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PHOTOSYNTHETIC ACTIVITY AND PRODUCTIVITY OF SUNFLOWER HYBRIDS IN ORGANIC AND TRADITIONAL CULTIVATION TECHNOLOGIES

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Abstract

The scientific paper presents the experimental data on the impact of different cultivation technologies on the indexes of assimilation surface area, chlorophyll content, its fractional composition (fractions "A" and "B") and the yields of sunflower hybrids under conditions of the Southern Ukrainian Steppe. The research was conducted in 2018-2019 on dark-chestnut soil in the semi-arid conditions. The research scheme consisted of the following factors and their variants: sunflower hybrids (PR64F66, Tunca); cultivation technologies (intensive; organic). The research results proved that the best conditions for the formation of the largest area of assimilation apparatus by sunflower plants were created in the organic technology (treatment of soil + seeds + plants with organic preparations during the growing season) when growing the hybrid Tunca: at the stage of 3 pairs of true leaves - 2.9; the formation of heads - 27.1; flowering - 37.1 and milky ripeness - 29.0 thousand m^2/ha. Under the same conditions there was maximum amount of chlorophyll (9.71 mg per 1 g of dry weight) and enzymes. Sunflower cultivation under the organic technology caused the formation of maximum yield (PR64F66 F_1 - 2.42 and Tunca F_1 - 2.41 t/ha), realization of biological productivity (90.9 and 90.7%) and fat content (48.7 and 49.8%).

***Key words**: chlorophyll, intensive and organic technologies of cultivation, leaf surface area, sunflower, yield.*

INTRODUCTION

Increasingly progressing expansion of marginal crops is a feature of the current agro-phytocenosis without any exceptions, indicating that agricultural producers bring economic indexes of farming to the foreground, while ecological aspects are either left without attention, or, at the best, considered by the leftover principle (Andrienko, 2011). Therefore, finding a solution to this problem (reduction of pressing on agro-landscapes and simultaneous maintenance of efficiency indexes of economic activity) is a promising and topical task for researchers (Tkalich et al., 2014; Lavrenko et al., 2019; Lavrenko & Maksimov, 2016).
Currently sunflower is not only a leading oil crop of the domestic agrocenosis, but it often takes a major place in the total structure of the sown areas of an ordinary agricultural enterprise. In 2019 the gross yield of sunflower in Ukraine made 14.5 million tons with the average yield of 2.6 tons per hectare. The complex of reasons causing this phenomenon includes objective and subjective factors of economic, social and technological nature, and the issues of the optimal amount of the crop in the field crop rotations are among the most discussed ones for both scientists and practitioners of agricultural production (Basali & Dobrovolsky, 2015).
However, more and more representatives of the scientific community and agricultural producers agree that the current state of the problem with excessive expansion of sunflower and systematic deviation from the scientifically substantiated zonal technologies require transition to modern technologies (Tkalich et al., 2014).
Biologization of sunflower production is a main method to solve the current problem in the market of agricultural products (Maslak, 2015; Giles, 2004; Leifeld & Fuhrer, 2010). It can be solved in a complex way taking into consideration both biotic and abiotic factors of agrocenosis (Basali et al., 2016).
According to the data obtained by the scientists, when cultivating sunflower by organic technologies it is important to follow

all the requirements that can be checked by means of δ15N or other markers (Joergensen et al., 2019; Camin et al., 2011).

Sustainable agricultural practices that enhance soil fertility and increase its capacity for carbon sequestration are increasingly needed (Abdallah et al., 2019)

It is also known that application of organic fertilizers increases the content of linoleic and oleic acids, improving oil quality. The use of them increases sunflower drought-resistance (Jami et al., 2019).

The application of manure doses of 12.5 and 15% of manure on a weight basis improved the early growth of the sunflower, with significant increases in the growth variables (Barros et al., 2019).

It is widely known that microbial biomass of soil is one of the main factors in determining soil fertility (Fließbach & Mäder, 2000; Tu et al., 2006; Lykhovyd et al., 2017). Organic agriculture ensures higher development of microbial community, than traditional agriculture (average 29.1 and 22.5 kg DNA ha^{-1}, respectively) (Verdi et al., 2019).

Currently the productivity of sunflower seeds in traditional systems of agriculture is higher than that of organic systems. Scientists think that it is a result of decreasing the amount of available forms of nitrogen of organic fertilizers (Verdi et al., 2019; Mäder et al., 2002).

