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Photosynthesis productivity of soybean

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ABSTRACT

The aim of the research was to study technological methods that determine the growth of intensity of photosynthesis of soybean cenosis, peculiarities of accumulation of organic matter during the growing period and its distribution in the organs of plants. In the article there are results of researches on studying of influence of different variants of primary tillage and herbicides in soybean cultivation technology on the performance of photosynthetic activity and seed yield. It is established that early moldboard plowing is the most preferred for the cultivation of soybeans in the conditions of Ulyanovsk region, especially with lack of moisture. The use of herbicides improves photosynthesis and yield of soybean, especially in the variant with zero tillage.

Keywords: soybean, methods of primary tillage, herbicides, leaf surface area, dry matter, yield.

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INTRODUCTION

The share of the organic compounds created by plants as a result of photosynthesis, accounts for about 90-95% of the total biomass of a plant. Therefore, one of the factors affecting the productivity of field crops is the value of the assimilation apparatus, which is a primary organ of photosynthesis (1). The efficiency of the process of photosynthesis and, ultimately, the yield depends on the operation of sowing as photosynthetic systems, which should, if possible, remain in the active state for a long time, creating plastic substance, both for the growth of plants and formation of storage organs.

In the conditions of forest-steppe of Volga region, soybean is able to build and maintain over a long period of time (from the phase of flowering to full filling of beans) leaf surface area at the level from 30 to 50 thousand m^2/ha (2-4), which according to the literature data corresponds to the values defining the most effective use of solar energy (5).

Given that soybean leaf surface area formation within the limits that define the maximum efficiency of photosynthesis is stable and persists under different conditions, it becomes important to identify the optimal level of energy consumption necessary for its cultivation, ensuring both the preservation of the indicators of photosynthesis and the stability of seed yield.

Primary tillage and plant protection products play an important role in energy-saving technologies of cultivation. The main criterion of the effectiveness of primary tillage and herbicides is the seed yield, representing the end result of symbiotic and photosynthetic activity of crops from grain legumes. The intensity of these processes is largely determined by both agrophysical indicators of fertility and the presence and magnitude of competition from weeds for light and mineral nutrients.

OBJECTS AND METHODS OF RESEARCH

The studies were conducted in 2011-2013 on the experimental field of the Ulyanovsk state agricultural academy. Two-factor field experiment was laid out in a fourfold repetition, in accordance with the methods and techniques of staging field experiments on fixed plots, accommodation of plots with systematic offset. Sown variety – USKhI 6. The experiment studied three methods of primary tillage and efficacy of different herbicides compared to the untreated (control) variant. Moldboard treatment and flat-carved tillage was conducted early – August 25-26, depth of processing – 25-27 cm.

The size of the plots of the first order – the study method, primary tillage – 600 m^2, the size of the plots of the second order – the study of the effects of herbicides – 50 m^2.

Sowing in the variant with zero tillage was performed by direct seeding seeder AUP -18, in the others – SZP-3,6.

THE RESEARCH RESULTS

Primary tillage determines the conditions of plant development. The availability of nutrients, phytosanitary condition of sowings, agrophysical indicators of fertility change (6,7).

It is established that in all varients, soybean plants formed a leaf surface area sufficient to ensure the formation of a high yield. Leaf surface area, regardless of the weather conditions of the year and variant of experience, reaches a maximum value at the phase of filling of seeds, leaf surface area is reduced to the full ripening of seeds, the average for years of researches by 1,22-1,57 times (table 1).

The increase in the degree of intensity of exposure to the soil with the primary tillage contributed to the growth of leaf surface area in all years of the study. The maximum was marked in the variant of moldboard plowing – the leaf area varied from 39,5 to 53,9 thousand m^2/ha. Flat carved tillage and sowing without treatment determine the formation of a smaller area of the leaf surface - to the phase of filling of seeds, the lag was 4,8-5,9 thousand m^2/ha and 8,2-8,8 thousand m^2/ha, respectively.

