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THE TECHNOLOGIC PROCEDURES OF UTILIZING STRAW SURPLUSES AS FERTILIZER ON THE CHERNOZEMIC SOILS

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Abstract

Tillage and removal of agricultural production from fields leave the soil increasingly poor in organic matter. Currently, the reimbursement of organic fertilizers to the soil, with rising fuel prices, has become very expensive, exceeding €30/t within a three-km radius. In this context, straw surpluses from cereal crops are welcome to meet the soil's organic matter needs. They do not require loading, transportation and distribution costs, increasing the profitability of application. Experience has shown that on the chernozemic soils, straw incorporated during cereal harvesting does not affect the nitrogen supply of plants. This process makes it possible to fertilize with straw without supplementing with nitrogen, especially where nitrogen fertilizers are not available. It was shown that among the organic fertilizers, straw combined with nitrogen fertilizers has the highest humus restoration potential. The research show, that humus content increase between 150 and 270 kg/t of straw, humifying 14-30% of organic matter from straw.

Key words: *chernozemic soils, nitrogen fertilizers, organic matter, straw surpluses.*

INTRODUCTION

Agriculture in the Republic of Moldova is in a deep crisis regarding the replenishment and maintenance sources of the agricultural soil's fertility. The prices of industrial fertilizers have increased considerably, and the use of traditional organic fertilizers is limited by an increase in prices for services for their preparation and application, as well as a significant regression of livestock. The lack of financial resources for seeds, the procurement of fertilizers and chemical preparations for crop care indicate a major problem for farmers.

On the other hand, according to the agronomic law of Yu. Liebig (1842), in order to maintain the fertility of the soil, it is necessary to return to it that part of the lost nutrients that man took from it in the form of a harvest. The reserves of nutrients in the soil are limited, therefore we cannot permanently alienate from it. History has shown us that the prosperity and death of entire peoples and civilizations are linked to the way they treated the land (soil) on which they lived (Montgomery, 2013).

In this situation, straw surpluses remain a welcome opportunity to compensate the organic fertilizers deficit. Straw is formed on the lands where it must be applied, is evenly distributed on the soil surface, does not require loading and transportation costs. The purpose of this research was to investigate the straw - nitrogen relationship in several straw fertilization processes on the chernozemic soil.

MATERIALS AND METHODS

Planning and organization of the experiment

Since the straw from the spikes has an extended C:N ratio, it can cause microbiological immobilization of mineral nitrogen in the soil and suppress the provision of nitrogen to plants. In the specialized literature, it is recommended that the straw applied as fertilizer must be supplemented with nitrogen (Lixandru et al., 1990; Turcan et al., 1993; Rusu et al., 2005; Nicholson et al., 2007; Mineev et al., 2017; Tiantian et al., 2021; Bai-Jian Lin et al., 2024).

So, the chernozem soils have a high nitrification capacity, which can almost entirely meet the nitrogen needs of medium-sized crops. Long-term research has demonstrated that chernozemic soils without fertilization have the capacity to form up to 100 kg/ha of mineral nitrogen in a season in the 100 cm soil profile (Lungu et al., 2017; Andriesh, 2018).

In this context, we suspected that on chernozemic soils the nitrogen-fixing influence of straw is less pronounced than on poor soils with low nitrification capacity, if straw is applied early. To verify this hypothesis, a field experiment was set up to expand and streamline straw fertilization.

The experiment was founded in the summer of 2009 in a rotation with field crops at the Experimental Station of Erosion and Pedology of National Institute for Applied Research in Agriculture and Veterinary Medicine, located in the Ursoaia com., Cahul district, Republic of Moldova. The soil of the experimental field was identified as a slightly eroded ordinary loamy-clayey chernozem. The experiment scheme included ten variants (Table 1).

