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PHOTOSYNTHETIC ACTIVITY OF WINTER WHEAT DEPENDING ON FERTILIZATION AND LIME APPLICATION ON SOD-PODZOLIC SOIL IN THE CONDITIONS OF WESTERN POLISSIA

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Topicality. *Increasing the productivity of crop photosynthesis, i.e. the amount of organic matter synthesised per unit of leaf surface in a day, is an essential condition for high crop yields. The area of the leaf surface depends on the biometric parameters of the plant, the nutritional regime, as well as the duration of leaf activity, which significantly affects the accumulation of organic matter.* ***Purpose****. To identify the influence of mineral nutrition optimization and chemical amelioration on the formation of leaf surface area, photosynthetic potential, and net photosynthetic productivity in the main development stages of winter wheat grown on sod-podzolic soil in the conditions of the Western Polissia.* ***Methods.*** *Field experiment, calculation and statistical methods.* ***Results.*** *In particular, with the application of dolomite meal at a dose of 1.0 Hh and different fertilisation variants, the leaf surface area of plants increased from 1.5 thousand m^2/ha to 4.12–6.99 thousand m^2/ha in the tillering stage, from 4.07 thousand m^2/ha to 14.16–21.34 thousand m^2/ha in the stem elongation stage, and from 2.59 thousand m^2/ha to 5.33–9.49 thousand m^2/ha in the heading stage, respectively, compared to the control (without fertilisation). It is noted over the years of research that the application of mineral fertilisers on the background of liming increased the indicator of photosynthetic potential by 2.6–3.5 times compared to non-fertilised one, and the net productivity of photosynthesis increased by 15.4–21.3 % compared to the control.* ***Conclusions.*** *The largest indicators of leaf surface area, photosynthetic potential, and net photosynthetic productivity in the tillering, stem elongation and heading stages were formed by application of $N_{150}P_{50}K_{125}$ + S_{40} + microfertilizer (two applications). The highest photosynthetic activity of winter wheat plants were noted in the stem elongation stage.*

Key words: *winter wheat, fertilization, amelioration, leaf surface area, photosynthetic potential, net photosynthetic productivity*

Introduction. The productivity of winter grain crops is determined by the parameters of plant growth and development and their photosynthetic apparatus, as well as the duration of the growing season and the functioning of the leaf surface as the main organ of photosynthesis. Their formation depends on the biological characteristics of varieties, environmental factors and the influence of technological practices [1, 2].

Winter wheat plants form and accumulate biomass during the growing season through photosynthesis. At the same time, the main role in the formation of biological yield of winter wheat (up to 82 %) is played by leaves [3]. Close correlation (R = 0.65–0.88) between the aboveground mass of plants and crop yield was established [4].

It is known that the photosynthesis intensity is determined by the assimilation area of the leaf surface, which depends on the growing conditions [5]. Reducing of the assimilation surface leads to a decrease in plant productivity, while the optimal yield of winter wheat is formed when the leaf area is 3.5–4.0 times higher than the occupied field area [6]. The power of the assimilation apparatus and the duration of its activity is a crucial factor in photosynthesis productivity, which determines the quantitative and qualitative indicators of the yield [7, 8].

The formation of the leaf surface area and the duration of the functioning leaf apparatus of plants are influenced by the level of mineral fertilisation and water supply [9, 10]. The level of nutrition significantly affects the growth of aboveground biomass, including the number and area of plant leaves. This pattern is evident in the cultivation of many crops in different zones [11–13].

According to the research by H. P. Ustenko [14], fertilisers increase this indicator by 20–30 %, while, according to H. M. Hospodarenko et al., nitrogen fertilisers increase the accumulation of aboveground mass of winter wheat by 8–16 % [15]. Therefore, we should create the most

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favourable nutritional conditions during the growing season allowing the plants to form the optimal leaf surface area for efficient photosynthetic activity of the phytocenosis.

The purpose of the research was to determine the effect of mineral fertilisers and chemical amelioration on the formation of leaf surface area, photosynthetic potential, net photosynthetic productivity in the main development stages of winter wheat grown on sod-podzolic soil in Western Polissia.

Materials and Methods. The study was conducted during 2021–2022 in a stationary field experiment on sod-podzolic, cohesive sandy soil of the Institute of Agriculture of Western Polissia NAAS.

