Economic efficiency of mineral fertilizers use in grain and steam crop rotation

A M Plotnikov and A V Sozinov
Kurgan State Agricultural Academy named after T S Maltsev, KGSHA, 15, Lesnikovo, Ketovo district, Kurgan region, 641300, Russia
E-mail: savrey@ya.ru

Abstract. The results of economic efficiency of mineral fertilizers application in grain and steam crop rotation in the conditions of Zauralie are presented. Agronomic efficiency has been determined, in which the payback of 1 kg of active substance (e.g.) of fertilizers applied to the variant with the use of three batteries averaged 1.7 - 1.9 kg for 3 years, the maximum payback was observed in the variant with a minimum dose of P40 - 2.6 kg/kg. Calculation of economic efficiency has shown that at increase in a dose of mineral fertilizers and industrial expenses there is a decrease in a recoupment on 0.16-0.30 rbl.

1. Introduction
In the conditions of modern agricultural production the fertility of black earths is constantly decreasing. Reduction of humus reserves, content of available forms of nutrients is observed, soil absorbing complex and soil structure is destroyed [1-3]. Such unfavorable processes have led to changes in the nutrient regime, agrophysical properties of soils, which ultimately affects the value of crop yields [4].

The problem of anthropogenic load on the soil is very topical today. One aspect of the anthropogenic load on the soil is intensive agricultural activity. In case of constant changes in the basic soil properties over time and space, the modern system of agriculture should be oriented towards the issues of soil fertility use, conservation and maintenance, as well as land resources protection [2, 5].

The chemical composition of soils is one of the main factors of soil fertility. Currently, 20 cells are installed, which are related to the required batteries. These are nitrogen, phosphorus, potassium, calcium, magnesium, sodium, iron, carbon, oxygen, hydrogen, sulfur, chlorine, copper, zinc, boron, molybdenum, iodine, manganese, cobalt, vanadium. In addition, 12 elements are considered conditionally necessary: silicon, aluminum, silver, lithium, nickel, fluorine, lead, titanium, strontium, cadmium, chromium, selenium [1, 6].

Rational system of fertilizers is a scientifically grounded complex of agronomic and organizational measures on ecologically safe and economically efficient use of fertilizers in order to increase crop yields, improve the quality of commercial products, preserve and expand soil fertility. The effectiveness of fertilizers, the degree of their impact on crop yields depends on the biological characteristics of crops, climatic conditions and the level of soil fertility, the precursors of the crop, the system of plant protection, the ratio and doses of elements in fertilizers, timing and methods of their application. In turn, the effectiveness of each of these factors is closely related to the use of mineral fertilizers [6-9].

At the same time, it is equally important to solve the problem of increasing the efficiency of mineral fertilizers, which, along with the provision of yield increases, should have a high economic return.
For the development of more advanced, less energy-intensive methods and technologies for the use of fertilizers, it is important to comprehensively evaluate them, taking into account the agronomic, economic and energy efficiency. The analysis of the actual payback, payment and economic efficiency of fertilizers application allows to reveal the reserves of their increase in the conditions of agricultural production at different levels of management: farm, district, region [7].

In this regard, the purpose of our research was to study the effectiveness of various types and norms of mineral fertilizers in the cultivation of grain crops in the Kurgan region.

Currently, for the forest-steppe zone of the Zauralie, scientifically based systems of fertilizers, crop rotations and soil treatment have been developed [4, 10].

2. Materials and methods

On the territory of Russia, in the forest-steppe zone, black earth soils as a type are represented by three subtypes: podzolized, leached and typical black earth soils, the distribution of which is subordinated to latitudinal zonality. The northernmost subtype is the podzolized chernozems in the Kurgan region, which is not widespread. The subzone of podzolized chernozems is well expressed to the north, on the territory of the Tyumen Region. Typical black earths in the Kurgan region are not identified. Alkaline and ordinary black earths occupy 2149.7 thousand hectares or 30.3% of the total area. The following types in the subtype of common chernozems on the territory of the region: common, saline, saline carbonate, carbonate, solodized, deep boiling. In the Kurgan Oblast, the arable area for a long time was 3 million hectares, now - 2.4 million hectares. Chernozems, i.e. leached and common saline soils, predominate in the arable land [3, 11].

