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Agrotechnological Fundamentals of Direct Sowing of Grain Crops in Russia's ARID Conditions

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Abstract
The authors presented the multiyear results of the research on testing the technological complexes of growing the grain crops with direct sowing in the black earth steppe of Russia's European part. In the zonal crop rotations, in comparison with a traditional technology, it did not lead to worsening of the agrophysical, agrochemical, water and biological soil features, increased the humus content by 0.55% (NSR_{05}- 0.42 %). In spring, during the crops sprouting, the P_2O_5 and K_2O quantity corresponded to 192 and 189 mg/kg of soil, which is 29 mg (17.8%) and 35 mg (22,7%) more than control. The established least production costs – 2975.1 rub/hectare on an option with direct sowing of the spring grain crops, which are 499.9 rub/hectare -16.8 % lower than the traditional technology figures, favored the acquisition of the highest contingent net income of 1220.1 rub./hectare and the profitability level of 41.0%. During the direct sowing of the spring hard wheat, the highest contingent net income is gained on options with the use of integrated plant protection and the fertilizer application – 9507.9-9753.9 rub/hectare, which is 3667.6-3913.6 rub/hectare (62.8-67.0 %) more than the control, and 825.8-3626.9 rub/hectare (9.5-59.2 %) higher than figures on other options. On the basis of the research conducted, the authors offer a new generation of technologies of growing the winter and spring wheat and the spring barley, which are built on the system basis.

Key-words: Direct Sowing, Productivity, Efficiency.

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1. Introduction

In the existing natural and economic conditions, one of the major aspects of plant growing in Russia is development and application of the direct sowing technologies and the No-till production systems. A focus on deeper market relations places on Russia's agriculture a number of strict demands that are hard to comply with within the old technologies (Korchagin et all, 2007).

The situation is getting worse because in Russia's countryside, for reasons beyond control and for internal reasons, the quantity of working machine operators and specialists decreases catastrophically. So, the main interest of agricultural producers in the direct sowing technologies and the No-till production system is generated by savings of material, energy and labor expenses (Korchagin et all, 2007; Alarcon, Sanchez, 2013).

The second reason for transition to the modern resource-saving technologies, which is not less important, is strengthening of negative influence of irrational antropogenous activities upon the soil and acceleration of the soil covering degradation processes that are caused, in the first place, by limited application of organic fertilizers and intensive plowing. Against this background, the erosion processes are getting more intense, the degradation grows, the dehumification with manifestation of steadily nonrecompensible humus mineralization and high atmospheric emission of CO_2 take place (Shevtsova et al, 2003; Korchagin et all, 2007; Rouw et al, 2010; Salvo et al, 2010; Alvaro-Fuentes, Cantero-Martinez, 2010; Blanco-Canqui, 2011; Laudicina et all, 2012; Soane et all, 2012; Martín-Lammerding et all, 2013; Goryanin et all, 2019).

The Samara Research Institute of Agriculture has accumulated 60-year experimental material on improving the soil-protective agriculture systems for the arid steppe of the Middle Volga region. Research of the agriculture department of the Samara Research Institute of Agriculture is coordinated with the theoretical basis of eminent scientists of Russia and non-CIS countries. It is established that one can keep the field crop cultivation efficiently in large steppe districts of the region with the wide use of the minimum soil cultivation instead of traditional plowing, keeping of the stubble and other vegetable refuses on the field surface, giving the crucial role in the plant nutrition to the top soil (Korchagin et all, 2007; Rátonyi et all, 2007).

The scientific foundation of modern technologies based on the minimum soil cultivation and sowing is an established regularity – the black-earth soils of steppe districts of the Trans-Volga area and other Russia's regions, having close values of optimum and steady-state soil density, do not need permanent plowing and other deep intensive cultivations to regulate the agrophysical, agrochemical and biological soil features (Goryanin et all, 2019).

One of the major reasons for negative results of applying the direct sowing technologies and No-till in Russia is related to the fact that agricultural producers connected the growing under such technologies only with the use of one or another way of the main soil cultivation and without account taken of a specificity of its influence upon the phitosanitary situation, food regime and with a total absence of the direct sowing machines.

