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Economic Effectiveness of Nitrogen Fertilizer Application in Agriculture

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Abstract: The efficiency of different types of nitrogen fertilizers used in agriculture is analyzed and the main forms of their production by the chemical industry are considered. The data on production dynamics of mineral fertilizers and their price change in Russia from 2009-2011 is provided. The fertilizers production conditions in the world and their consumption in agricultural industry, wherein Russia represents 9% of the global operating capacities of ammonia production (the third place in the world after China and the USA) are analyzed. Main nitrogen fertilizers produced by the industry are characterized and assessed. The researchers offer new forms of nitrogen fertilizers such as Urea-Formaldehyde Fertilizer (UFF) characterized as slowly-soluble and well absorbed by plants during the growing season and thus guaranteeing financial benefits. The slowly-soluble nitrogen fertilizer developed by the researchers positively affects the quality of crops at single application in spring (increases the amount of gluten in a spring wheat grain, decreases the amount of nitrates in green fodders). Such fertilizers increase the safety of pine seedlings sprout and do not demand additional fertilization in summer, thus reducing the material costs and increasing economic efficiency.

Key words: Nitrogen fertilizer, ammonium nitrate, urea, Urea-Formaldehyde Fertilizer UFF, production of mineral fertilizers, plants, dose

INTRODUCTION

Nitrogen is the most important nutrient for all plants. A plant contains an average of 1-3% of nitrogen by mass in its dry basis. It is contained in important organic substances such as proteins, nucleic acids, nucleoproteids, chlorophyll, alkaloids, phosphatids, etc. The content of nitrogen in proteins is 16-18% by mass. Fertilizers are one of the main sources of nitrogen for plants. As of today all types of mineral nitrogen fertilizers can be produced in Russia. The industry of mineral fertilizers seems to be the most successful in comparison with the other branches of chemical industry. This is proved by the world consumption of mineral fertilizers data scheme. Location of similar branch enterprises depends primarily on raw materials availability and consumption factors.

The peculiarity of nitrogen, phosphorus and potassium reserves location in soils also plays a certain role. The amount of nitrogen contained in the soil increases from the North to the South up to the forest-steppe zone, where it reaches the maximum level and decreases gradually afterwards. The same changes occur for phosphorus, except that it reaches its maximum in steppe zone. Amount of potassium contained in the soil reaches the maximum level in the forest zone and decreases to the South. There is more nitrogen in the Eastern than in the European territory at the same latitude, however, there is less phosphorus and potassium contained. High rates of heat and power consumption are peculiar for all types of mineral fertilizers production (the share of energy resources in product cost is 25-50%).

MATERIALS AND METHODS

Theoretical justification of the issue: Ammonia is a source raw material for nitrogen fertilizers production (ammonium nitrate, urea, ammonium sulfate, etc.). Recently, a coke and coking plant gas were substituted for natural gas as the main raw material for ammonia production, thus making it much easier to find the place for the nitrogen fertilizer plant. Some centers of nitric subsector have been formed on the basis of oil refinery wastes use (Salavat, Angarsk).

Russia represents 9% of the global operating capacities for ammonia production (the third indicator in

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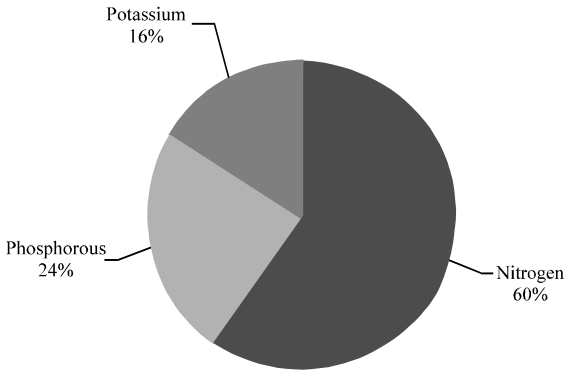

Fig. 1: The world consumption of mineral fertilizers in 2011 scheme (%) International fertilizer industry (IFA)

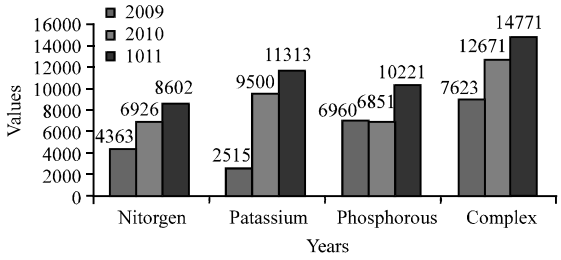

Fig. 2: Dynamics of prices for mineral fertilizers in the Russian Federation, 2009-2011 (rub./t; Rosstat). Price for 1 ton

the world after China and the USA) (Novenkova and Abdulganiev, 2014). However, the capacities of enterprises are not used completely, so Russia occupies only the fourth place in the world production of ammonia after China, the USA and India, thus producing only 6% of the world ammonia. The prime cost of the produced nitrogen fertilizers depends on the ammonia units' productivity. The less natural gas is wasted per one ammonia ton, the lower are the costs and the higher are the competitiveness (Fig. 1 and 2).

The world population growth rate is 70 million people a year. They have to be provided with vegetable food despite a steady decrease of areas under crops. (Moghaddam *et al*., 2015). The only solution of this problem is intensification of world agriculture which cannot be accomplished without increasing the volumes of mineral fertilizers production. In this regard, development prospects of the domestic industry of mineral fertilizers mostly focused on exportation are quite optimistic. As of today, ammonium nitrate and urea (carbamide) are the main nitrogen fertilizers used in agriculture all over the world. Ammonium nitrate is the most popular nitrogen fertilizer. It belongs to the group of the ammonium nitrate fertilizers containing nitrogen in ammonium and nitrate form Table 1.

