The ways of increasing of dark-chestnut soil fertility in West Kazakhstan

Vladimir Stepanovich Kucherov[1], Sergei Grigoryevich Tchekalin[2], Maria Maksimovna Fartushina[3], Kazhmurat Maksutovich Akhmedenov[1] and Guldana Zeinullaevna Kairgalieva[1]

[1]West Kazakhstan Agrarian Technical University named of Zhangir Khan, Zhangir Khan Street 51; 090009, Uralsk, Republic of Kazakhstan;
[2] "Uralsk agricultural experiment station" JSC, Barayev Str.,6, 090010, Uralsk, Republic of Kazakhstan;
[3]West Kazakhstan State University named of Utemissov M., Dostyk Ave., 162, 090000, Uralsk, Republic of Kazakhstan.

Abstract: The present research work shows the humus content change due to the long-term anthropogenic impact. In particular, there has been shown the humus content change under various soil treatments: plowing, flat-cutting treatment of 25-27 cm and 12-14 cm, and zero tillage. Involvement of the flat-cutting treatment (25-27 cm) in crop rotation has lead to a significant increase of humus content in soil layer of 0-40 cm in comparison with plowing on the same depth. The research has determined that under the influence of soil treatment in the 4 -field grain-fallow crop rotation with spring cultures a negative humus balance is formed. To eliminate the lack for organic matter it is necessary to add 12-16 t/ha of manure. In production, for the convenience and more effective agrotechnical solution of this problem it is necessary to apply manure in lea, based on the entire crop rotation. In the current situation in the agricultural production of the region, when the manure application is problematic, replenishment of organic matter in the soil can be done by means of the inclusion of perennial grasses in crop rotations. This is confirmed by long-term research.

[Kucherov V.S., Tchekalin S.G., Fartushina M.M., Akhmedenov K.M., Kairgalieva G.Z. **The ways of increasing of dark-chestnut soil fertility in West Kazakhstan.** *Life Sci J* 2013;10(12s):323-328] (ISSN:1097-8135). http://www.lifesciencesite.com. 56

Keywords: Humus, soil fertility, organic matter, soil treatment, organic fertilizer, mineral fertilizer, perennial grasses, soil layer, yield, adaptive cultures

1. Introduction

World farming experience shows that an increase in its productivity is only possible when considering all factors (light, warmth, air, nutrients) that stipulate the growth and development of plants, yield formation and its quality.

According to foreign researchers, the loss of humus in the soil of non-black earth during the long-term use is 13-25% of the original content; in some areas humus' decrease was up to 61-72% [1].

The ability of soil to satisfy the water, nutrients, heat, air, as well as the physical-chemical and biological environment demand of agricultural crops characterizes the fertility of agricultural land.

Soil fertility is the material basis of yields. It is characterized by a complex of chemical, physical-chemical, physical, and biological indicators of soil properties and phytosanitary condition. All the factors of plant life are equivalent, irreplaceable and are in close interaction with each other. Along with this, in order to identify critical periods of precipitation on the wheat crop in rain-fed semi-desert areas of Canadian prairies [2], the correlation of whole growing season between the amount of precipitation and the yield has been analyzed for the first time.

V.A. Kovda and his students initiated the study of soil as an integral part of the biosphere. This approach allows us to estimate the role of vegetation in the formation of soil and vice versa – value of soil in the development of plant communities [3].

Disunity of studies of plants and soil, one-sided approach to the plant as to the sole provider, to the source of economically useful product, leads to yield increase, what, in large part, has the disastrous effect on soil fertility. The problems of the entire set of plants' activity that intensively exhaust the soil, plants – soil dressers, plants – nurses, intensively and selectively clearing the soil of toxic elements, still poorly studied.

The humus content, its quality and qualitative composition are the integral indicators of soil fertility. Humus acts as a natural filter of soil cover.

The practice of the world agriculture has proved that with the intensification of farming systems in the XX century, there was a decrease of arable soil humus reserves by 15-25%. In some cases, losses have reached 40% or more of the original content. A sharp decrease in the cultivated land resistance to pollution arises under the soil degradation process [4].

On the example of sensitive to the adverse effects of sod-podzolic soils of M.F.Ovchinnikova (1991) [5] the chemical, physico-chemical, biochemical degradation, fixed at the agrogenic and

natural- agrogenic effects have been studied, and mechanical degradation, manifested in case of water erosion and man-made impacts.