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Table 1: Dynamics of leaf surface area of soybean, thousand m²/ha

Factor		Phase of development			
A	B	third ternate leaf	blossom	ripening of seeds	full ripening of seeds
on average for 2011-2013					
Moldboard tillage (plowing)	Conrol	17,4	27,1	44,1	31,8
	Pivot	16,6	28,1	46,1	32,5
	Harmony Classic	16,3	28,2	45,8	33,3
Without tillage (zero tillage)	Conrol	14,6	21,2	35,8	26,2
	Pivot	13,9	22,2	37,9	27,6
	Harmony Classic	14,2	22,8	37,0	27,2
Flat carved tillage	Conrol	16,1	24,7	39,3	29,3
	Pivot	17,0	25,7	40,2	29,4
	Harmony Classic	15,9	26,0	40,9	30,2

The herbicide Pivot and Harmony Classic show weak inhibitory effect on soybean, leaf surface area in the phase of the third ternate leaf is slightly behind control in all variants of primary tillage. However, in the later phases of development of soybean, the dynamics is reversed, which is a direct consequence of alleviating of interspecific competition at the beginning of the growing season and result of the creation of conditions for development of plants.

The study of the relation between leaf surface area and yield in soybean crops in years of research using correlation and regression analysis showed that the closest relation between the features is observed in the early phase of ripening seeds.

Area of leaf surface, defining the extent and nature of the dynamics of growth of dry biomass during the vegetation period, depends not only on the phase of plant development and its varietal characteristics, but also on the conditions of development, it is largely determined by the intensity of tillage and plant protection.

Table 2: Dry matter accumulation in soybean crops, kg/ha

Factor		Phase of development				
A	B	third ternate leaf	blossom	ripening of seeds	full ripening of seeds	full ripeness
on average for 2011...2013						
Moldboard tillage (plowing)	Conrol	978	1994	4078	7791	5808
	Pivot	971	1977	4248	8096	6038
	Harmony Classic	874	2106	4271	8082	6052
Without tillage (zero tillage)	Conrol	720	1573	3160	5628	3799
	Pivot	669	1643	3238	5795	4094

	Harmony Classic	661	1720	3204	5812	4155
Flat carved tillage	Conrol	899	1805	3757	7017	4888
	Pivot	841	1867	3777	7134	5123
	Harmony Classic	857	1839	3791	7107	5104

Data analysis showed that there was a continuous process of accumulation of dry weight of soybean plants to the phase of full seed ripening (table 2). Fall off, at the period of maturation of the leaves, reduces the total biological mass of sowing to the phase of full ripeness by 1,28-1,58 times. Moldboard tillage in all years of study contributed to the maximum accumulation of dry matter in the phase of full seed ripening, on average for 2011-2013, this indicator reached values of 7990 kg/ha. In the variant with flat carved tillage, the amount of dry matter, at the moment of the maximum formation, was less by 904 kg/ha, and in the variant with exclusion of primary tillage - by 2245 kg/ha compared to the variant with moldboard tillage.

The used herbicides contributed to the increase in the intensity of accumulation of dry matter. On average for years of research to the phase of complete ripeness, the excess over the control with moldboard tillage amounted 237 kg/ha, with zero tillage – 325 kg/ha, with flat carved tillage – 225 kg/ha. Significant differences between herbicides Pivot and Harmony Classic were not observed.

To obtain high yields it is important not only to create optimal leaf surface, but also increase the duration of its work with the highest productivity. The area of photosynthetic surface and the duration of its functioning is expressed by photosynthetic potential (PSP). The effectiveness of the implementation of the photosynthetic potential is expressed by the accumulation of dry mass in terms of unit of solid leaf surface for a certain period. This parameter characterizes the intensity of formation of organic matter and represents the net productivity of photosynthesis (NPP). According to the literature (8), its value is not very different in plants and is on average from 4 to 9 g/m^{2}day, however, certain crops may reach substantially higher values - 16,0-17,6 g/m^2 per day (9).

Studies established that the magnitude of photosynthetic potential, and leaf surface area, is largely determined by weather conditions and moisture conditions during the growing season (table 3). Maximum values of PSP – 4066,0 thousand m^{2}day/ha was recorded in 2012 in the variant with moldboard tillage and treatment with herbicide Pivot. The lowest values of PSP was observed in 2013 in the variant with zero tillage without the use of herbicides – 2499,4 thousand m^{2}day/ha.

