; 6 – $N_{30}P_{30}K_{30}$ (background)+ 2 - single application Avanhard R; 7 – $N_{30}P_{30}K_{30}$ (background)+Vuksal; 8 – $N_{30}P_{30}K_{30}$ (background) + 2 - single application Vuksal

per day in Aristei variety, which was higher than in the control variant by 1.3; 1.1 g/m^2 per day.

Under combined application of mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ and foliar nutrition of plants with Yara Vita microfertilizer in the phase of stem elongation and in the phase of earing in Aizhan and Aristei varieties, net productivity of photosynthesis in the period of stem-elongation-earing was 4.3; 3.9 and 4.4; 4.0, which was higher compared to the control by 1.5; 1.2 and 1.6; 1.3 g/m^2 per day. Under combined application of mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ and foliar nutrition of plants with Avanhard R microfertilizer in the phase of stem elongation and in the phase of tillering in Aizhan and Aristei varieties, net productivity of photosynthesis in the period of stem elongation-earing was 4.2; 4.0 and 4.3; 4.2, which was higher compared to the control by 1.4; 1.3 and 1.5 g/m^2 per day. Under combined application of mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ and foliar nutrition of plants with Vuksal microfertilizer in the phase of stem elongation and in the phase of earing in Aizhan and Aristei varieties, net productivity of photosynthesis in the period of stem-elongation-earing was 4.4; 4.1 and 4.5; 4.2, which was higher compared to the control by 1.6; 1.4 and 1.7; 1.5 g/m^2 per day. Thus, the highest values of net productivity of photosynthesis were obtained in this trial variant. Elements of yield structure of spring barley varieties depending on fertilization and foliar nutrition of plants are shown in Table 4. In the control variant of the experiment in Aizhan and Aristei varieties, the number of productive stems was 481.0±3.4 and 416.6±3.7 plants per m^2, ear length was 7.8; 7.4 cm, number of grains per ear was 19.4; 19.2 grains, grain mass per ear was 0.74; 0.73 g, and the mass of 1,000 grains was 38.3; 37.9 g/m^2. When mineral fertilizer was applied in a dose of $N_{30}P_{30}K_{30}$ the number of productive stems was 545.1±4.3 and 483.4±4.2 units per m^2, ear length was 9.0; 8.6 cm, grain number per ear was 20.9; 20.6, grain mass per ear was 0.84; 0.81 g, and the mass of 1,000 grains was 40.2; 39.1 g.

The highest indicators of the yield structure elements were obtained in the trial variant under combined application of mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ and foliar nutrition of plants with Vuksal microfertilizer in Aizhan and Aristei varieties. Thus, the number of productive stems was 549.3±4.0; 488.6±4.4 and 551.0±4.1; 489.8±4.4 units per m^2, ear length was 9.5; 9.0 and 9.7; 9.3 cm, grain number per ear was 22.9; 22.0 g and 23.5; 22.7 grains, grain mass per ear was 0.93; 0.87 and 0.97; 0.91 g, and the mass of 1,000 grains was 40.7; 39.8 and 41.2; 40.2 g.

Yield formation is a complex production process determined by the genetic program of plants and external conditions. To ensure a high yield, it is necessary to have complete information about

Table 4. Elements of the yield structure of spring barley depending on the fertilization and foliar nutrition (average of 2018–2020), AM + MAE

