Ways of Increasing the Grain Crops Yield under the Farming Biologization

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Abstract: In recent years the strengthening of anthropogenic impact onto an arable land, an unsystematic use of land and the lack of measures to preserve the fertility have led to the intensive soil degradation. In this regard, the priority direction was the increase of in the plant growing productivity and quality of crops while preserving the soil fertility by the biological factors activating that do not violate the natural essence and the ecological balance of agro-ecosystems. With the comprehensive research we could find an influence of organic fertilizers (animal manure, a straw, green manures) on the crop yields. In the conducted researches we have studied the dependence of crop yield on the conditions of their moisture provision, agrophysical and agrochemical indices of the dark chestnut soil.

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1. Introduction

Currently, with a relatively low application level of mineral fertilizers the ecological and energy expenses per unit of production have reached the highest rates due to imperfection of production relations and the low technological culture. Obviously, in these conditions the problem solving of soil fertility management in general, and the regime of organic matter in particular, as well as the productivity of grain crops shall be start with a search of cheaper, less energy intensive ways to complement the stock of humus in the soil.

The research conducted at the Russian Institute of fertilizers showed that the animal manure application into a clean steam at the rate of 30 t/ha provided the hard spring wheat yield increment of 3.2 t/ha compared with the control. The use of organic fertilizers on the southern black soils increases the crop rotation productivity in proportion to the dose of manure. At an annual crop rotation saturation with the manure at a dose of 3.3; 6.6 and 10 t/ha the increment is 2.2, 3.2 and 3.6 t/ha of grain units, respectively [1].

However, to ensure the requirement of organic fertilizer at the expense of animal manure is not possible and even more difficult task from a technical point of view. At the manure output from the livestock population can cover not much more than a half of the field requirement, and sometimes even less. This brings up the question of finding the alternative ways of regulating the soil fertility. In solving this problem is important to leave the straw when grain crops harvesting. On the one hand it is a resource-saving way in the technology of cultivation of grain crops, as you should not spend money to collect and transport straw from the field; on the other hand – the organic matter of straw renders a multilaterally positive influence on the physical, chemical and biological indices of the soil fertility and people everywhere attach it the great importance as an organic fertilizer. On average, over 14 years of research the straw yield from three fields of grain crops in the crop rotation with winter crops over the steam amounted to 109.5-113.5 dt/ ha, which is by 28.4-32.2 dt more than in the crop rotations with the spring crops. On the background of prolonged use of straw as an organic fertilizer in the grain steam crop rotations with a short rotation we observed the expanded reproduction of soil fertility [2, 3, 4].

In this context the great interest are also have the green manure grains. Sowing of green manure crops, their grinding and plowing does not require large material and labor costs. The green manure crops identified as the cheapest, environmentally beneficial and prospective organic fertilizers. The use of green manure crops helps to increase the crop yields. The use of winter rape as the green manure crops influenced the growth and development of tobacco and ensured the increase the harvests of tobacco leaves by 4.7 dt/ha [5, 6]. In the experiments conducted in different countries we also noted the positive impact of green manures on the crop yields, as well as on the properties of soil [7, 8, 9, 10].

2. Methods.

The researches were conducted in the West Kazakhstan Agro-Technical University named after Zhangir Khan in 2005-2012 years in the grain crop rotation with the crop sequences: steam - a winter wheat *(Triricum aestivum)* – a spring wheat *(Triticum aestivum)* – a barley *(Hordeum sativum)*. The trial was established in 2004. Prior the trial establishment the barley was cultivated on this site.

We studied different types of fertilizers: the control with no fertilizers; a mineral fertilizer: steam (P60) – a winter wheat (N30) – a spring wheat (N20P20) – a barley (N20P20); an organic fertilizer: steam (manure 40 t/ha) – a winter wheat – a spring wheat (a winter wheat straw) – a barley (a spring wheat straw); an organo-mineral fertilizer: steam (manure 40 t/ha) – a winter wheat (N30) – a spring wheat (N20P20+ a winter wheat straw) – a barley (N20P20+ a spring wheat straw); a green manure: sweet clover (a siderate) – a winter wheat – a spring wheat (manure 40 t/ha) – a barley (a spring wheat straw).

