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The productivity of direct sowing of heavy loamy podzolized soil on the Right-bank Steppe of Ukraine

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The purpose. To inform commodity producers of all patterns of ownership about efficiency of long term straight sowing at cultivation of the basic crops in conditions of risky farming agriculture. **Methods.** Field, laboratory, statistical. **Results.** It is fixed that in the humidified years and on the average for years of researches water-physical properties of soil and its security with nutrients varies as compares to plowing within the limits of HCP0.05. But in drought years at straight sowing the density of soil is always increased critical value (1,30 g/cm3) and may gain 1.43 g/cm3 with simultaneous increase of hardness of soil on 23.9% in comparison with plowing. High density and hardness in rainless conditions negatively influenced propagation of root system, receipt to it of water and nutrients, stipulating lower productivity of crops, especially tilling ones. In the humidified years the mentioned before is not observed. Weed infestation of crops in the first year of application of straight sowing remains at the level of plowing, and in the next years it sweepingly increases, and already on the 3-rd crop exceeds control index in 1.5 – 2 times. Change of species composition of weeds is simultaneously observed. If pink sowthistle (Cirsium arvense) and amaranth (Amaranthus) predominate at plowing, then yellow sowthistle and white goosefoot (Chenopodium album) — at straight sowing. On the average for years of researches productivity of crop rotation at straight sowing was lower as compared to plowing on 4.4%. However, general expenditures reduced on 52.6%, fuel — on 8.2 kg/hectare (42.7%), quotient of power efficiency increased on 76.4% and has made 6 against 3.4 at plowing. **Conclusions.** The basic deterrent of application of straight sowing on typical midhumus heavy clayloam chernozem with removal of plant residues at harvesting in comparison with plowing is substantial increase of density and hardness in rainless conditions.

Key words: *crop rotation, soil cultivation, water-physical properties, fertility, weediness of sowing, productivity, economic and power efficiency.*

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Soil cultivation is the base of productivity of crops. Seasonable and qualitative soil cultivation facilitates the formation of favorable physical properties of the soil, which causes accumulation, rational use and preservation of soil moisture - the main factor limiting the productivity of agricultural crops under conditions of risky agriculture. However, soil cultivation is also the most energy-intensive agricultural process which accounts for about 40% of the total consumption of crops cultivation. Ones can understand the desire of national and foreign scientists to improve the existing and develop new effective systems of cultivation, taking into account the soil-climatic conditions that would not reduce the productivity of crops and soil fertility with a decrease of energy use.

Analysis of recent research and publications. In recent decades, so-called zero cultivation (No-till), developed in the United States in the early 1950's, has been increasingly used in foreign countries since the publication of the book "The ploughman's madness" by farmer E. Folkner [1]. Especially fast this cultivation was embedded in the production after the opening of the Imperial Chemical Industries (ICI) in 1959 herbicides of biniridil (narakvat and dikvat), effective against the weeds, which enabled the radical change in

the technology of soil cultivation. It is estimated that [2] that No-till technology is used in the world on the area of 116.9 million hectares. Of 18 countries that implemented this soil cultivation in production, Ukraine has the last position - 100,000 hectares while in the USA – 26,5 million hectares, Argentina – 25,5, Brazil – 25,8 million hectares. The main advantages of direct sowing in comparison with traditional tillage ploughing are significant reduction of energy consumption, high soil protection effect (up to 50%), reduction of environmental pollution and shortening the time to prepare the soil for sowing [2, 3, 4, 5].

Researches in the field of direct sowing in Ukraine, both in crop rotations and under separate cultures, are conducted on different soils not enough. It is important to note the works of Tanchik S.P. [6], Kosolap M.P., Krotinov O.P. [7], where the authors raise the issue of using No-till agriculture in the conditions of Ukraine, which will occupy 20-30% of the arable land and will become an alternative to intensive (industrial) systems.

According to the researches of Hrabak N.H. [8], a significant decrease in the background of direct sowing comes in the third year for maize, in the fourth year for winter wheat, in the fifth year for barley and sunflower.

According to the dates of Pabat I.A. and other [9], the corn crop reduced in comparison with the ploughing in wet years to 1.48, in arid – to 2.19 t/ha, or more than twice by using the sowing machine «Kinza» due to the complication of weed control.