Thus, only a systemic approach and strict correspondence of the offered technologies to the natural-climatic and economic conditions can guarantee a success of their development. Disregarding of this only correct approach leads to the discrediting of these technologies (Korchagin et all, 2007).

The research is aimed at the scientific substantiation of agro-technological fundamentals of the direct sowing in the climate change conditions ensuring the stabilization of productivity of zonal crop rotations, reduction of the black earth degradation, decrease in energy and resource expenses of the agriculture in an arid part of the European Russia.

2. Materials and Methods

The research was conducted in the multiyear study areas, on the basis of the agriculture department in 1999-2017. The experimental field soil is ordinary, medium and middle loamy black earth.

Various systems of soil cultivation and the soil technologies during growing the grain crops with the use of the domestic and foreign complexes of the tillage tools and sowing units (1999-2002) were studied in the four-course grain-fallow crop rotation: clean fallow – winter soft wheat – spring soft wheat – spring soft wheat.

The experiment scheme included the following options: during growing the winter wheat 1. Ploughing PLN-5-35 (25-27 cm) + sowing SZ-3.6 (control); 2. Flat cultivation KPSh-5 (10-12 cm) + sowing STS-6; 3. Minimum soil cultivation Smaragd (10-12 cm) + sowing DMC Primera 601; 4. Mulch cultivation OPO-4.25 (10-12 cm) + sowing AUP-18.05; 5. Mulch cultivation OPO-4.25 (10-12 cm) + late autumn loosening PCh-4.5 (25-27 cm) + sowing AUP-18.05; 6. Without autumn cultivation + sowing AUP-18.05; 7. Without autumn cultivation + sowing DMC Primera 601. When growing the spring wheat and, on the whole, the crop rotation productivity was studied on 1, 4 and 6 options of the experience.

In 2000-2010 in the seven-course crop rotation, with alternation of clean fallow –winter wheat – millet – spring wheat – corn (since 2006 it has been green fallow) – spring wheat – spring barley in comparison with the tradition technology, the technological complex with direct sowing of grain crops was studied.

The check option of the experiment used the generally accepted machinery system (PLN -5-35, BZSS -1.0, KPS - 4, C3-3.6, 3KKSh-6). The new-generation technological complexes used the combined sowing units made by Selmash, LLC (AUP – 18.05).

In the six-course grain-ploughing crop rotation, various intensification levels with the direct sowing of the spring hard wheat were studied. The soya is a predecessor of the crop. The research was conducted in 2011-2017 on seven technologies (options):

1. Traditional technology: ploughing at 22-24 cm + seed treatment + crop vegetation herbicides – Secator turbo (control);
2. Control + application of the ammonium nitrate before sowing (N_{30}) + insecticides (Detsis Profi – two times).
3. Resource-saving technology: direct sowing – AUP-18.05 + seed treatment + grain crops vegetation herbicides – Secator turbo (Bacground);
4. Background + biologics to the spring wheat tillering (Bioneks Kemi, Fitosporin);
5. Background + application of the ammonium nitrate before sowing (N_{30});
6. Background + application of the ammonium nitrate before sowing (N_{30}) + insecticides (Detsis Profi – two times).
7. Background + application of the ammonium nitrate before sowing (N_{45}) + insecticides (Detsis Profi – two times).

The experiment is repeated three times, the plot size is 1100m^2.

The research zone climate is acutely continental. Over 18 years of the research, the years of 2000, 2001, 2004, 2006, 2014, 2016 were favorable for growth and development of the winter crops (the hydrothermal index for May-August =0.45-0.81), the years of 2003 and 2007, 2017 were favorable for development of all crops (the hydrothermal index for May-August=0.94-1.42), in 2002, 2005 the spring draught occurred. In 2008, 2009, 2015 the spring-summer draught occurred. The year of 2010 witnessed the severest spring-autumn draught over the last 100 years, with the hydrothermal index=0.13. In the other years the hydrothermal index for the grain crops vegetation was at the level of (0.65-0.74).

The experiments performed the following calculations and observations: the structural-aggregate constitution of soil – by the dry screening according to the method of N.I.