In 2014, the pilot field of FGBOU VPO Kurgan State Agricultural Academy on the chernozem of leached light loamy granulometric composition was used for short-term stationary experience in studying the effect of mineral fertilizers on grain yield in grain and steam crop rotation and economic efficiency of their application.

Placement of variants in the experiment is randomized and repeated four times. Record plot area in the experiment 12.5 m² (2.5x5 m).

The scheme of experience represents a matrix of full factorial experiment. Two-factor field experience was put in place for the research: factor A - nitrogen-potassium fertilizers (N40K40 and background without fertilizers), factor B - phosphate fertilizers (P40, P80 and control). On each background there are three variants with different doses and combinations of nitrogen (ammonium nitrate (34.6 %) in doses N40), phosphorus (superphosphate simple (26 %) in doses P40 and P80) and potassium fertilizers (potassium chloride (60 % B.V.) in dose K40).

The experiment included wheat (Triticum aestivum L.), Zygolewskia and barley (Hordeum vulgare L.), Prairie variety in 4-fold crop rotation with alternation of crops: fallow field - spring wheat - spring wheat - barley.

The amount of spring wheat and barley seeds was calculated based on the sowing rate of 5 million germinated grains per hectare. Sowing was carried out by the sowing complex APP-7.2.

The main and by-product yields were recorded manually from each plot using the trial sheave method and after weighing they were converted into t/ha at a standard humidity of 14 % and 100 % purity.

The climate of the Zauralie is significantly influenced by its location inside the mainland. The Ural Mountains prevent the penetration of warm and humid air masses from the Atlantic, while the dry cold air of the Arctic Ocean and dry warm air from Kazakhstan and Central Asia are constantly entering the region, defining the climate as sharply continental [3].

Weather conditions during the growing season 2014 were unfavorable for wheat - in the initial period of development high temperatures were recorded - by 3-5 degrees above average perennial. Absence of precipitation and drought was observed until the end of June - the hydrothermal coefficient (HTC) was 0.3. Later on, low air temperatures and heavy precipitation of different intensity prevailed during three weeks of July. July 2014 was the coldest and wettest year for SCC - 2.9. August was 1.7°C warmer, with 66.5 mm of precipitation. In 2015, the mean monthly air temperature in May and June was higher by 1.6 - 3.7°C. Precipitation was 59.4 mm, which was 212.1% of the average monthly temperature. In
June, precipitation was 24.1 mm, which is 40.8% of the monthly average. Cold weather prevailed in July and August, with average daily temperatures 1.7-2.0°C lower, precipitation 151.7% and 154.6% of the norm. The hydrothermal coefficient of May was 1.5, June - 0.4, July - 1.6, August - 1.7. As a whole, during the growing season SCC amounted to 1.3. The current weather conditions of the growing season 2016 can be considered favorable for barley. In May, the mean monthly air temperature was higher by 0.4°C and the amount of precipitation was 43% of the mean monthly data. Air temperatures were 0.2°C higher in June, with precipitation of 66 mm or 112% of mean annual precipitation. In July, the temperature was at mean multiyear levels and the sum of precipitation was 132 mm or 220 % of the norm. In August, the mean multiyear temperature was observed to be exceeded by 4.9 °C and the amount of precipitation was insignificant 2 mm (4.3% of the monthly average). The hydrothermal coefficient of May was 0.8, June - 1.3, July - 2.2, August - 0.03 units. The hydrothermal coefficient for the whole growing season is 1.07 units.

Sowing in 2014 was carried out on 1 June, cleaning on 10 October, in 2015 on 2 June and 10 September, respectively; in 2016 - on 28 May and 25 August.

In stationary field rotations, the cultivation of grain crops and the fertilizer doses used corresponded to those recommended for our zone [11].