Table 1. Experience with the quantities of the main fertilizing elements fully incorporated with fertilizers in 2009, 2013 and 2017, kg/ha

Variant	C	N	P_2O_5	K_2O
1. Control, without fertilizers	0	0	0	0
2. Straw, 4 t/ha	4804	83	10	114
3. Straw, 4 t/ha + $N_{20}P_{20}$	4804	143	70	114
4. Straw, 8 t/ha + $N_{20}P_{20}$	9608	226	80	228
5. Straw, 8 t/ha	9608	166	20	228
6. $N_{20}P_{20}$	0	60	60	0
7. $N_{170}P_{180}$	0	510	540	0
8. Straw, 4 t/ha + $N_{140}P_{175}$	4804	509	539	114
9. Straw, 4 t/ha + Sheep manure, 16 t/ha	10463	509	430	895
10. Sheep manure, 20 t/ha	6820	514	479	931

The experience was based on four repetitions with a plot area of 120 m² (6 x 20 m). Straw and manure were applied three times by overlapping the materials, once every four years, in July 2009, 2013 and 2017. With the same periodicity of four years, chemical fertilizers in the form of amorphous and ammonium nitrate were also added.

In variants 7, 8, 9 and 10, equivalent amounts of nitrogen and phosphorus were added to the fertilizers with the intention of establishing more clearly the comparative role of straw organic matter and sheep manure in crop nutrition and yield.

In this context, both straw alone, without nitrogen supplementation, and straw supplemented with reduced doses of nitrogen were tested. The combination of straw with sheep manure, as well as with high doses of chemical fertilizers with nitrogen and phosphorus, was also tested. In order to more clearly elucidate the influence of straw as a fertilizer and amendment, they were applied in two doses: 4 t/ha and 8 t/ha.

When harvesting the spikelets, the straw and fertilizers weighed according to the planned doses were distributed uniformly by hand on the plots. After each fertilizer distribution, the experimental field was harrowed three times with a heavy disc harrow.

Weather conditions. As is known, the climate of the Republic of Moldova is moderately continental. Winter is short, mild and with little snow, and summer - hot, long-lasting and with insufficient amounts of precipitation. In the southern part of the country, these characteristics are more pronounced. Here the climate is considered the most arid and warm in the republic, temperatures being 2-3°C higher than in other regions (Sivun, 1982). In addition to the positive aspects of the climate, the abundance of sunlight and heat, there are also negative aspects, namely dry periods and large temperature variations.

In the southern part of the republic, temperatures above +10°C begin in the second decade of April and extend until the second decade of October. Their sum varies between 3200°C and 3400˚C. Under the influence of these temperatures, the region differs from the rest of the territory by a pronounced lack of moisture in the soil, frequent and extensive droughts.

The average annual amount of precipitation at the Cahul weather station is 451 mm, and about 65% of this amount falls during the warm period in the form of short-term showers. During this period of the year, an average of 291 mm of precipitation is deposited and about 3300˚C of active temperatures accumulate. An average of 795 mm/year can be consumed through evaporation in the area (Melniciuc, 2021).

Therefore, the water evaporation capacity is about twice as high as the volume of atmospheric deposition. The humidity coefficient is 0.57 (451/795). The optimal water demand for crops sown in spring in the Cahul station area is about 360 mm, and the amount of water evaporated from the soil from sowing to harvesting for this group of crops is on average 220 mm.

Therefore, the coverage of water needs for plants from precipitation is about 61%.
During the experiment, the agricultural years 2010 and 2013 stood out for their higher than the annual norm rainfall, when about 20% more precipitation than the annual norm (Table 2).

The lowest amounts of precipitation were noted in 2011, 2015, 2020 and 2021. Thus, the lowest harvest in the experiment was recorded in 2015 in the control variant - 1800 kg/ha cereal units. During the corn vegetation period, only 184 mm of precipitation was deposited, or 64 percent of the statistical norm.

Table 2. Crop succession and yield in the Control variant

Harvest year	Cultivated plant	Rainfall, mm		Harvest, kg/ha	
		per agricultural year	for 04 - 09 months	physical mass	cereal units (c.u.)
2010	Corn grains	535	428	4840	3870
2011	Spring barley	322	261	2240	2240
2012	Sunflower	388	268	1700	2500
2013	Winter barley	649	526	4930	4930
2014	Corn grains	441	361	5280	4220
2015	Corn grains	293	184	2250	1800
2016	Pea grains	419	304	2120	2540
2017	Winter barley	426	332	5520	5520
2018	Corn grains	305	170	5640	4510
2019	Sunflower	401	353	2050	3010
2020	Winter wheat	291	243	5080	5080
2021	Corn grains	393	315	7950	6360
Statistical average		*451*	*287*	-	*4658*

According to the data obtained, the highest yield, 6360 kg/ha of corn grains, was formed in 2021. This is explained by the fact that, although the total amount of precipitation in that year was 58 mm lower than the statistical norm, 80% of it was deposited during the vegetation period. This case clearly shows that providing plants with water depends not only on the total amount of precipitation, but also on the quality of its distribution during the vegetation period.