Table 1: The use and losses of nitrogen in mineral fertilizers within the application year, percentage share (on the average across Europe) (Breus, 1996, 2001)

Balance figure	Fluctuation margins	Average
Carrying out with a crops	25-70	60
Leaching	0-60	6
Transition into organic substance of the soil with further mineralization	0-40	15
Gaseous losses of NG_3	0-50	5
Denitrification (losses of No_x)	0-40	15

RESULTS AND DISCUSSION

A significant amount of biogenous elements is being lost in the environment due to imperfections of properties and chemical composition of mineral fertilizers (Mineev, 2000; Kurayemen *et al*., 2013). Currently, most forms of nitrogen fertilizers are produced in Russia on the basis of water-soluble compounds; it causes the essential gaseous losses of nitrogen during their use. Nitrogen losses from urea and ammonium fertilizer occur in the form of free ammonia under the influence of chemical and microbiological processes in the soil. These losses are especially big at surface fertilization and in neutral, alkaline and high-carbonate soils with light granulometric compositions in areas with insufficient precipitation. Exhalation of NH_3 is the most essential chemical way of nitrogen loss from fertilizers.

Nitrogen losses from the highly soluble nitrogen fertilizers applied to the soil also occur in the following (biological) way: as a result of denitrification process. N_2, N_2O and NO gases are the gaseous products thus evolved from the soil reaching 15-25% of the applied nitrogen dose and exceeding it. According to scientists, emission of those gasses to the atmosphere leads to depletion of the ozone layer protecting life from rigid ultra-violet radiation. For elimination of the specified disadvantages it is desirable to use fertilizers with controlled release of nutritional chemicals, especially nitrogen, in the course of crop growth.

The physiological acidity of mineral fertilizers and residual acid present in their composition due to their production technology are their substantial drawbacks, especially for nitrogen ones. Intensive use of such fertilizers in crop rotation leads to a noticeable soil acidulation and hence the creation of unfavorable conditions for plants growth. So, the necessity in soil chalking and fertilizer deacidizing increases (Zakharenko, 2000).

Physical characteristics of mineral fertilizers require some improvements as well. Recently, granulation,

encapsulation and covering of granules with different films, elementary sulfur, etc. is paid special attention during their production (Pozin, 1989).

Nitrogen is considered to be the greatest hazard for ecology (Breus, 1996, 2001). Considerable environmental pollution occurs due to the production of ammonia, nitric acid and nitrogen fertilizers. Plants use only a little <50% of the nitrogen added to the soil so the considerable portion volatilizes and is being leached thus polluting natural reservoirs and ground waters (Table 1). Disrupting the optimum order for nitrogen fertilizer application (doses, forms, terms and methods) worsens the characteristics of the soil and leads to excessive accumulation of nitrates in plants.

Slowly-soluble nitrogen fertilizers (urea formaldehyde fertilizer) or nitrogen fertilizers with nitrogen release delay (granules covered with various synthetic materials or elementary sulfur) are being developed for the purpose of reducing the nitrogen losses and increasing the production technology effectiveness of slow-acting nitrogen fertilizers. Nitrification inhibitors are used for preservation of urea nitrogen and ammoniac fertilizers contained in the soil in ammonium form. These compounds slowdown a nitrification for 1.5-2 months and keep mineral nitrogen of the soil and fertilizers in ammonium form, when applied to the soil in a dose of 0.5-2 kg per 1 ha along with ammonium fertilizers and urea. Inhibitors (as has been revealed in experiments with 15 N) reduce the losses in a gaseous form and losses due to nitrates being leached 1.5-2 times by slowing down nitrification of nitrogen contained in a fertilizer. Field experiments with various crops have revealed that the crop yield and efficiency of nitrogen fertilizers are considerably increased under the influence of inhibitors. The most perspective is using the nitrification inhibitor in irrigated agricultural areas, especially in cotton and paddy fields and other light soils with sufficient moistening. Regular nitrogen fertilizers should be portion-wise applied to the soil to provide a plant with nitrogen during all growing season. That requires additional labor costs for transportation and fertilizer application (Nascimento *et al*., 2014).

Development of methods for slowly-soluble concentrated nitrogen fertilizer production is a new direction for development of nitrogen fertilizer technology (Breus, 2001; Kellici *et al*., 2015).

Such advantages as profitability of application of slowly-soluble nitrogen fertilizers in comparison with usually applied highly soluble nitrogen fertilizers are generally defined by slow release of nitrogen to plants during the long period, insignificant losses at leaching by soil waters and also a possibility to apply nitrogen in high doses once with no need of subsequent application (Gilyazov, 1999).

CONCLUSION

Such concentrated nitrogen fertilizers as urea-formaldehyde Iso-Butenedicarbamide (IBDN), oxalamide and Urea Formaldehydes (UFF) are produced by chemical means at condensation of urea (carbamide) with formaldehyde in certain conditions which considerably differ from the conditions required for plastic production on such basis. These products contain about 40% of nitrogen in poorly soluble form, however, that nitrogen is being completely absorbed by plants within the growing season (Gaysin, 1989).

The nitrogen fertilizers with controlled speed of dissolution developed by us (for example, urea-formaldehydes fertilizer (Sacristan *et al.,* 2015) allow saving up to 30% of nitrogen fertilizers application dose, despite the 10% increase in their cost. Besides, the specified fertilizers do not require additional dosage compensation during the growing season both for fodder and grain crops resulting in the production cost reduction.

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