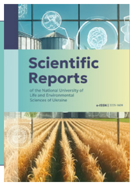
Received 03.12.2024 Revised 11.03.2025 Accepted 25.04.2025

Vol. 21, No. 2
2025



Scientific Reports of the National University
of Life and Environmental Sciences of Ukraine

Journal homepage: https://scireports.com.ua/en

UDC 633.174:631.5

DOI: 10.31548/dopovidi/2.2025.148

Photosynthetic productivity of grain sorghum hybrids depending on different forms and doses of fertilisers

Viktoriia Mohylevska*

Postgraduate Student
State Biotechnological University
61002, 44 Alchevskikh Str., Kharkiv, Ukraine
https://orcid.org/0009-0000-2840-0186

Abstract. The research relevance of the photosynthetic productivity of sorghum hybrids is determined by the need to optimise fertilisation to increase yields in the forest steppe of Ukraine. The study aimed to investigate the effect of complex granular mineral fertilisers on grain yield formation, specifically the photosynthetic productivity of grain sorghum plants. The research was conducted in 2021, 2023-2024 in the experimental field of the State Biotechnological University. The experiment was conducted using the method of systematic repetitions with three times repeatability to ensure the reliability and validity of the results. Sowing was conducted at a ten-centimetre soil layer temperature of 10-12°C with a sowing rate of 200 thousand seeds/ha using a wide-row method with a row spacing of 45 cm. Leaf surface area and net photosynthetic productivity were determined by the method of A.A. Nichiporovich. The study determined that the maximum possible leaf area per plant and hectare of sowing is formed by plants of the Aggil hybrid under the variant of fertiliser application Dura SOP at a dose of 80 kg/ha and Renovation Fuerza at doses of 80 and 100 kg, and plants of the Brigga hybrid under the variant of fertiliser application Renovation Fuerza at both doses. The photosynthetic productivity of both hybrids increased under the variant of application of all forms and doses of fertilisers compared to the absolute control. The net photosynthetic productivity was the highest in both studied hybrids under the variant of application of Renovation Fuerza mineral fertiliser in doses of 80 and 100 kg/ha. A linear correlation was established, and the regression equation between leaf area and net photosynthetic productivity for both studied hybrids is as follows: $y = 0.0479x - 0.098$ ($R^2 = 0.88$). The results can be used to optimise the mineral fertilisation of sorghum hybrids to increase yields and reduce costs in the forest-steppe of Ukraine

Keywords: grain sorghum; mineral fertilisers; leaf surface area; photosynthetic potential; net photosynthetic productivity

Suggested Citation:
Mohylevska, V. (2025). Photosynthetic productivity of grain sorghum hybrids depending on different forms and doses of fertilisers. *Scientific Reports of the National University of Life and Environmental Sciences of Ukraine*, 21(2), 148-158. doi: 10.31548/dopovidi/2.2025.148.

**Corresponding author*

Introduction

In the context of climate change and water shortages, the cultivation of drought-resistant crops, including grain sorghum, is becoming increasingly important. Due to its high adaptability to arid conditions, heat tolerance and stable yield, this crop is promising for expanding its cultivation in the central and southern regions of Ukraine. At the same time, the level of its productivity largely depends on photosynthetic activity, which is determined by both the hereditary characteristics of hybrids and mineral nutrition. Optimisation of the use of mineral fertilisers can activate photosynthesis, improve morphophysiological processes and increase dry matter accumulation. However, there is a lack of data in the scientific literature on the effect of different forms and doses of fertilisers on the photosynthetic productivity of grain sorghum hybrids under specific agroecological conditions. This necessitates in-depth research to improve the technology of crop cultivation.

Ya.V. Alekseev (2020) believe that hydrothermal changes in plant growing conditions in Ukraine require different approaches to the technology of growing major cereals, including sorghum. According to S.Yu. Davydenko & A.O. Rozhkov (2022), the main global areas of this crop are in India, Africa and the United States of America, which account for more than 70% of the world's sorghum acreage. The study argued that sorghum is one of the oldest crops in world agriculture, which is the undisputed leader among cereals grown in conditions of prolonged droughts and high temperatures. The wide range of its use for food, feed and technical purposes and its unpretentiousness to growing conditions make it important to research and improve the elements of its cultivation technology, namely the application of complex mineral fertilisers, which is one of the most urgent tasks that will contribute to the formation of high photosynthetic productivity of grain sorghum.

According to K.B. Abreha *et al.* (2022), in dry conditions, sorghum plants, due to morphological characteristics, consume moisture economically and form a significant leaf surface area with a specific type of photosynthesis. R.E. Grishchenko *et al.* (2020) studied photosynthetic productivity under variants of mineral fertiliser application and concluded that even under stressful conditions of vegetation periods, photosynthetic productivity increases with fertiliser application.