RESULTS AND DISCUSSIONS

Taking into account the fact that wheat straw has a C:N = 80:1 ratio, four times more extensive than the optimal one for the biochemical processes of providing plants with nitrogen, we set out to experiment with various models of combining straw with nitrogen. Nitrogen is contained in the soil in small quantities, which is why frequent fertilization of the soil and plants with this element is practiced. Monitoring the nutrition process is identified more correctly and precisely through chemical analysis of plants.

Description of the straw influence in the first year of action. Table 3 shows the results regarding the amount of nitrogen absorbed by corn from soil and fertilizers in 2010, a year with a good corn harvest. In the *Control* variant, the grain harvest was 4840 kg/ha. We owe this fact to favourable moisture conditions. In the agricultural year 2009-2010, 535 mm of precipitation was deposited and 80% of them watered the corn during the vegetation.
On this favourable moisture substrate, the tested fertilization procedures also manifested themselves appropriately. As expected, the highest yield in the experiment was formed in variant 10 (Sheep manure, 20 t/ha). Here, grain production increased, compared to the *Control* variant, by 39% (6740 x 100/4840). In clarifying the fertilizing influence of sheep manure, the fact that it has a higher concentration of nitrogen and other deficient elements was taken into account. In addition, before incorporation, it goes through several fermentation stages, through which the nutrients become accessible to plants. Straw, however, has a lower content of nutrients and in the experiment was applied in a fresh, unfermented state.

Table 3. Yield and nitrogen consumption from soil and fertilizers by corn crop in 2010

Variant	Grain			Secondary aerial production			Total N consumption kg/ha (***7)
	Yield, kg/ha (1)	N, % (2)	N assimilated kg/ha (*3)	Production kg/ha (4)	N % (5)	N assimilated, kg/ha (**6)	
1. Control, without fertilizers	4840	1.22	59	5664	0.86	49	108
2. Straw, 4 t/ha	4700	1.26	59	7293	0.85	62	121
3. Straw, 4 t/ha + $N_{20}P_{20}$	5240	1.40	73	7550	0.91	69	142
4. Straw, 8 t/ha + $N_{20}P_{20}$	5860	1.68	98	8036	0.97	78	176
5. Straw, 8 t/ha	5270	1.30	69	7728	0.91	70	139
6. $N_{20}P_{20}$	5100	1.41	72	6100	0.86	52	124
7. $N_{170}P_{180}$	5300	1.46	77	8183	0.91	74	152
8. Straw, 4 t/ha + $N_{140}P_{175}$	5540	1.51	84	9216	0.91	84	168
9. Straw, 4 t /ha + Sheep manure, 16 t/ha	6150	1.70	105	9600	0.93	89	194
10. Sheep manure, 20 t/ha	6740	1.59	107	11373	0.94	107	214
DL_{05}	*244*	*0.04*	*2.7*	*421*	*0.03*	*3.1*	*5.8*
Sx, %	*4,46*	*2.23*	*3.35*	*5,21*	*3.14*	*4.18*	*3.77*

Note: *3 = (1) x (2)/100; **6 = (4) x (5)/100; ***7 = (3)+ (6).

However, the straw incorporated separately demonstrated a fertilizing influence, even from the first year of action. In the variant 5 (Straw, 8 t/ha) the yield increased significantly compared to the *Control* by 430 kg/ha/year c.u. (cereal units) (5270-4840), or by 9%. In the variant (Straw, 4 t/ha) the yield was 3% lower than in the *Control* (4700 x 100/4840).

From a statistical point of view, this difference between the variants is considered irrelevant, that is, at the level of the reference variant. In other words, we can see that harvest mass was not negative, but at the level of the *Control*.

These results are somewhat contradictory to the data in the literature, mentioned above, where it is pointed out that straw applied separately decreases yields and must necessarily be supplemented with nitrogen-containing fertilizers. In the experimental case, when straw was applied in the dose of 4 t/ha, the yield was at the level of the *Control* variant, and when the dose of straw was doubled, a significant increase in yield was formed.

