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FORMATION OF MAIZE LEAF AREA DEPENDING ON THE FERTILISER SYSTEM

M. V. Stepanenko
Bila Tserkva National Agrarian University, 8/1 Soborna Sq., Bila Tserkva, Kyiv region, 09117, Ukraine

Topicality. *Achieving the maximum level of maize productivity requires optimising the rate of assimilation apparatus formation and promoting the maximum duration of leaf area activity. Adjusting the leaf area of maize crops by optimising plant nutrition ensures improved accumulation of organic matter through photosynthetic activity of plants.* ***Purpose.*** *Research was aimed at determining the effect of maize plants supply with macro- and microelements on the formation of leaf area of the mid-late maize hybrid SI Zefir (FAO 430) under different developmental stages in the Right-Bank Forest-Steppe of Ukraine.* ***Methods.*** *Field, laboratory and laboratory-field methods were used in the research. The research was conducted in the fields of Bila Tserkva National Agrarian University during 2021–2022.* ***Results.*** *It was found that the leaf area of maize varies depending on the stages of growth and development, due to the growth and death of the number of leaves in the process of ontogeny. The dynamics of leaf area decrease from the milk ripeness stage to the full grain ripeness stage was established, which is more related to the death of some leaves. The formation of the total leaf area of the SI Zefir hybrid significantly depended on the climatic conditions of the year and the supply of plants with micro- and macroelements.* ***Conclusions.*** *The best indicators of leaf area in the stages of milk ripeness (41,240 m^2/ha) and full grain ripeness (38,380 m^2/ha) were observed in 2021, which was more favourable in terms of temperature and moisture supply compared to 2022. The introduction of nitrogen fertiliser N_{40} in combination with microfertiliser Wuxal P Max before sowing provided the largest leaf area of the maize hybrid SI Zefir in the stages of milk ripeness – 41,350 m^2/ha and full grain ripeness – 37,600 m^2/ha. The application of nitrogen fertilisers in combination with the microfertiliser Wuxal P Max helps to optimise the nutrient supply of plants, which stimulates the development of leaf area, which increases in the milk and full grain ripeness stages by 3,700 m^2/ha and 2,850 m^2/ha, respectively, compared to the control variant (without fertilisation)*

Key words: *maize, leaf area, photosynthetic surface area, fertilisation*

Introduction. The growth and development of plants and the photosynthetic apparatus, particularly in maize, is the realisation of genetic potential, which significantly depends on agricultural practices, biotic and abiotic environmental factors. Achieving the maximum level of maize productivity requires optimising the rate of formation of the assimilation apparatus and promoting its maximum activity and increasing the leaf area. The size of the assimilative leaf apparatus and the period of its active functionning is a direct factor in the photosynthetic activity of the plant. Photosynthesis occurs in plant organs containing chlorophyll, however, the main organ of photosynthetic activity is the leaf, and for maximum photosynthetic efficiency, maize crops should form the optimal leaf area.

Currently, it is relevant and necessary to study methods for regulating the growth of the leaf area of maize plants by optimising plant nutrition, which will improve the accumulation of organic matter through the photosynthetic activity of plants.

It is difficult to overestimate the importance of corn as a grain and fodder crop, and nowadays also as a raw material for alternative fuels (bioethanol and biogas) [1–3]. The large cultivation areas of this crop indicate its significance both in Ukraine and in other countries of the world. Maize is one of the strategic crops used in many sectors of the national economy, in particular, in the animal husbandry, food and processing industries, and its grain is used to produce more than 300 types of products, including alcohol, flour, groats, molasses, glucose, oil, etc. [4–5]. The formation of the genetic level of maize yield directly depends on the productivity of photosynthesis, which changes during plant ontogenesis, and is influenced by the sowing structure of individual hybrids and growing conditions.

The productivity of photosynthesis also varies depending on the tier of leaves, their age and placement on the stems [6–8].