M. Stefanov *et al.* (2023) studied photosynthesis as a vital process under different drought conditions and concluded that the photosynthetic apparatus of sorghum plants should increase the area of the assimilative leaf surface as quickly as possible to provide plants with photosynthetic products. The study noted that the rapid deployment of the leaf apparatus can compensate for the effects of short-term stress and maintain yields. O.S. Titarenko & L.M. Karpuk (2022) believed that one of the factors of grain sorghum cultivation technology is the creation of optimal mineral nutrition for plants to form the leaf surface area. According to the observations, the use of fertilisers in balanced doses stimulates the development of a photosynthetically active surface, which increases the absorption of solar energy by plants.

W. Sun *et al.* (2024) studied the effect of irrigation water in arid conditions in China and proved that the leaf surface area varies greatly under different conditions of moisture supply, temperature, mineral nutrition and agronomic cultivation methods. R. Zhang *et al.* (2023) proved that the photosynthetic activity of plants is a rather mobile indicator. The rapid development and achievement of optimal leaf surface area increases photosynthetic productivity and keeps the leaves in the active layer for a longer period, which contributes to better use of photosynthetic productivity to accumulate as much organic matter as possible, which is the main component of the plant yield. T. Jayanti *et al.* (2021) proved that in different countries of the world, mineral fertilisers affect plant nutrition and fertiliser application increases plant growth and development and leads to an increase in photosynthesis of sorghum crops. The study noted that the use of balanced mineral complexes significantly improves photosynthetic activity and contributes to an increase in sorghum biomass and yield under different soil and climatic conditions.

Despite the availability of thorough research, the issue of the complex effect of forms and doses of mineral fertilisers on the photosynthetic productivity of grain sorghum hybrids under specific agricultural and ecological conditions of the Eastern Forest-Steppe of Ukraine remains insufficiently studied. This necessitates targeted research, the results of which can improve the elements of the technology for growing the crop.

The study aimed to determine the effect of forms and doses of mineral fertilisers on the yield and photosynthetic productivity of grain sorghum hybrids in the Eastern Forest-Steppe of Ukraine.

Materials and Methods

Field trials were conducted in 2021, 2023-2024 at the experimental field of the State Biotechnological University. The two-factor field experiment had the following scheme: *factor A* grain sorghum hybrids Aggil and Brigga F_1; *factor B* forms and doses of fertilisers Absolute control, zonal control (Nitroammophoska 100 kg/ha, NPK ratio 16:16:16), Dura SOP 80 kg/ha, Dura SOP 100 kg/ha (NPK ratio 10:10:17), Renovation Fuerza 80 kg/ha, Renovation Fuerza 100 kg/ha (NPK ratio 8:14:6). The experiment was set up using the method of systematic replication, with a constant seeding rate of 200 thousand seeds/ha, using a wide-row sowing method with a row spacing of 45 cm. Sowing was carried out when the ten-centimetre soil layer was warmed up to a temperature of 10-12 °C.

Leaf surface area and net photosynthetic productivity were determined by the method of A.A. Nichiporovich. The object of the research was an early ripe grain sorghum hybrid Brigga and a medium early hybrid Aggil of French selection and complex granular mineral fertilisers Dura SOP and Renovation Fuerza (Spain). Soils of the experimental field are typical chornozem, characterised by a deep humus profile reaching 120 cm, containing 5.0-6.0% humus, good physical properties, high content of mobile forms of NPK and generally high biological activity. The total depth of the humus profile of the regraded chornozem reaches 90-110 cm, with a humus content of 4.7-5.0%. The type of typical chornozem is a poorly washed, low-humus, heavy loamy soil on carbonate loess and is characterised by the following agrochemical parameters: pH of the salt extract 6.5-7.0; total humus content in the topsoil 5.0%; P_2O_5 102 mg per 1 kg of soil; K_2O 179 mg per 1 kg of soil (according to Chirikov).

The weather conditions during the study years were favourable in 2021 and 2023, and in 2024 there was an excess of air temperature and a prolonged period of drought compared to long-term averages. The research was conducted following the Convention on Biological Diversity (1992).

Results and Discussion

The studies conducted in the Eastern Forest-Steppe of Ukraine demonstrated that the leaf surface area was significantly influenced by the form and dose of fertiliser (Table 1). The introduction of all forms and doses of fertilisers ensured the formation of a larger photosynthetically active leaf area for a much longer period. The highest leaf surface area starting from the phenological phase of tillering was formed by both hybrids under the variants of Dura SOP and Renovation Fuerza application in doses of 80 and 100 kg/ha. In this phase, the highest leaf area was formed by the Brigga hybrid under the Renovation Fuerza application variant at a dose of 100 kg/ha, which provided the highest leaf area per hectare of 91 cm^2 and 16.56 thousand m^2/ha, respectively. In this variant, the leaf area of the Aggil hybrid was formed both on one plant and one hectare of crops, respectively, 88 cm^2 and 16.37 thousand m^2/ha.