The soil of pilot area is a dark chestnut and heavy loamy. The topsoil contains of 2.8-3.1% humus. The accumulation of carbonates was mentioned in the lower part of the mountains. B2 with a maximum of in the horizon IC (70-80 cm). The total absorbed bases in a layer of 0-10 cm is 27.8-28.0 mEq per 100 g of soil. At the beginning of the trial the content of agronomically valuable structural aggregates was 60.0%, the density of the arable layer is 1.22 g/cm3, the porosity is 51.5%.

The area of working plots is 100 m2; the four-time tier; the working plots location is randomized. We used the adopted for the West Kazakhstan region agrotechnics for the grain crops cultivation.

In the experience were studied he released varieties of crops: a winter wheat – Mironovskaya 808, a spring wheat – Saratovskaya 42, a barley – Donetskii 8, a sweet clover – Kaldybansky.

The soil treatment was conducted with the spreader plough with the plough-points to a depth of 25-27 cm. The winter wheat was harrowed with the middle harrows ZBZT-1. The pre-sowing cultivation was carried out at all early spring crops after the harrowing to a depth of seed placement. The sowing was carried out with a seeding-machine SZS-2, 1 with a simultaneous packing.

Among the mineral fertilizers we used an ammonium nitrate N_{aa} and double superphosphate P_{sd}.

As a green manure the yellow sweet clover *(Mellilotus officinolis)* was tilled. The sowing was produced under the cover of barley. The next year in a phase of flowering, the sweet clover was plowed to a depth of 25-27 cm. After plowing the plot was treated with the heavy disk harrows BDT-3, and then was packing with the star-wheeled rollers.

The weather conditions in the years of carrying out of researches were characterized at the long-time average annual level indices.

The plants were grown to the technological maturity. During the ontogeny the observation of their growth and development was carried out. The harvesting was carried out working plot by working plot.

The Statistical Evaluations of the research were carried out along to the method of Dospekhov [11].

3. Main body.

The fertilizers, improving the conditions of mineral nutrition of plants, create the favorable conditions for the yield formation. The positive impact of fertilizers at improving crop yields is undeniable. The essence of the rational use of fertilizers lies in the fact of making exactly as much nutrients as required for the formation of planned yield of high quality, while avoiding the loss of soil fertility and the environmental pollution.

The winter wheat was sown in the first four variants after the steam predecessor. In the second was introduced 60 kg of active substance phosphate fertilizers, in the third - 40 t/ ha of manure, in the fourth - 40 t/ ha of manure in combination with 60 kg of active substance phosphate fertilizers. In the fifth variant, was plowed a green manure in the form of sweet clover that was sow in the crops of barley, and during May and June increased to 20-25 t/ha of green mass, which is rich in nitrogen and moreover, kept up to 7-9 t/ha of stubble and root residues. During the years of second rotation of winter wheat yield on the control, depending on the weather conditions of the agricultural year amounted to 10.5-28.0 dt/ha (Table 1).

Table 1. Winter wheat grain yield on the options of experience over the years of the second crop rotation, dt/ ha

Fertilizer systems:	Years:			On average
	2010	2011	2012	
Control (no fertilizers)	10,5	25,7	28,0	21,4
Mineral	10,8	27,0	30,0	22,6
Organic	11,3	28,0	31,2	23,5
Organo-mineral	11,8	28,8	32,0	24,2
Green manure organic	11,0	27,5	30,5	23,0
SMD_{05}, dt / ha	0,26	0,17	0,17	

When we made the mineral fertilizers dressing the winter wheat yield, depending on the year, ranged from 10.8 to 30.0 dt/ ha, or compared to the control was higher by 2,9-7,1%. The manure application into the fallow field increased the yield of winter wheat compared to the control by 7.6-11.4%, or from 11.3 to 31.2 dt/ha. At a combination of manure with the mineral fertilizers the winter wheat yield in 2010 was 11.8 dt/ha, in 2011- 28.8 dt/ha, and in 2012 - 32.0 dt/ ha, what compared to the control is more by 12.4, 12.0, 14.3% respectively. The sweet clover burying increased the winter wheat grain yield slightly less than the manure.

