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Research Article

PHOTOSYNTHETIC ACTIVITY OF WINTER WHEAT CROPS DEPENDING ON THE ELEMENTS OF CULTIVATION TECHNOLOGY IN THE CENTRAL NON-CHERNOZEM REGION

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ABSTRACT. Photosynthesis plays an essential role in plants to produce their own food which acts as a source of energy for growth, cell development and the formation of cellular structures. Therefore, the search for mechanisms to manage the production process is an important task, the solution of which will allow improving technological methods of cultivation to obtain high yields. The aim of the study was to determine the influence of various elements of cultivation technology on plant photosynthesis and winter wheat yield. The objects of research were winter wheat crops of Nemchinovka 85, Moskovskaya 27 and Moskovskaya 40 varieties. Results: depending on the varieties and technologies, the net productivity of photosynthesis of wheat crops showed fluctuations from 3.7 to 6.6 million g/m^2 day. As technology intensity increased, net photosynthetic productivity (NPP) increased. The article presents the results of the evaluation of the photosynthetic activity of new winter wheat varieties studied. The highest NPP under the conditions of the year was noted for the Moskovskaya 27 variety. According to intensive technology, the indicator was 6.3 million g/m^2 day, for high-intensity technology - 6.6 million g/m^2 day. For the Nemchinovskaya 85 variety, the current indicator was lower on average by 4.6, the variants by 4.3–5.7 with intensive and high-intensity technologies, respectively. The new varieties have high rates of net photosynthesis productivity, photosynthetic potential, and high production potential. Scientific novelty. The features of the influence of various cultivation technologies on photosynthesis in plants and the yield of winter wheat crops of new varieties of selection of the Technological Center for Agriculture of the Federal Research Center, Federal Research Center "Nemchinovka" were revealed. The correlation between the leaf area index, photosynthesis, photosynthetic potential, net photosynthetic productivity and yield of winter wheat plants for these varieties was determined.

Keywords: Winter wheat, cultivation technology, variety, photosynthesis, grain yield

INTRODUCTION

Agricultural yields must be significantly improved to meet the future demands for food from an ever-growing global population. Due to advances in agricultural practices, agricultural yields largely increased in line with demand during the second half of the 20th century [1]. Wheat is a plant widely cultivated throughout the world due to its high yield and good technological value. These characteristics make it the most important cereal sold on international markets. The area sown by wheat in the world is approximately 220.76 million ha [2].

Photosynthesis in plants is considered an electric motor in the formation of primary organic substances. Yields can be increased through improved photosynthesis. For wheat, this is supported by the positive relationship between photosynthesis, biomass and yield [1,3]. The rate of photosynthesis is a crucial determinant of grain yield in wheat cultivation [4]. 80 to 90% of dry biomass stock is formed and accumulated during the process of photosynthesis [5]. Therefore, the efficiency of the photosynthesis process influences the mass of organic matter formed and the yield of the plant's main products [6].

Photosynthesis constitutes the most crucial source of biomass accumulation in plants and plays an important role in modern winter wheat cultivars [7]. The chlorophyll content of leaves is one of the main indicators of the photosynthetic capacity of plant tissues [8]. The chlorophyll content characterizes the size of the assimilation apparatus and is therefore an important indicator of the photosynthetic productivity of plants [9].

Agricultural technologies play a very important role in the cultivation of winter wheat. Tillage, which often takes first place among other agrotechnological techniques, is very important, especially since it influences the creation of favorable conditions on which the processes of photosynthesis, growth and development of plants depend. For this, it is necessary to optimize the photosynthetic activity of plants in agrocenosis to obtain maximum yield.

The objective of our work was therefore to determine the influence of various elements of cultivation technology on the photosynthetic activity and yield of winter wheat.

MATERIALS AND METHODS

Field Trial Site and Experimental Treatments

Experimental studies on the topic of our research were carried out in 2020–2022 at the experimental site for varietal agricultural technologies of winter grain crops and plant protection systems of the Technological Center for Agriculture of the Federal Research Center, Federal Research Center "Nemchinovka" in the village of Sokolovo, Moscow region. The soil of the experimental plots is medium loamy, soddy-podzolic.