Autor information:
Mykola V. Stepanenko, *PhD candidate,* e-mail: Mykola.Stepanenko@syngenta.com, https://orcid.org/0000-0002-1286-4151

Based on many scientific studies [9–11], it was found that a decrease in the assimilating area of maize crops leads to a decrease in plant productivity. It is also worth noting that favourrable conditions for yield formation are when the total leaf area of the crop is 3–4 times or even 6 times larger than the cultivation area [4, 8].

The productivity of maize plants significantly depends on the uniformity of illumination of the photosynthetic area, given that a significant advantage in the context of global warming is the ability of maize to use light energy more intensively by fixing CO_2 with one molecule with four carbon atoms [12]. Therefore, maize belongs to the group of C_4 photosynthesis plants [13].

According to V. O. Prykhodko and S. P. Poltoretskyi [10], increasing the leaf area from 10,000 to 30,000 m^2/ha leads to an increase in the PAR assimilation coefficient from 0.28 to 0.67 %, and at the leaf area of 50,000 m^2/ha - up to 0.72 %. They explain this phenomenon by the fact that regardless of the photosynthetic area of the crop, the amount of radiation received per unit area of multiple crops remains constant. Control of plant photosynthetic activity and increase of its productivity is one of the most effective ways to improve crop yield and quality [14]. The total leaf area, intensity of leaf formation and photosynthetic capacity of the leaf area are important given that 90–95 % of plant organic matter is formed from substances formed in the leaves [15]. An important role in the formation of high productivity of photosynthetic activity of plants is played by the application of new environmental friendly and effective microfertilisers [16, 17].

The efficiency of micronutrient application in maize crops due to the higher raw mass of plants was reported by T. Yu. Marchenko, Yu. O. Lavrynenko, O. O. Piliarska, and et al. [18]. The direct dependence of the maize biomass yield and the assimilation (photosynthetic) surface area is also indicated by other researchers in their studies [14, 19–21]. Therefore, in the context of modern cultivation practices, the formation of maize agrocenosis capable to accumulate the maximum solar energy in the form of organic matter has a great importance.

Optimisation of plant nutrition in the fertilisation system, as one of the most significant agronomic practices, significantly improves the photosynthetic activity of maize crops and increases the total plant yield. In addition to macronutrients, microelements (zinc, copper, iron, etc.) are also essential for photosynthetic activity, as they significantly affect the activity of the entire photosynthetic system of plants [17, 22, 23].

The study was aimed at determining the influence of maize plants availability of macro- and microelements on the formation of leaf area in the mid-late maize hybrid SI Zefir (FAO 430) in different development stages in the Right-Bank Forest-Steppe of Ukraine.

Materials and Methods. The research was conducted on the experimental field of the Research and Production Centre of Bila Tserkva National Agrarian University on the maize hybrid SI Zefir during 2021–2022.

The soil of the experimental plot is a typical leached, medium-deep, low-humus, coarse-dusty and light loamy chernozem on carbonate loess with a humus content of 3.4 %. According to the latest agrochemical survey, the content of easily hydrolysed nitrogen (according to the Kornfield method) is 85–115 mg/kg of soil, mobile phosphorus – 130–160 mg/kg and potassium – 120–130 mg/kg of soil (according to the Chirikov method).

The cultivation technology of the mid-late maize hybrid SI Zefir (FAO 430) in the experiments was generally acceptable, except for the factors under study. The experiment was repeated three times. The registration plot area was 38.6 m^2.

Sowing was carried out with an eight-row planter Great Plains (YP-825A-16TR) with a seeding rate of 75,000 seeds/ha.

The experimental design included variants of the fertilisation system: 1) No fertilisation (control); 2) introduction of N_{40} before sowing; 3) introduction of N_{40} before sowing + Nutrivant Plus Maize; 4) introduction of N_{40} before sowing + Wuxal P Max; 5) introduction of N_{40} before sowing + Rosaliq Zn, P, N, S.

The nitrogen fertiliser used was ammonium nitrate with a nitrogen content of 34.6 %. The rate of application of Nutrivant Plus Maize microfertiliser was 3 kg/ha, Wuxal P Max – 2 l/ha, Rosaliq Zn, P, N, S – 3 l/ha. Consumption rate of the working solution was 300 l/ha.