Table 1. *Effect of different forms and doses of fertilisers on the leaf area of grain sorghum hybrids (average for 2021, 2023-2024)*

Hybrid	Variant	The area of the sheet metal floor in the phase:							
		bushing		tubing		flowering panicle shedding		maturation	
		per plant, cm^2	per 1 ha of sowing area, thousand m^2/ha	per plant, cm^2	per 1 ha of sown area, thousand m^2/ha	per plant, cm^2	per 1 ha of sowing area, thousand m^2/ha	per plant, cm^2	per 1 ha of sowing area, thousand m^2/ha
Aggil	1*	66	10.36	792	14.67	844	17.38	796	16.40
	2	72	12.89	838	17.85	996	22.11	858	19.05
	3	77	13.78	933	19.71	1024	24.88	964	23.42
	4	82	15.17	990	22.16	1079	26.86	1023	25.47
	5	87	16.01	1066	24.91	1106	28.53	828	21.36
	6	88	16.37	1144	27.87	1289	34.03	1218	32.15
Brigga	1*	72	11.09	780	13.21	809	15.37	732	13.91
	2	77	12.86	828	16.18	886	19.23	804	17.45
	3	80	14.00	897	18.52	934	22.79	863	21.06
	4	84	15.20	963	21.09	1028	25.70	941	23.52
	5	88	16.02	1031	23.45	1099	28.24	998	25.65
	6	91	16.56	1066	24.64	1134	28.69	1049	26.54
LSD 0.5			0.71		1.92		2.84		0.96

Note: 1* – absolute control, 2 – zonal control (Nitroammophoska 100 kg/ha), 3 – DuraSOP 80 kg/ha, 4 – Dura SOP 100 kg/ha, 5 – Renovation Fuerza 80 kg/ha, 6 – Renovation Fuerza 100 kg/ha
Source: compiled by the author

The highest values were recorded during the interphase period of panicle emergence and flowering for all fertiliser application options and doses. The area of one plant of the Aggil hybrid with Renovation Fuerza applied at a dose of 100 kg/ha was 1289 cm^2, and the area per hectare of crops was 34.03 thousand m^2/ha, which was slightly lower than that of the Brigga hybrid by 155 cm^2 and 5.34 thousand m^2/ha, respectively. The largest number of preserved leaves with the application of Renovation Fuerza at a dose of 100 kg/ha on average over three years was preserved in the Aggil hybrid, which provided a total leaf area at this point of 1218 cm^2 per plant and 32.15 thousand m^2/ha per hectare of crops. Lower values for this option were found in the Brigga hybrid, 169 cm^2 and 5.61 thousand m^2/ha, respectively.

The application of all forms and doses of fertilisers contributed to the formation of a larger leaf area per plant and per hectare of crops in both hybrids compared to the absolute control. In the Aggil hybrid, starting from the tillering phase, with the application of Dura SOP and Renovation Fuerza at doses of 80 and 100 kg/ha, the leaf area of one plant increased by 11, 16, 21 and 22 cm^2, respectively; in the stem elongation phase, the excesses were 141, 198, 274 and 352 cm^2, and in the interphase of panicle emergence, 180; 235; 262 and 445 cm^2; the increases were slightly lower in the ripening phase, 168; 227; 32 and 422 cm^2. Accordingly, the leaf area per hectare of crops increased in the variants. Compared to the zonal control variant (Nitroammophoska 100 kg/ha), the increase in leaf area per plant and per hectare of crops was lower compared to the absolute control variant. The Brigga hybrid retained the patterns of growth in leaf area per plant and per hectare of crops. The excesses were significantly lower compared to the absolute and zonal controls than in the grain sorghum hybrid Aggil. The application of Dura SOP and Renovation Fuerza at doses of 80 and 100 kg/ha resulted in an increase in the tillering phase compared to the absolute control by 8, 12, 16 and 19 cm^2; in the tube stage by 117, 183, 251 and 286 cm^2; in the interphase of panicle ejection by 125, 219, 290 and 325 cm^2; and in the maturity stage by 131, 209, 266 and 317 cm^2. The best development of leaf surface area in both hybrids was observed in the variant of Renovation Fuerza 100 kg/ha and amounted to 32.15 thousand m^2/ha in the phenological phase of ripening in the Aggil hybrid and 26.54 thousand m^2/ha in the Brigga hybrid, respectively.

Indicators of net photosynthetic productivity reflect the photosynthetic potential of crops, the average data are provided in Table 2. The highest net productivity of photosynthesis of the assimilation apparatus of the grain sorghum hybrid was in the Renovation Fuerza variant application at a dose of 100 kg/ha 4.67 g/m^2. In the variant of this fertiliser application, but in a lower dose, a tendency to decrease the net productivity of photosynthesis was noted, but mathematically the advantages of their application in a higher dose of 100 kg/ha compared to the dose of this fertiliser 80 kg/ha were not proved.