The goal of our field study was to discover the best agro-technological options for sunflower production (including hybrids, cultivation technologies etc.) in the European semi-arid climatic zone of southern Ukraine to obtain the highest grain yield of the crop, quantitative and qualitative indexes of the sunflower leaf apparatus.

MATERIALS AND METHODS

Field trials on the sunflower cultivation technology were conducted during 2018-2019 in the non-irrigated lands of the Farm "Vera" in Hola Prystan district of Kherson region. The experimental plots were located at the latitude 46°20'16.11"N, longitude 32°17'31.38"E, and were elevated to 9 m above the sea level. The field experiments were conducted in four replications by using the split plot design method. The study was dedicated to evaluation of the following cultivation technology elements:

- A - sunflower hybrid: A1 - sunflower hybrid PR64F66 F_1 (bred by Pioneer); A2 - sunflower hybrid Tunca F_1 (bred by Limagrain);
- B - cultivation technology: B1 - intensive; B2 - treatment of soil with organic preparations; B3 - treatment of seeds with organic preparations; B4 - treatment of plants with organic preparations during the growing season; B5 - treatment of soil + seeds + plants with organic preparations during the growing season.

The climate of the experiment zone is characterized as comparatively dry and hot, with the average annual air temperature of 9.8ºC that has a tendency to further increase (Lykhovyd et al., 2018). According to the data provided by Kherson regional hydro-meteorological center, the total rainfall amounts in the zone average to 441 mm, while evapotranspiration reaches 1000 mm. The main meteorological indexes for the period of sunflower vegetation in the experiments are given in Table 1.

Table 1. Meteorological indexes during the period of sunflower vegetation in the field experiments

2018			2019			Long-term data			Months
AT, ºC	PA, mm	RH, %	AT, ºC	PA, mm	RH, %	AT, ºC	PA, mm	RH, %	
3.6	71.9	77	6.6	46.2	81	3.3	26.0	79	March
10.6	8.2	60	11.4	62.3	67	10.0	33.0	70	April
15.3	47.1	61	14.9	29.7	70	16.0	42.0	66	May
21.3	62.0	56	21.1	38.1	64	19.9	45.0	65	June
22.5	5.9	60	22.8	137.0	65	21.9	49.0	63	July
24.2	39.5	59	24.3	0.6	67	21.3	38.0	62	August
18.0	19.5	62	16.3	83.0	70	16.4	40.0	68	September

The soil of the experimental plots was represented by the dark-chestnut middle-loamy middle-saline soil with the humus content of 2.34-2.60%. The content of mobile forms of the elements of mineral nutrition: nitrogen - 1.7-2.0; phosphorus - 4.9-6.5; potassium - 28-36 mg-eq in 100 g of soil, pH - 6.9-7.2. The soil has moderate natural fertility, which mainly depends on nitrogen content.

The sunflower cultivation technology in the experiments was based on the generally accepted recommendations for the crop cultivation in the South of Ukraine. The experiments used the medium-early simple sunflower hybrids of a linoleic type PR64F66 from Pioneer and Tunca F_1 from Limagrain.

The hybrid PR64F66 is resistant to the sunflower broomrape (*Orobanche cumana*) of 7 races (A-G), resistant to lodging (8 points), resistant to phomosis, phomopsis, false powdery mildew (7 points), white head rot (6 points), white stem rot (6 points) and it also has excellent drought-resistance (9 points). The average duration of the growing season is 110-115 days, the yield potential is 5.5 tons per hectare, the head is convex and oil content (6 points) is medium.

The hybrid Tunca is resistant to the sunflower broomrape of 7 races (A-G). The average diameter of the head is 15.9 cm, the average weight of 1000 seeds is 73 g and the height of the plants is an average of 1.5 m. It is distinguished by its plasticity to the growing conditions of the soil. It is resistant to drought, cold and lodging, that affects its stability in various climatic conditions, and on soils of different quality. It is capable of sustaining steady yields. It is tolerant to white head rot, has immunity to stressful conditions and genetic resistance to various diseases. The hybrid is characterized by resistance to such pathogens as *Phomopsis*, *Sclerotinia*, *Macrophomina*, *Rhizopus* and *Phoma*.