It was estimated by Tsykov V.S. and Matiukha L.P. [10], that direct sowing improves the structure of the soil and its humus state, reduces erosion processes, and also reduces 70-80% of energy consumption compared to ploughing.

The efficiency of direct sowing depends on both the humidification zone and the mechanical composition of the soil where the research was conducted.

According to the researches of Tanchik S.P. and Mykolenko Y.O. [11]conducted on the middle loamy podzolized chernozem with an average long-term rainfall of 555 mm, on the formation of a moisture crop by direct sowing was spent 31.7 mm less, but the yield of corn increased to 0.5 t/ha compared to ploughing.

It was estimated by Tsykov V.S. and other [12], that by direct sowing on heavy loamy podzolized soil in the area of risky agriculture (by rainfall <500 mm), maize was 16 cm lower than the growth in comparison with ploughing; the length of corncobs, its kernel and the weight of corn were 12,8; 5-8 i 4-7 % less accordingly.

We should accept the conclusion of Medvediev V. V. and Lyndina T. E. [13], that there is not enough experimental data to justify the introduction of direct sowing in Ukraine.

Taking into account that commodity producers are very interested in this problem in seminars of all levels held at the Kirovograd research station (now Agrarian Institute of the Steppe by the National Academy of Agrarian Sciences of Ukraine), we have decided to publish the results of our research on this issue. Although the efficiency of the direct sowing in separate cultures has been already covered in our publications before, the impact of this research in the crop rotation with the distinguishing of arid years is given for printing for the first time.

The purpose of research. To inform producers of all forms of ownership about the efficiency of perennial direct sowing of heavy loamy podzolized soil by the growing of the essential crops in the conditions of risky agriculture.

Studies and methods of research. In our research we used field, laboratory, dispersion and correlation methods. The research was conducted in a stationary experiment, which was laid in 1973 in the Kirovograd Agricultural Experimental Station (reorganized into Agrarian Institute of the Steppe by the National Academy of Agrarian Sciences of Ukraine in 2018). Typical for the subzone of the Right-Bank Steppe in Ukraine rotation crop included the alternation of such crops: 1) black fallow; 2) winter wheat; 3) sugar beets; 4) barley; 5) grain corn; 6) peas; 7) winter wheat; 8) silage corn; 9) winter wheat; 10) sunflower. Since direct sowing was implemented in 1979, its influence is given for the cultures that have passed the No-till technology for 3 years (peas) and 4 years: winter wheat - silage corn - wheat winter - sunflower. In the experiment, we studied

a whole range of activities, but the purpose of our work is to highlight the efficiency of direct sowing compared to ploughing. The research program provided for the removal of plant remains during harvesting.

The experimental field is characterized by the following indicators: the granulometric composition of heavy loamy podzolized soil has the following fractions: sand (0,25-0,05 mm) – 1,5%; dust (0,05-0,01 mm) – 41,5%; physical clay (0,01-0,001) – 55%. Humus content in the layer is 0-40 cm – 5,2%, hydrolyzed nitrogen – 7-8 mg/kg, movable phosphorus– 7-20 mg, exchangeable potassium – 10-20 mg/100 g; the amount of wagon bases – 32,5-42,0 mg/100 g;pH – 6,5-7,2. The plow PN-4-35 was used for ploughing, and for direct sowing we used a special sowing machine of the Czechoslovakian production 20-Sexbi 150.

When laying experiments and carrying out experimental work, the general methodological requirements have been followed. According to Hydrothermal Coefficients (HTC), the vegetation period of such years as 1980, 1984, 1985 was sufficiently wet. HTC comprised 1,62; 1.08; 1.34 accordingly, 1982 was moderately dry (HTC 0,96); 1981; 1983; 1986 were very dry with HTC 0,84; 0,76; 0,40 accordingly.