Field experiments on varietal agricultural technology of winter grain crops were carried out on field Nº 5 and Nº 2 of a five-field crop rotation. A field survey carried out in 2020 showed that the soil is characterized by a strongly acidic to moderately acidic reaction of the soil environment (pHsol. 4.3-5.7). The content of mobile phosphorus remains at a high level (155-316 mg/kg), the supply of mobile potassium is increased (125-181 mg/kg). Winter wheat varieties selected by the Federal Research Center "Nemchinovka": Nemchinovskaya 85, Moskovskaya 27, Moskovskaya 40 and Moskovskaya 56.

Soil and Weather Conditions

The 2020-2021 and 2021-2022 weather conditions for winter crops were generally rated as favorable. The hydrothermal coefficient of the winter wheat growing season was 1.50 to 1.52, meaning both years were optimal in terms of moisture supply (Figure 1). The plants entered winter in good conditions; spring conditions allowed the plants to develop normally. In September, warm weather was observed with an average daily air temperature of 9.7 °C. The hottest was the first decade of the month, with 11.3 ° C, but below the norm of 1.7 ° C. The change in the average daily air temperature to +5 ° C was produced on November 7. The temperatures of the second and third decade differ little from the long-term average values. Precipitation fell unevenly. In total, 94.2 mm fell over the month (51% above the long-term average). Despite the postponement of winter wheat sowing to a later date (September 13), climatic conditions contributed to the emergence of plants at the beginning of the first decade of October. Average daily temperatures in October were 2.9°C higher than usual (13.9°C versus 11.0°C). Total precipitation was 40.3 mm (34% below normal) and was extremely patchy. There was no precipitation during the first decade of October. Most of them, 29.7 mm (47% above the norm), occurred during the 2nd decade of the month. The change to +5°C was noted at the end of the first decade of November (November 7). The month of November was characterized, contrary to long-term average values, by positive air temperatures. Precipitation in the form of rain and sleet fell by 66.3 mm (31% above normal). Average daily temperatures in December differed little from long-term average values. A stable snow covers up to 1 cm in height was established during the first ten days of the month. The sugar content of the tillering node was 20-23%.

Snowfall fell on the unfrozen ground. Snow cover was established during the second decade of December with fluctuations in the average daily air temperature from -3.7°C to -5.3°C. The soil temperature at the tillering node approached freezing. The winter months (January and February) were snowy. In the first ten days of January 2022, the height reached 9 to 12 cm and by the end of the month it increased to 27 to 38 cm. The amount of precipitation in January exceeded the norm by 73% (61.2 mm versus 35.4 mm). Over the months, 114.2 mm fell. The maximum amount of precipitation in the form of snow was recorded in the second decade of February - 32.3 mm. The height of the snow cover in March reached 1.5 m, and the snow completely melted in the first decade of April. The average monthly air temperature in April was 2°C higher than the average summer value. Vegetation resumed in the second decade of April. The air temperature was 5.8°C, 2.2°C lower than the long-term value, with fluctuations over decades of 0.9°C to 2.4°C. The air temperature in May, June and July was marked by higher values, especially the second decade of May - on average 18.3 °C, the third decade of June - on average 24.4 °C, the second decade of July - average 22.2 °C.

During the first two decades of February, average daily temperatures were -0.1 °C to -3.7 °C, with total precipitation of 26.8 mm. Due to snow compaction, at the end of the 2nd decade of February, the height of the snow cover was 33 centimeters. The soil temperature at the tillering node of winter crops in the 3rd decade of November was + 1.5 °C, in December it varied from -0.3 °C in the first decade to - 0.5 – -0.7°C in the first decade. next ten days of the month. Then, as snow cover depth increased in January and February 2022, the ground temperature at the tillering node stabilized in the range of -0.3°C to -0.2°C.

The winter cereal growing season resumed in the third decade of April. The air temperature during each decade did not differ from long-term average values and averaged 5.6 °C per month.

In 2021, a large amount of precipitation during the spring-summer growing season was observed in the third decade of April (44.8 mm), with an excess of long-term average values of 6.4 times, and the first decade of May - 48.3 mm, respectively, by 3.3 times. This resulted in a delay in spring sowing of spring crops, later than the optimal sowing period. Monthly precipitation in April was 74.6 mm and in May it was 85.7 mm. At high air temperatures in June and July, precipitation fell less than the long-term average values in the first and second decade of July - 71 (2.4 times) and 47 mm (1 ,7 times). The hydrothermal coefficient for the spring-summer period was 1.36.

