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Use of Distillery Waste as a Fertilizer

T. X. Kabaloev, S. C. Dzanagov, S. A. Bekuzarova, I. M. Subbotin, I. K. Esenov

Federal State Budgetary Educational Institution Gorsky State Agrarian University, 362040, 37 Kirov Street, Vladikavkaz, Russian Federation

Abstract

The Gorsky State Agrarian University (SAU) has developed a method of obtaining a multinutrient fertilizer for acidic soils by mixing the waste of the distillery industry with quicklime in a certain ratio. A considerable amount of moisture is lost from grain during mixing due to the release of thermal energy of the chemical reactions occurring in the mixture, and the acid reaction of the fertilizer is neutralized. The application rate is 0.6-0.8 to 1.0 t/ha, depending on the soil acidity and the need for nutrients. The application of fertilizer on soddy gley soil in growing clover and alfalfa in field experiments in 2016-2017 allowed to almost double their fresh yield and increase the accumulation of biological nitrogen 1.5-2.0 times. At the same time, the reaction of the soil solution turned out to be neutral (pH 6.8).

Keywords: *acidity, alfalfa, biological nitrogen, clover, distillery waste, quicklime, yield.*

INTRODUCTION

The distillery industry is closely linked with agriculture through the production of plant raw materials, from which alcohol is produced. After the extraction of carbohydrates at the distilleries, waste is formed in the form of distillery waste that contains protein, vitamin and other components and is a good feed for livestock. However, the volume of the accumulated distillery waste is so high that a problem of its utilization arises, and the ecological situation in the regions with developed distillery industry sharply worsens. One of the most efficient ways to solve this problem is to use distillery waste as a nontraditional organic fertilizer [1].

The use of distillery waste as nontraditional organomineral fertilizers can significantly reduce the costs associated with acquisition of industrial mineral fertilizers and increase the yield of many crops while improving the environmental situation. The use of distillery waste as a fertilizer allows to solve the problem of its disposal and improvement of the environmental situation in the region [2-11].

MATERIALS AND METHODS

The research was conducted in a research laboratory and under field conditions on soddy gley soils of the educational experimental plot of the Gorsky SAU in 2016-2017.

Soddy gley soils of the forest-meadow zone of North Ossetia-Alania have a nearby level of groundwater occurrence (and are therefore waterlogged), heavy granulometric composition, high hydrolytic acidity (up to 10-15 meq/100 g soil), pH 4.0-4.7, humus by Turin 6-8%, the sum of absorbed bases 32-42 meq./100 g soil, nitrogen 0.30-0.48, phosphorus 0.25-0.33, potassium 2.2-2.3%, readily hydrolyzable nitrogen by Turin-Kononova 5-6, mobile phosphorus by Truog 7-10, and exchangeable potassium by Brovkina 8-10 mg/100 g of soil [12].

Field experiments were carried out according to the scheme provided in Table 1. The efficiency of the application of distillery waste was studied, which was mixed with different parts of quicklime in the mixture. The object of the study was red clover and blue-hybrid alfalfa. The plot area was 25 m^2, the repetition was 4-fold, and the placement of the options in the experimental plot was randomized. Fertilizers in the plots were manually applied for cultivation. The sowing was carried out with a seeding rate of 10 kg/ha. The fresh yield was accounted in the flowering phase by the continuous mowing method followed by weighing.

Laboratory tests to define the content of nitrogen, protein in the fresh yield, pH of the soil solution, as well as the chemical composition of distillery waste were carried out by conventional methods in the research laboratory of the Gorsky SAU.

RESULTS AND DISCUSSION

Academicians of the Gorsky SAU have developed a method of obtaining a multinutrient (mixed) fertilizer for acidic soils, such as soddy gley soils of the forest-meadow zone of North Ossetia-Alania [7, 8]. This fertilizer is obtained by mixing the 10-15% of the total weight of distillery waste with quicklime. It is used in agricultural production at the rate of 0.6-0.8 to 1.0 t/ha.