The climatic conditions over the years of research were characterised by differences from the long-term average. In particular, describing the conditions of 2021, it should be noted that this year was the most favourable in terms of precipitation and the effective temperature sum compared to 2022, which was characterised by uneven distribution of precipitation, deviation from the long-term temperature average, which ultimately affected the leaf area of plants.

The assimilating leaf area of the studied maize hybrid SI Zefir was determined by the formula [5, 13, 24]:

$$S=0.75*a*b$$

where: S – total leaf area of the sample, cm^2; 0.75 – conversion factor for maize; a – leaf length, cm; b – leaf width at the widest point, cm.

Leaf area was measured only in physiologically healthy plants. The number of plants selected was 10, the experiment was repeated twice.

Results. The leaf surface area varies depending on the stage of maize growth and development, since both increasing the number of leaves and dying of 5–7 leaves occur during ontogenesis. According to the results of our research, it was found that the leaf area in the milk ripeness stage of maize hybrid SI Zefir significantly depended on the fertilisation system (Table 1).

Analysing the data on the total leaf area

Table 1. Total leaf area of maize hybrid SI Zefir depending on fertilisation system, thousand m^2/ha

Fertilisation system	2021	2022	Average for 2021–2022
No fertilisation (control)	39.60	35.70	37.65
N_{40} before sowing	40.90	37.60	39.25
N_{40} before sowing + Nutrivant Plus Maize	41.60	39.20	40.40
N_{40} before sowing + Wuxal P Max	42.10	40.60	41.35
N_{40} before sowing + Rosaliq Zn, P, N, S	42.00	40.10	41.05
LSD_{05}, thousand m^2/ha	1.65	1.54	–

of the maize hybrid SI Zefir, it should be noted that the average value of this trait in 2021 was 41,240 m^2/ha in the best climatic conditions, and in 2022 it was 38,640 m^2/ha, with a decrease of 2,600 m^2/ha. The highest total leaf area of maize hybrid SI Zefir, on average for two years (41,350 m^2/ha) was achieved by applying nitrogen fertiliser N_{40} in combination with microfertiliser Wuxal P Max before sowing. In the control variant (without fertilisation), the total leaf area was 37,650 m^2/ha. The application of nitrogen fertiliser at a rate of N_{40} before sowing ensured an increased leaf area by 1,600 m^2/ha. Using a combination of nitrogen fertiliser at a rate of N_{40} with Nutrivant Plus Maize microfertiliser before sowing increased the total leaf area by 2,750 m^2/ha, and with Rosaliq Zn, P, N, S microfertiliser – by 3,400 m^2/ha compared to the control variant.

In the course of the study, the dynamics of reducing the leaf area of maize from the milk ripeness stage to the full grain ripeness stage was established. At the same time, a positive dynamic was noted in the increase of leaf area depending on the mineral fertilizer system (Table 2).

According to the received data, a signifycant difference by indicators was noted in the full ripeness stage depending on the fertilisation variants. Thus, on average for two years, the leaf area of the maize hybrid SI Zefir in the control variant was 34,750 m^2/ha, while the application of N_{40} nitrogen fertiliser contributed to an increase in leaf area by 1,250 m^2/ha. In the variant with the introduction of N_{40} and microferti-

Table 2. Leaf area of maize hybrid SI Zephyr in the full grain ripeness depending on the fertilisation system, thousand m^2/ha

Fertilisation system	2021	2022	Average for 2021–2022
No fertilisation (control)	36.70	32.80	34.75
N_{40} before sowing	38.00	34.00	36.00
N_{40} before sowing + Nutrivant Plus Maize	39.00	35.20	37.10
N_{40} before sowing + Wuxal P Max	39.20	36.00	37.60
N_{40} before sowing + Rosaliq Zn, P, N, S	39.00	35.70	37.35
LSD_{05}, thousand m^2/ha	1.54	1.39	–

liser Nutrivant Plus Maize, the leaf area was 37,100 m^2/ha, and in the variant N_{40} + Wuxal P Max – 37,600 m^2/ha and was the highest among all fertilisation variants.