The previous crop was winter wheat. The soil was prepared by carrying out double disking at the depths of 6-8 and 10-12 cm. In 14 days after the last disking, the stubble was plowed to the depth of 25-27 cm. In the areas with the intensive cultivation technology, mineral fertilizers were applied at the basic tillage at the dose of P_{30} (in the form of granular super phosphate). In the spring, early spring harrowing was conducted to further level the soil. 14 days after harrowing, weeds were cultivated at the depth of 8-10 cm after weeding. The pre-sowing cultivation was carried out at the depth of 4-6 cm, under which the fertilizer was applied at the dose of $N_{30}P_{20}$ (in the form of ammonium nitrate and double super phosphate). In the areas where the organic cultivation technology was implemented, no fertilizer was used. Sunflower seeds in the variant of the traditional cultivation technology were inlaid with the mixture Cruiser 350 FS (the active substances include active ingredient thiamethoxam, 350 grams per liter) + Maxim (the active substances include fludioxonil, 25 grams per liter), seeds that were sown in the organic areas were treated with the preparation "Gilea-Start"® of 0.7 liter per ton (the active substances include chelate complex Mg, Fe, Co, Mo, Zn, Cu + EDTA).

Sunflower sowing was performed with the John Deere 7000 seeder when the soil temperature at the depths of 10 cm was 8-10°C, which corresponded to 2nd of April in 2018 and 11th of April in 2019. After sowing, the crops were rolled.

Amistar Extra fungicide at the rate of 1.0 liter per hectare (the active substances include azoxystrobin, 200 grams per liter + cyproconazole, 80 grams per liter) was used to protect the plants against diseases in the areas of the traditional cultivation during the vegetation. The organic technology used the organic bacterial fertilizer Gilea-Oliinyi, at the rate of 1.5 liter per hectare (the active substances include chelate complexes of macro, meso and trace elements "Gilea"® - Mg, Fe, Co, Mo, Zn, Cu, B, Mg + EDTA). Prior to the emergence of seedlings, the harrowing of the soil was carried out. During the growing season row spacing was cultivated at the depths of 5-7 and 6-8 cm.

Sunflower seeds were harvested using the continuous method from all the variants of the experiment at the full ripeness stage with the CLAAS Lexion combine. The harvesting took place on 29th of August in 2018 and 24th of August in 2019. The data obtained resulted in basic moisture (7%) and 100% purity.

The leaf surface area index and architectonics of a leaf blade were examined with the method of express-scanning, the content of a green pigment and its fractional composition was investigated with a photometric colorimetric method and spirit extract, the content and fractional content of ferments - with a photometric colorimetric method and acetone extract with hydrogen peroxide with further photoseparation. The experimental data of sunflower were processed by the standard procedure of ANOVA within MS Excel software. Significance of the differences was proved for the reliability level of 95% (LSD_{05}).

RESULTS AND DISCUSSIONS

The results of the study are given in Tables 2, 3, 4. The organic technology of growing sunflower hybrids was characterized by more favorable conditions for the formation of the assimilation apparatus: the total leaf surface area index and the index of foliage clumping of agro-phytocenosis by all the stages of the crop development were higher by 5.5-31% when compared to the plots where the intensive cultivation technology was implemented.

By the results of our research, the intensity of the formation of the assimilation apparatus area of both sunflower hybrids and its absolute value were higher in the organic technology of growing the crop.

The variant of the complex organic technology was characterized by the most essential impact on the index of the crop foliage clumping according to the results of our research. For instance, by the variant of the hybrid PR64F66 this index was 3.69 against 3.15 at the sunflower flowering stage on the average for the years of the research in the intensive cultivation technology; by the variant of the hybrid Tunca the assimilation apparatus area exceeded the crop sown area 3.71 times at the background of the complex organic cultivation technology against 3.22 in the traditional cultivation technology. At the same time we identified more essential dynamics of the loss of the crop assimilation apparatus at the final stages of the crop ontogenesis at the background of implementing the intensive cultivation technology.

Not only a green pigment content in the crop parenchyma is a very important index, but its fractional composition is also significant. With regard to this, the most technological measures are considered in terms of their impact on the content of the chlorophyll fraction "A" as the one that is the most essential in the formation of organic substance by a plant organism. (Table 3). The analysis of the experimental data given above allows drawing a conclusion that in the organic technology of growing sunflower more favorable conditions were created for the formation of a green pigment, the content of the physiologically active fraction "A" in it and the ferments responsible for antioxidant properties and oxygen exchange in the plant cells, resulting in the drought-resistance and heat tolerance of a plant organism in the years of the research.

The architectonics of the leaf blade and the plant general habitus on the test plots were less than the corresponding indexes on the plots where the elements of the organic technology were implemented, causing the change of the leaf blade (a more elongated and thinner blade of a light-green color, a more elongated plant with a longer distance between the levels of leaves). This variant of the technology of growing both hybrids ensures the maximum content of a green pigment in the crop leaves, its optimal fractional composition, and also the content of ferments maintaining the traffic of oxygen to the plant tissues under stressful conditions by the hydro-chemical coefficient (peroxidase and catalase).