The technology of fertilizer preparation is as follows. Finely grinded quicklime in an amount of 10-15% of the total weight of distillery waste (100-150 kg per 1 ton) is placed in the container with distillery waste with moisture content of 85-95%. In this case, moisture rapidly evaporates, and the moisture content of the mixture reduces to 28-35% within 20-30 minutes.

Distillery waste contains a significant amount of macro- and microelements, along with various organic components required for the nutrition of plants and soil microorganisms.

Along with chicken droppings, the most concentrated organic fertilizer, distillery waste has significant content of nitrogen, phosphorus, potassium, protein, fat and fiber, i.e. an essential fertilizer composition.

The stillage itself as a liquid waste of the technological process of obtaining alcohol from grains has an acid reaction (pH 4-5), which affects the soil microflora and the root system of plants, especially on acidic soils. Its pure use on soddy gley soils is undesirable, as it acidifies soil, therefore, it should be mixed with quicklime to neutralize the acidity. Besides, the addition of quicklime to distillery waste evaporates a significant amount of moisture – up to 60-70% of the initial humidity. At the same time, the inevitable costs of removing moisture from distillery waste are automatically eliminated.

The lime share should not exceed 15% of the total weight when mixed with distillery waste because along with the water vapor the nitrogen compounds of distillery waste begin to volatilize, and the protein content that is the nutrient medium for soil microorganisms decreases; it should be at least 10% of the total weight of distillery waste because otherwise the distillery waste acidity is neutralized insufficiently (Table 1).

Experimental studies indicated that the proportion of lime in the mixture within the range of 2-9% increased the pH of the medium by only 0.9, i.e. the medium remained acidic. Increasing it up to 10-15% increased the pH value to 9.8, which meant creating an explicit alkaline medium required to neutralize the soil acidity. Its further increase up to 16-20% created an almost maximum alkaline medium, which was accompanied by a sharp decrease in the content of nitrogen and protein. This fall indicated a decrease in the nutritional value of the fertilizer, which was undesirable. Therefore, the best option was the addition of 10-15% lime from the total weight to distillery waste, i.e. 100-150 kg per ton of distillery waste. When applied to acid soil, the mixed fertilizer obtained under this option promoted the normal development of microflora, increased activity of nitrogen-fixing soil bacteria and nodule bacteria of leguminous grasses, including perennial legumes: clover and alfalfa.

Data from Table 2 indicate that when applying a mixed fertilizer for clover on soddy gley soil, the fresh yield and the amount of biological nitrogen accumulated by nodule bacteria increased for all doses. The same was observed in alfalfa crops, with the only difference that the fresh yield and, in some cases, the amount of the accumulated biological nitrogen were higher in alfalfa. Of the several doses under study, the one that was added to the mixture in the amount of 10-15% was the best, while the fresh yield and the amount of the accumulated biological nitrogen were greatest for both legumes.

The introduction of lime in the mixture with distillery waste also had a positive effect on the acidity of the soil medium: pH increased from 5.0 to 8.1, which indicated the neutralization of acidity and alkalinization of the soil solution under the influence of a higher dose of lime.

Energy characteristics and chemistry of the process of neutralization of distillery waste with quicklime

The main components of distillery waste are the following ones: water, grain mash, protein colloids, organic acids formed during fermentation, free amino acids, minerals, as well as a small amount of H_2SO_4 added during the starch saccharification. The pH value of distillery waste is in the range of 4-5, and is mainly determined by the content of acetic acid $COOH$ and lactic acid $CH_3 - CH(OH) - COOH$, as well as H_2SO_4 in it.