Over the years of research, the average leaf area of the hybrid SI Zefir was 38,380 m^2/ha in 2021, and 34,740 m^2/ha in 2022. Therefore, the climatic conditions of 2021 were more favourable for the development of the leaf apparatus of the maize hybrid under study.

Conclusions. The development of the total leaf area of the mid-late maize hybrid SI Zefir significantly depended on the climatic conditions of the year and the availability of micro- and macroelements. The best indicators of the total leaf area both in the milk ripeness stage (41,240 m^2/ha) and at full grain ripeness stage (38,380 m^2/ha) were observed in 2021, which was more favourable in terms of temperature and moisture during the maize growing season compared to 2022.

The application of nitrogen fertiliser N_{40} in combination with microfertiliser Wuxal P Max before sowing provided the largest leaf area of the maize hybrid SI Zefir in the milk ripeness stage (41,350 m^2/ha) and in the full grain ripeness stage (37,600 m^2/ha). Improving the nutrition conditions under this fertilisation variant contributes to the leaf surface growth by 3,700 m^2/ha and 2,850 m^2/ha, respectively, in the milk and full grain ripeness stages, compared to the control (without fertilisation).

In the future, optimising the nutrition of maize plants and increasing the leaf area will increase grain and silage yields and improve product quality.

References

1. Palamarchuk, V. D., Pidlubnyi, V. F., Krychkovskyi, V. Yu., Kovalenko, O. A. (2020). Starch content in corn grains depending on foliar fertilization. *Silske hospodarstvo ta lisivnytstvo* [Agriculture and forestry], *4 (19)*. 15–28. [in Ukrainian].
2. Palamarchuk, V. D., Telekalo, N. V. (2021). Prospects for growing corn for grain to obtain bioethanol. *Silske hospodarstvo ta lisivnytstvo* [Agriculture and forestry], *2 (21)*. 47–61. [in Ukrainian].
3. Palamarchuk, V. D., Vinnik, O. V., Kovalenko, O. A. (2021). Starch content in corn grains and bioethanol yield depending on vegetation conditions and growing technology factors. *Ahrarni innovatsii* [Agrarian innovations], *5*. 143–156. [in Ukrainian].
4. Mazur, V. A., Palamarchuk, V. D., Polishchuk, I. S., Palamarchuk, O. D. (2017). *Novitni ahrotekhnolohii u roslynnytstvi* [The latest agricultural technologies in crop production]. Vinnytsia: FOP Rohalska I. O. [in Ukrainian].
5. Palamarchuk, V. D., Didur, I. M., Kolisnyk, O. M., Aleksieiev, O. O. (2020*). Aspekty suchasnoi tekhnolohii vyroshchuvannia vysokokrokhmalnoi kukurudzy v umovakh Lisostepu pravoberezhnoho: monohrafiia* [Aspects of modern technology for growing high-starch corn in the conditions of the right-bank Forest-Steppe: monograph]. Vinnytsia: TOV Druk. [in Ukrainian].
6. Zinchenko, O. I. (2016). Roslynnytstvo: pidruchnyk [*Crop production: a textbook*]. (3d ed., rev.). Uman: Vydavets «Sochinskyi M. M.». 2016. [in Ukrainian].
7. Palamarchuk, V. D. (2019). The effect of foliar fertilization on the chlorophyll content of corn hybrids of different maturity groups. *Silske hospodarstvo ta lisivnytstvo* [Agriculture and forestry], *3 (14).* 43–53. [in Ukrainian].
8. Palamarchuk, V. D., Kolisnyk, O. M. (2022). *Suchasna tekhnolohiia vyroshchuvannia kukurudzy dlia enerhoefektyvnoho ta ekolohobezpechnoho rozvytku silskykh terytorii: monohrafiia* [Modern corn cultivation technology for energy-efficient and ecologically safe development of rural areas: monograph]. Vinnytsia: TOV Druk. [in Ukrainian].
9. Mazur, V. A., Shevchenko, N. V. (2018). The formation of the leaf surface area of corn hybrid plants depending on the technological methods of cultivation. *Bioresursy i pryrodokorystuvannia* [Bioresources and nature management], *10*. 1–2. 108–114. [in Ukrainian].
10. Prykhodko, V. O., Poltoretskyi, S. P. (2019). Leaf surface area and productivity of mixed crops of corn and legumes. *Ahrarnyi visnyk Prychornomoria* [Agrarian Bulletin of the Black Sea Region], *92.* 22–32. [in Ukrainian].
11. Mynkin, M. V., Berdnikova, O. H., Mynkina, H. O. (2019). The formation of corn productivity per grain depending on nutrition and stand density in the conditions of Southern Ukraine. *Tavriiskyi naukovyi visnyk* [Taurian Scientific Bulletin], *106.* 103–109. [in Ukrainian].
12. Yaroshko, M., Shtanhela, Y. (2012). Corn – the main requirements for cultivation. *Ahronom* [Agronomist], *2 (36).* 138–140. [in Ukrainian].
13. Nad Yanosh (2012). Kukuruza [*Corn*]. Vinnytsia: FOP D. Iu. Korzun. [in Ukrainian].
14. Sonko, R. S., Marchenko, O. A., Starodub, M. F., Kolomiiets, V. M. (2012). The influence of cultivation technology on the indicators of chlorophyll fluorescence induction during the cultivation of corn plants. *Naukovyi visnyk natsionalnoho universytetu bioresursiv i pryrodokorystuvannia Ukrainy* [Scientific Bulletin of the National University of Bioresources and Nature Management of Ukraine], *178*. 127–132. [in Ukrainian].
15. Kovalchuk, I. (2015). Criteria for the selection of corn hybrids for different growing conditions. *Farmer the Ukrainian, 12 (72).* 82–84. [in Ukrainian].
16. Palamarchuk, V. D., Kovalenko, O. A. (2018). The