Results of research. Favorable physical properties of the soil, on which the direction and parameters of water-air, nutrient, microbiological and other modes depend, are created by qualitative and timely soil cultivation (Table 1). The data in Table 1 indicate that most physical indicators, in addition to the content of water-proof units for direct sowing, are worse than ploughing. However, our observations show that these disadvantages do not affect the productivity of crops in favorable humidity years. Average soil solidity in the layer 0-30 cm comprises: 1,20 g/cm^3 by ploughing, 1,27 g/cm^3 direct sowing, that is within the optimal range for the growth and development of crops. However, in dry years by direct sowing, the soil density can rise above 1,4 g/cm^3 with a simultaneous increase in solidity to 20-27%.

1. Physical properties of the soil depending on the systems of its cultivation in arable layer 0-30 cm (average of 2 fields after harvest)

Indicators	Ploughing at different depths	Direct sowing	± to control	LSD_{05}
Aggregate content, % (dry sifting, fraction)	63,3	58,6	- 4,7	3,2
Wet sifting, fraction 0,25-0,50 mm, %	46,1	47,8	+ 2,7	2,9
Soil density, g/cm^3	1,18	1,26	+ 0,08	0,07
Soil solidity, kg/cm^3	26,0	33,8	+ 7,8	-
Soil porosity, %	52,7	48,7	- 4,0	4,0

Especially, the year 1981should be noted, when more than 600 mm rainfall has been recorded. However, the spring was cold and long, and the second half of the vegetation season (July) was characterized by a severe drought, when the maximum temperature on the soil surface reached 56 °C. The number of days with relative humidity of 30% was 14.In such conditions average soil solidity in the layer 0-10 cm comprised 1,50 g/cm^3 by direct sowing, in the layer 0-30 cm 1,43 g/cm^3 by ploughing 1,33 та 1,32 g/cm^{3}accordingly. Soil solidity was 23% more compared to ploughing (in the layer – 30 cm and 50.3 і 40.6 kg/cm^3. High soil density and solidity in arid conditions adversely affected the growth of the root system, its flow of water and nutrients, causing a decrease in the productivity of cultivated crops. In such conditions, the dependence of their productivity on the physical conditions of the soil is expressed by a high negative coefficient of determination (dyx = -0.8-0.9-1.0). In years with a sufficient amount of rainfall this is not observed.

The influence of different soil tillage systems on moisture-providing is practically the same. On average, during the years of research (1979-1986) spring reserves of available moisture in the layer 0-150 cm were: 217 mm by ploughing and 214 mm by direct sowing. And only in a very dry year (1983) there was a decrease in the autumn-winter period to 7.8% by direct sowing compared to ploughing.

The weed of agricultural crops comprised 30 and 47 pcs/m^2 on average during this period, that is, by direct sowing it was 17 pcs/m^2 more or 57% more compared to ploughing. The weed of sowing in the first year by direct sowing remains at the level of ploughing, and during the following years it grows rapidly and already on the 3rd crop rotation crop exceeds the control index by 50% or more. At the same time, there is a change in the species composition of weed. If pink thistle and amaranth predominate by ploughing, then by direct sowing technology yellow thistle and Chenopodium album predominate. Correlation analysis shows that not always weed reaches the threshold of harmfulness, and if the correlation bond exists, then the average force is r = -0.4-0.5.

In our studies, differentiation of the soil layer 0-40 cm in the fertility of both systems of cultivation has been demonstrated, but by direct sowing increasingly. This is especially noticeable in the content of mobile phosphorus and exchangeable potassium. If their content in the soil considered as 100% after direct sowing, these indicators will be in a layer 0-20 cm 122.4, respectively; 131.9% in a layer of 20-40 cm 93.6 and 88.3%. In dry years, the difference in the layer 0-10 cm can grow more and more reaches 150-200% compared to ploughing. However, accumulation of nutrients in the surface layer 0-10 cm in arid years by direct sowing does not lead to increase of crops productivity and more often – to their decrease. This is explained by the fact that the bulk of the root system, according to this technology of cultivation, is placed in a layer of 0-10 cm, which rapidly dries in dry conditions, which causes the physiological inaccessibility of nutritional elements of cultivated plants.

There is no clear pattern in the distribution of nitrate nitrogen over the soil layers. In the years with sufficient rainfall, as well as in spring, it more often accumulated in a layer of 20-40 cm, than in a layer 0-20 cm. Reverse process is observed in arid years. The total amount of nutrients in the soil layer of 0-30 cm by different types of cultivation was approximately equal.