The experimental design included the following variants: without fertilisers (control); background + $CaMg(CO_3)_2$ (1.0 H_h); background + $N_{120}P_{60}K_{90}$ (recommended rate) + S_{40} + microfertiliser (two applications); background + $N_{130}P_{25}K_{35}$ (rate calculated by the normative method based on the main product output) + S_{40} + microfertiliser (two applications); background + $N_{150}P_{50}K_{125}$ (rate calculated by the normative method based on the output of the main product and by-products) + S_{40} + microfertiliser (two applications); background + N_{130} (rate calculated by the normative method based on the main product output) + S_{40} + microfertiliser (two applications); $CaMg(CO_3)_2$ (1.5 H_h) + $N_{120}P_{60}K_{90}$ + S_{40} + microfertiliser (two applications); $CaCO_3$ (1.0 H_h) + $N_{120}P_{60}K_{90}$ + S_{40} + microfertiliser (two applications).

The sown area of the plot was 99 m^2 (16.5x6), the registration area was 50 m^2 (12.5x4), and the experiment was repeated three times. In the experiment, the variants were arranged sequentially. Mineral fertilisers were applied according to the experimental design; nitrogen, phosphorus, potassium and sulphur fertilisers were applied as the basal fertilisers. Nitrogen feeding of winter wheat, according to the experimental design, was carried out in the spring tillering stage and at the beginning of the heading stage. For foliar feeding with microelements, Nutrivant Universal microfertiliser (N – 18 %, P_2O_5 – 18 %, K_2O – 18 %, MgO – 2 %, Cu – 0.0025 %, Fe – 0.04 %, Mn – 0.02 %, Zn – 0.01 %, Mo – 0.0025 %) was used at a rate of 2 kg/ha in the appropriate stages.

Sampling of winter wheat plants for determination of biometric parameters was carried out during the growth resumption and in the stem elongation and heading stages. The assimilation area of the leaf surface was determined by the calculation method i.e. multiplying the length of the lamina by its width and the coefficient 0.67. The net productivity of photosynthesis was determined by the method of A. A. Nychyporovych according to the Kidd-West-Briggs formula [16].

Results and Discussion. Determination of leaf surface area during the spring-summer period in different developmental stages of winter wheat showed a high dependence on the cultivation conditions, in particular, on the level of mineral nutrition and chemical ameliorants. According to the analysis, we note that the leaf surface area grew rather slowly at the beginning of the growing season and reached its maximum at the end of the stem elongation in all experimental variants, and then decreased due to leaf death and outflow of nutrients to the generative organs.

It was found that mineral fertilisers and liming significantly influenced the leaf area of winter wheat plants at all developmental stages. According to two-year studies, it was found that the leaf area increased significantly due to an increased amount of nutrients applied against the background of liming. Therefore, in early winter wheat growing season, the smallest leaf area (2.97 thousand m^2/ha) was in the control variant (without fertilizers), while on the background of dolomite flour application at a rate of 1.0 Hh and different fertilizer variants against liming, it increased by 1.5 thousand m^2/ha and 4.12–6.99 thousand m^2/ha, respectively (Fig. 1).

The photosynthetic apparatus area reached its maximum in the stage of stem elongation at 8.08–29.42 thousand m^2/ha, which is 172–195 % more than in the tillering stage.

The application of mineral fertilizers $N_{150}P_{50}K_{125}$ on the background of 1.0 dose of ameliorant ensured the formation of a quite large vegetative mass, while the highest leaf area of winter wheat plants reached 29.42 thousand m^2/ha, which was almost3.5 times higher than the control variant. Application of only N_{130} + S_{40} + microfertiliser (two applications) on the background of $CaMg(CO_3)_2$ (1.0 H_h) resulted in a 16.2–32.3 % lower value compared to the variants with complete mineral fertilisers.