Table 2. *Indicators of photosynthetic productivity of grain sorghum hybrids depending on the forms and doses of mineral fertilisers (average for 2021, 2023-2024)*

Hybrid	Variant	Photosynthetic potential, (thousand m^2/ha)×day	Pure performance of photosynthesis, g/m^2
Aggil	AC (absolute control)	0.80	2.19
	ZC (zone control Nitroammophoska 100 kg/ha)	1.03	2.46
	Dura SOP 80 kg/ha	1.32	3.35
	Dura SOP 100 kg/ha	1.49	3.65
	Renovation Fuerza 80 kg/ha	1.28	4.65
	Renovation Fuerza 100 kg/ha	2.02	4.67
Brigga	AC (absolute control)	0.66	2.64
	ZC (zone control Nitroammophoska 100 kg/ha)	0.92	2.87
	Dura SOP 80 kg/ha	1.18	3.17
	Dura SOP 100 kg/ha	1.36	3.38
	Renovation Fuerza 80 kg/ha	1.54	3.66
	Renovation Fuerza 100 kg/ha	1.62	3.74
LSD 0.5		0.26	0.98

Source: compiled by the author

The correlation and regression analysis between leaf surface area and net photosynthetic productivity of both studied grain sorghum hybrids was performed (Fig. 1).

The results of correlation and regression analysis indicate a close correlation between leaf area and net photosynthetic productivity in grain sorghum hybrid Aggil, where the coefficient of determination is $R^2 = 0.88$, and the correlation coefficient is $R = 0.80$. The results of the correlation-regression analysis also indicate a close correlation between leaf area and net photosynthetic productivity in the grain sorghum hybrid Brigga, where the coefficient of determination is $R^2 = 0.88$, and the correlation coefficient is $R = 0.80$. The increase in leaf area of grain sorghum hybrid Aggil plants was due to a change in the form and dose of complex granular mineral fertiliser Renovation Fuerza up to 100 kg/ha for pre-sowing soil cultivation. The net productivity of photosynthesis in both hybrids under this variant was also the highest. Analysing the results of the research, it is worth noting that there is a direct correlation between the data on leaf area and photosynthetic potential, as well as between the data on leaf area and net photosynthetic productivity.

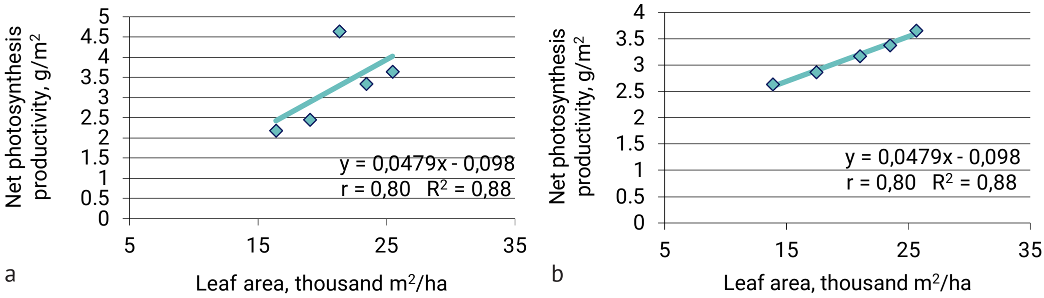


Figure 3. *Correlation and regression relationship between leaf surface area and net photosynthetic productivity of grain sorghum hybrids Aggil and Brigga, average for 2021, 2023-2024*
Note: a) Aggil hybrid; b) Brigga hybrid
Source: compiled by the author

The presence of the same values of correlation and determination coefficients in the two hybrids indicates the constant influence of leaf surface area as a key factor that determines the level of sorghum assimilation capacity under different variants of mineral nutrition. The regression curves have a positive slope, which confirms the linear nature of the relationship, and thus the possibility of predicting photosynthetic productivity based on leaf morphometric characteristics. Notably, under conditions of increased supply of plants with minerals, not only a quantitative increase in the area of the assimilation surface was observed, but also a qualitative increase in its efficiency in the context of net photosynthetic productivity. Such results are a strong justification for further optimisation of fertiliser doses and forms in the technological maps of sorghum cultivation in the Eastern forest-steppe of Ukraine.

The obtained research results, but for the Eastern part of the Forest-Steppe of Ukraine, correlate with the studies of L.A. Pravdyva & V.A. Doronin (2022), which were conducted in 2016-2020 at the Bila Tserkva Experimental Breeding Station of the Institute of Bioenergy Crops and Sugar Beet of the National Academy of Agrarian Sciences of Ukraine in the Right-Bank Forest-Steppe of Ukraine to determine the effect of different doses of complex mineral fertilisers. The studies proved that an increase in the leaf area of grain sorghum plants occurred due to an increase in the dose of mineral fertilisers. The application of the calculated rate ($N_{50}P_{40}K_{70}$) and higher doses of fertilisers ($N_{90}P_{90}K_{90}$ and $N_{120}P_{120}K_{120}$) during the period of ejection of the flowering panicle contributes to the formation of a larger leaf surface area. Under the variants, the highest net productivity of photosynthesis and grain yield of the studied grain sorghum varieties were obtained.