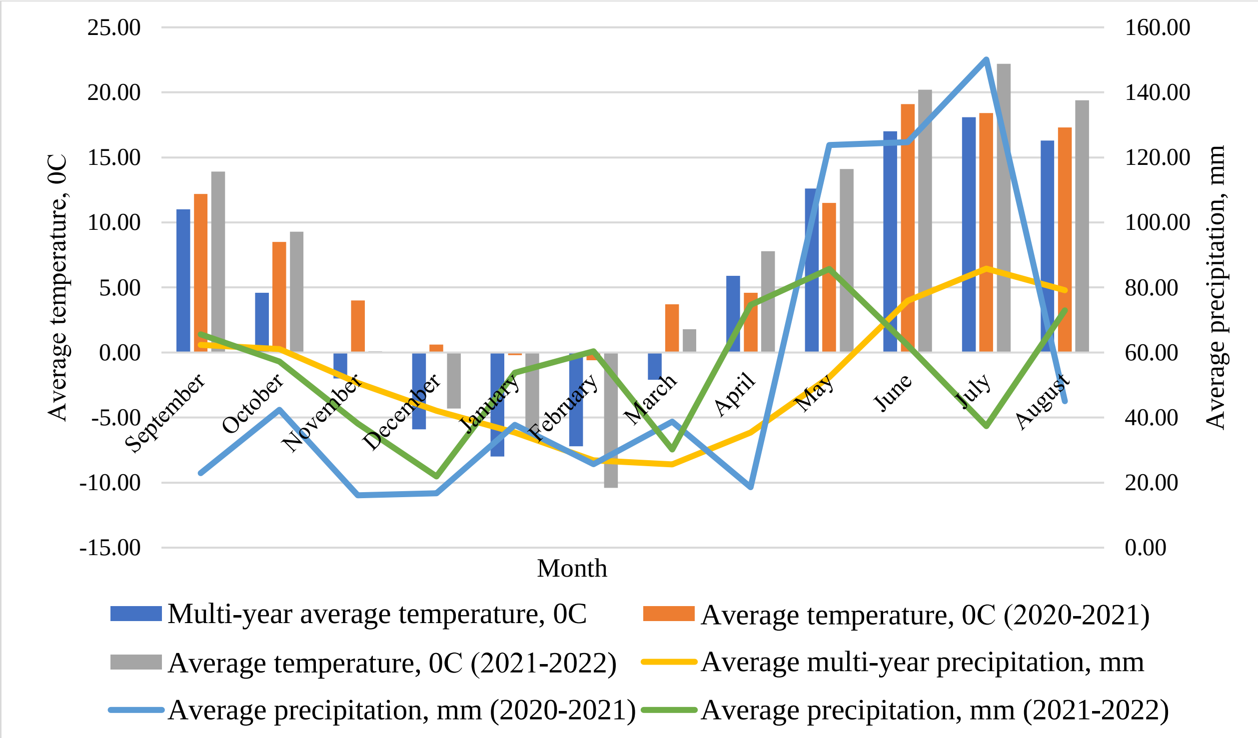

Figure 1. *Weather conditions in 2020-2022 (Nemchinovka weather station)*

In 2022, the amount of precipitation that fell during the month was 56% higher than long-term observed values. Spring 2022 was characterized by a clear absence of positive temperatures in May; the first ten days of May were particularly cool - on average 2°C below the long-term average values for this period. Added to this is the lack of precipitation. During the first decade of May, precipitation was 50% below normal. The 2nd and 3rd decades of May were characterized by lower temperatures.

The weather conditions of the first summer month (June) were generally favorable for the growth and development of plants, they were humid and warm. The development of winter wheat plants was more intense due to the hydrothermal conditions of the autumn-winter period, mainly due to the accumulation of moisture. However, it should be noted that there is a period of lack of moisture and drought in the third ten days of the month. Only 2 mm of precipitation fell.