The introduction of 1 hectare of crop area of 5 tons of manure and 129 kg of mineral fertilizers was insufficient to maintain the content of humus at the initial level. We could note its further decrease to 2.4 t/ha by ploughing and 2.0 t/ha by direct sowing.

Harvest is the main link of a scientific experiment, the results of which are judged by the efficiency of agrotechnical product.

In our experiment, crop harvest varied, depending on soil tillage systems and weather conditions during years of research within the growing season (Table 2).

2. Rotational crop yield depending on the systems of soil cultivation, c/ha

Crop rotations	Years of research	Tillage type		± to control		LSD_{05}
		Ploughing at different depths	Direct sowing	c	%	
Peas	1980-1982	16,9	17,5	+0,6	3,6	0,7-1,3
Winter wheat	1980-1983	40,3	38,2	-2,1	-5,2	3,6
Maize silage	1981-1984	336,0	292,0	44,0	-13,1	31,7
Winter wheat	1982-1985	23,8	25,5	+1,7	7,1	1,9-4,5
Sunflower	1983-1986	26,1	25,2	-0,9	-3,4	2,6-3,8
Productivity out of 5 crops, c/grain unit	-	206,0	197,0	-0,9	-4,4	-

Remark: The data is given in the table in c/ha, because mathematical processing is done using c/ha.

Analysis of Table 2 shows that the productivity of 5 crop rotations during the years of research by direct sowing decreased to 4.4% compared to ploughing. However, only in one culture - silage corn - it was significant and comprised 4.4 tons/ha or 13.1%. It is noteworthy that perennial cultures react more negatively

on soil tillage technology than crops of continuous sowing. Reduced yields of individual crops were observed mainly in arid years. However, the results show that this trend can also occur in humid years, but with a cold and prolonged spring. The most significant drop in agricultural productivity was observed in the arid vegetation period of 1983.So, if in the arid vegetation period of 1981 (HTC = 0.84), the yield of green maize decreased in the case by direct sowing to 3.4 tons/ha, or 9.3%, then in an even more arid 1983 (HTC = 0,76) – already to 13,1 tons/ha, or 49,0% compared to ploughing. In the same year, other crop rotation crops reduced yields by direct sowing: winter wheat after peas – to 0,85 t/ha (34,0 %); winter wheat after maize silage – to 0,13 t/ha (12,7 %); sunflower – to 0,77 t/ha (28,7 %). In a moderately dry year 1982 (HTC= 0,96) with a cold and prolonged spring, a tendency was observed to decrease the yield of winter wheat after maize silage by direct sowing, which was 0.31 t/ha or 8.0% LSD_{05}= 0.36 t. This is explained by the insufficient amount of effective temperatures, and by slowing down the processes of nitrification and inflow into the root system NO_3, P_2 O_5, Ca. However, when preparing the soil for winter wheat harvesting in winter next year, direct sowing technology is most effective. So, in arid 1983, the soil for ploughing under winter wheat planting in 1984 was badly developed, which led to the use of additional cultivation measures: bending, compaction. Under such conditions, in a favorable amount of precipitation and heat in 1984, direct sowing ensured increase of yield compared to ploughing to 1.53 t/ha, or to 46.9% (1.73 and 3.26 t/ha accordingly).The advantage of direct sowing technology was caused by the lack of mechanical soil mellowing, preservation of residual moisture, equal wrapping of seeds in the soil, which resulted in more friendly and more complete stairs, and hence yields. The results show that although by direct sowing, the productivity of crop rotation decreased to 4.4% during the years of research, but as a result of the reduction of total expenditures to 52.6%, fuel to 8.2 kg (42.7%), conditionally net profit increased from 1714.7 UAH to 2399 UAH/ha (40.0%) and profitability level from 64.2 to 126.4% (96.9%). The coefficient of energy efficiency increased from 3.4 to 6.0 (76.4%).

According to the analysis, it becomes clear why in foreign countries, especially in the United States, direct sowing has been implemented so rapidly in agriculture, as it is a significant saving of energy resources.