Similar results to the current research were obtained by R.E. Grishchenko *et al.* (2020) in a study on the productivity of grain sorghum in the northern forest-steppe zone of Ukraine under the influence of basic fertilisation and top dressing on the background of seed treatment with BTU. The use of $N_{45}P_{60}K_{60}$ as the main fertiliser and N_{15} as a top dressing contributed to the formation of the maximum leaf area of crops. An increase in the dose of fertilisers to $N_{60}P_{60}K_{60}$ contributed to the accumulation of significant dry mass, at this dose photosynthetic productivity and net photosynthetic productivity increased, and it is proposed to use fertiliser doses of $N_{60}P_{60}K_{60}$ to obtain the maximum possible yield in this growing zone.

The effect of soil irrigation with three different concentrations of $CdCl_2$ on pigment content, photosynthetic activity, carbohydrate content and productivity of *Sorghum bicolour* L. cultivar Dorado at different stages of plant growth and development was studied by H.S. Aldesuquy & A.A. El-Saied (2004). The study also addressed the effect of pre-soaking the grain with kinetin to reduce the toxic effects caused by different levels of $CdCl_2$. The results of the studies demonstrated that in most cases, pretreatment of grain with kinetin increased the amount of photosynthetic pigments, photosynthetic activity, Hill's reaction, and carbohydrate content in leaves of sorghum plants treated with cadmium. In general, there was a decrease in yield and yield parameters of sorghum plants in response to Cd^{2+} treatment, especially when the grain was pre-soaked in kinetin. The improving effect of kinetin was more pronounced at 1 mM $CdCl_2$. Grain priming with kinetin increased grain biomass, carbohydrate, protein and ion content in yielding grains of sorghum plants treated with cadmium. The cadmium treatment changed the balance of growth bioregulators in the developed grains of sorghum plants. From the results obtained, the scientists concluded that $CdCl_2$ in all concentrations used led to a significant decrease in the level of growth stimulants with an increase in the level of growth-inhibiting substances equivalent to abscisic acid. On the other hand, grain priming with kinetin increased the level of growth-promoting substances and decreased the level of abscisic acid.

V.V. Ivanina *et al.* (2021) conducted the study in the zone of insufficient moisture in the forest-steppe of Ukraine. A high grain yield was obtained with the fertilisation system for the main tillage of $P_{90}K_{90}$ and N_{150} in the pre-sowing cultivation. The study determined that a balanced balance of nutrients can be achieved by applying $P_{30}K_{40}$ for ploughing and N_{140} for pre-sowing cultivation. Another way of sowing and applying mineral fertilisers was found by V.G. Lypovy *et al.* (2020) in a study on the effect of mineral fertilisers on the leaf surface area in the zone of stable moisture. The largest leaf surface area and the duration of its active work were obtained in grain sorghum at a dose of mineral fertiliser $N_{120}P_{90}K_{120}$. Under this variant, the maximum value of photosynthetic potential was obtained. The study was conducted with intercropping of sorghum and soybeans. This variant of research formed the highest yield of green mass.

Other components of the cultivation technology were studied by O.S. Titarenko & L.M. Karpuk (2022) in the Right-Bank Forest-Steppe of Ukraine, analysing the effect of microfertilisers and growth regulators under different options of foliar feeding and found an effective effect of microfertilisers and plant growth regulators on photosynthesis and the formation of higher yields. R.M. Vasylenko (2018) and L.I. Storozhik (2017) proved that high photosynthetic activity of agrocenosis is determined by leaf surface area, photosynthetic potential and net photosynthetic productivity, which are the key to high yields of grain sorghum.

A certain parallel with the results of this study was traced in the study by O. Prysiazhniuk *et al.* (2022), where the influence of the timing of growth regulators application on the productivity of sorghum hybrids depending on the phenological phase according to the BBCH and Kuperman scales was established. The authors proved that early application of growth regulators at BBCH 21 provided a significant increase in grain yield in grain hybrids, as well as biomass and dry matter in sugar sorghum hybrids. Particularly noteworthy is the emphasis on the need to consider the exact phenological phases when applying the products, which echoes our findings on the dependence of photosynthetic activity and leaf area on the timeliness and form of fertilisation. This once again confirms the expediency of an individual approach to fertilising sorghum hybrids, which incorporates not only the dose and form of fertiliser but also the dynamics of plant development.