The second summer month (July) was characterized by elevated temperatures: 3-4 °C above the long-term average values in the first and third decades. The amount of precipitation per month fell 26% less (63.1 mm) from the long-term average value (85.8 mm). In terms of air temperature and precipitation this year, August should be considered a dry month. The air temperature in the first ten days exceeded the long-term average values by 3.4 °C, with a precipitation deficit of 93%. Precipitation in the second ten days of August did not interfere with harvesting. Only 0.3 mm fell over the decade.

Research methodology

The experiment was carried out according to a two-factor design. Winter wheat varieties (factor A) were placed in experimental variants that differed in the level of application of plant protection products - basic technology (1), intensive (2), high-intensity (3) (factor B). Sowing was carried out at the following rates: 5 million germinating grains per hectare.

To maximize the productivity potential of new varieties of winter wheat, it was necessary to place them in mastered crop rotations according to the best predecessors. Crop rotation with rational alternation of cultivated crops provides a high agrotechnical background for all crops included in it. In crop rotation, due to the change of crops that differ in biological characteristics, requirements for growing conditions and effects on soil regimes and properties, a reduced level of weediness, soil contamination with pests and diseases, and favorable water-physical, microbiological, and nutritional regimes are created.

Table 1. *Outline of experience on agricultural technologies of winter grain crops varieties breeding by fits "Nemchinovka." Factor A (variety): winter wheat – Nemchinovskaya 85, Moskovskaya 40, Moskovskaya 27.*

Predecessor	**Processing system soil**	**Technology (factor B)**	
		Doses of fertilizers, kg per hectare	Plant protection system
			Basic technology
Black steam	Plowing to a depth of 20-22 cm, cultivation to 10-12 cm; pre-sowing cultivation at 6-8 cm, treatment with the Katros unit. Sowing: "Amazone -US"	Main application $N_{30}P_{60}K_{90}$; feeding N_{60}	Seed dressing + treatment of crops in the fall (phase 2-3 leaves) with a tank mixture of pesticides (herbicide + fungicide + insecticide), in the spring (phases tillering - booting) treatment with pesticides according to forecast
			Intensive technology
		Main application $N_{30}P_{90}K_{120}$; feeding N_{60} + N_{30}	Seed dressing + treatment of crops in the fall (phase 2-3 leaves) with a tank mixture of pesticides (herbicide + fungicide + insecticide), in the spring (phase end of tillering - exit to the tube) - treatment of crops (herbicide + fungicide + insecticide + retardant), protection ear according to forecast (fungicide + insecticide).
			High-intensity technology
		Main application $N_{30}P_{120}K_{180}$; feeding N_{60} + N_{30}+N_{30}	Seed dressing + treatment of crops in the fall (phase 2-3 leaves) with a tank mixture of pesticides (herbicide + fungicide + insecticide + retardant), in the spring (phase end of tillering - exit to the tube) - treatment of crops (herbicide + fungicide + insecticide + retardant), mandatory ear protection in the flag leaf phase (fungicide + insecticide).

For all technology options, seeds were treated with Vincit forte 1.25 l/t and Picus 1 l/t. Spraying of crops was carried out using an Amazon US - 605 machine.

Varieties of winter crops were sown following the predecessor annual grasses on September 07. 2020 (field No. 5) and September 13. 2021 (field No. 2) respectively. The field area was 2.0 hectares, under the experiment - 1.0 hectares. The total size of the plot is 160 m^2, the recording area on varieties is 30 m^2, the repetition rate is fourfold, the agricultural technology for cultivating winter grain crops is generally accepted for the Central region of the Non-Black Earth Zone. Preparing the field for sowing included plowing green manure and harrowing. Cultivation to a depth of 10 - 12 cm. Mineral fertilizers were applied according to the planned yield level (basic 4-5 tons, intensive 6-8 tons, high-intensity 8-10 t/ha), cultivation to a depth of 4-5 cm with rolling (unit "Katros). Winter wheat was sowed using an Amazon D 9 seeder. Harvesting was carried out by direct combining with a Sampo-500 combine.

