RESEARCH REGARDING THE USE OF STRAW AS FERTILIZER ON ERODED SOILS

Andrei SIURIS[1]

e-mail: ipaps_dimo@mtc.md

Abstract

Straw originating from cereal plants served as object of study. The straw was studied as a fertilizer during a field experience on moderately eroded ordinary chernozem in the Southern region of the Republic of Moldova in order to elaborate some rational processes for its use. The application of straw had a mobilizing impact on the nitrogen and the phosphorus found in the soil. It favoured the provision of the cultivated plants with nitrogen, phosphorus and potassium. The apparent density and the coefficient of water use in the soil have been reduced and the plant productivity has increased. The organic matter contained in the straw constitutes 820 kg/t and possesses an energetic potential of 4.4. Gig calories/t. In the Republic of Moldova, the straw is the only re-generable resource which possesses the highest potential to break up, to structure and to increase the soil capacity for water and air. Each ton of straw, applied as fertilizer, favours the completion of humus reserve in the soil by about 150 kg and that of nitrogen by 8 kg.

Key words: straw, fertilizer, eroded soil, ordinary chernozem

Erosion is the main factor of soil cover degradation and pollution of water resources in the Republic of Moldova. In the period of 40 years, the surface of eroded soils increased by 284,000 ha (594,000 ha in 1965 and 878,000 ha at present, increasing annually by 7,100 ha [Krupenikov I., 2004]). Most affected by erosion are the chernozems, occupying 788,207 ha (91 %) of eroded land surface. The annual damage caused by erosion is estimated at 2.5 billion lei or 200 million U.S. dollars.

In the past 20 years, the amount of organic fertilizers decreased by 60 times and constitutes 0.8 t/ha; the surface of alfalfa decreased by 4-5 times, the vegetal wastes are set fire to on large surfaces. Therefore, the soil humus balance is negative – minus 0.7 t/ha, while erosion losses constitute –minus 1.1 t/ha. According to recent estimates, 2.4 million tons of humus are annually lost from the agricultural lands. The forecast calculations show that if the current situation is maintained, the content of humus in Moldova's soils will decrease to the critical level of 2.5- 2.8 %.

An important source of eroded soil fertility recovery is straw surpluses. The present paper attempts to highlight these possibilities.

MATERIAL AND METHOD

In 1996, in order to test the use of straw as fertilizer, a long term experience was founded in the Experimental Station of Pedology and Soil Erosion of "Nicolae Dimo" Institute of Pedology, Agrochemistry and Soil Protection in the village Lebedenco, Cahul district on a slope with an inclination of 5-6˚ degrees to the Northeast. The experience was based on moderately eroded ordinary chernozem possessing a loam-clay texture, whose content of humus was 2.07 -2.54 %, mobile phosphorus 1.54 – 1.93 mg/100 g of soil, exchangeable potassium 15.3 – 16.8 mg/100 g of soil and a slight alkaline reaction (pH 7.5-7.8). The surface rocks are composed from loess with alternation. The size of the plots is of 6 m x 40 m (120 m^2) in the form of rectangles situated in one line across the slope. The long sides of the plots are oriented along the slope. The experience scheme includes the following variants: 1. The control plot (without fertilizers); 2. $N_{60}P_{60}$ (variant); 3. Variant + straw, 4 t/ha once in 4 years. Each variant is placed in three repetitions. Before the foundation of the experience, initial samples of soil tests were collected from each plot. At incorporation, the straw was chopped by PON-5 chopper and was evenly spread on the plot to mineralize its organic matter which is low in nitrogen. 10 kg/ha of nitrogen was added to every ton of straw. The fertilized soil was disked and in late autumn it was ploughed. Oat straw was

[1] Institutul de Pedologie, Agrochimie şi Protecţie a Solului "Nicolae Dimo"

incorporated into the soil in the autumn of 1996, wheat straw in 2000 and barley straw in 2004.

RESULTS AND DISCUSSION

The straw, secondary production of crop harvest is annually gathered in huge amounts (1.6 million tons). The chemical composition of straw depends on the species of the crop, the conditions and methods of cultivation and the harvesting time. As plant residues, the straw contains all nutritive elements in approximately the amount the plants need (Table 1).