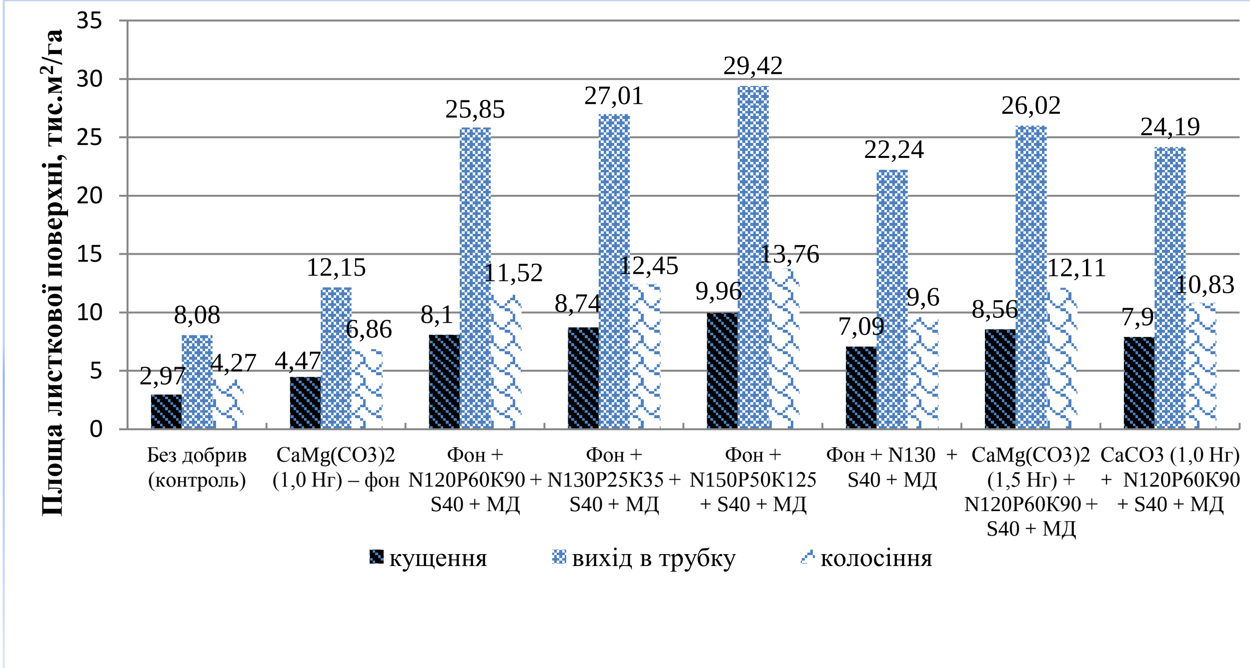

Fig. 1 Leaf surface area of winter wheat depending on fertilisation and liming, thousand m²/ha, average for 2021–2022.

During heading stage, the leaf area of winter wheat plants reduced slightly in all experimental variants, as a result of the leaf apparatus dying off in the lower tier of plants. Leaf surface area development in this stage followed the same pattern as in the previous developmental stages and ranged from 4.27–13.76 ths. m^2/ha.

While comparing the effect of dolomite meal and lime on the leaf surface area, it was found that in case of application of 1.0 dose of ameliorants and the recommended dose of $N_{120}P_{60}K_{90}$ + S_{40} + microfertiliser (two applications), the leaf surface area of winter wheat was 2.5, 6.4 and 6.0 % higher by the developmental stages in the variant with application of dolomite meal instead of lime.

The period of active functioning of the formed assimilation surface is one of the important conditions for high crop productivity, i.e. the photosynthetic potential indicator generally characterises the photosynthetic activity of plants during the growing season and varies significantly depending on the growing conditions. The photosynthetic potential depended on the size of the leaf surface area during the growing season, which was influenced by the application of different rates of mineral fertilizers and chemical ameliorants (Table 1).

On average, over the years of research, the mineral fertiliser application on the background of liming increased the photosynthetic potential to 0.92–1.24 million m²-days/ha, which was 2.6–3.5 times higher than in the control. The highest indicator of the photosynthetic potential of winter wheat was formed at a rate of $N_{150}P_{50}K_{125}$ on the background of 1.0 dose of dolomite meal.

It should be noted that the value of photosynthetic potential alone does not fully indicate the productivity of photosynthesis, since the calculation of this indicator does not consider the intensity of dry matter accumulation in plant cultivation conditions.

For a more complete evaluation of the photosynthetic activity of winter wheat plants, the net photosynthetic productivity is also used, determining the amount of dry matter formed in the process of photosynthesis during the day per 1 m^2 of leaves. This indicator can vary from 0 to 15–18 g/m^2 per day during the growing season [17].

The study results showed that each square metre of winter wheat leaf area produced from 4.88 to 5.92 g of dry matter per day, depending on the variants studied. This indicator increased by 15.4–21.3 % compared to the control in the case of mineral fertilisers application on the background of liming. The highest net photosynthetic productivity of the assimilation apparatus of winter wheat plants was due to the application of $N_{150}P_{50}K_{125}$ on the background of ameliorant and reached 5.92 g/m^2 per day, which is 1.2 times higher than the control.

