Monitoring of agrochemical and agrophysical properties of dark gray soil with different ways of its use

S.I. Veremeenko *(National University of Water and Environmental Engineering)*, ***V.M. Poliovyi*** *(Institute of Agriculture of Western Polissia NAAS)*, ***V.I. Zatserkovnyi, P.I. Trofymenko, N.V. Trofimenko*** *(Taras Shevchenko National University of Kyiv)*

SUMMARY

The article presents the results of monitoring of the straw usage as an organic fertilizer on the complete mineral fertilizer, supplemented by additional nitrogen to narrow the *C:N* ratio in order to improve its decomposition into basic agrophysical and agrochemical indicators of dark-gray soil. It was found that during two rotations of crop the straw helped to reduce soil density, but there was a significant acidification of the soil. With a positive balance of organic matter in crop rotation, the use of straw fertilizer on the significant dominance of nitrogen in the composition of mineral fertilizers did not ensure the reproduction of humus reserves of the studied soils. During dump tillage, a significant decrease in the content of humic acid fraction was observed when using mineral fertilizers only. The usage of straw and additional nitrogen in the plowing led to a significant loss of total humus by reducing the proportion of fulvic acids. While the surface cultivation with this fertilizer, there is a tendency to increase the proportion of fulvic acids and reduce the amount of humus acids associated with calcium.

Introduction

In modern production conditions, the use of traditional organic fertilizers in the cultivation of field crops is minimized. Straw, hyphae and other parts of non-commodity plant remains are increasingly used to compensate for the loss of soil organic matter (Dehodyuk et al., 2013; Formuvannya..., 2012, Karami et al., 2013). In the world, the use of secondary biomass of crops to restore soil fertility is currently seen as a cheap replacement for manure, compost and other traditional types of organic fertilizers. In addition, plant residues contain the whole set of macro- and microelements and can partially compensate for the loss of chemical elements that are alienated from the fields with the commodity part of the product (Zhang et al, 2016; Truskavets′kyy, Tsapko 2016; Bakht et al, 2009). The recent period in crop production in Ukraine has formed a deficit balance of macronutrients while the use of fertilizers covers less than 70% of their removal with the marketable part of crop yields (Veremeenko, Semenko, 2019). Therefore, the use of crop and other non-marketable residues of plant biomass in such a situation can play a significant role in maintaining soil fertility.

The results of the research show that the use of straw and other plant residues is an effective measure to compensate for the loss of organic matter and biophilic elements of arable soils (Yevtushenko et al, 2018, Romanenko et al, 2017). However, it is known that the level of humification of fresh plants in the soil and in general the efficiency of using plant residues as fertilizers depends on many factors, including the overall fertilization system, soil solution reaction, tillage system. At present, the issue of long-term use of crop residues as fertilizers on the complex of agroecological and agrochemical indicators of soil against the modern energy-saving technologies of tillage and cultivation of crops is insufficiently studied.

The aim of the study

The main purpose of the study was to assess the impact of long-term use of by-products of crops and high doses of mineral fertilizers on the main agrophysical and agrochemical parameters of dark-gray soil in a stationary field experiment.

Methods

Monitoring of dark-gray soil was carried out in a stationary field experiment established in 2009 on the basis of the Institute of Agriculture of Western Polissya NAAS of Ukraine in a four-field short-rotation crop: winter rape – winter wheat – corn for grain – barley. The two-factor experiment included three options for mechanical tillage: 1) plowing to a depth of 20-22 cm without straw; 2) disking by 10-12 cm; 3) disking by 6-8 cm; and two fertilizer options: 1) $N_{128}P_{90}K_{120}$, without straw; 2) $N_{128}P_{90}K_{120}$ + straw for fertilizer + N_{10} ammonium nitrate per 1 ton of straw. Mineral fertilizers for crop rotation were applied in the form of ammonium nitrate, potassium chloride and ammophos. Phosphorus-potassium fertilizers were applied under the main tillage, nitrogen – under pre-sowing cultivation. The soil of the experimental site is dark-gray podzolic with a humus content of 1.9%, easily hydrolyzed nitrogen (according to Cornfield) 99 mg / kg, mobile forms of phosphorus and potassium (according to Kirsanov) – 238 and 85 mg / kg.