Savinov (A. F. Vadiunina, 1986); soil density – by the cylinders method according to S.I. Dolgov, GOST 27593-88; soil humidity – by the thermostatic-weight method, GOST 282687-89; content of nitrates in the soil – by the ionometric method in modification of Central Institute of Agrochemical Service of Agriculture, GOST 26951-86; labile compounds of phosphorus and potassium – by the method of Chirikov, GOST 26204-91; humus in % – by the method of Tyurin, GOST 26213-91; determination of hydrolytic acidity in soil – by the method of Kappen in modification of Central Institute of Agrochemical Service of Agriculture, GOST 26212-91; salt pH – by the method of Central Institute of Agrochemical Service of Agriculture, GOST 26483-85.

3. Results

Climatic conditions exert a significant influence upon conditions of the plants growth and development (Santoyo et al, 2017). Apart from that, the moisture is the main limiting factor in the greater part of the European Russia.

When studying the soil cultivation systems and the sowing technologies, with practically the same deposits of productive moisture and crop capacity, there are no significant differences in the moisture consumption per unit of products on the black fallow options. When growing the winter wheat with the early fallow (without the autumn soil cultivation + sowing AUP-18.05), the increase in a water-use ratio in comparison with other options by 3.8-6.7 % is established.

The use of machines made by Selmash LLC (OPO-4,25 + AUP-18.05) ensured a more rational moisture consumption per unit of products of the spring wheat – 1232.4 m^3/t, which is 4.4-6.3 % fewer than the control and direct sowing with the use of AUP-18.05.

Against the background, with the use of fertilizers, with different systems of the soil cultivation and the winter wheat sowing technologies, there were no significant differences in supplying of its crops with nitrates. The content of labile phosphates and exchange potassium in the soil on the studied options was very high and, depending on the options tested, changed insignificantly too. The same tendency on the content of available nutrients in the soil with various soil cultivation systems and the sowing technologies against the background with the use of fertilizers, is established during growing the spring wheat.

In the winter wheat crops, due to the good infestation-cleaning function of the fallows and the haulm density of crop plants, on all the experiment options studied, the crops infestation with weeds was weak, and did not influence the crop capacity.

The resource-saving technologies of growing the winter wheat with the use of domestic tools and units, including the refusal from the basic cultivation of the fallow fields, did not lead, in comparison with the control, to the decrease in its crop capacity.

On the average, over the years of the research, the highest winter wheat crop capacity is established on technologies with the use of the sowing unit AUP-18.05 – 4.41-4.69 t/hectare.

When applying the researched soil cultivation systems and the sowing technologies of the spring wheat, no differences in its crop capacity were detected, which favored the leveling of productivity of the grain-fallow crop rotation on the experience options (Table. 1).

With the same cost of the products with a traditional system, the contingent net income, in growing the grain crops according to the resource-saving systems of the soil cultivation and the sowing technologies, increased by 421.4-441.8 rub/hectare (42.0-44.1 %), the profitability level increased by 25.5-29.8%.

The research, which was conducted in Samara Research Institute of Agriculture in 2000-2010, showed that the direct sowing, in combination with a complex of its mandatory elements, does not lead to the worsening of agrophysical features, the water and food regimes of the soil. The crops infestation was not increased and the biological soil activity was not weakened.

During the sowing of the spring grain crops, density of the ploughing layer soil depended on biological features of the plants in a greater degree, and on ways of the basic soil cultivation and the growing technologies in a smaller degree, and it stayed within the optimal values, including the steady-state density.

Under the winter wheat crops, through the smaller humidity and condensing action of the root system, which is well-developed in spring, upon the soil, the soil was denser (1.07-1.12 g/cm3), than on other fields (1.03-1.08 g/cm3).

The use of the direct sowing of the spring grain crops ensured an exact increase in the spring deposits of moisture in the meter-deep layer of the soil, in comparison with the traditional technology. Here the water regime was improved through great deposits of the residual moisture in the autumn period and improvement of taking of the non-vegetation period precipitation. On the average, in terms of the crop rotation, the deposits of productive moisture on a technology with direct sowing of the grain crops were 105.3 mm, which is 22.2 mm or 26.9 % more than with the traditional technology. Apart from that, the soil water regime improvement was detected in a plowing layer as well as in a subsurface layer.