In the years of research, observations were made of the water regime, agrophysical properties, the content of nutrients in the soil, phytometric and photosynthetic indicators of plants (according to generally accepted GOSTs), the structure of the crop, the yield of winter what was determined by plot, separately for each technology, content NPK in soil and grain [10], crude protein content [11], the formula N×6.25 was used, grain nature according to the Methodology of state variety testing of agricultural crops [12].

Statistical Analysis

Statistical processing of research results was carried out according to B.A. Dospehova [13]. The obtained results were statistically analysed with the analysis of variance (ANOVA). Tukey's test was used to determine a statistically significant difference at the level of $p = 0.05$. Statistical analysis of the results was performed using the RStudio 4.3.0

RESULTS AND DISCUSSION

Physiological parameters

Leaf area index

Leaf area index (LAI) is the most important parameter that reflects the dynamic growth rate of crops. The LAI determines the size of the area of photosynthetic active radiation (PAR) on which the efficiency of the photosynthesis process depends. One of the most important tasks in achieving high yields is to ensure optimal development of the leaf area of winter wheat with maximum efficiency.

The formation of the leaf surface depends on several factors, including the biological characteristics of the variety and cultivation technology. Depending on the intensity of leaf surface formation by winter wheat plants, a total biological yield is created, which is determined by the characteristics of photosynthesis. The qualitative characteristics or yield of the main product (grain) largely depend on the agrometeorological conditions of the growing season. A significant role in the formation of high yields of winter wheat belongs to the rapid development of leaf surface, associated with the use of fertilizers and plant protection products.

The cultivation technologies used in the experiment, mineral fertilizers and plant protection products also influenced the dynamics of leaf area during the spring growing season, with the highest area indicators observed during all periods of plant growth and development.

According to our study of the dynamics of the formation of leaf area of winter wheat, its area changed according to the phases of plant vegetation depending on weather conditions, under the influence of wheat cultivation technology and doses of fertilizers applied. The smallest leaf surface area of winter wheat was observed from the beginning of the resumption of spring vegetation in the tillering phase when grown using basic technology - 0.56 m^2/m^2. The use of intensive and high-intensity technologies, respectively, provided a noticeable increase in leaf area from 3.81 to 4.52 m^2/m^2 (Table 2).

Table 2. *Influence of cultivation technology and fertilizers on the dynamics of leaf area of winter wheat crops, m^2/m^2 (average for 2021–2022)*

Phenological phase	**Технология**					
	B	I	H	B	I	H
	2020–2021			**2021–2022**		
Tillering	0,58	1,14	1,22	0,56	1,38	1,42
Tube output	2,01	3,13	3,58	1,72	3,08	3,42
Heading	2,60	3,01	3,28	2,47	3,81	4,52
Milky ripeness	1,86	2,48	2,90	1,52	1,87	2,57
Average	1,76	2,44	2,75	1,57	2,36	2,98

Note: B – Basic; I – intense; H – high-intensity technology

The leaf area in all experimental variants increased as the phenological phases progressed, reaching maximum values during the heading phase. After passing through this heading phase, associated with the aging of plants and the death of leaves, the leaf area began to gradually decrease. However, in all phases of the growing season, the patterns of crop development area remained the same - the smallest leaf area with basic technology; fertilizing increased this indicator, but it remained lower than when cultivating winter wheat with intensive and high-technology.

Weather conditions also affected the leaf area of winter wheat. Therefore, the short period of autumn growing season did not allow plants to form well-developed leaf apparatus in the fall. However, under the current climatic conditions over the years of research, crops using high-intensity technology had a higher assimilation area than those using intensive and basic technologies.

Numerous studies of leaf surface area have shown that it directly affects crop formation, especially winter wheat. A study conducted by I. I. Gasanova and Soludushko [14,15] proved that there is a direct relationship between the yield of wheat grain and the area of its leaves. Indeed, the photosynthetic activity of the leaf determines the yield of winter wheat. In other words, leaf surface area depends on numerical gradients in the efficiency of the photosynthetic process. According to Shatilov I. S. and Stolyarov A. I. [16] and Matveev A. G. [17], for most agricultural crops the optimal leaf surface area is in the range from 2 to 7 m^2/m^2. That is, in all variants of the experiment and in all years of research, winter wheat crops using both technologies and all doses of fertilizers reached optimal values of leaf surface area by the heading phase, but they were higher when cultivating winter wheat using high-intensity technology.