Results

Monitoring of the agrophysical condition of dark-gray soil after two rotations of four-field crop showed that different systems of cultivation and use of by-products affected the soil density. In the version with shelf dump tillage, the soil density was significantly lower to a depth of 30 cm compared to surface tillage and was 1.27-1.33 g/cm^3 without the introduction of straw, while with shallow tillage was – 1.29-1.41 g/cm^3 and at the surface – 1.28-1.40 g/cm^3 (Table 1). When using side straw, there is a decrease in soil density. When shelf tillage for the soil layer 0-30 cm, the soil density was close to optimal and showed 1.03-1.31 g/cm^3. In the variants with surface tillage, a certain decrease in soil density during the introduction of by-products is observed only for the layer of 0-10 cm, to the depth of which the soil is cultivated. For the layer of 10-20 cm and 20-30 cm, the use of by-products had almost no effect on the density of the studied soil.

Monitoring of the studied soils condition showed that after two rotations there were changes in the main agrochemical parameters. There was a significant decrease in pH_{KCl} in all variants of the experiment. If at the time of laying the stationary experiment the reaction of the soil solution in the arable layer was in the range of 5.2 – 5.4, then, back in 2018 the pH_{KCl} value ranged from 4.8 to 4.3, decreasing by 1.0 – 0.4 units for nine years (table 2).

Table 1 *Soil density depending on tillage and fertilizer systems, May, 2019*

The method of tillage	The usage of straw	Soil layer, cm	Density, g/cm^3
Shelf on 20-22 cm (controlled)	exclusion	0-10	1,27
		10-20	1,30
		20-30	1,33
	fertilizer	0-10	1,03
		10-20	1,25
		20-30	1,31
Shallow on 10-12 cm	exclusion	0-10	1,29
		10-20	1,40
		20-30	1,41
	fertilizer	0-10	1,24
		10-20	1,39
		20-30	1,40
Surface tillage on 6-8 cm	exclusion	0-10	1,28
		10-20	1,38
		20-30	1,40
	fertilizer	0-10	1,24
		10-20	1,40
		20-30	1,41

Table 2 *Change in organic carbon content and soil acidity under the influence of fertilizers and tillage (soil layer 0 – 20 cm)*

Tillage	Fertilizers (per 1 ha of crop rotation on average)	$C_{org.}$, %		pH_{KCl}	
		2009	2018	2009	2018
Plowing at 20–22 cm	$N_{128}P_{90}K_{120}$	1,0	1,01	5,2	4,8
	$N_{128}P_{90}K_{120}$ + 7,2 t/h side products + N_{72}	1,0	0,88	5,2	4,5
Disking at 10–12 cm	$N_{128}P_{90}K_{120}$	1,11	1,25	5,4	4,8
	$N_{128}P_{90}K_{120}$ + 7,2 t/h side products + N_{72}	1,11	1,07	5,4	4,4
Disking at 6–8 cm	$N_{128}P_{90}K_{120}$	1,02	1,15	5,3	4,8
	$N_{128}P_{90}K_{120}$ + 7,2 t/h side products + N_{72}	1,02	1,06	5,3	4,3

The introduction of by-products into the soil on the basis of mineral fertilizers has strengthened the tendency of soil acidification. Thus, if on the variants with different tillage systems we use only mineral fertilizers, at the end of the experiment pH_{KCl} was 4.8, the use of by-products using a compensatory dose of nitrogen fertilizers on plowing reduced pH_{KCl} to 4.5, disking – to 4.4 - 4.3 (table 2). Obviously, the application of a fairly high compensatory dose of nitrogen fertilizers N_{72} was a factor in intensifying the acidification of the soil solution.

According to theoretical calculations, the balance of organic matter for this crop rotation is positive. With the application of complete mineral fertilizer, the balance of organic carbon on the plowing is + 0.18 t/ha, disking at 10-12 cm is + 0.15 t/ha and disking at 6-8 cm is + 0.04 t/ha. The introduction of by-products into the soil has significantly improved the balance of organic carbon. On plowing it was + 0.86 t/ha, disking at 10-12 cm it was + 0.81 and disking at 6-8 cm was + 0.51 t/ha (table 3).

However, the results of real studies of the organic carbon content in the soil showed that in combination with high doses of nitrogen, by-products did not contribute to the accumulation of carbon stocks in the soil. On the contrary, the use of by-products against the increasing soil decalcification has led to a decrease in its content in the soil. Thus, the use of complete fertilizer contributed to the maintenance or some accumulation of organic carbon: while plowing – from 1.0% to 1.01%; disking at 10-12 cm – from 1.11% to 1.25%, disking at 6-8 cm – 1.02% to 1.15%. The use of by-products with the additional introduction of N_{72} mainly reduced the carbon content. At the end of the experiment during plowing the content of organic carbon in the soil was 0.88%, disking at 10-12 cm – 1.07%, disking at 6-8 cm – 1.06%. High doses of nitrogen contribute to the formation of an acid reaction of the soil environment, decalcification of the soil, as a result of which the introduction of by-products does not ensure the reproduction of humus and the mineralization of organic matter, regardless of tillage.

