ISSN 1064-2293, Eurasian Soil Science, 2013, Vol. 46, No. 2, pp. 198–203. © Pleiades Publishing, Ltd., 2013.
Original Russian Text © A. Marcinkeviciene, V. Boguzas, S. Balnyte, R. Pupaliene, R. Velicka, 2013, published in Pochvovedenie, 2013, No. 2, pp. 219–225.

AGRICULTURAL CHEMISTRY AND SOIL FERTILITY

Influence of Crop Rotation, Intermediate Crops, and Organic Fertilizers on the Soil Enzymatic Activity and Humus Content in Organic Farming Systems

A. Marcinkeviciene, V. Boguzas, S. Balnyte, R. Pupaliene, and R. Velicka

Aleksandras Stulginskis University, Studentu str. 11, Kaunas, 53361 Lithuania

Received January 26, 2010

Abstract—The influence of crop rotation systems with different portions of nitrogen-fixing crops, intermediate crops, and organic fertilizers on the enzymatic activity and humus content of soils in organic farming was studied. The highest activity of the urease and invertase enzymes was determined in the soil under the crop rotation with 43% nitrogen-fixing crops and with perennial grasses applied twice per rotation. The application of manure and the growing of intermediate crops for green fertilizers did not provide any significant increase in the content of humus. The activity of urease slightly correlated with the humus content ($r = 0.30$ at the significance level of 0.05 and $r = 0.39$ at the significance level of 0.01).

Keywords: Urease, perennial herbs, humus

DOI: 10.1134/S1064229313020105

INTRODUCTION

Crop rotation is an important agrotechnical and biological method of restoring soil fertility; it is of great significance in the context of the phytosanitary state of cultivated soils [4]. In organic farming, the crop rotations should be composed taking into account the following factors: the possibility of using organic fertilizers under certain crops, the biological particularities of alternating crops in agrocenoses, the maximum filling of the crop rotation with legumes, using green fertilizer, and increasing of the natural soil fertility [28].

The enzymatic soil activity is an important factor of its fertility and a sensitive ecological and agronomical indicator of the anthropogenic influence on it [11, 23]. The enzyme activity is related to the acknowledged indicators of the biological activity of soil: the respiration intensity; the nitrifying capacity; the total number of microorganisms; and, to a greater degree, the organic carbon and nitrogen, the mobile P_2O_5 and K_2O, the indicators of acidity, and the productivity of the plants [16, 27, 29, 31, 34]. It was found that, in organic farming, the activity of the urease enzyme increased reliably compared with intensive farming, while the activity of the invertase enzyme decreased [25].

Intermediate sowing on green fertilizer is an important way of biologization of farming [10]. Many researchers proved the positive effect of the intermediate sowing on the activity of soil enzymes [14, 16, 22, 33]. Volynskaya and Loshakov et al. have shown that organic and green manure have a positive influence on the enzymatic soil activity, increasing the activity of urease by 52%, that of protease by 45%, invertase by 10%, and catalase by 17% [3, 8].

According to the nomenclature and classification of enzymes accepted and confirmed in 1961 by the International union of biochemistry and molecular biology, the urease and invertase enzymes belong to the class of hydrolases. Hydrolases are enzymes that, with the participation of water molecules, destroy the links between C–O, C–N, and C–S. Urease (classification number 3.5.1.5) is an enzyme from the group of amidases, which catalyzes the hydrolysis of amides (urea) formed during the splitting of proteins evolved by the micro- and macrofauna into ammonia, carbon dioxide, and water. The urease characterizes the nitrous exchange of the soil. The invertase (classification number 3.2.1.26), with the participation of a water molecule, catalyzes the intensity of the reaction of the decomposition of the saccharose carbohydrate into fructose and glucose. The invertase characterizes the process of the organic carbon compounds transformations in the soil [27].

The content of the organic substance, humus, is of particular importance for the soil fertility [24]. Publications indicate a connection between the quantitative and qualitative composition of the humus with the specific composition of the plants in specialized crop rotations [32] with using organic fertilizers [24, 35]; the dependence of the soil fertility on the biological activity [7, 11] and the best budget of the soil humus [20] is emphasized.

The intensity of the organic matter decomposition depends on the ratio of carbon to nitrogen in the soil

[1]. Studies showed that the most intense decomposition of the green mass occurs in the first 30–40 days after the plowing. Over this period, up to 47–63% of the organic mass is mineralized, while, in the subsequent 50 days, only 5–6% is mineralized. Thus, leaving the soil in the unsown condition for a long period after plowing the greens may lead to a loss of nitrogen due to its leaching beyond the root-inhabited layer, especially in humid years [10]. The generalization of numerous studies of researchers all over the world shows that, on soils with small fertility, growing intermediate crops on green fertilizers without adding other organic substances does not increase the content of humus owing to the quick mineralization of the green mass [2, 12, 17, 21].

