Anatoliy Petrovich Solodovnikov et al /J. Pharm. Sci. & Res. Vol. 9(9), 2017, 1583-1585

ISSN:0975-1459
Journal of Pharmaceutical Sciences and Research
www.jpsr.pharmainfo.in

Spring Crops Yield Dynamics using Energy-Efficient Methods of Primary Tillage of Southern Black Soil in the Volga Region

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Abstract.

The article presents the results of six-year research on various methods of primary tillage of Southern black soil in the Saratov Oblast and their influence on the yield of lentils, spring wheat, oats and spring barley.

The research results have revealed that under the conditions of insufficient moistening at the initial stage of minimum and no-till implementation, the crops in question have shown the highest yield. During the years with favorable moisture conditions, the results of different tillage methods became more even.

Six years of research indicate that energy-efficient methods of primary tillage of Southern black soil in the Saratov Oblast have led to a decrease in yield of true grasses (Poaceae family) and beans (Fabaceae family).

Over the period of record, the highest average yield (lentils – 1.13 t/ha, spring wheat – 1.11 t/ha, oats – 1.65 t/ha, and spring barley – 1.36 t/ha) was attained at the ploughing depth of 23-25 cm, exceeding the minimum ploughing depth of 10-12 cm with a disk harrow by 15.0%, 15.3%, 11.5%, and 17.6%, and no-till by 33.6%, 18.9%, 19.4%, and 21,3% respectively.

The most demanding crops in terms of soil tillage are lentils, spring barley and spring wheat, with the coefficients of yield variation being 16.3%, 10.7% and 9.2% respectively. These crops require deep moldboard ploughing. Oats were the least affected by the change in ploughing depth, with the yield variation coefficient of 8.9%.

Statistical analysis of the results allowed us to establish that among the crops growing in Southern black soil in the Volga region, lentils and oats are the most resistant to change in weather conditions, with the variation coefficients of 33.7-49.4% and 37.0-49.6% respectively. Spring wheat and spring barley showed a less stable yield (variation coefficients of 48.3-50.0% and 70.3-91.0% respectively).

Key words: primary tillage, ploughing, no-till, minimum tillage, yield, lentils, spring wheat, oats, barley, weather conditions.

INTRODUCTION

In the modern context of development and implementation of different soil tillage methods, agricultural science aims at balancing the farming ecosystem to maintain high agricultural output. To achieve these fundamental provisions, minimum and no-till approaches are applied.

No-till approach suggests no application of tillage tools, so that the upper layer of soil may be fertilized with plant residues. As a result, entomofauna increases soil porosity, stabilizing the agricultural output [1]. After the application of energy-efficient methods of soil tillage, there was an increase in springs crops yield in the Middle Zavolzhye [2], and the Kuznetsk Basin [3]. According to other scientists, minimum and no-till led to a decrease in yield of grain and legume crops in the forest steppes of Priobye [4], Northern Zauralye [5], Belgorod Oblast [6] and Western Siberia [7] regions.

This is why the study of minimum and no-till impact on the yield of early spring crops on the right bank of the Volga River is relevant and requires further investigation.

MATERIALS AND METHODS

The research has been performed on Southern black soil (humus content – 3.26%) on the practice ground of the Saratov State Agrarian University named after N.I. Vavilov over the period of 2009–2014. During the experiment, three methods of primary soil tillage were applied in field crop rotation (1. Lentils; 2. Spring wheat; 3. Oats; 4. Barley): 1. Soil tillage using the plough PLN-5-35 at the depth 23-25 cm (control); 2. Minimum tillage using the disk harrow Catros-3001 at the depth of 10-12 cm; 3. No-till.

The experiment was performed in quadruplicate, with the cultivated area of 250 m^2 and record area of 125 m^2 on randomly located plots.

Long-term data indicates that the average precipitation over the vegetation period of early spring crops (May–July) is 132 mm. In 2009, it was 112.6 mm, in 2010 – 72.3 mm, in 2011 – 79.6 mm, in 2012 – 80.2 mm, in 2014 – 110.1 mm, being 19.4, 59.7, 52.4, 51.8, and 21.9 mm lower than the average long-term rate. In 2013, precipitation over the specified period was 222.2 mm, thus exceeding the average rate by 90.2 mm.

Yield amount was registered continuously per plot. Grain was milled, weighed and dried. After that, yield was calculated based on its percentage and standard moisture regain (14%).