When adding quicklime CaO to distillery waste, the following processes start: $CaO + H_2O \rightarrow Ca(OH)_2 + 64\ kJ$ (1)

$$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + H_2O + 77{,}17\ kJ\ (2)$$

the resulting slaked lime $Ca(OH)_2$ enters into neutral reactions

$$2CH_3COOH + Ca(OH)_2 \rightarrow (CH_3COO)_2Ca + 2H_2O$$

$$2CH_3 - CH(OH) - COOH + Ca(OH)_2 \rightarrow (CH_3 - CH(OH) - COO)_2Ca + 2H_2O$$

When neutralizing distillery waste with quicklime, heat is released and moisture evaporates due to reactions (1) and (2). The process of the moisture evaporation is not significantly affected by neutralization of acetic and lactic acid, thus, they can be ignored in calculations.

Along with the neutralization process, $Ca(OH)_2$ can participate in at least two other processes.

1. Interaction with free amino acids in the form of:

$$2H_2N - CH_2 - COOH + Ca(OH)_2 \rightarrow (H_2N - CH_2 - COO)_2Ca + 2H_2O$$

pH does not substantially change in this reaction, since the amino acids have buffer properties. When interacting with amino acids, the alkalinity of the medium during $Ca(OH)_2$ consumption is replaced by alkalinity arising from the released amino groups contained in the amino acids.

2. Interaction with micelles of the colloid fraction in the form of the charge exchange, which can cause coagulation of the colloid system that can facilitate the separation of the solid and liquid phases of distillery waste. This process helps to thicken the neutralized distillery waste.

$$[(core)]^{-2n}2n \cdot Na^{+} + n \cdot Ca(OH)_2 \rightarrow [(core)]^{-2n}n \cdot Ca^{+2} \downarrow + 2Na \cdot OH$$

In the processes under study, CaO can be replaced with $Ca(OH)_2$, $CaCO_3$, $CaCO_3 \cdot MgCO_3$.

In this case, all the reactions under study, except for the coagulation of the colloidal system in case of using $CaCO_3$ and $CaCO_3 \cdot MgCO_3$, will be much slower when interacting with free amino acids.

When CaO or $Ca(OH)_2$ are used for distillery waste neutralization, $Ca(OH)_2$ remaining in excess will begin to interact with the carbon dioxide CO_2 contained in the air:

$Ca(OH)_2 + 2CO_2 \rightarrow Ca(HCO_3)_2$ or $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 \downarrow + H_2O$

These processes will gradually reduce the concentration of free alkali $Ca(OH)_2$ in the neutralized distillery waste.

Conclusions

As such, a relatively cheap multinutrient mixed fertilizer can be obtained utilizing the waste of the distillery industry (distillery waste) without additional costs for drying. At the same time, the acidity of the soddy gley soil is significantly reduced (pH has increased from 5.0 to 6.8), which has resulted in the 23.2 t/ha of fresh yield of clover with the nitrogen content of 112 kg/ha and in the 29.3 t/ha of fresh yield of alfalfa with the nitrogen content of 123 kg/ha, over 2 years of research on average.

Table 1. Change in the chemical composition of fertilizer depending on the proportion of lime in a mixture with distillery waste

Lime share	Total nitrogen, %	Protein content, %	pH
Distillery waste without lime	4.87	30.43	5.0
Distillery waste +2-9% lime	3.12	19.50	5.9
Distillery waste + 10-15% lime	2.63	16.43	9.8
Distillery waste + 16-20% lime	1.53	9.56	13.4

Table 2. Efficiency of leguminous grasses depending on the share of lime in a mixture with distillery waste

Option	Fresh yield, t/ha	Amount of biological nitrogen, kg/ha	Fresh yield, t/ha	Amount of biological nitrogen, kg/ha	Soil pH
Clover			**Alfalfa**		
Distillery waste 0.5 t/ha (reference)	11.5	70	15.6	65	5.0
Distillery waste 0.5 t/ha + lime 2-9%	18.8	86	21.8	78	5.9
Distillery waste 0.5 t/ha + lime 10-15%	23.2	112	29.3	123	6.8
Distillery waste 0.5 t/ha + lime 16-20%	22.6	94	25.8	108	8.1

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