Photosynthetic potential and net photosynthetic productivity

Photosynthetic potential is a feature of the assimilation apparatus of wheat and is more complex in relation to leaf area [8,12,13]. Photosynthetic potential characterizes the sum of the surface area of plant leaves over a certain period. The value of photosynthetic potential is determined to predict the productivity and yield of agricultural crops [18]. This indicator is obtained by adding the values of the leaf area involved in photosynthesis during a certain growing season; their sum over interphase periods constitutes the total photosynthetic potential.

In our studies, the average optimal values of photosynthetic potential were achieved by planting winter wheat using high-intensity technology - 2.18-2.62 million m2×day/ha. With intensive and basic technologies, it amounted to 1.56-2.04 million m2×day/ha and ... million m2×day/ha, respectively (Table 3).

The increased leaf area and relatively longer period of its operation provide an increase in photosynthetic potential. According to researcher Pigorev and Semykin [19], crops with a photosynthetic potential within 2 million m^2 × days/ha produce a yield of only 5.0 t/ha, while 3–4 million m^2 × days/ha can give a yield of 8.0 t/ha.

In our study 2020-2021, the average optimal values of photosynthetic potential were obtained when sowing winter wheat using high-intensity technology - 2.18-2.62 million m^2×day/ha. With intensive and basic technologies, it amounted to 1.56-2.04 million m^2×day/ha and ... million m^2×day/ha, respectively (Table 3).

Table 3. *Photosynthetic potential and net photosynthetic productivity of winter wheat by varieties and cultivation technologies (g/m^2 day, average for 2021–2022)*

Variety	Technology	PP, million m^2/ha · days		NPP, g/m^2. day	
		2021	2022	2021	2022
Nemchinovskaya 85	B	2,7	3,2	3,9	3,7
	I	6,5	5,5	4,2	4,3
	H	7,5	6,7	4,4	5,7
Moskovskaya 27	B	2,9	3,4	3,3	3,7
	I	3,9	3,7	4,9	6,3
	H	4,5	4,2	5,5	6,6
Moskovskaya 40	B	2,4	2,7	3,8	4,4
	I	3,8	4,2	4,9	5,2
	H	4,5	4,7	5,2	5,7

Note: B - basic, I - intensive, H - high-intensity technology

Analysis of our research data showed that the overall photosynthetic potential of agricultural crops is most influenced by weather conditions and technologies (Table 3). Thus, photosynthetic potential and leaf area of plants are closely related. Analysis of our research data showed that weather conditions and technologies had the greatest impact on the total photosynthetic potential of agricultural crops.

The highest photosynthetic potential (7.5 million m^2×day/ha and 6.5 million m^2×day/ha) was observed in the 2021 experiments with the Nemchinovskaya 85 variety under high-intensity technology and intensive technology, respectively, for sowing on September 07. The Moskovskaya 56 variety had the lowest photosynthetic potential: 2.2 million m^2 × day/ha with basic technology.

Observations of the photosynthetic activity of wheat crops in humidified conditions in 2021 showed that, according to varieties and technologies, photosynthetic potential indicators varied markedly from 2.2 to 7.5 million m^2/ha · days. With increasing technology intensity, photosynthetic potential increased. The highest photosynthetic potential under the conditions of the year was noted for the Nemchinovka 85 variety. According to intensive technology, the indicator was 6.5 million m^2/ha · days, and according to high-intensity technology – 7.5 million m^2/ha · days. For the varieties Moskovskaya 40, Moskovskaya 27 and Moskovskaya 56, the indicator was lower in the variants of intensive and high-intensity technologies by 4.6.

Depending on the varieties and technologies, observations of the net productivity of photosynthesis of wheat crops in humid conditions in 2022 showed fluctuations from 3.7 to 6.6 million g/m^2 day. The results showed that as technology intensity increased, net photosynthetic productivity increased. The highest NPP under the conditions of the year was noted for the Moskovskaya 27 variety. According to intensive technology, the indicator was 6.3 million g/m^2 day, for high-intensity technology - 6.6 million g/m^2 day. For the Nemchinovskaya 85 variety, the current indicator was lower on average by 4.6, the variants by 4.3–5.7 with intensive and high-intensity technologies, respectively.