effect of foliar fertilization on the area of the cob leaf in corn]. *Silske hospodarstvo ta lisivnytstvo* [Agriculture and forestry], *2 (9).* 68–78. [in Ukrainian].

17. Ivanyshyn, O. S. (2020). The area of the assimilation surface of leaves and the yield of corn hybrids depending on fertilization in the conditions of the Western Forest Steppe. *Tavriiskyi naukovyi visnyk* [Taurian Scientific Bulletin]. *112*. 77–81. [in Ukrainian].
18. Marchenko, T. Iu., Lavrynenko, Yu. O., Piliarska, O. O., Zabara, P. P., Khomenko, T. M., Mykhalenko, I. V., Ivaniv, M. O. (2019). Dynamics of raw and dry biomass accumulation by corn hybrids for drip irrigation. *Zroshuvane zemlerobstvo: zbirnyk naukovykh prats* [Irrigated agriculture: collection of scientific papers], *71*. 108–113. [in Ukrainian].
19. Zabolotnyi, O. I., Zabolotna, A. V. (2019). The dependence of the formation of the height and leaf surface of corn plants on the application of the herbicide "Batu V. G.". *Tavriiskyi naukovyi visnyk* [Taurian Scientific Bulletin], *106*. 65–71. [in Ukrainian].
20. Kaletnik, H. M., Palamarchuk, V. D., Honcharuk, I. V., Yemchyk, T. V., Telekalo, N. V. (2021). *Perspektyvy vykorystannia kukurudzy dlia enerhoefektyvnoho ta ekolohobezpechnoho rozvytku silskykh terytorii: monohrafiia* [Prospects for the use of corn for energy-efficient and ecologically safe development of rural areas: monograph]. Vinnytsia: FOP Kushnir Yu. V. [in Ukrainian].
21. Palamarchuk, V. D., Krychkovskyi, V. Iu., Rudska, N. O., Kolisnyk, O. M. (2023). *Novitni tekhnolohii vyroshchuvannia ovochevykh kultur ta kukurudzy za vykorystannia dyhestatu biohazovykh stantsii: monohrafiia* [The latest technologies for growing vegetable crops and corn using the digestate of biogas plants: monograph]. Vinnytsia: Drukarnia «Druk». [in Ukrainian].
22. Palamarchuk, V. D., Demchuk, B. S. (2021). The role of foliar fertilization in modern grain corn cultivation technologies. *Silske hospodarstvo ta lisivnytstvo* [Agriculture and forestry], *1 (20).* 60–76. [in Ukrainian].
23. Palamarchuk, V. D., Solomon, A. M. (2021). Study of the formation of the assimilation surface area in corn depending on foliar fertilization. *Kormy i kormovyrobnytstvo* [Fodder and fodder production], *92.* 82–94. [in Ukrainian].
24. Fedorchuk, M. I., Fedorchuk, V. H., Kovalenko, O. A., Tkachova Ye. S. ta Rozhok O. F. (2020). *Praktykum z fiziolohii roslyn: navchalnyi posibnyk* [Workshop on plant physiology: study guide]. Mykolaiv: MNAU. [in Ukrainian].