So, among the factors that conditioned the harvest formation in the variants treated only with straw, the accessible nitrogen was not the minimal factor that limited the yield formation. Indirectly, it is assumed that the soil compaction was the condition that limited the harvest level in this variant. Since, when incorporating 8 t/ha of straw, the yield increased suggestively compared to the variant treated with 4 t/ha of straw and to the *Control*.

The incorporated straw influences, first of all, the physical properties of the soil. With their very low density, of about 50 kg/m^3, they maintain the soil in a loose state. The quantity of 8 tons of freshly harvested straw occupies a volume of about 160 m^3 (8000/50). And when mixed with the ploughed soil layer, with an apparent density of about 1.20 t/m^3, it loosens its state up to 1.11 t/m^3 (2000 m^3 x 1.20 t/m^3 / 2000 m^3 + 160 m^3).

For loamy-clayey soils, which dominate in the Republic of Moldova, the calculated parameter means a very low apparent density, very high porosity and moderately loose soil (Canarache, 2000). Reducing the apparent density of the soil means increasing the permeability and water retention capacity. The value of 1.11 t/m^3 also highlights a decrease in resistance to root penetration, as well as to soil tillage mechanisms.

On the other hand, straw also demonstrated a direct biochemical fertilizing action. In variants 7 and 8, the same doses of 170 kg/ha of nitrogen were applied. The only difference is that in variant 8 (Straw, 4 t + $N_{140}P_{175}$, 30 kg nitrogen per dose) the amount contained in the straw was applied. Compared to variant 7, a suggestive increase of 240 kg/ha c.u. (5540-5300) was formed. The corn plants in variant 8 were more fully provided with nitrogen. If in variant 7 the plants assimilated a total of 152 kg for the formation of the harvest, then in variant 8, significantly more - 168 kg/ha of nitrogen.

But the results are even more striking if we add to the comparison variant 9 (Straw, 4 t + Sheep manure, 16 t/ha). Here the same amount of nitrogen was applied, 170 kg/ha, but completely in the form of organic matter. The increase in grain yield in this variant was 1310 kg/ha (6150-4840) or 27% compared to the *Control* variant (1310 x 100 /4840). We assume that this phenomenon is explained by the fact that the plants were more fully provided with other nutritional elements from the sheep manure, which they did not find in the soil of other variants.

Variant 10 (Sheep manure, 20 t/ha), similarly, with the amount of 170 kg/ha nitrogen was placed for comparison with the other variants in the scheme. It is known that sheep manure is the most complex, widespread and common fertilizer with which other forms of organic fertilizers are compared (Țurcan, Sergentu, Banaru et al., 1993). In experience, the variant 10 served as a reference, as a measure of comparison of the tested procedures. Here the indicators taken in the research were the highest. The yield index increased by 1900 kg/ha of cereal grains (6740-4840) or by 39% (6740 x 100/4840). Nitrogen consumption by corn doubled, compared to the reference variant (214/108).

Evolution of harvests over time in the experiment. For a more clarification of the fertilizing influence of straw, the results on aboveground plant production and nitrogen used by plants were monitored over 12 years. The given period was divided into three quadrennial time intervals, according to the application of fertilizers in the experiment (Table 4). Fertilizers, according to the scheme, including chemical ones, were administered quadrennial three times in 2009, 2013 and 2017.

Table 4. Yield and nitrogen consumption in the experiment by fertilization stages, kg/ha

Variant	Average annual saleable harvest in grain units by years				The amount of nitrogen assimilated seasonally by plants			
	2010-2013	2014-2017	2018-2021	Average	2010-2013	2014-2017	2018-2021	Average
1. Control, without fertilizers	3385	3523	4738	3882	83	112	111	102
2. Straw, 4 t/ha	3447	3691	4567	3902	86	114	110	103
3. Straw, 4 t/ha + $N_{20}P_{20}$	3909	3771	5422	4367	119	118	132	123
4. Straw, 8 t + $N_{20}P_{20}$	4069	4102	5539	4570	134	139	139	137
5. Straw, 8 t/ha	3846	3611	4928	4128	114	111	118	114
6. $N_{20}P_{20}$	3537	3705	4715	3985	96	117	112	108
7. $N_{170}P_{180}$	3851	3658	5380	4296	116	119	136	124
8. Straw, 4 t /ha + $N_{140}P_{175}$	4082	4352	5680	4705	126	129	137	130
9. Straw, 4 t/ha + Sheep manure, 16 t/ha	4195	4546	5577	4773	111	145	141	133
10. Sheep manure, 20 t/ha	4492	4278	5297	4689	124	136	133	131
Average of variants	*3881*	*3924*	*5184*	*4330*	*111*	*124*	*127*	*121*