Conclusions

With a decrease in the productivity of crop rotation to 4.4% compared to plowing, direct sowing technology provides 60% energy savings. However, the main factor inhibiting the use of direct sowing on heavy loamy podzolized chernozem of Right-bank Steppe of Ukraine by the removal of plant remains during harvesting is a significant increase in the density and hardness of the soil in arid conditions compared to ploughing. High physical parameters hinder the entry into the root system of water and nutrients, causing a decrease in the productivity of crops, especially cultivated. It is not observed in sufficiently wet years.

References

1. Cogeriy, R. (1972). Zero-tillage after 10 years. *The Furrav*. Apr., 30–31.

2. Derpsch, R., Franzluebbers, A., Duiken, S.W., et al. (2014). Why do we need to standardize no-tillage nesearch? *Soil & Tillage Research*, *137,* 16–22. https://doi.org/10.1016/j.still.2013.10.002

3. Duseja, D.R., & Dennis, S. (2010). Long-term effects of two tillage systems on soybean (*Glicine max* (L.) Merrill (var. Forrest) production, soil properties and plant nutrient uptake. Materials of the World Congress of Soil Science, Soil solutions for a Changing World. *1–6*, 75–77. Brisbane, Australia.

4. Yash, Dang. (2018). Can Cultivation Be Pant of A No-Till Farming System? Retrived from https://www.researchgate.net/publication/326822393

5. Conservation agriculture: opportunities for intensified farming and environmental conservation in dry areas. (2012). Retrived from http://hdl.handle. net/20.500.11766/7922

6. Tanchyk, S. P. (2009). *No-till i ne tilky. Suchasni systemy zemlerobstva* [No-till and not only. Modern farming systems]. Kyiv: UnivestMedia. (In Ukrainian).

7. Kosolap, M. P., & Krotinov, O. P. (2011). *Systemy zemlerobstva No-till* [Farming systems No-till]. Kyiv: Logos. (In Ukrainian).

8. Hrabak, N. H. (2003). Polipshennia obrobitku gruntu v Stepu [Improvement of soil cultivation in the Steppe]. *Bulletin of Agricultural Science*, *3*, 12-14. (In Ukrainian).

9. Pabat, I.A., Shevchenko, M.S., Horbatenko, A.I., & Horobets, A.H. (2004). Minimalizatsiia obrobitku gruntu pry vyroshchuvanni silskohospodarskykh kultur [Minimalization of soil cultivation by crops growing]. *Bulletin of Agricultural Science*, *1*, 11-14. (In Ukrainian).

10. Tsykov, V.S., & Matiukha, L.P. (2003). Udoskonalennia system kontroliu zaburianenosti v Stepu [Improvement of weed systems in Steppe]. *Bulletin of Agricultural Science*, *7*, 20-24. (In Ukrainian).

11. Tanchyk, S.P., & Mykolenko, Ya.O. (2017). Vplyv system osnovnoho obrobitku gruntu na vmist dostupnoi volohy ta produktyvnist kukurudzy v Pravoberezhnomu Lisostepu [Effect of ground tillage systems on the availability of moisture content and maize productivity in the Right-bank Forest Steppe]. *Bulletin of Agricultural Science*, *4*, 12-16. https://doi.org/10.31073/agrovisnyk201704-02 (In Ukrainian).

12. Tsykov, V.S., Tkalich, Yu.I., & Bokun, O.I. (2014). Produktyvnist kukurudzy zalezhno vid obrobitku gruntu i system zakhystu vid burianiv u Pivnichnomu Stepu [Corn yields depending on soil cultivation and weed protection systems in the Northern Steppe]. *Bulletin of Agricultural Science, 8,* 18-21. https://doi.org/10.15421/2017_48 (In Ukrainian).

13. Medvediev, V.V., & Lyndina, T.Ie. (2001). Naukovi peredumovy minimalizatsii osnovnoho obrobitku gruntu i perspektyvy yoho vprovadzhennia v Ukraini [Scientific prerequisites for minimization of basic soil cultivation and prospects for its introduction in Ukraine]. *Bulletin of Agricultural Science*, *7*, 5-8. (In Ukrainian).