3. Results and Discussion
Determining the optimal fertilizer dosage for crops in the development of the fertilizer system in the crop rotation, finding the right balance between nitrogen, phosphorus and potassium is usually given key importance. The majority of authors believe that the main method of determining the optimum in the application of mineral fertilizers is field experience, in which it is possible to compare the effect of increasing doses of each of the nutrients, responsiveness to fertilizers by increasing crop yields and the response curves for increasing doses to determine the optimal doses.

In order to evaluate the developed system of fertilizer application, the expected agrotechnical and economic effect of the planned volume of fertilizers applied is calculated (Table 1).

Table 1. Return on mineral fertilizers by increasing yields in grain and steam crop rotation (2014-2016)

| Variant | Productivity of the crop rotation in t/ha, units | Yield increase in units, t/ha | Amount of fertilizers applied, kg/ha d.v. | Payback, kg/kg d.v. |
|---------|-----------------------------------------------|--------------------------------|------------------------------------------|-------------------|
| 1. Control variant (without fertilizers) | 5.14. | – | – | – |
| 2. P40 | 5.49 | 0.35 | 120 | 2.9 |
| 3. P80 | 5.50 | 0.36 | 240 | 1.5 |
| 4. N40K40 | 5.64 | 0.50 | 240 | 2.1 |
| 5. N40P40K40 | 5.81 | 0.67 | 360 | 1.9 |
| 6. N40P80K40 | 5.95 | 0.81 | 480 | 1.7 |

In the control variant without fertilizer application, a total of 5.14 tons from 1 hectare was collected in three years. Improvement of the soil nutrient regime under the influence of fertilizer application promoted the increase of productivity of the studied crops of crop rotation. Annual application of phosphate fertilizers resulted in an increase of 0.35-0.36 t.e./ha (or 0.12 t/ha annually).

Annual complex fertilizer application (N40P80K40) resulted in maximum crop rotation productivity of 5.95 tons of grain per hectare. In general, the fertilizers used increased the productivity of crop rotation in grain units by 68-15.8%.

When determining agronomic efficiency, an additional output per 1 kg of active fertilizer substance is set. The increase in the dosage of mineral fertilizers resulted in a decrease in the payback period for grain crops. The payback of 1 kg of fertilizers applied to the variant with three batteries averaged 1.7-1.9 kg over 3 years. The maximum return on investment was observed in the variant with a minimum
dose of P40 - 2.6 kg/kg of fuel oil.

In addition to private agronomic issues, any question on crop cultivation technologies should be directly accompanied by economic analysis, as they cannot be used in production if they are unprofitable. The essence of economic efficiency is to get the maximum amount of production from each hectare of arable land with the least labor and money spent per unit of production.

The cost-benefit calculation showed the highest return on investment in wheat production using phosphate fertilizer. In 2014, with a yield of 1.81 t/ha, production costs amounted to 7591 rubles/ha, and the cost recovery amounted to 2.38 rubles. Other experience options for increasing fertilizer doses showed a decrease in payback to 2.08 RUB (Table 2).

In 2015, the control option without fertilizer application had a yield of 1.43 t/ha of second wheat after steam, while production costs per hectare amounted to RUB 7,041, and the cost recovery was 1.62 rubles. On other variants of experience the payback of expenses has made 1.46-1.57 rubles.

Table 2. Cost-effectiveness of fertilizer application in the production of spring wheat grain and barley