Under the conditions of dry 2010 epy yields in this variant was 11.0 dt/ha, in comparison with the control higher by 4.8%.

Under the conditions of favorable 2011 and 2012 the winter wheat seeded after the sweet clover ensured the yield to 27.0 and 30.5 dt/ ha, it is, in comparison to the control, higher by 7.0 and 8.9%, respectively by year.

The yields ranged by years, greatly, due to the different provision of winter wheat with the moisture. The close correlation link of rainfalls with the yield of winter wheat, which was changed by periods of vegetation, was noted. The correlation coefficient of the winter wheat yield values (y1, y2, y3) with the amount of rainfalls (x1) for the autumn - winter and early spring periods (September-April) was equal to 0,711_ with the amount of rainfalls in May (x2) - 0,638, with the amount of rainfalls for May-August (x3) - 0,647.

The polynomial equation of these dependencies had the following form:

$y_1 = - 88,575 + 2,100x_1 - 0,0175x_1^2 + 6,32*10^{-5}x_1^3 - 8,24*10^{-8}x_1^4$;(1)

$y_2 = - 0,850 + 0,514x_2 - 0,018x_2^2 + 2,5*10^{-4}x_2^3 - 1,17*10^{-6}x_2^4$; (2)

$y_3 = - 8,379 + 0,319x_3 - 3,28*10^{-3}x_3^2 + 1,4*10^{-5}x_3^3 - 2,23*10^{-8}x_3^4$.(3)

From the solution of the equations we can be see that the maximum grain yield is provided at occurrence of rainfalls in September - April in an amount of not less than 240 mm, and in May-August, at least 160 mm. The winter wheat yield in the conditions of experiment was dependent on the rainfall for 40-50%.

The dependence of yield from the nitrogen and phosphorus content in the soil layer of 0-30 cm was noted. The correlation coefficients in this case amounted to 0.728 and 0.928. The dependence was expressed by the polynomial equations of third order. For the nitrogen, it had the following form:

$y = 13,632-12,944x_1 + 4,651x_1^2 - 0,505x_1^3$, (4)

and for the phosphorus, containing in the 0-30 cm layer:

$y = 7,666 - 6,854x_2 - 2,478x_2^2 - 0,252x_2^3$,(5)

where y – is a winter wheat grain yield, dt/ha;

x_1, x_2 – is a nitrate nitrogen and a labile phosphorus content, mg per 100 g of soil in a layer of 0-30 cm.

The soil density was also influenced to the winter wheat yield. The correlation coefficients of these values were equal to 0.625. The polynomial equation of fourth order had the following form:

$y = - 56,071 + 59,871x + 37,611x^2 - 37,910x^3 - 4,632x^4$, (6)

where y – is a winter wheat grain yield, dt/ha;

x – is a soil density, g/cm^3.

The solution of the equation shows that the optimal soil density for the winter wheat on the dark chestnut soils is 1,10-1,17 g/cm^3. When the soil packing to this value, the winter wheat yield was increased and after that it began to fall.

The influence of valuable agronomic structure on the grain yield of winter wheat was expressed by the polynomial equation:

$y = 27,583 - 1,006x + 1,529*10^{-2}x^2 - 7,081*10^{-5}x^3$. (7)

The optimal agronomically valuable soil structure (10-0.25 mm) for the winter wheat should be considered as 75-80%.

The spring wheat, seeded after the winter wheat on the second crop rotation field, significantly increased the grain yield under the influence of applied fertilizers. As the winter wheat yield, as the spring wheat yield was dependent on the weather and climatic conditions of the year. Under the conditions of the arid year 2010 the spring wheat grain yield on the control was 7.0 dt/ha, with the mineral fertilizers dressing - 7.2 dt/ ha, i.e. a slight yield increase.