In order to improve soil fertility and productivity of agriculture it is necessary to implement a set of measures to protect the soil from erosion, to a more wide use of biological nitrogen, organic and mineral fertilizers, pesticides and other means of chemization.

The content and quality of humus is not a stable conservative indicator, and that is why quickly responds to the anthropogenic impact. Humus substances, accumulated in the mud and silt particles vary significantly in composition, properties, forms of linkage with the mineral components, functional features [6,7,8,9,10]. According to the Institute of Soil Science, 4.3 billion tons of humus reserves of topsoil were irretrievably lost in the period of virgin lands exploitation as a result of organic matter mineralization, harvest removal, wind and water erosion of 1.2 billion tones, or 28 and 35 % [11].

Under anthropogenic impact on soil one of the factors, which fundamentally changes the conditions of humus formation and have a significant impact on the character of organic matter transformation is mechanical tillage.

2. Materials and methods.

In the north-west of the country, at the Ural Agricultural Experiment Station the determination of the humus content in the soil depending on the processing system have been implemented in a 4-field grain-fallow crop rotation.

Crop sequence was as follows: naked fallow, spring wheat, spring wheat, and millet (Panicum). The following have been studied in the crop rotation: annual plowing by 25-27 cm, annual flat-cutting processing by 25-27 cm, annual flat-cutting ploughing by 12-14 cm, a "zero" (herbicide) treatment in vapor, and without treatments for a second and a third cultures.

The research results have showed that the major changes in the humus reserves compared with stubble variants have occurred in 0-20 cm of soil layer. The involvement of the flat-cutting treatment into crop rotation by 25-27 cm. has led to a significant increase of humus content in the soil layer in 0-40 cm (Table 1) in comparison with the ploughing on the same depth [12].

Table 1. Content (%) and reserves (t/ha) of humus over 4 crop rotations depending on tillage

Soil layer, cm	Ploughung by 25-27 cm		Flat-cutting treatment by 25-27 cm		Flat-cutting treatment by 12-14 cm		"Zero" treatment		The least substantial difference, 0,05%
	%	t/ha	%	t/ha	%	t/ha	%	t/ha	
0-20	2,06	23,7	2,25	26,1	2,22	25,8	2,20	25,5	0,12
20-40	1,99	24,5	2,06	25,3	2,05	25,2	2,06	25,3	0,10
0-40	2,03	48,2	2,15	51,4	2,13	51,0	2,13	50,8	0,10

According to the State Statistics Committee, about 2.5 million tons of nutrients are annually removed from soil with the yield, and their replenishment is impossible without application of organo-mineral fertilizers and biologization of arable farming.

Strained ecological situations in modern arable farming of some regions, due to the contamination of soil, crop production and environment by the nitrates and their derivatives, as well as by other chemicals, make demands to the development of environmentally safe systems for the agricultural crops fertilizing.

The use of organic and mineral fertilizers, farming biologization – is the main way for soil fertility improvement. By the increasing of yield and root mass, the fertilizers (organic and mineral) increase the positive effect of plants on the soil, contribute to increasing of humus content in it, improve its chemical, water-air and biological properties. A strong root system of perennial grasses also contributes to it.

The current practice of mineral and organic fertilizers application, and farming in general, does not provide a normal level of plants nutrition and does not guarantee the reproduction of soil fertility.

3. Results and discussions.

As a result of research at the Ural Agricultural Experiment Station in cooperation with the Kazakh Institute of Agriculture named of. V.R. Williams, it

has been revealed that under the influence of tillage in 4-field grain-fallow crop rotation with spring crops, a negative balance of humus occurs. In order to eliminate the shortage of organic matter the application of 12-16 t /ha manure is necessary. Therefore there is an urgent need to study the soil fertility considering the balance of organic matter and humus.

Duration of dark-chestnut soil use leads to a reduction of total nitrogen content. Grain-steam 4 and 5 – field crop rotations do not provide a positive nitrogen balance. The increase of naked fallow percentage in grain-steam crop rotations, leads also to a reduction of total nitrogen (in comparison with virgin soil – by 33%). The most effective method of nitrogen reproduction in grain-steam crop rotations – manures application.