Table 3: Photosynthetic potential of soybean crops

Factor		Photosynthetic potential (th.m^{2}day/ha)				Σ
A	B	sprouts – third ternate leaf	third ternate leaf – budding - blossom	budding - blossom– beginning of seed ripening	beginning of seed ripening – full ripening of seeds	
2011						
Moldboard tillage (plowing)	Conrol	496,6	540,0	961,4	1575,6	3573,6
	Pivot	465,4	538,0	1000,5	1612,0	3615,9
	Harmony Classic	470,6	572,0	975,2	1669,2	3687,0
Without	Conrol	416,0	412,0	795,8	1398,8	3022,6

tillage (zero tillage)	Pivot	408,2	422,0	816,5	1424,8	3071,5
	Harmony Classic	390,0	452,0	802,7	1435,2	3079,9
Flat carved tillage	Conrol	473,,2	462,0	862,5	1430,0	2754,5
	Pivot	465,4	480,0	908,5	1388,4	3242,3
	Harmony Classic	447,2	480,0	940,7	1476,8	3344,7
2012						
Moldboard tillage (plowing)	Conrol	558,0	578,0	1168,2	1642,2	3946,4
	Pivot	555,0	592,0	1201,2	1717,8	4066,0
	Harmony Classic	534,0	570,0	1190,2	1755,6	4049,8
Without tillage (zero tillage)	Conrol	468,0	450,0	926,2	1306,2	3150,4
	Pivot	441,0	474,0	979,0	1419,6	3313,6
	Harmony Classic	447,0	458,0	957,0	1360,8	3222,8
Flat carved tillage	Conrol	510,0	532,0	1018,6	1541,4	3602,0
	Pivot	540,0	526,0	1038,4	1495,2	3599,6
	Harmony Classic	516,0	542,0	1009,8	1583,4	3651,2
2013						
Moldboard tillage (plowing)	Conrol	333,5	558,8	712,5	1513,8	3118,6
	Pivot	305,9	611,6	763,8	1484,8	3166,1
	Harmony Classic	299,0	602,8	777,1	1513,8	3192,7
Without tillage (zero tillage)	Conrol	278,3	448,8	583,3	1189,0	2499,4
	Pivot	262,2	477,4	642,2	1252,8	2634,6
	Harmony Classic	289,8	501,6	619,4	1258,6	2669,4
Flat carved tillage	Conrol	299,0	534,6	649,8	1368,8	2852,2
	Pivot	345,0	587,4	642,2	1502,2	3076,8
	Harmony Classic	305,9	589,6	680,2	1426,8	3002,5

On average for the study years, vegetation conditions defined by moldboard tillage enabled soybean plants to consistently generate the highest PSP – 3118,6-4066,0 thousand m^2day/ha, which comparing with the variants with flat carved tillage and zero tillage was higher by 11,4-13,2% and 22,7-24,8%, respectively.

The results of correlation and regression analysis show the dependence of the yield from PSP of soybean: for 2011, the regression equation has the form y = 0,032x – 26,29 (R = 0,819, D = 90,5%); 2012 – y = 0,025x – 14,77 (R = 0,849, D = 92,1%); 2013 – y = 0,030x – 20,79 (R = 0,852, D = 92,3%).

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Parameter NPP, which characterizes the intensity of the formation and accumulation of organic matter of yield, during the years of the studies varied substantially in the range from 1,37 g/m^{2}day to 6,31 g/m^{2}day (table 4). The most intensive accumulation of dry matter by soybean of all variants is characterized for the period from flowering to full ripening of the fruit. Moldboard tillage contributes to the greatest intensity of accumulation of dry matter, on average for years of research, NPP in the variants was 1,88-2,57 g/m^{2}day.

Table 4: Net productivity of photosynthesis, g/m2 day

Factor		NPP (g/m^{2}day)				on average
A	B	sprouts – third ternate leaf	third ternate leaf – budding - blossom	budding - blossom – ripening of the seeds	beginning of seed ripening – full ripening of seeds	
2011						
Moldboard tillage (plowing)	Conrol	2,18	3,98	4,48	5,13	2,26
	Pivot	2,32	4,05	4,48	5,27	2,35
	Harmony Classic	1,98	3,83	4,62	5,13	2,32
Without tillage (zero tillage)	Conrol	1,88	3,89	4,10	4,09	1,89
	Pivot	1,72	3,90	4,26	4,18	1,94
	Harmony Classic	1,86	3,86	4,35	4,23	1,97
Flat carved tillage	Conrol	1,96	4,12	4,47	4,79	2,49
	Pivot	1,94	3,94	4,42	5,04	2,16
	Harmony Classic	2,02	3,99	4,20	4,86	2,15
2012						
Moldboard tillage (plowing)	Conrol	1,55	3,39	3,19	4,61	1,92
	Pivot	1,55	3,17	3,24	4,45	1,88
	Harmony Classic	1,37	3,56	3,34	4,39	1,90
Without tillage (zero tillage)	Conrol	1,43	3,55	3,39	4,66	1,93
	Pivot	1,47	3,45	3,19	4,43	1,90
	Harmony Classic	1,40	3,65	3,24	4,59	1,94
Flat carved tillage	Conrol	1,72	3,31	3,26	4,59	1,97
	Pivot	1,44	3,46	3,34	4,79	1,99
	Harmony Classic	1,51	3,29	3,27	4,44	1,93
2013						
Moldboard tillage (plowing)	Conrol	2,97	3,36	5,91	5,09	2,47
	Pivot	3,19	3,07	5,73	5,49	2,57