With the manure application and with the combined application of organic and mineral fertilizers the spring wheat yield, compared to the control, was higher by 10,0-11,4% or amounted to 7.7 and 7.8 dt/ha, respectively. With the of sweet clover burying, the yield increased to 7.9 dt/ha, or compared to the control was higher by 12.9%.

In the favorable conditions of 2011 and 2012 agricultural years, the spring wheat yield under the control was 20.0 and 23.7 dt/ha. If we compare the dry year of 2010 with the favorable moisture 2011 and 2012 years, the spring wheat grain yield, while dressing the mineral, organic and green manure fertilizers, was high. Thus, when the mineral fertilizers dressing the grain yield compared to the control was higher by 7,5-11,8% (Table 2).

Table 2. Spring wheat grain yield on the options of experience over the years of the second crop rotation, dt / ha

Fertilizer systems:	Years:			On an average
	2010	2011	2012	
Control (no fertilizers)	7,0	20,0	23,7	16,9
Mineral	7,2	21,5	26,5	18,4
Organic	7,7	22,2	26,5	18,8
Organo-mineral	7,8	22,3	26,9	19,0
Green manure organic	7,9	22,7	27,3	19,3
SMD_{05}, dt / ha	0,17	0,33	0,46	

The application of manure increased the grain yield to 22.2 and 26.5 dt/ha or in comparison to the control to 11.0-11.8%. At the combined application of manure and mineral fertilizers, the spring wheat grain yield in 2011 was 22.3 dt/ ha, and in 2012 - 26.9 dt/ ha, which is, in comparison with the control, more by 2.3 and 3.2 dt/ha. In the variant with the plowing of green mass of sweet clover, in 2011 the spring wheat grain yield was 22.7 dt/ ha, which is, in comparison with the control, higher by 13.5%, and in the conditions of 2012, respectively, by 15.2%.

The close correlation of grain yield for the spring wheat on the amount of rainfalls was revealed. The closest correlation was with the rainfalls during the vegetation period (May-August). Here, the correlation coefficient was 0,571. Less close correlation was made with the rainfalls separately in May (0.221) and from September to April (0,239). The solution of the equations shows that to get the grain yield of soft spring wheat is required the amount of rainfalls for May-August at least 180 mm, including for May not less than 60 mm, September-April, at least 180 mm.

The dependence of grain yield for the spring soft wheat on the content of nitrate nitrogen and the labile phosphorus in the soil was revealed. The correlation coefficients of these indices respectively equal to 0.965 and 0.940.

Equations of relationship:

$y= - 0,183 + 0,513x_1 + 0,227x_1^2 - 0,0441x_1^3$, (8)

$y= - 91,013 - 68,316x_2 - 16,617x_2^2 - 1,339x_2^3$, (9)

where y – a spring wheat grain yield, dt/ha;

x_1, x_2 – nitrate nitrogen and labile phosphorus content, mg per 100 g of soil in a layer of 0-30 cm

The spring soft wheat yield dependence on the soil density was characterized by a correlation coefficient - 0.539, and the following equation:

$y = - 30,609 + 53,615 - 15,630x^2 - 4,500x^3$, (10)

where y – a spring wheat grain yield, dt/ha;

x – a soil density, g/cm^3.

The solution of the equation shows that the best soil density for the development of soft wheat accounted 1.15-1.18 g/cm^3.

The Interrelation of yield (y) with a number of agronomically valuable structural aggregates (x), was characterized by the correlation coefficient of 0.580 and the regression equation:

$y= -2043,124+85,218x-1,171x^2+5,310*10^{-3}x^3$.(11)

The solution of the equation shows that the optimal number of structural aggregates on the chestnut soils for the spring wheat is 70-80%.

Barley.

The barley yields on the control in the conditions of 2010 was 8.0 dt/ ha, in 2011 - 23.4 dt/ha and in 2012, - 25.0 dt/ha. In the second variant, using the mineral fertilizers depending on the year the barley yields ranged from 8.1 to 25.6 dt/ ha, or in comparison to the control was higher, respectively, by 1.3 and 2.4%

The application of manure increased the barley yield in 2010 to 8.4 dt/ ha, or compared to the control by 0.4 dt/ha, in 2011 - to 24.8 dt/ ha, compared to the control by 1.4 dt / ha or by 6%. In 2012 these differences compared to the control was 1.8 dt/ha or 7.2%.