Thus, photosynthetic potential and leaf area of plants are closely related. A well-developed photosynthetic apparatus is the main condition for high plant productivity, since it can create a large amount of assimilator. The degree and duration of operation of the assimilation apparatus are the main factors limiting biological productivity under certain plant growing conditions and are closely related to grain yield. Photosynthetic potential and net productivity of photosynthesis, reflecting, as a rule, a close direct relationship with the yield of biomass, are an integral indicator of changes in the size of the assimilation surface and the duration of its work [20–22].

The photosynthetic potential of plants reflects and obeys the same patterns the nature of the dynamics of leaf area. According to the data in Table. 5, the change in the photosynthetic potential of crops according to the experimental variants was like the change in the photosynthetic area of leaves.

Photosynthetic activity of winter wheat plants

Depending on the intensity of leaf surface formation by winter wheat plants, a total biological yield is created, which is determined by the characteristics of photosynthesis. The qualitative characteristics or yield of the main product (grain) largely depend on the agrometeorological conditions of the growing season. A significant role in the formation of high yields of winter wheat belongs to the rapid development of leaf surface, associated with the use of fertilizers and plant protection products. Photosynthetic potential (PP) shows the work intensity of the assimilating surface during the growing season.

Photosynthesis is the main factor in the formation of plant yield, which accounts for up to 95% of all energy stored in the plant. Creating optimal conditions for the functioning of the photosynthetic apparatus throughout the growing season is a necessary condition for the formation of high yields [23–25].

Observations of the photosynthetic activity of winter wheat crops in moist conditions in 2021 showed that the indicators of photosynthetic potential and net photosynthetic productivity varied significantly depending on the variety and technology (Table 4). With increasing technological intensity, photosynthetic potential has increased.

Table 4. *Photosynthetic activity of winter wheat plants under different cultivation technologies (g/m^2 day) 2021*

Variety	**Technology**	**Interphase period**			
		Tillering-exit into the tube	**exit to the earing tube**	**Heading - milky ripeness**	**Tillering-milk ripeness**
Nemchinovskaya 85	B	3,7	6,4	4,4	4,8
	I	5,7	7,6	5,2	6,4
	H	6,6	7,8	6,0	6,8
Moskovskaya 27	B	3,7	6,8	4,4	5,0
	I	4,3	7,6	4,9	5,6
	H	6,3	7,9	5,7	6,6
Moskovskaya 40	B	4,4	6,9	3,9	5,1
	I	5,2	7,7	4,8	5,9
	H	5,7	8,2	5,4	6,4

Data on the photosynthetic activity of winter wheat collected in 2022 under humid conditions showed that photosynthetic potential and net photosynthetic productivity vary significantly depending on the variety and technology (Table 5). With increasing technological intensity, photosynthetic potential has increased.

Table 5. *Photosynthetic activity of winter wheat plants under different cultivation technologies (g/m^2 day), 2022*

Variety	Technology	Interphase period			
		Tillering-exit into the tube	exit to the earing tube	Heading - milky ripeness	Tillering-milk ripeness
Nemchinovskaya 85	B	3,7	6,0	4,4	4,7
	I	4,4	6,8	5,2	5,5
	H	5,4	7,4	6,0	6,3
Moskovskaya 27	B	4,4	5,7	4,5	4,9
	I	6,0	6,9	5,7	6,2
	H	6,3	7,6	5,9	6,6
Moskovskaya 40	B	4,4	4,9	3,9	4,4
	I	5,4	5,7	4.8	5,3
	H	6,2	6,9	5,4	6,2

Note: B – Basic; I – intense; H – high-intensity technology

With the advent of new intensive and high-intensity varieties of winter wheat, it is necessary to establish how the indicators of photosynthetic activity of its crops change depending on technology in the central non-chernozem zone, since this issue has not been sufficiently studied. Leaf area, photosynthetic potential and net photosynthetic productivity are important indicators of photosynthetic activity of crops. Their size depends on external environmental factors during the development of the plant, as well as on the characteristics of the variety.

Grain Yield

Timely treatment of seeds with phytosanitary preparations and the use of mineral fertilizers ensured an increase in the yield of the studied varieties of winter wheat. The best response to mineral nutrition and phytosanitary products was observed in the Moskovskaya 27 variety (8.56 t/ha).