	Harmony Classic	3,19	3,48	5,57	5,27	2,50
Without tillage (zero tillage)	Conrol	2,55	3,39	5,28	5,28	2,03
	Pivot	2,49	3,45	4,85	5,14	1,95
	Harmony Classic	2,18	3,47	4,87	5,10	1,92
Flat carved tillage	Conrol	2,98	3,28	6,31	5,21	2,50
	Pivot	2,44	3,22	6,00	4,82	2,35
	Harmony Classic	2,91	3,08	6,05	4,98	2,37

The main parameter in plant breeding, determining the feasibility of the application of specific agrotechnical method, is productivity. The value of the yield of grain legumes is closely associated with indicators of symbiotic activity and photosynthetic activity of crops. The positive effect of moldboard tillage on the performance of photosynthetic activity ultimately affected the yield formation of soybean seeds (table 5).

Table 5: Soybean yield depending on the method of tillage and application of herbicides, t/ha

Factor		2011	2012	2013	on average
A	B				
Moldboard tillage (plowing)	Conrol	2,40	2,69	2,33	2,47
	Pivot	2,61	3,07	2,67	2,78
	Harmony Classic	2,82	3,09	2,71	2,87
Without tillage (zero tillage)	Conrol	1,63	1,74	1,51	1,63
	Pivot	1,94	2,19	1,78	1,97
	Harmony Classic	2,07	2,30	1,67	2,01
Flat carved tillage	Conrol	1,94	2,25	2,08	2,09
	Pivot	2,16	2,40	2,24	2,27
	Harmony Classic	2,30	2,37	2,15	2,27
NSR $_{05}$ for private secondary		1,00	0,98	1,09	-

Analysis of yield of soybean seeds allows to note its dependence on weather conditions developing during the growing season, the maximum values were obtained in 2012 and ranged from 1,74 t/ha to 3,09 t/ha. Moldboard tillage for all years of study contributed to the growth of productivity of plants compared to other variants, on average for 2011-2013 in the variant with moldboard tillage the yield was 2,47-2,87 t/ha, which is by 0,38 to 0,60 t/ha more comparing to the flat carved tillage and by 0,81-0,86 t/ha with zero tillage.

Sustainable trends and significant differences, which could characterize the influence of these herbicides on yield, were not identified – Harmony Classic and Pivot acted differently directed. Both preparations in all variants of tillage provided a significant increase in yield compared to control variant – it was, on average for the years of the study, 0,31-0,4 t/ha, in the variant without primary tillage 0,34-0,38 t/ha, with flat carved tillage 0,18 t/ha.

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CONCLUSION

The study the effect of methods of primary tillage on the productivity of photosynthesis of soybean allowed to establish the positive effect of deep dump loosening on parameters and performance of production process, identify patterns of assimilation apparatus formation and accumulation of dry matter.

The relation between the leaf surface area, photosynthetic potential and yield was established using correlation and regression analysis; dry matter accumulation and leaf area under different conditions of variants of experience that allows to predict features of development of the soybean according to biometrical analysis and to take, if necessary, measures for its correction.

Features of the influence of herbicide Pivot and Harmony Classic on the development of the soybean are shown. Immediately after application there is the inhibitory effect, slowing down the formation of leaf surface area, however, with the development, the gap disappears, the lack of competition determines the conditions for the formation and implementation of photosynthetic potential.

Generally, the conducted research allowed to assume that moldboard plowing to a depth of 25-27 cm and the use of herbicides Pivot or Harmony Classic during the growing season, depending on prevailing types of weeds, will create conditions to ensure the maximum realization of potential yield while the cultivation of soybeans in the conditions of forest-steppe of Volga region.

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