At a combination of manure with the mineral fertilizers, the barley grain yield depending on the year ranged from 8.5 to 27.1 dt/ha, the differences compared to the control from 6.3 to 8.4% (Table. 3).

Table 3. Barley grain yield n the options of experience over the years of the second crop rotation, dt/ha

Fertilizer systems:	Years:			On average
	2010	2011	2012	
Control (no fertilizers)	8,0	23,4	25,0	18,8
Mineral	8,1	23,9	25,6	19,2
Organic	8,4	24,8	26,8	20,0
Organo-mineral	8,5	25,0	27,1	20,2
Green manure organic	8,7	25,5	27,3	20,5
SMD_{05}, dt/ha	0,27	0,23	0,40	

The incorporation of green mass of sweet clover significantly increased the barley yields. Thus, in this variant, the barley yields ranged from 8.7 to 27.3 dt/ha. Compared with the control, in 2006 the yield was higher by 0.7 dt/ha or 8.8%; in 2007 - by 2.1 dt/ha or 9.0%; in 2008, respectively - by 2.3 dt / ha, or 9.2%.

By years the barley yield was well correlated with the rainfalls, especially in May and August. The correlation coefficient of considered values in this period was equal to 0,486. For the rainfalls in May it was 0,644, and for the autumn-winter-spring rainfalls (September-April) - 0,223. This agrees with the biology of growth and development of barley as the early spring culture.

The dependence of yield barley on the content of nitrate nitrogen and labile phosphorus in the soil was revealed. It is characterized by the correlation coefficients of 0.991 and 0.873. The regression equations had the following form:

for nitrogen

$y = 7,274 - 5,177x_1 + 1,487x_1^2 - 0,131x_1^3$,(12)

and for phosphorus

$y = - 3,857 + 1,508x_2 + 0,183x_2^2 - 0,0497x_2^3$,(13)

where y – is a yield, dt/ha;

x_1, x_2 – is a nitrate nitrogen and labile phosphorus content, mg per 100 g of soil in a layer of 0-30 cm.

The barley grain yield dependence on the soil density was characterized by a correlation coefficient - 0,878 and the following regression equation:

$$y = 11{,}237 - 52{,}688x + 74{,}846x^2 - 30{,}277x^3, \quad (14)$$

where y – is a grain yield, dt/ha;

x – is a soil density, g/cm^3.

The solution of the equation shows that the optimal dark chestnut soil density for the barley is 1.14–1.18 g/cm^3.

The soil pedality significantly affected on the barley yield. The correlation coefficient for the relationship of those indices was 0.782. The regression equation had the following form:

$$y = 23{,}063 - 0{,}897x + 0{,}012x^2 - 5{,}645 \cdot 10^{-5}x^3. \quad (15)$$

The solution of the equation showed us that the optimal number of structural units for the growth and development of barley was 70–83%.

4. Conclusion. After many years of comprehensive research in the conditions of the West Kazakhstan we could develop the plant growing biologization techniques that ensure the sustainable harvesting with a high product quality and the performance indicators.

The obtained results give us the reasons to believe that the use of biological receptions, namely, the application of organic fertilizers (animal manure, straw and the green manure crops) provides an increase in the grain crop yields.

When applying the animal manure and a straw, the grain yield from the crop rotation areas, compared to the control, increased by 2.8 dt/ha, the crude protein yield increased by 0.52 dt/ha, the fodder units yield increased by 4.2 t/ha, and when we used a sweet clover as a green manure crops it was increased by 3.1; 0.50 and 3.7 dt/ha, respectively.

5. Findings.

Under the conditions of the West Kazakhstan region, it is advisable to use the biological resources in farming, namely the organic (animal manure, straw) and the green manure (sweet clover green manure) fertilizers, to preserve the fertility of dark chestnut soils and to increase the grain crop yields.

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