It has been determined that in the crop rotations and in monocrops there is a transfer of total nitrogen into the lower layers of the soil profile. According to information received, the nitrogen content in the dark-chestnut soil in Western Kazakhstan has increased, for example, in a layer of 60-100 cm in grain-steam crop rotation and in monocrop of spring wheat- by 1.23-1.32 t / ha. The increase of total nitrogen content in subsurface is due to the migration of nitrates into the deeper layers of soil profile and due to the transition of the part of mineral nitrogen into the hard-hydrolysable and non-hydrolysable forms. Formation of nitrates in the fallow field is directly connected with the biological activity of soil, which was determined in the experiments by the decomposition of linen. In summer period in naked fallows the decomposition of linen fabric in the 0-20 cm layer is more intensive (60 to 80%) than in the 20-40 cm layer (40%). The determining factor of the phosphorus content in soil – is source rock. Dark-chestnut soil in different regions of Kazakhstan contains the same amount of total phosphorus (0,127-0,196%). Due to the agricultural activity its content is reducing. The phosphorus content in dark-brown soils of Western Kazakhstan over 18 years has decreased by 20%. The content of labile phosphorus increases and moves from low class to middle class of medium yield under the long use of phosphate fertilizers, manure, especially in high doses. Calculations of actual changes of total phosphorus in arable soils of rainfed agriculture show that for the creation of positive phosphorus balance in grain-steam crop rotations it is necessary to apply phosphate fertilizers or compensate the application into the steam of organic fertilizers. Systematic application of mineral fertilizers and manure contributes to the large flow of plant residues into the soil and, therefore, to some reduction in the loss of humus. Thus, in Aktobe region in grain-plowing crop rotation the mineral fertilizers (N45 P45 K30) and manure (20 t / ha) were applied for corn.

During 18 years, against the background of nitrogen-phosphorus-potassium fertilizers the humus content in arable layer has increased up to 1.97%, and against the background of manure - to 2.4%, and without fertilizers amounted only to 1.66, with its content of 2 72% in the virgin soil [13].

Tillage in grain-steam crop rotations allows creating the different conditions for the accumulation and decomposition of plant residues. As per the experimental data, a dark chestnut soil under the plowing , approximately over 12 years, accumulates in the layer of 0-30 cm a less amount of crop residues (2.8 t/ha) than under the flat-cutting treatment (3.4 t/ha). The process of linen fabric decomposition goes more intensively under the plowing in grain-steam crop rotations: 13%; under the flat-cutting treatment - a little lower: 11%. Although under the flat-cutting treatment there more plant residues accumulated, their reserve does not make up for the loss of humus under the cultures of grain-steam crop rotation and the humus balance remains negative (530-560 kg/ha).

Long-term studies have proved that for the creation of a positive balance of humus on dark chestnut soils of the Western Kazakhstan in the 4-field crop rotations with spring crops it is necessary to apply 12-16 t/ha of partly-fusty manure. In production process, for the convenience and better agronomic solutions of this problem it is necessary to apply manure into the steam field based on one crop rotation cycle. Using the calculations on the application of manure for the 4-field crop rotations, special experiments were carried out to solve the problem of preservation of soil fertility in 5- field rotations with the application of high-yielding adapted crops. Among the studied 5- field grain-fallow crop rotations by humus accumulation, the crop rotations with the inclusion of winter crops and the placing of the latter by black fallow with plowing of 80 t/ha of manure have an advantage. Only through the use of manure the humus is replenished in the fallow up to 2400 kg/ha and through plant residues - up to 636 kg/ha. At that, its losses are only 1052 kg/ha. Consequently, there are favorable conditions for humus accumulation.

Under the cultures of 5-field crop rotations (steam, corn, millet, spring wheat, barley) an unequal amount of crop residues accumulates. At that, their main part is concentrated in the top of soil layer (0-20 cm). The winter crops surpass the spring wheat in the accumulation of organic matter. This difference (on an average) is 0.4-2.2 t/ha. The black pairs (with and without the manure application) (Table 2).

Table 2. The dynamics of humus in the soil of 5-field grain-fallow crop rotation, t/ha

Fallow	Soil layer, cm	Humus reserves		Humus balance in rotation
		at the beginning of rotation	at the end of rotation	
Black with flat-cutting treatment	0-20	46,87	47,52	+0,65
	20-40	48,61	46,02	-2,59
Green	0-20	46,87	47,08	-0,21
	20-40	48,61	44,84	-3,77
Black with tillage 80 t/ha	0-20	46,87	54,43	+7,65
	20-40	48,81	50,97	+2,36

Mineral fertilizers also have a beneficial effect on the accumulation of crop residues. At their application an increase of plants biomass, yield and, therefore, delivery to the soil of plant residues were observed.