Agricultural practices: after preceding crops had been harvested, Roundup herbicide was applied at 4 l/ha. Primary soil tillage was performed in two weeks after herbicide application, according to the design of experiment. Secondary tillage in the first and second variants included tandem disk harrowing and pre-sowing cultivation at seed level. Sowing was performed using Beregynia AP-421 seed drill.

MAIN CONCEPT

The basic concept of this article is that different cultures react differently to different methods of basic tillage. Primary tillage is one of the key elements of the technology of crops' cultivation and is the factors responsible for the moisture accumulation in the soil. Tillage minimizing (reduction the impact on the soil) brings it to its natural state. Crops' yield is the effectiveness factor of the processes in the soil while reducing the intensity of its treatment. Study of the dependence of productivity of various crops on the way of primary tillage allows us to determine the potential of adaptability. On that basis it is possible to choose different methods of primary tillage in terms of a particular year.

RESULTS

The conducted research has shown that implementation of minimum and especially no-till of Southern black soil increases topsoil density, though within the range of optimal values (1.1-1.3 g/cm^3), for close-growing crops. Moisture content in soil less than 0.5 m deep remained practically unaffected by topsoil density. Maximum moisture content was not measured for this horizon either in fluffy consistency (tillage) or with compacted undisturbed structure (no-till). The lower layers (0.5-1.0 m deep) of ploughed soil had shown an increase in moisture content, according to the earlier works [8, 9, 10, 11].

Final productivity of agricultural plants depends on a combination of many factors: biological properties of specific crops, sufficient moisture content in soil during the vegetation period, nutrient content and availability, current weather conditions over the years of research, agrophysical properties of soil, and the development of weed plants on practice grounds.

In the first year of implementation of conservation agriculture techniques, maximum productivity of lentils (1.60 t/ha) was observed on a plot tilled with a disk harrow at the depth of 10-12 cm. In the extremely dry 2010, yield of lentils declined. The harvest of 2011 indicated insignificant differences in three variants. The lowest yield of lentils was observed under minimum tillage – 1.08 t/ha, which was less than control by only 8.5%. In the dry 2012, maximum yield of lentils was observed under no-till – 0.51 t/ha, as compared to 0.43 t/ha on a control plot. In the wet 2013, maximum productivity was observed on a ploughed plot – 1.56 t/ha. The different levels of crops yield using minimum tillage were within the limits of experimental error. In 2014, the control variant exceeded minimum tillage by 44%, and no-till – by 63% (Table 1).

On average over the six years, minimum productivity was registered for no-till – 0.75 t/ha, which was less than control by 33.6%. Minimum tillage using Catros-3001 at the depth of 10-12 cm showed a 15% decrease in the yield of lentils.

Coefficient of lentils yield variation over the specified period was no more than 33.7% for control, 49.4% – for disk harrowing, and 48.7% – for no-till. Variation coefficient for variants involving soil tillage was 16.3%. This implies that grain legume crops require more intensive soil tillage.

According to the records of spring wheat yield, maximum differences between the variants (27-30%) were in the extremely dry 2010. In the moderately wet 2009 and wet 2013, variations from control were 15-19% and 19-21% respectively (Table 2).

Table 1. Lentils yield dynamics using different methods of soil tillage

Experimental variants	Crop yield, t/ha							Deviations from control	
	2009	2010	2011	2012	2013	2014	average	t/ha	%
Ploughing (control)	0,96	0,56	2,26	1,03	0,93	0,90	1,11	-	-
Minimum tillage	0,82	0,41	1,89	0,84	0,73	0,92	0,94	-0,17	15,3
No-till	0,78	0,39	1,79	1,10	0,75	0,60	0,90	-0,21	18,9
LSD_{05}	0,09	0,05	0,12	0,08	0,10	0,10	0,09		

Table 2. Spring wheat yield dynamics using different methods of soil tillage

Experimental variants	Crop yield, t/ha							Deviations from control	
	2009	2010	2011	2012	2013	2014	average	t/ha	%
Ploughing (control)	0,96	0,56	2,26	1,03	0,93	0,90	1,11	-	-
Minimum tillage	0,82	0,41	1,89	0,84	0,73	0,92	0,94	-0,17	15,3
No-till	0,78	0,39	1,79	1,10	0,75	0,60	0,90	-0,21	18,9
LSD_{05}	0,09	0,05	0,12	0,08	0,10	0,10	0,09		