In the arid zone of China, F. Zhang *et al.* (2019) investigated the effect of different irrigation doses on photosynthesis and chlorophyll accumulation in grain sorghum leaves. Under drought and waterlogging conditions, chlorophyll content in leaves and photosynthesis intensity varied. The results confirm the high adaptability of sorghum to drought and waterlogging stress by reducing the rate of photosynthetic product transport and chlorophyll content. Under Indian conditions, S. Li *et al.* (2021) studied different sorghum genotypes that showed significant variability in photosynthetic capacity, leaf nitrogen content and specific leaf area depending on the ozone dose. Bioenergy sorghum is ozone-resistant and can be used to increase biomass productivity in ozone-polluted regions.

Increased tropospheric ozone concentration significantly reduces sorghum photosynthesis and productivity, which requires consideration of environmental factors in the development of fertiliser technologies. A valuable addition to the general scientific context is the results of the research by M.G. Salas Fernandez *et al.* (2015), who studied the photosynthetic capacity of leaves in a large panel of sorghum genotypes. The study determined significant variability in photosynthetic parameters, which is due to both genetic characteristics and nutritional conditions. S. Tang *et al.* (2018) substantiated the prospects of growing sorghum as a crop for high biomass production, emphasising the importance of photosynthetic parameters for realising this potential. A study by H.A. Ajeigbe *et al.* (2018), conducted in Nigeria, demonstrated that the application of different nitrogen rates had a positive effect on the efficiency of moisture use and sorghum productivity, which echoes the conclusions about the feasibility of balanced mineral nutrition in the forest-steppe of Ukraine. A study by M. Bagayoko (2012), conducted in Mali, demonstrated that the optimal combination of plant density, organic matter and nitrogen provided a significant increase in yield, which indicates the importance of adapting technological approaches to specific climatic conditions and resource capabilities of farms.

Thus, the results of the study confirmed the significant influence of forms and doses of mineral fertilisers on the level of photosynthetic activity and yield of grain sorghum hybrids. The highest values of leaf surface area, photosynthetic potential and net photosynthetic productivity were observed with the use of *Renovation Fuerza* complex fertiliser at a dose of 100 kg/ha, which provided effective nutrition during all phases of plant development. A reliable correlation between the morphometric parameters of the leaf apparatus and the level of assimilation productivity was established, which gives grounds for predicting the yield. The data obtained are consistent with the results of domestic and foreign studies while specifying the effective elements of sorghum cultivation technology in the Eastern forest-steppe of Ukraine.

Conclusions

The study determined that the highest development of leaf surface area in both hybrids was observed in the variant of Renovation Fuerza 100 kg/ha and amounted to 32.15 thousand m^2/ha in the phenological phase of ripening in the Aggil hybrid and 26.54 thousand m^2/ha in the Brigga hybrid, respectively. The study noted for the variants of application of all forms and doses of fertilisers in the interphase period of panicle ejection and flowering that the highest area of one plant in the Aggil hybrid was formed in the variant of application of the mineral fertiliser Renovation Fuerza at a dose of 100 kg/ha 1289 cm^2, and the area per hectare of sowing was 34.03 thousand m^2/ha, the figures were slightly lower than the area of the leaf floor in the Brigga hybrid by 155 cm^2 and 5.34 thousand m^2/ha, respectively.

The study determined that the highest photosynthetic potential of grain sorghum crops in the Aggil hybrid was 2.02 thousand m^2/ha×day when Renovation Fuerza fertiliser was applied at a dose of 100 kg/ha and in the Brigga F_1 hybrid 1.62 thousand m^2/ha. The study determined that the net productivity of photosynthesis depends on the use of different forms and doses of fertilisers. It was the highest in the variant of application of mineral fertiliser Renovation Fuerza at a dose of 100 kg/ha in both grain sorghum hybrids. Correlation and regression analysis of the data between photosynthetic potential of crops and leaf area showed a close correlation, with the coefficient of determination being $R^2 = 0.88$ and the correlation coefficient $R = 0.80$ for both grain sorghum hybrids Aggil and Brigga F1. The regression equation of the linear correlation between leaf area and net photosynthetic productivity for both hybrids under study is y = 0.0479x - 0.098 (R^2 = 0.88). Net photosynthetic productivity was the highest in the medium-early hybrid Aggil at 4.67 g/m^2 with the variant of Renovation Fuerza fertiliser at a dose of 100 kg/ha and was lower in the early-ripening hybrid Brigga at 3.74 g/m^2, respectively. The use of Dura SOP fertiliser at doses of 80 and 100 kg/ha contributed to the growth of leaf surface area compared to the absolute and zonal controls in both hybrids. The doses of fertiliser contributed to the formation of higher photosynthetic potential and net photosynthetic productivity.

In the future, it is necessary to study the effect of complex mineral fertilisers Dura SOP and Renovation Fuerza in different organo-mineral systems and doses and identify the most effective options for their use in grain sorghum cultivation technology, which in turn fulfil the potential yield of grain sorghum.