Mineral fertilizers exercised the greatest influence upon the accumulation of organics against the background of organic fertilizers. The annual intake of organic residues per hectare of crop rotation area was 6.6-6.9 t/ha, with 5.3 in black fallow, with the flat-cutting basic cultivation.

Final humus content depends not only upon the intake of an organic substance, but also upon the intensity of mineralization of the latter, which, in turn, depends on the biological activity of soil. The latter was determined in experiment on the decomposition of linen and varied under the cultures of crop rotation. Thus, in crop rotation with black fallow, decomposition of linen is reduced in the layer of 0-40 cm, from 23 to 13% with distance from the first field.

In rotation with manure plowing in fallow field the biological activity of soil is above. During three years it was 31-32%. So, in the crop rotation with manure plowing the best conditions for the formation of new humus substances were created, and the actual content of humus in the arable layer has increased (Table 3).

Table 3. Changes in humus content (%) in dark-chestnut soil over the first and second circles of grain-steam crop rotations depending on fertilization (layer 0-40 cm)

Variant	Humus content					
	After the first rotation (1982-1986)			After the second rotation (1987-1991)		
	fall rye	winter wheat	spring wheat	fall rye	winter wheat	spring wheat
Black fallow (control)	1,81	1,83	1,85	1,77	1,8	1,81
The same + mineral fertilizers	1,84	1,93	1,91	1,8	1,86	1,85
Black fallow with plowing of 80 t/ha of manure	2,05	2,09	2,04	2,16	2,15	2,1
The same + mineral fertilizers	2,16	2,08	2,09	2,23	2,2	2,18
HCP05	0,21	0,18	0,18	0,19	0,2	0,19

Based on data about the level of the multiple regressions (model), it can be assumed that such indicators as mobile humus, nitrification power, productive moisture and bulk density are the dominant features of dark-chestnut soil in the formation of grain yields in the Ural steppes.

The experiment succeeded in obtaining higher yield of winter wheat, spring wheat and winter rye as per the black fallows, where the mineral fertilizer elements have been added.

Manure application into the fallow had an aftereffect, especially on millet and barley. The yield increase accounted here for 2.9-3.8 t/ha.

The results of observations over the all research years show that the highest yield of winter crops is being provided by winter seeding (17,5-22,4 t/ha). The best predecessor for them is the black fallow with the manure plowing. With the removal of crops from fallow the effect of organic fertilizers reduces (Table 4).

The application of mineral fertilizers usually contributed to the growth of productivity of all the crops. However, they did not always provide the projected level of productivity.

The highest yield from mineral fertilizers has been achieved in crop rotations with black flat-cutting steam and with placing of winter crops along them. In this case each kilogram of the active substance NP provided 3.4 kg of grain increase.

Table 4. Yield (dt/ha) of cereal crops in crop rotations (average for 1989 - 1994)

Variant	As per fallow		As per winter tillage		
	fall rye	winter wheat	millet	spring wheat	barley
Black fallow	26,3	19,6	16,2	8,3	13,4
The same + mineral fertilizers	28,3	21,8	17,5	8,7	14,4
Black fallow with chaff	25,6	19,1	15,2	7,8	13,4
The same + mineral fertilizers	25,7	21,0	17,0	8,3	14,4
Black fallow with manure plowing	28,8	26,0	19,1	9,3	17,2
The same + mineral fertilizers	28,3	25,8	19,8	9,2	17,3

In 1986, the station was plowed, and the next year it was sown by perennial grasses (wheat grass + alfalfa + melilot + sainfoin) after 15 years; 3 rotations nominally, the humus content by layers have been defined. In layer of 0-20 cm it (humus) amounted to - 1.68% as per the black fallow. According to the fallow, where the manure was applied before – 3.86% and 1.78% respectively. In the second case, a previously induced manure had a positive impact on the growth and development of grasses and, consequently, on the accumulation of organics.

4. Conclusions. Thus, in severe weather conditions, in which the West-Kazakhstan is located, for the cost-effective management of field-husbandry it is necessary to take into account the biological capacity of the cultivated adapted cultures. In other words, diversify of agricultural production is required for the saturation of crop rotations with field crops, as well as with perennial grasses.