Table 6. *Productivity of winter wheat varieties in technologies of varying degrees of intensity, 2021-2022.*

Variety (factor A)	Technology	Average (factor A)	Increase to base T/ha	%	Average (factor A)	Increase to base T/ha	%
		2021			2022		
Nemchinovskaya 85	B	6,44	-	-	4,52	-	-
	I	9,15	2,71	42	5,66	1,14	25,2
	H	9,54	3,10	48	6,43	1,91	42,2
Average by variety		7,65			5,53		
Moskovskaya 27	B	7,21	-	-	5,91	-	-
	I	9,96	2,75	38	6,55	0,64	10,8
	H	10,83	3,62	50	7,15	1,24	20,9
Average by variety		8,56			6,53		
Moskovskaya 40	B	6,13	-	-	4,62	-	-
	I	8,81	2,68	44	5,33	0,71	15,3
	H	9,34	3,21	52	6,24	1,62	35,0
Average by variety		7,44			5,39		
Среднее (фактор B)		B 6,59	I 9,31	H 9,90	B 5,02	I 5,85	H 6,61
Increase to base T/ha		-	2,27	3,31	-	0,83	1,59
%		-	41,33	50,0	-	17,10	32,70
SSD 0.5							
- by factor A			0.23 t/ha			0.12 t/ha	
- by factor B			0.20 t/ha			0.10 t/ha	
- according to experience			0.45 t/ha			0.20 t/ha	

Note: SSD 0.5 - Smallest Significant Difference for the 5% significance level. B – Basic; I – intense; H – high-intensity technology

The yield of winter wheat varieties in 2021 and 2022 increased with the level of intensification of their cultivation. The weather conditions of the year had a decisive influence on the level of crop yield. In a year characterized by a lack of precipitation, especially in the summer, there is usually a shortage of grain harvest. However, the implementation of measures for the use of fertilizers and plant protection products ensured the yield of winter wheat on average by variety at the level of 45.2 - 71.5 centers/ha of grain.

In experiments with winter wheat, the use of high-intensity technology increased the yield of varieties by 17,10-55% compared to basic technologies and amounted to 102-263 g/m^2. High grain yield was noted due to an increase in field germination, an increase in the number of productive stems and grain weight per ear. To a lesser extent due to an increase in the mass of 1000 grains. In the Nemchinovskaya 85 variety it varies from 40.0 to 47.0 grams.

The yield of the Moskovskaya 27 variety according to the technologies ranged from 7,21-10,83 t/ha. The increases were 0.64-3.62 t/ha compared to the basic (10,8-50%). With an increase in the level of cultivation intensity of the Nemchinovskaya 85 variety, its yield increased from 4.52 t/ha to 7.54 t/ha, and the yield increase was 1.14 - 3.10 t/ha. On average, according to the experience, the yield of winter wheat was 6.85 t/ha. According to the intensive technology, the yield increased by 1.59 to 2.72 t/ha (17.10-41.33%), high-intensity - by 0.83 to 3.31 t/ha (32.70-50%).

CONCLUSIONS

Crop productivity is an integral indicator that reflects a set of factors for the growth and development of a given crop. Cultivation technologies are designed to ensure close to optimal plant requirements for soil preparation, timing and quality of sowing, level of nutrition (soil fertility), timing and quality of harvesting work. They provide protection against pests and diseases. The size of the harvest shows the extent to which the efforts of producers to achieve the planned results were fulfilled and justified. With increasing technology intensity, the yield of the Nemchinovskaya 85 variety increased to 6.40 t/ha, Moskovskaya 27 - to 7.10 t/ha, Moskovskaya 40 - to 6.20 t/ha.

Thus, the formation of high grain yields of the new varieties studied is due to the work of photosynthetic elements: leaf surface area, photosynthetic potential, photosynthesis productivity. Among the varieties studied in terms of yield, the new varieties Moskovskaya 27 and Nemchinovskaya 85 stand out. The new promising variety Moskovskaya 27 is characterized by higher efficiency of the photosynthetic apparatus and production potential, which determine the accumulation rate and grain yield of this variety.

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