Acknowledgements

The author are grateful to Doctor of Agricultural Sciences, Professor Artur Rozhkov for the idea of researching the impact of fertilisers on the productivity of grain sorghum hybrids.

Funding

None.

Conflict of Interest

None.

Introduction

[1] Abreha, K.B., Enyew, M., Carlsson, A.S., Vetukuri, R.R., Feyissa, T., Motlhaodi, T., Ng'uni, D., & Geleta, M. (2022). Sorghum in dryland: Morphological, physiological, and molecular responses of sorghum under drought stress. *Planta*, 255, article number 20. doi: 10.1007/s00425-021-03799-7.

[2] Ajeigbe, H.A., Alhassan, S.A., Akinseye, F.M., & Kamara, A.Y. (2018). Productivity and water use efficiency of sorghum (*Sorghum bicolor* (L.) Moench) grown under different nitrogen applications in Sudan Savanna Zone, Nigeria. *International Journal of Agronomy*, 2018(1), article number 7676058. doi: 10.1155/2018/7676058.

[3] Aldesuquy, H.S., Haroun, S.A., Abo-Hamed, S.A., & El-Saied, A.A. (2004). Ameliorating effect of kinetin on pigments, photosynthetic characteristics, carbohydrate contents and productivity of cadmium treated *Sorghum bicolor* plants. *Acta Botanica Hungarica*, 46(1-2), 1-21. doi: 10.1556/ABot.46.2004.1-2.1.

[4] Alekseev, Ya.V. (2020). Productivity of sorghum grain hybrid Prime depending on the area of feeding in the conditions of the Northern Steppe of Ukraine. *Podilian Bulletin: Agriculture, Engineering, Economics*, 33, 9-15. doi: 10.37406/2706-9052-2020-2-1.

[5] Bagayoko, M. (2012). Effects of plant density, organic matter and nitrogen rates on rice yields in the system of rice intensification (SRI) in the "Office du Niger" in Mali. *ARPN Journal of Agricultural and Biological Science*, 7(8), 620-632.

[6] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

[7] Davydenko, S.Yu., Rozhkov, A.O., & Romanov, O.V. (2022). Photosynthetic potential of grain sorghum crops depending on the row spacing and seeding rate. In *Modern science: Innovations and prospects: Proceedings of XII international scientific and practical conference* (pp. 10-15). Stockholm: Science Publishing Group.

[8] Grishchenko, R.E., Lyubchych, O.G., Glieva, O.V., & Alekseev, Ya.V. (2020). Photosynthetic productivity of grain sorghum crops depending on the fertilization system. *Cereal Crops*, 1, 122-129. doi: 10.31867/2523-4544/0115.

[9] Ivanina, V.V., Pashynska, K.L., & Smirnykh, V.M. (2021). Removal and balance of nutrients in the agrocenosis of grain sorghum depending on fertilization. *Bulletin of Agrarian Science*, 12, 28-32. doi: 10.31073/agrovisnyk202112-03.

[10] Jayanti, T., Himani, P., Anurag, M., Sangwan, S.S., Devi, S., Sarita, D., & Shweta, M. (2021). Growth performance, nutritional status, forage yield and photosynthetic use efficiency of sorghum (*Sorghum bicolor* (L.) Moench) under salt stress. *Range Management and Agroforestry*, 42(1), 59-70.

[11] Li, S., Moller, C.A., Mitchell, N.G., Lee, D., & Ainsworth, E.A. (2021). Bioenergy sorghum maintains photosynthetic capacity in elevated ozone concentrations. *Plant, Cell & Environment*, 44(3), 729-746. doi: 10.1111/pce.13962.

[12] Lypovy, V.G., Shevchuk, O.A., & Knyazyuk, O.V. (2020). Photosynthetic productivity of single-species and mixed crops of sugar sorghum with soybeans. *Agriculture and Forestry*, 18, 81-90.

[13] Pravdyva, L.A., & Doronin, V.A. (2022). The influence of mineral fertilisers on the photosynthetic productivity of grain sorghum. *Foothill and Mountain Agriculture and Livestock*, 72(1), 51-64. doi: 10.32636/01308521.2022-(72)-1-4.

[14] Prysiazhniuk, O., Storozhyk, L., Humentyk, M., Sviridov, A., & Svyrydova, L. (2022). Optimal time of plant growth regulator application to Sorghum canopy according to BBCH and Kuperman crop growth scales. *Plant and Soil Science*, 13(4), 46-56. doi: 10.31548/agr.13(4).2022.46-56.

[15] Salas Fernandez, M.G., Strand, K., Hamblin, M.T., Westgate, M., & Heaton, E.A. (2015). Genetic analysis and phenotypic characterization of leaf photosynthetic capacity in a sorghum (*Sorghum* spp.) diversity panel. *Genetic Resources and Crop Evolution*, 62(6), 939-950. doi: 10.1007/s10722-014-0202-6.