For the first time the problems of soil fertility study in Priuralie, under the seedings of perennial grasses were touched at the Ural Agricultural Experiment Station in the 30's by N.V. Orlovsky, and in the 40s – by N.A. Korneev. After the classical studies of P.A. Kostychev, the balance of humus, nitrogen and phosphorus was re-considered, as per the crop rotation links. The carried out works have convincingly proved the feasibility of the soil fertility restoring by cultivation of perennial grasses. Further, perennial grasses, which mainlt consist of wheat grass in the north-west of the country, have always been paid a great attention. Their area on the arable land reached up to 146 thousand hectares (1977), and on the lands of indigenous improvements - 356.7 thousand hectares (1989), which is 8% in the first case of the arable area in crop rotations, and 18% of the arable land in treatment. In some years, the average yield of seeds hay in region reached 11.0 dt/ ha. The production norms of the Ural Agricultural Experiment Station – is 21. 6– dt/ha.

Perennial grasses - is the most important factor of agriculture biologization. Introduction of perennial grasses into the field allows improving of soil fertility.

According to the observations of the Ural Agricultural Experiment Station, conducted in 2003, the humus content of the soil in layers of 0-20 and 20-40 cm under the perennial grasses (wheat grass 12 years) was 3.07 and 2.78% in 5-field grain-fallow crop rotation (one rotation) –2.82 and 2.76% respectively. On the old arable lands of humus there were 2.50 and 2.16%.

With the current state of affairs in agriculture, when the application of manure to fields is a problem, the expanding of perennial grasses acreage on the plowed field will significantly reduce the loss of humus, and if there is a sufficient area of grass the soil fertility stabilizes.

Corresponding Author:
Dr.Kucherov,
West Kazakhstan Agrarian Technical University named of Zhangir Khan, Zhangir Khan Street 51;
090009, Uralsk, Republic of Kazakhstan

References

1. Swift R.S., 1996. Organic matter characterization. Methods of soil analysis. Part 3. Chemical methods. Ed. D.L. Sparks. SSSA Book Series. #5.pp: 101-106.
2. He, Yong, Wei, Yongsheng, DePauw, Ron et. al., 2013. The Yield of spring wheat in the semiarid Canadian prairies: effects of precipitation, time and the soil texture in the past 30 years. FIELD CROPS RESEARCH Journal. Volume: 149 pp: 329-337

3. Kovda V.A., 1973. Fundamentals of soil, Moscow, “Nauka” publishing house.
4. Fedorin Y.V., 1988. Humus state of the arable land soils. “Zemledelie”, pp: 40.
5. Ovchinnikova M.F., 1991. The influence of different factors on properties, humus status and bioproductivity of soddy podzolic soils. Proceedings of the X international symposium “Humus et Planta”, Prague.
6. Blair, G.J., R.D.B. Lefroy , L. Lisle, 1995. Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for the agricultural system. Australian Journal of Agricultural Research 46, pp: 1459–1466.
7. Tarchitzky, J., Y. Golobati , R. Keren & Y. Chen, 1999. Wastewater effects on montmorillonite suspensions and hydraulic properties of sandy soils. Soil Sci. Soc. Am. J. 63, pp: 554–560.
8. Laird, D.A., D.A. Martens , W.L. Kingery, 2001. Nature of clay-humic complexes in an agricultural soil. Chemical, biochemical, and spectroscopic analyses. Soil Science Society of America Journal. 65, pp: 1413–1418.
9. Chefetz, B., M.J.Salloum , A.P. Deshmukh, P.G. Hatcher, 2002. Structural amounts of humic acids as determined by chemical modifications and carbon-13 NMR, pyrolysis-, and thermochemolysisgas chromatography/mass spectrometry. Soil Science Society of America Journal 66, pp: 1159–1171.
10. Talli Ilani, Elke Schulz, and Benny Chefetz, 2005. Interactions of Organic Compounds with Wastewater Dissolved Organic Matter: Role of Hydrophobic Fractions. Reproduced from Journal of Environmental Quality. Published by ASA, CSSA, and SSSA. Published in J. Environ. Qual. 34:552–562, pp: 552 -562.
11. Akhanov Z.U., et.al., 1997. The problems of soil fertility restoration in Kazakhstan. In: The condition and the rational use of fertilizers. Almaty, pp: 8-14.
12. Kucherov V.S., S.G. Chekalin, 2005. Basics of the fertility optimization of the dark -chestnut soils of West Kazakhstan. Proceedings: Ecology and steppe management. Uralsk, pp: 165-174.
13. Kucherov V.S., S.G. Chekalin, 2000. Increasing the productivity of the dry steppe agro-ecosystems. Uralsk, pp: 96.

15/11/2013