An overview of the presented results indicates an increase in plant productivity at the fertilization stages. The phenomenon was demonstrated in all variants of the experiment both in terms of plant productivity indices and nitrogen consumption values. In variant 2 (Straw, 4 t/ha) the average annual production value in the period 2010-2013 was 3447 kg/ha c.u. In the period 2014-2017 the average annual production increased by 244 kg/year, reaching 3691 kg/ha. And, in the period 2018-2021 wheat production increased, compared to the previous four-year period, by 876 kg/year (4567-3691).

More relevant was the increase in marketable production according to the average values of all variants. In the first period (2010-2013) the average production per experience was 3881 kg/ha c.u. In the second period (2014-2017) - 3924 kg/ha, with an increase of 43 kg/year (3924-3881). And, in the next period of years, 2018-2021, the average annual harvest per experience evolved to 5184 kg/ha, forming a difference of 1260 kg/year, compared to the previous period.

The same evolution was also noted according to the indices of nitrogen consumption from the soil and fertilizers by plants in the experimental variants. For example, on the plots of variant 8 (Straw, 4 t/ha + $N_{140}P_{175}$) the amount of nitrogen concentrated in the aboveground part of the plants constituted 126 kg/ha/year in the first observation stage. In the second - 129 kg and in the third - 136 kg/ha/year nitrogen. Similar increases in the amount of nitrogen assimilated by plants were also observed according to the average annual indices of nitrogen absorption by plants in the experiment.

We assume that the increase in productivity and nitrogen assimilation by crops, across the entire experimental field over time, is due to the increasingly efficient agrotechnique implemented at the station. The average productivity per stage of plants grown on the experimental soil increased, compared to the stage of 2010-2013, by about 12% (4330 x 100/3881). Amount of nitrogen absorbed annually increased by 9 % (121 x 100/111).

The significance of the combined application of straw with other fertilizers. In addition to the beneficial changes in yields and nitrogen assimilation over time, the experience also noted advantageous transformations from combining straw with other fertilizers. For example, in variant 5 (Straw, 8 t/ha), the production increased compared to the *Control* by 461 kg in the first stage of fertilization (3846-3385). In the second stage - by 88 kg and in the third - by 190 kg/ha/year grain units. The average value of the yield supplement in this variant on all three stages of fertilization was 246 kg/ha/year grain units (4128-3882).

When combining straw with sheep manure or chemical fertilizers, the yields increased more clearly and suggestively. Even in tiny doses, of 20 kg/ha of active substance and applied at a considerable periodicity, of four years, ammonium nitrate and amorphous essentially stimulated the fertilizing potential of straw. If in the years 2010-2013 in variant 2 (Straw, 4 t/ha) the average annual yield increased compared to the *Control* by 62 kg (3447-3385), then in variant 3 (Straw, 4 t/ha + $N_{20}P_{20}$) the annual yield increases advanced more than 8 times, making up 524 kg/ha (3909-3385).

Similar differences in the mentioned variants were also noted in the second period of fertilizer application from 2014 to 2017. However, here the amplitudes of the differences compared to the *Control* were shorter, amounting to 168 kg (3697-3523) and, respectively, 248 kg/ha c.u. (3771-3523). Such stimulating influences on plant productivity were also observed at other doses of straw and fertilizer incorporation.

When straw was applied together with chemical fertilizers, a very advantageous synergistic phenomenon was also detected. The joint action of straw with chemical fertilizers formed a production increase greater than the sum of the increases from straw and fertilizers applied separately. For example, according to the average indices from all three stages of experimentation, in variant 3 (Straw, 4 t + $N_{20}P_{20}$) the increase was 485 kg/ha/year c.u. (4367-3882). In variant 2 (Straw, 4 t/ha) the increase was 20 kg (3902-3882), and in variant 6 ($N_{20}P_{20}$) – 103 kg (3985-3882). The sum of the yields increases from the separate application of fertilizers amounted to 123 kg/ha (20 + 103), being 3.9 times lower than the increase obtained from the combined incorporation of straw with chemical fertilizers (485/123).