Variety (A)	Fertilization (B)	Number of productive stems, units per m^2	Ear length, cm	Grain number per ear, grains	Mass of grain per ear, g	Mass of 1,000 grains, g
Aizhan	Without fertilizers (control)	481.0±3.4	7.8±0.2	19.4±0.4	0.74±0.04	38.3±0,6
	$N_{30}P_{30}K_{30}$ (background)	545.1±4.3	9.0±0,3	20.9±0.5	0.84±0.05	40.2±0.5
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	547.8±4.1 548.4±4.0	9.4±0.3 9.6±0.3	22.2±0.5 23.0±0.5	0.90±0.04 0.94±0.04	40.5±0.6 40.7±0.6
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	547.5±4.0 548.4±3.9	9.3±0.3 9.5±0.3	21.8±0.5 22.3±0.5	0.88±0.05 0.91±0.05	40.3±0.5 40.6±0.6
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	549.3±4.0 551.0±4.1	9.5±0.4 9.7±0.4	22.9±0.5 23.5±0.5	0.93±0.04 0.97±0.04	40.7±0.5 41.2±0.6
Aristei	Without fertilizers (control)	416.6±3.7	7.4±0.2	19.2±0.4	0.73±0.03	37.9±0.5
	$N_{30}P_{30}K_{30}$ (background)	483.4±4.2	8.6±0.3	20.6±0,5	0.81±0.04	39.1±0.6
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	487.2±4.5 488.6±4.5	8.8±0.3 9.0±0.3	21.7±0.5 22.3±0.5	0.86±0.04 0.89±0.05	39.6±0.6 39.8±0.6
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	487.0±4.4 488.0±4.4	8.7±0.3 8.9±0.3	21.4±0,5 21.8±0.5	0.84±0.04 0.86±0.05	39.4±0.6 39.6±0.6
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	488.6±4.4 489.8±4.4	9.0±0.3 9.3±0.3	22.0±0.5 22.7±0.5	0.87±0.05 0.91±0.04	39.8±0.7 40.2±0.7

Note: in the numerator – nutrition in the phase of "stem elongation"; in the denominator – double foliar nutrition in the phase of "stem elongation" and "beginning of earing".

the diversity of individual factors and their interactions involved in plant growth and development, be able to predict plant response to them. The yield value is determined by such processes as photosynthesis, growth and development, air, water and heat regimes, mineral nutrition, plant structure, etc (Vyslobodska et al., 2013; Mazur et al., 2021; Yatsenko et al., 2023).

Grain yield of spring barley is an integral indicator, and it is largely determined by the genotype of the variety and growing conditions. It also makes it possible to assess the effectiveness of elements of the cultivation technology in general. After all, 50% of the total yield increase is achieved due to the application of fertilizers. According to the data provided by the research institutions, application of mineral fertilizers increases barley grain yield by 0.7–1.0 Mg·ha^{-1}, and under very favorable conditions by 1.4 Mg·ha^{-1} (Shevnikov, 2012).

The study and comprehensive assessment of some basic elements of the technology for growing spring barley varieties on the basis of in-depth analysis of elements of crop formation structure, varietal characteristics and quality of products obtained during this period will increase the efficiency of this crop (Bunchak, 2018). Since the variety is one of the main means of production, which plays an important role in obtaining high and stable yields. Modern varieties of spring barley are characterized by high adaptability not only to environmental factors, but also to certain agricultural practices and are able to provide a stable level of high yields under optimal economic costs (Miroshnychenko et al. 2011; Bunchak, 2018).

It should be noted that the processes of absorption, movement, distribution of metabolites and assimilation of mineral nutrients play an important role in the formation of crops, including spring barley. The use of synthetic growth regulators, namely retardants makes it possible to regulate the production process. An important aspect of the action of these substances is their ability to affect the donor-acceptor system of the plant, which ensures artificial redistribution of the flow of assimilates to valuable organs (Vasylenko, Dushko, 2019). Influence of fertilizers and foliar fertilization on the yield of spring barley varieties is shown in Table 5. Grain yield was directly determined by both hydrothermal regime and varietal characteristics, but to a greater extent by technological methods of cultivation (fertilization and foliar nutrition).

The grain yield varied from 2.54 to 6.29 Mg·ha^{-1}, depending on the trial variant. The highest grain yield was observed in the trial variants in the conditions of 2019 and varied from 4.33 to 6.29 Mg·ha^{-1} in Aizhan variety and from 3.54 to 5.15 Mg·ha^{-1} in Aristei variety.