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Степаненко М. В. Формування площі листкової поверхні кукурудзи залежно від системи удобрення. *Зернові культури. 2023. 7 (2). 291–295.*

Білоцерківський національний аграрний університет, площа Соборна, 8/1, м. Біла Церква, 09117, Україна

Актуальність. Для отримання максимального рівня продуктивності кукурудзи важливо оптимізувати швидкість формування асиміляційного апарату та сприяти максимальній тривалості активності і площі листової поверхні. Регулювання площі листкової поверхні посіву кукурудзи за рахунок оптимізації живлення рослин буде сприяти покращенню накопичення органічної речовини за рахунок фотосинтетичної активності рослин. **Метою досліджень** було визначення впливу забезпеченості рослин кукурудзи макро- і мікроелементами на формування площі листкової поверхні середньопізнього гібрида кукурудзи СИ Зефір (ФАО 430) у різних фазах розвитку в умовах Лісостепу правобережному. **Методи.** В дослідженнях застосовувались польові, лабораторні та лабораторно-польові методи. Дослідження проводили в польових умовах Білоцерківського національного аграрного університету впродовж 2021–2022 рр. **Результати.** Встановлено, що площа листкової поверхні кукурудзи може змінюватися залежно від фаз росту і розвитку, оскільки відбувається наростання кількості листків і відмирання 5–7 листків у процесі онтогенезу. Встановлено негативну динаміку зменшення площі листкової поверхні від фази молочної стиглості до фази повної стиглості зерна, що більшою мірою пов’язано із відмиранням частини листків. Формування загальної площі листкової поверхні гібрида кукурудзи СИ Зефір істотно залежало від кліматичних умов року та забезпеченості рослин мікро- та макроелементами. **Висновки.** Найкращі показники площі листкової поверхні, як у фазах молочної стиглості (41,24 тис. м^2/га) так і повної стиглості зерна (38,38 тис. м^2/га) відмічено у 2021 р., який виявився краще забезпеченим температурними показниками та вологою в порівнянні із 2022 р. Внесення азотних добрив N_{40} перед сівбою у поєднанні із мікродобривом Вуксал Р Мах забезпечило найвищу площу листкової поверхні гібрида кукурудзи СИ Зефір у фазах молочної стиглості – 41,35 тис. м^2/га та повної стиглості зерна – 37,60 тис. м^2/га. Поліпшення умов живлення за рахунок внесення азотних добрив у поєднанні із мікродобривом Вуксал Р Мах сприяє оптимізації забезпечення рослин елементами живлення, що, в кінцевому результаті, стимулює утворення листкової поверхні яка зростає на 3,70 тис. м^2/га та 2,85 тис. м^2/га, порівняно із контрольним варіантом (без внесення добрив), відповідно у фазах молочної та повної стиглості зерна.

Ключові слова: *кукурудза, площа листкової поверхні, фотосинтетична поверхня, удобрення*