Table 1

Straw chemical composition related to natural humidity mass, %

Analysed component	straw specification		
	autumn wheat	autumn barley	oats
organic matter	81	81	79
N	0.50	0.50	0.65
P_2O_5	0.20	0.20	0.35
K_2O	0.90	1.00	1.60
Ca	0.28	0.33	0.38
Mg	0.11	0.09	0.12
S	0.04	0.15	0.17
ash	4.86	4.49	6.45
C:N	80	80	60

Compared with other organic fertilizers, the straw contains a more valuable and deficient organic matter for soil fertilization such as cellulose, hemicelluloses and lignin which serves as energy for soil microorganisms.

In the last decades, however, a more pronounced indifference to straw is remarked, which is manifested by burning it directly in the field after grain harvest. This significantly damages both the soil and the atmosphere. It seriously affects the soil biota by destroying a lot of microorganisms which maintain the dynamic balance of synthesis processes and mineralization of the organic matter – the main condition for maintaining life on our planet. Direct use of straw as organic fertilizer exactly matches the basic principle of agriculture which consists in transforming the sun kinetic energy into potential energy of organic matter. This helps maintain a balanced flow of energy and matter in nature.

The only drawback of straw as fertilizer is its extremely low nitrogen content (0.50 – 0.65 %) and hence the high carbon: nitrogen ratio (60 – 80:1). This circumstance requires completing the straw with nitrogen (8 – 10 kg N/t of straw) at incorporation. The recommended amount of nitrogen fertilizer may be calculated according to the formulae (Popov P., 1987):

$$D = \left(\frac{K*N}{25} - N\right) * 10 * C, \text{ where}$$

D – dose of nitrogen fertilizer, etc. kg/ha;
K – C:N ratio in straw, %;
N – nitrogen content in straw, %;
25 – optimum C:N ratio;
C – amount of straw incorporated into soil per 1 ha, t.

For example, at the incorporation of 4 tons of wheat straw, we will need 44 kg of active substance nitrogen:

$$D = \left(\frac{80*0{,}5}{25} - 0{,}5\right) * 10 * 4 = 44\ kg\ etc.$$

The fertilizing impact of straw is beyond doubt. The results of numerous experiments carried out by different researchers unequivocally demonstrated that straw has a beneficial influence, practically all the indicators determine the soil fertility (Emcev V., 1980; Popov P., Novicov M., 1987; Scripnik V., 2004; Lixandru Gh., 2006; Siuris A., 2008; Rusu A., 2009).

Table 2

Modification of humus content in 0-20 cm of moderately eroded ordinary chernozem as result of using straw

Experiment variant	Humus content, % of soil mass		Total humus increase in 10 years		annual humus	
	1996	2006	%	t/ha	%	t/ha
1. Unfertilized control variant	2.07	2.11	0.04	1.0	0.004	0.1
2. $N_{60}P_{60}$ (variant)	2.28	2.41	0.13	3.1	0.01	0.2
3. variant + straw, 4 t/ha once in 4 years	2.08	2.34	0.24	6.4	0.03	0.7
DL 05	0.05	0.07	0.08	2.43	0.006	0.09

Our research has shown that fertilization with 4 t/ha once in 4 years contributed to the improvement of supply of moderately eroded ordinary chernozem with humus, mobile phosphorus and exchangeable potassium (Table 2, 3). In the tenth year of action, the humus content in the variant fertilized with straw increased by 0.24 % compared with the control variant. The increase of mobile phosphorus, compared with the initial one, increased in the tenth year of action by 1.64 mg/100 g of soil. The value of exchangeable potassium was increased by 3.8 mg/100 g of soil.

Table 3

Modification of phosphorus and potassium available in the 0-20 cm layer of moderately eroded ordinary chernozem at the use of straw

Variant	P_2O_5 mg/100 g soil			K_2O mg/100 g soil		
	1996,initial content	2006, content	increase	1996, initial content	2006, content	increase
1. Control	1.89	2.04	0.15	16.7	16.8	0.1
2. $N_{60}P_{60}$ (variant)	1.80	2.65	0.85	17.1	17.3	0.2
3. Variant +straw, 4 t/ha once in 4 years	1.78	3.42	1.64	16.5	20.3	3.8
DL 05			0.94			2.14

The application of 4 t of straw per ha has reduced the rough fractions (< 10 mm) by 26.6 %, thus simultaneously increasing the structural formations with a diameter under 0.25 mm by 11.2 % (Table 4).