Table 3 *Balance of organic carbon depending on tillage and fertilizer systems in crop rotation, t/ha*

Tillage	Fertilizers (per 1 ha of crop rotation on average)	Losses of humus due to mineralization	Accumulation $C_{org.}$ of humus			Balance +, -
			total	at the expense of		
				Plant residues	straw	
Plowing at 20–22 cm (controlled)	$N_{128}P_{90}K_{120}$	0,66	0,84	0,84	-	+0,18
	$N_{128}P_{90}K_{120}$ + 7,2 t/h side products + N_{72}	0,66	1,52	0,81	0,71	+0,86
Disking at 10–12 cm	$N_{128}P_{90}K_{120}$	0,66	0,81	0,81	-	+0,15
	$N_{128}P_{90}K_{120}$ + 7,2 t/h side products + N_{72}	0,66	1,47	0,79	0,68	+0,81
Disking at 6–8 cm	$N_{128}P_{90}K_{120}$	0,66	0,70	0,70	-	+0,04
	$N_{128}P_{90}K_{120}$ + 7,2 t/h side products + N_{72}	0,66	1,17	0,65	0,52	+0,51

Analysis of the qualitative composition of humus showed that the use of straw and additional nitrogen for fertilizer affected the correlation of humic and fulvic acids, as well as the content of humic acids associated with calcium (table 4). Thus, in the variant with plowing against the application of only mineral fertilizers due to the decrease in the content of humic acids, a significant increase in the share of fulvic acids was observed, the content of which even exceeded the content of humic acids.

Table 4 *Differentiation of quality humus indicators depending on fertilization and tillage (end of the second rotation, 2018)*

Tillage	Fertilizers	Soil layer, cm	% by weight of soil				Humic acids	
			C_{hum}	C_{fulv}	$\frac{C_{hum}}{C_{fulv}}$	Chumin on the rest of the soil	Free and con. to R_2O_3	Con. to Ca
Plowing at 20–22 cm	$N_{128}P_{90}K_{120}$	0-20	0,236	0,249	0,94	0,626	0,203	0,034
	$N_{128}P_{90}K_{120}$ + 7,2 t/h side products + N_{72}	0-20	0,268	0,164	1,63	0,552	0,218	0,050
Disking at 10–12 cm	$N_{128}P_{90}K_{120}$	0-20	0,358	0,228	1,57	0,690	0,298	0,061
	$N_{128}P_{90}K_{120}$ + 7,2 t/h side products + N_{72}	0-20	0,323	0,232	1,39	0,560	0,275	0,048
Disking at 6–8 cm	$N_{128}P_{90}K_{120}$	0-20	0,330	0,216	1,53	0,680	0,266	0,064
	$N_{128}P_{90}K_{120}$ + 7,2 t/h side products + N_{72}	0-20	0,268	0,241	1,11	0,621	0,233	0,035

The correlation of humic to fulvic acids decreased to 0.94 whereas the introduction of straw led to a sharp decrease in the content of fulvic acids from 0.249 to 0.164% and an increase in the correlation to 1.63 (table 4). In addition, regarding the change in the total humus content in two rotations, it can be said that while plowing the use of straw on the mineral fertilizers led to the loss of humus due to the fraction of more labile fulvic acids.

Surface tillage with the use of mineral fertilizers ensured the preservation of soil humus. The proportion of humic acids was much higher than in plowing, and the correlation of humic acids to fulvic acids was 1.53-1.57. The use of straw with the mineral fertilizers in soil disking contributed to a certain increase in the content and proportion of fulvic acids. And the correlation decreased to 1.39-1.11. In the result the content of humic acids bound to calcium decreased in these variants, in contrast to the one with plowing.

Conclusion

The monitoring data of the agroecological condition of the dark-gray loamy soil showed that the long-term use of the mineral fertilizer system led to the intensification of decalcification processes and significant acidification of the soil solution. The use of straw with a compensatory dose of nitrogen fertilizers enhances the acidification of soils.