The use of the direct grain crops sowing technologies ensured, in comparison with the traditional technology, improvement of the phosphatic and potassium regimes of the soil. On average of the crop rotation, here the content of P_2O_5 and K_2O made up 192 and 189 mg/kg of the soil, respectively, which is exactly 29 mg (17.8%) 35 mg (22.7%) more than the control (when NSR_{05} is 20 and 21 mg).

A tendency of significant improvement of the phosphorus and potassium regimes of the plants nutrition during the direct sowing, in comparison with the traditional technology, is established during the whole vegetation period.

The continuous application of the grain crops direct sowing, with the use of the shredded straw and stubbly root remains as fertilizers, ensured, especially in the years with insignificant quantity of precipitation, a lower humus mineralization, in comparison with the control. On the average, over the years of the research, the humus content was 3.86%, which is exactly 0.55% higher than the control (NSR_{05}- 0.42).

The research, which the authors conducted, did not establish any significant changes in the soil acidity depending on ways of the basic soil cultivation and technological systems of soil cultivation and the sowing. On the average, in 2001-2011 pH sal. in the 0-30 cm soil layer made up 5.64-5.94, which corresponds to the subacid soils.

Rational combination in the crop rotation of the agrotechnical and chemical agents ensured the efficient crops protection against the weeds in the tested technological complexes. Total grain crops infestation, on the average of the crop rotation, made up 18,5 units/ m^2 in the ear formation with the traditional technology, on an option with the direct sowing – 22.0 units/ m^2.

The direct sowing technology, due to optimization of the agrophysical and agrochemical features of the soil, ensured the crop rotation of the winter wheat and the spring grain crops, which is equal to the control. On the average of the crop rotation, the grain crop rotation made up 1.67 – 1.69 t/hectare (Table 2).

With calculations of the economic efficiency, the smallest production expenses – 2975.1 rub/hectare, on the option with the direct sowing of the spring grain crops, which is 499.9 rub/hectare (16.8 %) fewer than the figures on the traditional technology, favored the generation of the highest contingent net income of 1220.1 rub./hectare and the profitability level of 41.0%. The profitability level, which is received, on the average, over the years of the research, on the new-generation technological system, allows performing the expanded grain production.

Until recently, due to smaller demands on the soil-climatic conditions, the spring soft wheat was more widespread in Russia, that hard wheat was (Allahverdiyev, Huseynova, 2017). At present, for reasons beyond control, the situation exchanged. Therefore, he research for detecting the adaptive intensification means, with high sowing of the spring hard wheat were conducted.

On the average for 2011-2017, in the period of the crop sprouting, detected high deposits of the productive moisture – 164.4 mm (control), 162.7-167.1 mm (direct sowing), which did not depend on the applied ways of the basic soil cultivation and the sowing and the intensification means.

The use of fertilizers and insecticides against the background with direct sowing (4, 6 options) ensured a more rational moisture consumption for the harvest receipt – 1264-1271 m^3/t, which is 173-198 m^3/t (13.6-15.7 %) less than the values of an option with application of the biologics and the ammonium nitrate into the tillering stage.

In the wheat sprouting period, the nitrates content against the natural background according to the fertility (1-3 options) did not depend on the studied technologies and made up 28.2-30.2 mg/kg. The pre-sowing application of the ammonium nitrate ensured the nitrates content increase in the direct sowing by 17.1-18.4 mg/kg (58.0-65.2 %).

The conducted research established that the spring hard wheat crop capacity essentially depends on the hydrothermal index in the vegetation period. in the years with a figure of more than 0.8, a considerable increase in the crop capacity is detected, in comparison with arid years, with 0.95-1.31 t/hectare to 1.85-2.62 t/hectare (41.2-275.8 %). The greatest harvest increase from the intensification means is received on the option with direct sowing as a result of joint action of fertilizers and insecticides. In the arid years, it made up 0.33-0.36 t/hectare (34.7-37.9 %), in the moist years – 0.68-0.70 t/hectare (36.8-37. 8%). (Table 3).