Table 4

Structural state of moderately eroded ordinary chernozem at the application of straw in the ploughed layer Statistics mean (x±s), 2006

Variant	Contents of structural elements (%) with the diameter (mm)				Quality of structure (dry sieving)	Hydro-stability (humid sieving)
	> 10	< 0.25	> 10-0.25	>10 + < 0.25		
1.Unfertilized control	49.5 ± 4.4 / –	3.6 ± 0.9 / 72.5 ± 3.3	47.0 ± 5.3 / 27.5 ± 3.3	53.1 ± 5.3 / 72.5 ± 3.3	average	low
2. $N_{60}P_{60}$ (variant)	48.3 ± 4.1 / –	3.9 ± 0.8 / 71.5 ± 3.2	26.5 ± 3.0 / 28.5 ± 3.4	52.4 ± 5.0 / 71.5 ± 3.2	average	low
3. Variant +straw, 4 t/ha once in 4 years	22.9 ± 9.4 / –	14.8 ± 4.1 / 71.6 ± 2.9	62.3 ± 7.9 / 28.4 ± 2.9	37.7 ± 7.9 / 71.6 ± 2.9	good	low

Numerator – total aggregate content (dry sieving), Denominator – hydro-stable aggregate content (humid sieving)

Fertilization with straw of moderately eroded ordinary chernozem contributed to the formation of structural elements with agronomic value. Thus, if the sum of fractions between 10 – 0.25 mm constitutes 47 % in the control variant, in the variant fertilized with straw it increased by about 16 %.

Both the content of fine clay and of natural clay remains constant in all variants (Table 5).

Table 5

Impact of straw on the physical indicators of moderately eroded ordinary chernozem in the ploughed layer. Statistical parameters mean (x±s), 2006

Variant	Fractions, %		Density, g/cm^3	Apparent density, g/cm^3	Porosity, %	Resistance to penetration, kg F/cm^2
	< 0.001 mm	< 0.01 mm				
Unfertilized control	25.9±3.5	45.9±1.7	2.66±0.02	1.26±0.04	52.6±2.8	23.4±1.1
Straw, 4 t/ha once in 4 years+$N_{60}P_{60}$	26.3±3.7	45.4±1.6	2.64±0.01	1.22±0.05	53.8±1.5	16.1±1.3

The dusty clay-loam texture may be appreciated as favourable, since it provides normal conditions for plant growth. The loam-clay soils with physical humidity maturity are easy to treat. The low hydro-stability of structural aggregates formed at soil treatment, poor resistance to secondary compaction and the high danger of erosion may be considered as negative factors. The application of straw on moderately eroded ordinary chernozem leads to the decrease of density and of soil apparent density. These modifications had an impact on the increase of the gap space up to 55 %, which relates the soil to the "high" class. The resistance to penetration decreased by about 7.3 kg F/cm^2 or by 31 % compared to the control variant. As a result of optimizing the agrochemical and agro-physical indicators of moderately eroded ordinary chernozem through the application of straw, the productivity of field crops increased (Table 6). The application of straw once in 4 years led to obtaining an increase in the yield of 46.9 g/ha in the period of 9 years.

Table 6

The impact of straw on field crop productivity on moderately eroded ordinary chernosem, g/ha

Variant	Yield on the control variant and the increase on fertilized variants									
	1997, autumn barley	1998, corn seeds	1999, oats+ peas	2000, autumn wheat	2001, corn seeds	2002, autumn barley	2003, corn seeds	2004, sun flower	2005, autumn wheat	Total in 9 years, grain units
1. Unfertilized control	29.6	33.3	56.6	12.4	31.7	14.3	34.2	12.7	14.3	198.7
2. $N_{60}P_{60}$ (variant)	6.6	7.3	8.3	1.3	5.5	2.4	5.2	1.2	2.1	33.7
3. Variant +straw, 4 t/ha once in 4 years	6.4	11.0	24.0	2.4	5.2	2.7	7.3	3.1	3.1	46.9

CONCLUSIONS

1. The application of 4 t/ha straw once in 4 years on moderately eroded ordinary chernozem led to the increase of humus and mobile forms of phosphorus and potassium contents. In the course of 10 years, the quantity of humus increased by 0.24 %, of the mobile phosphorus and exchangeable potassium by 1.64 and 4.0 mg/100 g of soil respectively.
2. The fertilization with straw of the moderately eroded ordinary chernozem reduced the clod structural fractions (>10 mm) by 26.6%, simultaneously increasing the structural formations by 11.2 %. The soil mechanical properties were improved. The penetration resistance decreased by 31 %.
3. As a result of straw application on moderately eroded ordinary chernozem in the course of 9 years, a yield increase of 46.9 h/ha of grain units or by 24 % higher compared to the control variant was registered. It was established that straw should be applied on eroded soils in the dose of 4 t/ha once in 4 years.

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