| Variant                      | Yield, t/ha | Production costs, RUB per 1 ha | Product value from 1 ha, thousand rubles. | Cost recovery, RUB. |
|------------------------------|-------------|--------------------------------|------------------------------------------|--------------------|
| 2014                         |             |                                |                                          |                    |
| 1. Control variant (without fertilizers) | 1.61        | 6761                           | 16.1                                     | 2.38               |
| 2. P40                       | 1.81        | 7591                           | 18.1                                     | 2.38               |
| 3. P80                       | 1.77        | 7942                           | 17.7                                     | 2.23               |
| 4. N40K40                    | 1.79        | 8024                           | 17.9                                     | 2.23               |
| 5. N40P40K40                 | 1.85        | 8601                           | 18.5                                     | 2.15               |
| 6. N40P80K40                 | 1.83        | 8781                           | 18.3                                     | 2.08               |
| 2015                         |             |                                |                                          |                    |
| 1. Контроль (без удобрений)  | 1.43        | 7041                           | 11.4                                     | 1.62               |
| 2. P40                       | 1.52        | 7741                           | 12.2                                     | 1.57               |
| 3. P80                       | 1.51        | 8164                           | 12.1                                     | 1.48               |
| 4. N40K40                    | 1.50        | 8230                           | 12.0                                     | 1.46               |
| 5. N40P40K40                 | 1.62        | 8842                           | 13.0                                     | 1.47               |
| 6. N40P80K40                 | 1.69        | 9073                           | 13.5                                     | 1.49               |
| 2016                         |             |                                |                                          |                    |
| 1. Control variant (without fertilizers) | 2.10        | 7360                           | 14.7                                     | 2.00               |
| 2. P40                       | 2.16        | 8139                           | 15.1                                     | 1.86               |
| 3. P80                       | 2.22        | 8559                           | 15.5                                     | 1.82               |
| 4. N40K40                    | 2.35        | 8760                           | 16.4                                     | 1.88               |
| 5. N40P40K40                 | 2.34        | 9254                           | 16.4                                     | 1.77               |
| 6. N40P80K40                 | 2.43        | 9573                           | 17.0                                     | 1.78               |

In 2016, barley yields increased to 2.22 tonnes per hectare when applying 80 kg/ha of phosphate fertilisers, and production costs increased from 7,360 to 8,559 tonnes per hectare without the need to apply fertilisers, while cost recovery decreased from 2.00 to 1.88 tonnes per hectare. At the joint application of mineral fertilizers in the dose of N40P80K40 the yield was 2.43 t/ha, production costs amounted to 9573 rubles, cost recovery - 1.78 rubles.

The highest cost recovery for grain production in all years of research was obtained in the control version. Annual fertilizer application increases production costs, reduces payback by 0.16-0.30 rubles.
4. Conclusion
The applied mineral fertilizers increased the productivity of crop rotation in grain units by 6.8-15.8%. Return on mineral fertilizers by increasing the crop yield in the steam and grain crop rotation of 1 kg of fertilizer applied for an average of 3 years was 1.5-2.9 kg of grain, the maximum return on investment was observed in the version with a dose of P40. An increase in fertilizer doses resulted in a decrease in the payback period for grain crops.

High cost recovery for grain production in all years of research is obtained in the control version. With annual fertilizer application, the payback period is reduced by 0.16-0.30 rubles.

References
[1] Aristarkhov A N 2000 Optimization of plant nutrition and application of fertilizers in agroecosystems (Moscow: CINAO) p.522
[2] Dobrovolsky G V, Nikitin E D 2012 Soil ecology. Doctrine on ecological functions of soils (Moscow: Moscow University Press) p.412
[3] Egorov V P, Krivonos L A 1995 Soils of the Kurgan region (Kurgan: Urals Publishing House) p.176
[4] Milashchenko N Z 1998 Chernozem fertility in Russia (Moscow: Agricultural Consultant), p.688
[5] Mineyev I N 2004 Agrochemistry (Moscow: Moscow State University, KolosS Edition) p. 720
[6] Yeremin D I, Ufimtseva M G 2013 Agrarian Bulletin of the Urals 118 63–66
[7] Mineyev V G 1988 Ecological problems of agrochemistry (Moscow: Published by MSU) p. 320
[8] Carpenters A M, Kabdunova G S 2018 Problems of Agrochemistry and Ecology 1 38–41
[9] Plotnikov A M, Kabdunova G S 2018 Theoretical and applied problems of agro-industrial complex 1(34) 3-6
[10] Sinyavskiy I V, Chinyaeva Y Z, Kalganov A A 2017 News from higher education institutions. Ural Region 1 110–117
[11] Adaptive Landscape Agriculture System of the Kurgan Oblast (Kurtamysh: State Unitary Enterprise "Kurtamyshskaya Printing House") p. 494