The highest productivity of sunflower seeds was found to be 3.8% for growing the hybrid PR64F66 compared to the hybrid Tunca F1. It was also shown that growing crops in the organic technology contributed to the formation of seed yields higher by 10.3% when compared to the intensive technology.

Similar results were observed in terms of realization of biological productivity of the crop. The biological yield of the sunflower hybrid PR64F66 ranged from 87.4 to 90.9%, which is 3.6% more than the hybrid Tunca. The use of the organic technology for the sunflower cultivation compared to the intensive technology increased the biological yield from 80.5-87.4 to 90.7-90.9%.

The fat content of sunflower seeds was the highest for the cultivation of Tunca F1 - 48.6-49.8%, which is 0.8 less than that of the hybrid PR64F66. The use of the organic technology also contributed to the accumulation of fatty oil in the seeds up to 48.7-49.8%, which is higher by 0.9% when compared to the intensive (traditional) technology.

Table 2. Dynamics of the formation of the leaf area of the sunflower hybrids depending on the cultivation technology. thousand m^2 per ha (average for the period 2018-2019)

Sunflower hybrid	Cultivation technology	Crop development stages			
		3 pairs of true leaves	head formation	flowering	milky-wax ripeness
A1 (PR64F66 F_1)	B1	2.2	20.0	31.5	22.4
	B2	2.4	22.2	32.9	26.8
	B3	2.3	22.4	33.8	27.2
	B4	2.6	22.8	35.0	27.0
	B5	2.8	23.9	36.9	28.1
A2 (Tunca F_1)	B1	2.4	21.7	32.2	23.3
	B2	2.4	21.5	33.0	27.0
	B3	2.5	25.2	32.7	26.7
	B4	2.7	26.0	34.4	29.2
	B5	2.9	27.1	37.1	29.0
LSD_{05} for factors	A	0.17	0.54	0.86	0.57
	B	0.11	0.71	1.14	0.43
	AB	0.19	0.88	1.32	0.77

Note: All the differences between the studied variants are significant.

Table 3. Pigment and enzyme composition of the spongy parenchyma of sunflower hybrid leaves depending on the cultivation technology (average for the period 2018-2019)

Sunflower hybrid	Cultivation technology	Chlorophyll			Enzymes	
		total content, mg per 1 g dry weight	fraction "A",%	fraction "B",%	peroxidase, conventional unit per 1 g of wet weight	catalase, conventional unit per 1 g of wet weight
A1 (PR64F66 F_1)	B1	5.29	60.2	39.8	6.36	1524
	B2	5.88	64.2	35.8	6.39	1726
	B3	6.39	62.9	37.1	6.51	1752
	B4	8.11	70.1	29.9	6.57	1754
	B5	9.02	73.3	26.7	6.88	1789
A2 (Tunca F_1)	B1	6.23	74.0	26.0	6.43	1549
	B2	6.50	75.1	24.9	6.49	1622
	B3	6.37	75.8	24.2	6.61	1646
	B4	8.28	78.4	21.6	6.72	1690
	B5	9.71	79.9	20.1	6.82	1695
LSD_{05} for factors	A	0.79	9.33	12.2	0.05	13.30
	B	0.43	1.68	3.03	0.09	18.07
	AB	0.85	10.02	12.77	1.05	22.12

Note: All the differences between the studied variants are significant.

Table 4. Seed yield of sunflower hybrids and fat content depending on the cultivation technology (average for the period 2018-2019)

Sunflower hybrid	Cultivation technology	Yield, t per ha	Realization of biological productivity, %	Fat content, %
A1 (PR64F66 F_1)	B1	2.27	87.4	48.1
	B5	2.42	90.9	48.7
A2 (Tunca F_1)	B1	2.11	80.5	48.6
	B5	2.41	90.7	49.8
LSD_{05} for factors	A	0.07		
	B	0.12		
	AB	0.21		

Note: All the differences between the studied variants are significant.