Table 3. Oats yield dynamics using different methods of soil tillage

Experimental variants	Crop yield, t/ha							Deviations from control	
	2009	2010	2011	2012	2013	2014	average	t/ha	%
Ploughing (control)	1,22	1,02	2,86	1,44	1,95	1,40	1,65	-	-
Minimum tillage	1,09	0,83	2,79	1,14	1,88	1,02	1,46	-0,19	11,5
No-till	0,89	0,74	2,56	1,12	1,80	0,87	1,33	-0,32	19,4
LSD_{05}	0,07	0,04	0,05	0,09	0,08	0,10	0,07		

Table 4. Oats yield dynamics using different methods of soil tillage

Experimental variants	Crop yield, t/ha							Deviations from control	
	2009	2010	2011	2012	2013	2014	average	t/ha	%
Ploughing (control)	1,08	0,79	3,48	0,69	1,05	1,06	1,36	-	-
Minimum tillage	0,88	0,37	3,24	0,58	0,84	0,80	1,12	-0,24	17,6
No-till	0,76	0,35	3,22	0,61	0,76	0,69	1,07	-0,29	21,3
LSD_{05}	0,12	0,04	0,22	0,08	0,07	0,11	0,11		

Over the period of record, the highest average yield of spring wheat was attained with ploughing – 1.11 t/ha, exceeding the minimum tillage by 15.3% and no-till – by 18.9%.

Coefficient of spring wheat yield variation over the specified period was 50.0% for no-till, 48.4% – for ploughing, and 48.3% – for minimum tillage. Variation coefficient for all experimental variants amounted to 9.2%. This implies that spring wheat yield depends on weather conditions five times greater than on primary tillage methods.

The yield of oats was least affected by varying weather conditions over the years. According to long-term observations, minimum oats yield was registered under no-till – 1.33 t/ha, which was less by 0.32 t/ha or 19.4% than under ploughing. Minimum tillage at the depth of 10-12 cm reduced oats productivity by 0.19 t/ha or 11.5% (Table 3).

Coefficient of oats yield variation over the specified period fluctuated from 37.0% for ploughing to 49.6% for no-till. Variation coefficient for all experimental variants amounted to 8.9%. Weather conditions influenced oats productivity 4-5 times more than the change of primary tillage methods.

Minimum yield of oats for the control variant (0.69 t/ha) was registered in 2012. The same value for energy-efficient methods was 0.37 and 0.35 t/ha in 2010. Maximum oats yield was registered in 2011, fluctuating from 3.22 t/ha under no-till to 3.48 t/ha under ploughing. Variations between different methods of primary soil tillage were within the limits of experimental error. In terms of average long-term oats yield, the results for minimum tillage were less than that of control by 17.6%, and that of no-till by 21.3% (Table 4).

Coefficient of spring wheat yield variation over the specified period was 70.3%, 86.1%, and 91.0% respectively for experimental variants. Variation coefficient for the methods of primary tillage amounted to 10.7%

DISCUSSION

According to the analysis of crops yield over the period of implementation of energy-efficient tillage methods, the greatest response to minimum tillage was observed on oats (reduction in yield being only 11.5%), while the greatest response to no-till was observed on spring wheat (18.9%). Maximum reduction in yield under no-till was observed on barley (21.3%) and lentils (33.6%).

Calculated variation coefficients indicate that among the crops growing on black soil in the Volga region, the most resistant to change in weather conditions are lentils (variation coefficient – 33.7-49.4%) and oats (37.0-49.6%). A less stable yield was registered on spring wheat (variation coefficient – 48.3-50.0%) and barley (70.3-91.0%).

CONCLUSIONS

During the first years of implementation of energy-efficient tillage methods, all crops showed a decrease in productivity. Minimum soil tillage with a disk harrow at the depth of 10–12 cm reduced spring crops yield by 11-18%, while no-till reduced it by 19-34%. During the years with favorable moisture conditions, the results for different tillage methods were more or less even. During the dry years, ploughing resulted in a slightly higher crops yield. The most responsive to the intensity and depth of primary soil tillage were lentils, spring barley and spring wheat, with yield variation coefficients of 16.3%, 10.7% and 9.2% respectively. The least responsive were oats, with the variation coefficient of 8.9%.

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