Table 1. Photosynthetic potential and net productivity of photosynthesis of winter wheat depending on different fertilisation and liming systems for the tillering-heading stages, average for 2021–2022

Variant	Photosynthetic potential, mln m^2 – days/ha	Net photosynthetic productivity, g/m^2 per day
Without fertilisers (control)	0.35	4.88
$CaMg(CO_3)_2$ (1.0 H_h) – background	0.53	5.21
Background + $N_{120}P_{60}K_{90}$ + S_{40} + microfertiliser (two application)	1.07	5.7
Background + $N_{130}P_{25}K_{35}$ + S_{40} + мікродобриво (two application)	1.13	5.82
Background + $N_{150}P_{50}K_{125}$ + S_{40} + microfertiliser (two application)	1.24	5.92
Background + N_{130} + S_{40} + microfertiliser (two application)	0.92	5.63
$CaMg(CO_3)_2$ (1.5 H_h) + $N_{120}P_{60}K_{90}$ + S_{40} + microfertiliser (two application)	1.09	5.78
$CaCO_3$ (1.0 H_h) + $N_{120}P_{60}K_{90}$ + S_{40} + microfertiliser (two application)	1.00	5.67
LSD_{05}	0.05	0.26

Conclusions. It was found that mineral fertilisers and chemical ameliorants had a positive effect on the photosynthetic activity of winter wheat plants on sod-podzolic soil. The largest leaf surface area (29.42 thousand m^2/ha) was formed in the stage of stem elongation after application of $N_{150}P_{50}K_{125}$ + S_{40} + microfertiliser (two applications).

In the period between tillering and heading of plants, the photosynthetic potential of crops and net photosynthetic productivity were also maximal in the variant with the application of $N_{150}P_{50}K_{125}$ + S_{40} + microfertiliser (two applications) against the background of 1.0 dose of ameliorant and amounted to 1.24 million m^2-day/ha and 5.92 g/m^2 per day, respectively.

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Ювчик Н. О. Фотосинтетична діяльність пшениці озимої залежно від удобрення та вапнування на дерново-підзолистому ґрунті в умовах Західного Полісся.

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Актуальність. Важливою умовою формування високих врожаїв сільськогосподарських культур є збільшення продуктивності їх фотосинтезу, тобто кількості синтезованої органічної речовини на одиницю площі листкової поверхні за добу. Накопичення органічної речовини залежить від величини листкової поверхні, яка визначається біометричними параметрами рослин і значною мірою залежить від режиму їх живлення, а також від тривалості активної діяльності листків. **Мета.** Полягала у виявленні впливу оптимізації мінерального живлення та хімічної меліорації на формування площі листкової поверхні, фотосинтетичного потенціалу, чистої продуктивності фотосинтезу в основні фази розвитку пшениці озимої за вирощування на дерново-підзолистому ґрунті в умовах Західного Полісся. **Матеріали та методи**. Польовий дослід, розрахунковий і статистичний методи. **Результати**. Встановлено, що на дерново-підзолистому ґрунті мінеральні добрива та хімічні меліоранти позитивно впливали на фотосинтетичну діяльність рослин пшениці озимої. Так, за внесення доломітового борошна в дозі 1,0 Нг та різних варіантів удобрення площа листкової поверхні рослин порівняно з контролем (без добрив) зросла з 1,5 тис.м^2/га до 4,12–6,99 тис. м^2/га у фазу кущіння, з 4,07 тис. м^2/га до 14,16–21,34 тис. м^2/га – у фазу виходу в трубку та з 2,59 тис. м^2/га до 5,33–9,49 тис. м^2/га – у фазу колосіння, відповідно. Відзначено, що за роки досліджень внесення мінеральних добрив на фоні вапнування підвищувало величину показника фотосинтетичного потенціалу, порівняно із неудобреним, в 2,6–3,5 рази, а чиста продуктивність фотосинтезу зростала на 15,4–21,3 % порівняно з контролем. **Висновки.** Найбільші площа листкової поверхні, фотосинтетичний потенціал, чиста продуктивність фотосинтезу у фази кущіння, виходу в трубку та колосіння сформувалися за внесення $N_{150}P_{50}K_{125}$ + S_{40} + мікродобриво (двічі). Максимальні показники фотосинтетичної діяльності рослин пшениці озимої відзначені у фазі виходу в трубку.

Ключові слова: *пшениця озима, удобрення, меліорація, площа листкової поверхні, фотосинтетичний потенціал, чиста продуктивність фотосинтезу*