[16] Stefanov, M., Rashkov, G., Borisova, P., & Apostolova, E. (2023). Sensitivity of the photosynthetic apparatus in maize and sorghum under different drought levels. *Plants*, 12(9), article number 1863. doi: 10.3390/plants12091863.

[17] Storozhik, L.I., & Music, O.V. (2017). Photosynthetic potential of sugar sorghum crops in the conditions of the Central Forest-Steppe of Ukraine. *Scientific Works of the Institute of Bioenergy Crops and Sugar Beet*, 25, 79-85.

[18] Sun, W., He, Z., Liu, B., Ma, D., Si, R., Li, R., Wang, S., & Malekian, A. (2024). Changes in photosynthetic efficiency, biomass, and sugar content of sweet sorghum under different water and salt conditions in arid region of Northwest China. *Agriculture*, 14(12), article number 2321. doi: 10.3390/agriculture14122321.

[19] Tang, S., Xie, Q., Wang, Z., Yan, J., & Xu, W. (2018). The prospect of sweet sorghum as the source for high biomass crop. *Journal of Agricultural Science and Botany*, 2(3), 5-11. doi: 10.35841/2591-7897.2.3.5-11.

[20] Titarenko, O.S., & Karpuk, L.M. (2022). Efficiency of sorghum photosynthesis depending on the influence of elements of cultivation technology. *New Agricultural Technologies*, 10(3). doi: 10.47414/na.10.3.2022.287179.

[21] Vasylenko, R.M. (2018). Photosynthetic productivity of grain sorghum depending on moisture conditions in the south of Ukraine. *Bulletin of Agrarian Science of the Black Sea Region*, 2, 46-50.

[22] Zhang, F., Zhu, K., Wang, Y.Q., Zhang, Z.P., Lu, F., Yu, H.Q., & Zou, J.Q. (2019). Changes in photosynthetic and chlorophyll fluorescence characteristics of sorghum under drought and waterlogging stress. *Photosynthetica*, 57(4), 1156-1164. doi: 10.32615/ps.2019.136.

[23] Zhang, R., Yue, Z., Chen, X., Huang, R., Zhou, Y., & Cao, X. (2023). Effects of waterlogging at different growth stages on the photosynthetic characteristics and grain yield of sorghum (*Sorghum bicolor* L.). *Scientific Reports*, 13, article number 7212. doi: 10.1038/s41598-023-32478-8.

Фотосинтетична продуктивність рослин гібридів сорго зернового залежно від різних форм і доз добрив

Вікторія Могилевська
Аспірант
Державний біотехнологічний університет
61002, вул. Алчевських, 44, м. Харків, Україна
https://orcid.org/0009-0000-2840-0186

Анотація. Необхідність вивчення фотосинтетичної продуктивності гібридів сорго зумовлена потребою оптимізації удобрення для підвищення урожайності в умовах Лісостепу України. Метою роботи було дослідити вплив комплексних гранульованих мінеральних добрив на формування врожайності зерна, зокрема фотосинтетичну продуктивність рослин сорго зернового. Дослідження проводили у 2021, 2023-2024 рр. в умовах дослідного поля Державного біотехнологічного університету.Дослід проводили за методом систематичних повторень із триразовою повторюваністю для забезпечення надійності та достовірності отриманих результатів. Сівбу здійснювали за прогрівання десяти сантиметрового шару ґрунту до температури 10-12°C з нормою висіву 200 тис. шт./га широкорядним способом з шириною міжрядь 45 см. Площу листкової поверхні та чисту продуктивність фотосинтезу визначали за методикою А.А. Ничипоровича. З'ясовано, що максимально можливу площу листкової поверхні однієї рослини та з одного гектару посіву формують рослини гібриду Aggil за варіанта застосування добрив Dura SOP в дозі 80 кг/га та Renovation Fuerza в дозах 80 і 100 кг/, а рослини гібрида Brigga за варіанта застосування добрив Renovation Fuerza в обох дозах. Фотосинтетична продуктивність обох гібридів зростала за варіанта внесення усіх форм і доз добрив порівняно з абсолютним контролем. Чиста продуктивність фотосинтезу найвищою була у обох досліджуваних гібридів за варіанта застосування мінерального добрива Renovation Fuerza в дозах 80 і 100 кг/га. Встановлено лінійну кореляційну залежність, рівняння регресії між площею листкової поверхні та чистої продуктивності фотосинтезу для обох досліджуваних гібридів має вигляд: $y = 0,0479x - 0,098$ ($R^2 = 0,88$). Результати можна використати для оптимізації мінерального удобрення гібридів сорго для підвищення урожайності та зниження витрат у Лісостепу України

Ключові слова: сорго зернове; мінеральні добрива; площа листкової поверхні; фотосинтетичний потенціал; чиста продуктивність фотосинтезу