Such significant synergistic increases in size were also observed when increasing the dose of straw or incorporated chemical fertilizers. The average value of the yield increase in variant 4 (Straw, 8 t/ha + $N_{20}P_{20}$) was 688 kg/ha/year c.u. (4570-3882). In variant 5 (Straw, 8 t/ha) an addition of 246 kg (4128-3882) was formed and in variant 6 ($N_{20}P_{20}$) - 103 kg/ha c.u. (3985-3882). Therefore, the sum of the production increases from the separate application of straw and chemical fertilizers amounted to 349 kg/ha (246 + 103). The sum being about two times

lower than the increase obtained by applying these two fertilizers together (688/349).
Since the association of straw with chemical fertilizers, the provision of nitrogen to plants has improved. According to the seasonal average values, it was seen that in variant 2 (Straw, 4 t/ha) plants used an average of 1 kg/ha/year more nitrogen than in the *Control* (103-102). In variant 6 ($N_{20}P_{20}$), plants assimilated an average of 6 kg/ha/year more nitrogen (108-102). The nitrogen supplement from these two variants, with separate application of fertilizers, amounted to 7 kg/ha. And, applied together, these two fertilizers multiplied the amount of nitrogen absorbed three times, reaching 21 kg/ha/year (123-102).
These indicators were characterized with even more relevant parameters when the straw dose was increased. According to the average results by stages, the annual amount of nitrogen assimilated by plants in variant 5 (Straw, 8 t/ha) increased, compared to the *Control*, by 12 kg (114-102). In variant 6 ($N_{20}P_{20}$) 6 kg/ha more nitrogen was used. The sum of the nitrogen increase compared to the *Control* from the separate application of fertilizers was 18 kg (12 + 6). And, from the associated incorporation of these two fertilizers - 35 kg/ha/year nitrogen (137-102). The synergistic effect from the joint action of fertilizers was 17 kg/ha nitrogen (35-18). In relative units, the synergistic increase was 48% (17 x 100/35). In fact, half of the assimilated nitrogen was made available to the plants for free, through synergy, only through the process of applying fertilizers together.
After carbon, nitrogen is considered the second chemical element that ensures life and is indispensable for living beings. It enters the structure of proteins, nucleic acids and other organic compounds, which constitute the physical body of living beings. It is the element of greatest importance in plant nutrition and the decisive factor in the growth of agricultural crops. However, in soils it is found in small quantities, frequently limiting the development of plants.
Analysis of the phenomenon of synergy on the yield and provision of plants with nitrogen when straw is applied together with chemical fertilizers allows us to certify that not only chemical fertilizers increase the fertilizing potential of straw, but also straw increases the yield of chemical fertilizers.

CONCLUSIONS

1. Soils in the agricultural circuit need to be supplemented with organic matter and primary elements alienated as a result of long-term plant cultivation. However, organic fertilizers accumulate too little and are very expensive to use. Chemical fertilizers, and to this day, are made at high prices. In this context, straw surpluses are appreciated as an accessible and considerable resource of organic matter for agricultural soils.
2. On chernozem soil, where the experiment was carried out, the phenomenon of a decrease in plant production from straw incorporation was not confirmed. This is due to the ability of chernozemic soils to form, through humus mineralization, sufficient nitrogen necessary for the microbiological processing of the applied straw. Therefore, in the pedoclimatic conditions of the Republic of Moldova, straw surpluses can be incorporated as fertilizer in advance and without being supplemented with nitrogen-containing fertilizers.
3. Of course, where available, nitrogen fertilizers should be associated with straw. By combining straw with nitrogen fertilizers, the fertilizing effect of both fertilizers is increased. A synergistic crop yield is formed that is more than twice as high as the sum of the increases from both fertilizers applied separately. The higher the dose of straw or chemical fertilizers in the mixture, the more impressive the synergistic increase becomes.
4. The most efficient method of applying straw as fertilizer has proven to be the method consisting of 4 t/ha of chopped straw and distributed at harvest in the stubble. Over which chemical fertilizers were distributed in doses of $N_{20}P_{20}$. In physical quantities for one hectare, these fertilizers can be represented by 40 kg of ammophos and 44 kg of ammonium nitrate. Both types of fertilizers are incorporated once for four years. Wheat also returns to field rotations with about the same periodicity. This method ensures an average annual increase of 480 kg/ha of conventional grain wheat.

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