The use of straw reduces the density of the studied soils. However, due to strong acidification and decalcification of the soil and because of an increase of nitrogen in the total mineral fertilizer dose, the use of straw significantly improved the theoretical balance of organic matter in crop rotation on one hand, but did not actually contribute to the preservation and accumulation of organic carbon in the form of humus on the other. In this fertilization, the greatest decrease in humus content during two rotations of crop was observed during dump tillage, and there was a deterioration in the quality of humus – the proportion of fulvic acids increased and the content of humic acids associated with calcium decreased.

References

Bakht, J.; Shafi, M.; Jan, M.T.; Shah, Z. [2009]. Influence of crop residue management, cropping system and N fertilizer on soil N and C dynamics and sustainable wheat (Triticum aestivum L.) production. *Soil Tillage Res*., 104, 233–240. https://doi.org/10.1016/j.still.2009.02.006.

Budzyak, O.S., Budzyak, V.M. [2018]. Ecologization of use of land in the context of euro integration processes. *Investytsii: praktyka ta dosvid*, 11**,** 5–11. [In Ukrainian].

Calzadilla, A., Carr, T. [2020]. Land degradation and food security: water erosion impacts and adaptation options. *Global Economic Analysis Beyond 2020: 23rd Annual Conference on Global Economic Analysis (online), 17–19 June 2020. 1–24.* Retrieved from https://www.gtap.agecon.purdue.edu/events/Conferences/2020/index.aspx.

Dehodyuk, S., Dehodyuk, E., Litvinova, O., Kyrychenko, A. [2013]. Stratehiya zastosuvannya solomystykh reshtok dlya udobrennya ta enerhetychnykh potreb v Ukrayini. *Visnyk L'vivs'koho natsional'noho ahrarnoho universytetu. Ser.: Ahronomiya*, 17(1), 205-211.

Formuvannya bioenerhetychnykh ahroekosystem v zoni Polissya Ukrayiny (Rekomendatsiyi) [2012]. Naukovo-tekhnolohichne zabezpechennya ahrarnoho vyrobnytstva Livoberezhnoho Polissya. K.: DIA, 248. [In Ukrainian].

Karami, A.; Homaee, M.; Afzalinia, S.; Ruhipour, H.; Basirat, S. [2012]. Organic resource management: Impacts on soil aggregate stability and other soil physico-chemical properties. *Agric. Ecosyst. Environ.,* 148, 22–28. https://doi.org/10.1016/j.agee.2011.10.021. [In Netherlands].

Pysarenko, P.V., Laslo, O.O., Pankova, O.V. [2017]. Agro-ecological territories zoning for the cultivation of organic agricultural products. *Visnyk Dnipropetrovskoho derzhavnoho ahro-ekonomichnoho universytetu,* 4**(**46), 30–33. [In Ukrainian].

Romanenko, O.L., Kushch, I.S., Solodushko, M.M., Zayets′, S.O. [2016]. Dynamika rodyuchosti gruntiv stepu. *Ahroekolohichnyy zhurnal*, 4, 81-89. [In Ukrainian].

Truskavets′kyy, R. S., Tsapko, YU. L. [2016].Osnovy upravlinnya rodyuchistyu hruntiv: monohrafiya. K.: FOP, 388. [In Ukrainian].

Veremeenko, S.I., Semenko, L.O. [2019]. Suchasni problemy dehradatsiyi gruntiv – trofichnyy aspect. *Naukovi horyzonty, ZHNAEU*, 1 (74), 69-75. https://doi.org/10.332491/2663-2144-2019-74-1-69-75. [In Ukrainian].

Vodyanitskiy, Yu.N., Dobrovolskiy, V.V. [1998]. Zhelezistyie mineralyi i tyazhelyie metallyi v pochvah. M.: Pochvennyiy institut im. V. V. Dokuchaeva RASHN, 216. [In Russian].

Yevtushenko, T. V., Tonkha, O. L., Pikovs'ka, O. V. [2018]. Ahrofizychni pokaznyky chornozemu typovoho zalezhno vid udobrennya ta obrobitku. *Naukovyy visnyk Natsional'noho universytetu bioresursiv i pryrodokorystuvannya Ukrayiny. Seriya: Ahronomiya,* 286, 188-196. [In Ukrainian].

Zhang, P.; Chen, X.; Wei, T.; Yang, Z.; Jia, Z.; Yang, B.; Han, Q.; Ren, X. [2016]. Effects of straw incorporation on the soil nutrient contents, enzyme activities, and crop yield in a semiarid region of China. *Soil Tillage Res*., 160, 65–72. https://doi.org/10.1016/j.still.2016.02.006. [In Netherlands].