The highest protein content was observed in the arid years, with small fluctuations depending on the options researched, – 15.4-16.3 %, which is 1.1-3.5 % higher than the figures in moist years.

Application of the nitrogen fertilizers with the traditional technology, when raising the level of the crop capacity, did not decrease the protein content in all the years of the research. During the direct sowing, improvement of the plant mineral nutrition, when ensuring the productivity increase, favored the protein content increase in moist years by 0.9-1.8 %. on the average, for the years of the research by 0.5-1.0 %.

The use of direct sowing, when ensuring the same wheat grain crop capacity, in comparison with the traditional technology, did not decrease the quantity and did not lower the quality of fibrin.

The fibrin quantity, with the traditional technology, made up 32.6-33.9 %, with the direct sowing – 30.6-33. %. With the direct sowing, a higher fibrin quality – 99.8-101.4 is detected, which is 1.0-2.7 % more than the traditional technology.

While calculating the economic efficiency at the extensive background of direct sowing (2 option) through cutting the production expenses by 15 %, the contingent net income, in comparison with the control, increased by 286.7 rub/hectare (4.9%). The direct sowing ensured the a high recoupment of the intensification means. The maximum contingent net income is gained on options with the use of insecticides (6, 7 options) – 9507.9-9753.9 rub/hectare, which is 3667.6-3913.6 rub/hectare (62.8-67.0 %) more than the control and 825.8-3626.9 rub/hectare (9.5-59.2 %) than figures on other options (Table 4).

4. Discussion and Conclusions

The use of direct seeding has great prospects, both in the World and in Russia. This is due to the need to increase the production of food and biofuels, to preserve soil fertility.

In world agricultural production, the main element of direct seeding is seeding with an anchor or disc Coulter. At the same time, the technologies are characterized by:

- The absence of any mechanical treatment of the soil when cultivating crops;
- Permanent presence of organic residues on the soil surface;
- Expediency of application of fruit-bearing crop rotations.

The advantages of direct seeding include:

- Preservation of soil moisture and soil fertility;
- Improving the structure of the soil and increasing the content of nutrients in it;
- Reduction of soil compaction, water and wind erosion;
- Improving the environment by reducing CO2 emissions into the atmosphere;
- Saving material and labor costs, cost reduction (Korchagin et all, 2007, Alvarez R., Steinbach H.S. 2009, Alvaro-Fuentes J., Cantero-Martinez, 2010, C. Lordan J., et al. 2013).

The results obtained in our research indicate that the use of growing technologies from the direct sowing of field crops in the existing situation is top-priority in Russia. Apart from that, in the arid conditions, the sowing has its peculiarities. When there are too little straw and stubble remains, the mulch direct sowing has the advantage. An obligatory condition of successful growing of the field crops is observation of all the technology elements and their adaptivity to the soil-climatic conditions.

The tested technological complex with mulch direct sowing in the zonal crop rotation did not lead to the worsening of agrochemical, water and biological features of the soil. The crop infestation did not grow against the background of the herbicides use, the primary soil fertility elements did not become worse.

The technology with direct sowing showed a high economic and energetic effect with the use of a combine sowing unit made by Syzranselmash LLC - AUP-18.05 for direct sowing.

On the basis of the research conducted, the resource-saving technologies of growing the winter and spring wheat, barley are offered, and they include.

- Placement in the zonal crop rotations (4–6 fields);
- Sowing of the fields, which were not cultivated since autumn, with the use of contact herbicides or the tank mixtures of the new-generation herbicides with a multi-year type of infestation in the autumn period;
- The spring-summer maintenance of fallows (during growing the winter wheat) with the use of the new generation tillage combines (OPO-4.25 and OPO-8.5 and others);
- Non-drill sowing with the use of the combined sowing machines AUP-18.05, AUP-18.07 with simultaneous application of starting fertilizer rates in drill rows during the sowing, the use of side-dressing;
- Integrated protection of the plants;
- Sowing of the varieties that are adaptive to the local weather conditions which and able to recompense the intensification means well;
- Direct combining with straw shredding for fertilizers.

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