Table 5. Influence of fertilization and foliar nutrition on the spring barley grain yield, Mg·ha^{-1}

Variety (A)	Fertilization (B)	Yield, Mg·ha^{-1}			
		2018	2019	2020	Mean
Aizhan	Without fertilizers (control)	2.92	4.33	3.56	3.58
	$N_{30}P_{30}K_{30}$ (background)	3.8	5.44	4.56	4.57
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	4.02 4.18	5.98 6.29	4.89 5.05	4.93 5.13
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	3.96 4.11	5.78 5.96	4.78 4.96	4.81 4.98
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	4.45 4.62	5,97 6,21	4.99 5.27	5.12 5.35
Aristei	Without fertilizers (control)	2.54	3.54	3.06	3.04
	$N_{30}P_{30}K_{30}$ (background)	3.14	4,63	3.99	3.89
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	3.43 3.56	4.94 5.05	4.26 4.48	4.18 4.34
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	3.41 3.5	4.73 4.85	4.23 4.32	4.11 4.21
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	3.55 3.74	4.99 5.15	4.35 4.56	4.27 4.46
LSD$_{0.0}$ of the main effect of factor A		0.07	0.06	0.05	
LSD$_{0.05}$ of the min effect of factor B		0.14	0.12	0.1	
LSD$_{0.05}$ of interaction AB		0.1	0.09	0.07	

Note: in the numerator – nutrition in the phase of "stem elongation"; in the denominator – double foliar nutrition in the phase of "stem elongation" and "beginning of earing".

Table 6. Influence of mineral fertilizer and foliar nutrition of plants on the indicators of spring barley grain, % on dry matter content (average of 2018–2020), AM + MAE

Variety (A)	Fertilization (B)	Protein	Starch	Extractivity
Aizhan	Without fertilizers (control)	9.5±0.8	67.6±1.1	78.0±1.2
	$N_{30}P_{30}K_{30}$ (background)	11.4±0.9	65.3±1.0	77.3±1.1
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	11.9±0.9 12.6±0,95	65.5±1.0 65.9±1.0	76.8±1.1 76.4±1.1
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	11.7±0.8 12.3±0.9	65.2±1.0 65.7±1.1	76.5±1.1 76.1±1.2
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	12.3±0.94 12.9±0.95	65.4±1.0 65.8±1.0	76.4±1.2 76.0±1.1
Aristei	Without fertilizers (control)	9.1±0.7	66.5±1.0	78.0±1.2
	$N_{30}P_{30}K_{30}$ (background)	11.1±0.9	64.4±1.1	77.1±1.1
	$N_{30}P_{30}K_{30}$ (background) + Yara Vita	11.3±0.9 11.9±0.9	64.6±1.0 65.4±1.0	76.5±1.1 76.2±1.1
	$N_{30}P_{30}K_{30}$ (background) + Avanhard R	11.4±0.8 11.8±0.9	64.4±1.0 65.3±1.1	76.4±1.1 76.0±1.1
	$N_{30}P_{30}K_{30}$ (background) + Vuksal	11.8±0.9 12.4±0.95	64.9±1.1 65.5±1.1	76.2±1.2 75.8±1.1

Note: in the numerator – nutrition in the phase of "stem elongation"; in the denominator – double foliar nutrition in the phase of "earing" and "beginning of earing".

Yields increased when fertilization and foliar nutrition were applied. When applying mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$, the yield increased in Aizhan variety – 4.57 and Aristei variety – 3.89 $Mg \cdot ha^{-1}$, which was higher than in the control variant by 0.99; 0.85 $Mg \cdot ha^{-1}$. Under combined application of mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ and foliar nutrition of plants with Yara Vita microfertilizer in Aizhan and Aristei varieties, the yields were 4.93; 4.18 and 5.13; 4.34 $Mg \cdot ha^{-1}$, which was higher than in the control variant by 1.35; 1.14 and 1.55; 1.3 $Mg \cdot ha^{-1}$. The lowest grain yield was observed in the trial variants in 2018 and varied from 2.92 to 4.62 $Mg \cdot ha^{-1}$ in Aizhan variety and from 2.54 to 3.74 $Mg \cdot ha^{-1}$ in Aristei variety.