The aim of our study is to give a complex estimation of the influence of crop rotations with various nitrogen-fixing crops, intermediate crops sown on green fertilizer, and the litter manure on the enzymatic activity of the soil and humus content in organic farming.

EXPERIMENTAL

The experiments were conducted in 2003–2009 in the experimental station of the Lithuanian University of Agriculture on a certified organic plot. The station is situated on the Mid-Lithuanian plain on the left bank of the Nyamunas River (54°53′ N, 23°50′ E). The parent rock is the lacustrine–glacial sediments underlain by a moraine. The soil is a *Calc(ar)i – Epihypogleyic Luvisol* (WRB, ISSS–ISTRIC–FAO, 1998) with loam on clay and cultivated and drained; the water pH is 7.26–7.30, the humus content is 2.26–2.43%, the mobile P_2O_5 is 254–296 mg/kg, and the mobile K_2O is 131–158 mg/kg.

A three-factor experiment was performed. Factor A included four crop rotations with varying ratios of nitrogen-fixing crops:

C1—43% (perennial grasses of the first year: a mixture of clover (*Trifolium rubens*) and fodder catstail (*Phleum*) > perennial grasses of the second year > winter wheat > summer barley > pea > winter wheat > summer barley with undersown perennial grasses);

C2—43% (perennial grasses of the first year: winter wheat > pea > summer barley with undersow of perennial grasses > perennial grasses of the first year > winter wheat > summer barley with undersown perennial grasses);

C3—29% (perennial grasses of the first year > potato > oats > summer barley > pea > winter wheat > summer barley with undersown perennial grasses);

C4—14% (perennial grasses of the first year > winter wheat > potato > summer barley > winter rape > winter wheat > summer barley with undersown perennial grasses).

Factor B included the use of manure: (M0) without manure and (M1) 30 t/ha of manure.

Factor C included intermediate crops: (I0) without intermediate crops and (I1) intermediate crops sown on green fertilizer.

The intermediate crop of white mustard (*Sinapis alba* L.) was sown (25 kg/ha) on the stubble field; the mustard's biomass was plowed as fertilizer under the next crop late in the fall (except before the winter wheat and winter rape, as well as the perennial grasses). Litter manure (30 t/ha) was introduced twice per rotation (in 2003 and 2007, late in the fall). Only in the first crop rotation was manure introduced in 2004 after the second year of perennial herbs. In 2003, in the fall, the biomass of the perennial grasses (5.2 t/ha of dry matter) was plowed as a green manure in crop rotations C2, C3, and C4. In the first crop rotation, perennial grasses (5.6 t/ha of dry matter) were plowed in the fall of 2004 after two years of use. In the second crop rotation, perennial grasses (5.0 t/ha of dry matter) were plowed in the fall of 2007.

Soil samples were collected from each plot in 2004 in the early spring and in 2009 after harvesting barley.

The size of the plot was 76.0 m^2, the experiment was conducted in three replicates according to the method of split plots. The agrotechnology followed the one accepted for the zone.

The following agrochemical characteristics of the soil were determined: the pH (potentiometrically); the humus content (according to the method of Turin); and the mobile nutrients, namely, the P_2O_5 and K_2O (using the A-L method). The activity of the hydrolytic enzymes (invertase and urease) in the air-dried samples was determined by the methods of Gofman et al. in modification by Chunderova [13].

A variance analysis of the data was performed using the SYSTAT computer program and the correlation links were determined using the STAT_ENG program with the probability level of 95 and 99%, respectively.

RESULTS AND DISCUSSION

The data obtained showed that, in the soil of all the crop rotations, in the early spring of 2004, the urease activity changed from 0.07 to 0.11 mg of NH_3/g soil per 24 h (Fig. 1). The highest activity of the urease enzyme (0.11 mg of NH_3/g soil per 24 h) was recorded in the soil of the crop rotation with 29% nitrogen-fixing crops. In the soils of the other crop rotations, the urease activity was significantly lower: by 36.4%. It is known that the introduction of manure increases the activity of the soil enzymes [18]. According to our data, manure (30 t/ha) significantly (by 42.9%) increased the activity of the urease enzyme. However, it was noted that the activity of the urease tends to increase after plowing of the green mass of perennials into the soil as well.

The highest activity of the invertase enzyme (15.3 mg of glucose/g soil per 48 h) was registered in the soil of the crop rotation with 29% nitrogen-fixing