The best conditions for the formation of the largest area of assimilation apparatus of sunflower plants were created in the organic technology (treatment of soil + seeds + plants with organic preparations during the growing season) when growing the hybrid Tunca: at the stage of 3 pairs of true leaves - 2.9; the formation of heads - 27.1; flowering - 37.1 and milky ripeness - 29.0 thousand m^2/ha. Under the same conditions there was maximum amount of chlorophyll (9.71 mg per 1 g of dry weight) and enzymes. Sunflower cultivation in the organic technology caused the formation of the maximum yield (PR64F66 F_1 - 2.42 and Tunca F_1 - 2.41 t/ha), realization of biological productivity (90.9 and 90.7%) and fat content (48.7 and 49.8%).

The previous experimental research proved that the prevailing majority of scientists prefer fragmentary examination of individual elements of biologization of sunflower cultivation technologies (application of bio-fungicides and organic fertilizers, minimization of application or flat refusal to use some types of mineral fertilizers, reduction of their doses and rates, revision of the methods of applying them, involvement of biologically active substances of organic nature to the cultivation technology etc.) (Kadyrov & Silin, 2015). Another group of scientists follow a different concept: they declare scientifically substantiated amount of the crop in agro-phytocenosis (15-16%) without any principal revision of the zonal cultivation technology towards the implementation of the elements of biologization into it (Zhuk et al., 2011).

The issue of the research on the content of ferments directly causing the resistance of a plant organism to soil and, first of all, to air droughts - peroxidase and catalase - in spongy leaf parenchyma has been left without any attention in scientific periodicals and dissertation theses.

According to the results of our research, the intensity of the formation of the assimilation apparatus area of both sunflower hybrids and its absolute value were higher in the organic technology of the crop cultivation (Table 2).

According to the research results, the most essential impact on the index of the crop foliage clumping was characteristic of the variant B5 (treatment of soil + seeds + plants with organic preparations during the growing season). When growing the hybrid PR64F66, this index was 3.69 at the stage of sunflower flowering on the average for the years of the research against 3.15 in the intensive cultivation technology. The assimilation apparatus area of the hybrid Tunca exceeded 3.71 times the crop sown area in the technology under study B5 when compared to B1, where the corresponding index was 3.22.

We noticed more considerable loss of sunflower photosynthetic assimilation apparatus at the stage of full ripeness in the intensive cultivation technology.

Examining not only the content of chlorophyll in the crop parenchyma, but also its fractional composition is a modern trend of agronomy science. Currently the issue of fractional composition of chlorophyll and enzymes depending on different types of sunflower cultivation technology has not been thoroughly investigated. And the majority of technological measures are examined in the aspect of their impacts on the content of the fraction of chlorophyll “A” as the one that is the most essential in the formation of organic substance by a plant organism (Table 3).

Our research shows that in the organic technology of sunflower cultivation (B1-B5) for the years of the research there were more favorable conditions for the formation of a green pigment, the content of physiologically active fraction “A” in it and the ferments responsible for antioxidant properties and oxygen exchange in the plant cells, and it resulted in drought- and heat-resistance of a plant organism.

The previous research conducted on many agricultural crops proved inhibiting impact of synthetic pesticides on the amount and activity of micro-biota available in the soil (Fadeev, 2016: Lavrenko, 2007). Application of high rates of mineral fertilizers and a large number of chemical substances essentially reduce micro-biota in the soil and affect further reduction of the activeness of organic substance degradation, reduction of soil fertility and quality and also the crop productivity (Baghbani-Arani et al., 2017; Bajgai et al., 2015; Fliebbach et al., 2007; Leskovar et al., 2018; Lima et al., 2009; Ushkarenko et al., 2008).

An average of two years of the research proved that the yield of the conditioned seeds of the hybrid PR64F66 exceeded that of Tunca according to the variant of the traditional cultivation technology by 0.16 t, while no significant difference was recorded in the organic cultivation technology. At the same time, the variant of the organic cultivation technology was characterized by a significantly higher level of realization of biological yield (90.8% against 83.9%) and the index of fat content in the seed (49.3% against 48.3% respectively).

CONCLUSIONS

The best conditions for the formation of the largest area of assimilation apparatus by sunflower plants were created in the organic technology (treatment of soil + seeds + plants with organic preparations during the growing season) when growing the hybrid Tunca: at the stage of 3 pairs of true leaves - 2.9; the formation of heads - 27.1; flowering - 37.1 and milky ripeness - 29.0 thousand m^2/ha. Under the same conditions there was maximum amount of chlorophyll (9.71 mg per 1 g of dry weight) and enzymes.

Sunflower cultivation under the organic technology caused the formation of maximum yield (PR64F66 F_1 - 2.42 and Tunca F_1 - 2.41 t/ha), realization of biological productivity (90.9 and 90.7%) and fat content (48.7 and 49.8%).

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