The influence of fertilization and foliar nutrition of plants on the indicators of spring barley grain quality are shown in Table 6. According to the research results, it was found that application of mineral fertilizers at a dose of $N_{30}P_{30}K_{30}$ increased protein content by 1.9 and 2.0% compared to the control variant in Aizhan and Aristei varieties. The highest protein content was observed in the trial variant under combined application of mineral fertilizer at a dose of $N_{30}P_{30}K_{30}$ and double foliar fertilization of plants with Vuksal microfertilizer in Aizhan and Aristei varieties by respectively 12.9 and 12.4%, that is 3.4 and 3.3%, more. However, starch content and extractivity decreased in all variants of the experiment, except the control variant, where starch content and extractivity in Aizhan and Aristei varieties were the highest and amounted to 67.6±1.1; 78.0±1.2% in the first variety and 66.5±1.0; 78.0±1.2% in another one.

When applying mineral fertilizers at a dose of $N_{30}P_{30}K_{30}$, starch content and extractivity decreased by 2.3; 2.1 and 0.7; 0.9%, respectively. Under double application of Yara Vita, Avanhard R and Vuksal microfertilizers on the background of mineral fertilizers, starch content of Aizhan and Aristei varieties was reduced by 2.4; 2.1% and 1.7; 1.0%, respectively. It contributed to the extractivity reduction in these trial variants in spring barley Aizhan and Aristei varieties by 2.0; 2.2 and 1.2; 1.5%, respectively.

CONCLUSIONS

During the period of research, the influence of fertilisation and foliar feeding on the germination and preservation of spring barley plants was assessed. The results of the research indicate that these indicators depend on the effect of both mineral fertilisers and foliar feeding. Since mineral fertilisers promote seed germination and activation of growth and development processes in spring barley plants, they improve the development of the root system, moisture absorption, as well as the absorption of macro- and microelements and their efficiency. At the same time, the highest field germination in varieties Aizhan (84.1%) and Aristey (83.3%) was observed in the experimental variants where mineral fertilizers were applied at a dose of $N_{30}P_{30}K_{30}$, which is respectively 1.2% higher than in the control variant.

Foliar fertilisation can improve the supply of mineral nutrients to plants during critical periods of growth and development, which has a positive effect on the establishment and formation of generative organs, plant resistance to disease, plant stress resistance at high temperatures and drought. Thus, with the combined application of mineral fertiliser at a dose of $N_{30}P_{30}K_{30}$ and foliar feeding of plants with Vuksal microfertiliser at the microstage of BBCH 30-34 and BBCH 51-54 in Aristey and Aizhan varieties, plant preservation was 81.6; 81.7% and 81.4; 81.5%, which is 3.7; 3.8 and 4.0; 4.1% higher than in the control. Increased yield and quality of spring barley varieties Aizhan and Aristey under the combined application of mineral fertiliser at a dose of $N_{30}P_{30}K_{30}$ and foliar feeding of plants with Vuksal microfertiliser, grain yield increased by 1.54; 1.23 $Mg{\cdot}ha^{-1}$ under one-time foliar feeding compared to the control variant; with two-time foliar feeding by 1.77; 1.42 $Mg{\cdot}ha^{-1}$, and protein content by 2.8; 2.7 and 3.4; 3.3% compared to the control variant.

During the research period, the impact of fertilizers and foliar nutrition on the germination and survival of spring barley plants was assessed. The obtained research results indicate the dependence of these indicators on mineral fertilizers and foliar nutrition, since mineral fertilizers promote seed germination and intensify the processes of growth and development of spring barley plants, improve the root system development, moisture absorption, as well as assimilation of macro- and micronutrients and their effectiveness. Foliar nutrition can improve the supply of mineral nutrients during critical periods of growth and development, which has a positive effect on the establishment and formation of generative organs, plant resistance to diseases, stress resistance of plants under high temperatures, drought, increases activity of photosynthetic apparatus, increases the amount and quality of grain harvest in Aizhan and Aristei.

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