State of Humus in Soils under Rice Cultivation

A Kh Sheudzhen$^{1,2}$ and O A Gutorova$^{1,2}$

$^1$Kuban State Agrarian University named after I.T. Trubilin, Kalinina, 13, Krasnodar, 350044, Russian Federation
$^2$Federal scientific rice centre, Belozerny, 3, Krasnodar, 350921, Russian Federation

E-mail: ashad.sheudzhen@mail.ru

Abstract. The study investigates an anthropogenous influence on the humus content in meadow and meadow-bog soils under rice cultivation in Adygea (Gleyic Phaeozems and Calcic Chernic Gleysol). A field experiment focused on the use of mineral fertilizers $\text{N}_0\text{P}_0\text{K}_0$ (control); $\text{N}_9\text{P}_0\text{K}_{45}$; $\text{N}_{120}\text{P}_{30}\text{K}_{80}$; $\text{N}_{150}\text{P}_{10}\text{K}_{75}$ and $\text{N}_{180}\text{P}_{20}\text{K}_{60}$ is carried out on rice paddies. Soil samples are taken from the plow layer before seeding and after harvesting of rice; a total humus content and fraction-group composition are studied. An increase in fulvic acids is detected in soils as a consequence of dominant reduction and oxidative degradation of humic acids. Heightened amounts of fertilizers make humus more fulvic. A labile fraction in the total humus content is determined to be 7.97-11.02 % in meadow soil and 5.38-8.33 % in meadow-bog soil. In labile humus of meadow soils fulvic acids prevail over humic acids ($\text{HA}-1$: $\text{FA}$ (1a+1) = 0.71-0.89). A share of fulvic compounds is higher in meadow-bog soils ($\text{HA}-1$: $\text{FA}$ (1a+1) = 0.38-0.55). Mineral fertilizers taken in ratios of $\text{N}_{150}\text{P}_{10}\text{K}_{75}$ and $\text{N}_{180}\text{P}_{20}\text{K}_{60}$ raise a percentage of newly formed humus substances.

1. Introduction

The soil use for rice crops is associated with an additional anthropogenous factor – long-term soil flooding. This fact necessitates an annual 4-5 month recovery of paddy soils. This dramatically changing environment leads inevitably to transformations in essential elementary soil processes and affects the soil balance. Humus-related impoverishment or enrichment of paddy soils depends on the amount and biochemical composition of a coming organic matter and its decay rate. The intensification of crop residues mineralization when irrigated is supposed to be a natural process because there is a specific dynamic balance in humus of soils not irrigated for a long time. Its content and composition are in line with certain bio-hydrothermal conditions, transforming, they make old humus irresistible to the new environment, facilitating its degradation. Over time, properties of humus substances tend to change and they are not in conflict with new biochemical and hydrothermal conditions [1-3].

The humus lability develops in periodically flooded paddy soils. Processes of reduction to evolve in excessively moistened soils decrease a share of humus for water soluble organic matters are taken away, and humification shifts increasingly to the formation of fulvic acids [4-7]. Both a total quantaty of humic acids and their calcium-related content decline, i.e. the most active humus fraction important to soil buffering is removed. At the same time, groups of tightly bound humic acids and humin, i.e. low-active humus rise [8].

The study aims to explore an influence of anthropogenous factors on the humus content of paddies.
2. Objects and methods
The research was carried out on meadow and meadow-bog soils of rice paddies in Takhtamukaysky District of the Republic of Adygea (Gleyic Pheozems and Calcic Chernic Gleysol in WRB [9]). In geomorphology the northern part of the territory belongs to the Kuban delta and floodplain, which includes low highlands and quite wide and extended depressions. The southern region is a part of the Pre-Kuban sloping plain. The hydrographic network covers the river of Kuban with its tributaries - mountain rivers: Psekups, Afps, Tsitsa, Apgas, Shunduk, etc.

Soil-geographical regionalization attributes the district to steppe lands of the chernozym region in the Azov-North Caucasian steppe facies of the soil area in the lower reach of the Kuban River. Basically, the soil mantle consists of meadow soils, i.a. meadow gleic and meadow-bog types. Soils are referred to as classified in [10].

Geographically, meadow soils are found in the floodplain of the Kuban and its tributaries, meadow gleic soils – in lower zones, and meadow-bog ones in closed low floodplains and ravine bottoms.

A field experiment on fertilization was carried out in a rice paddy. Fertilizers were applied before rice seeding in ratios: N₀₈P₀₉K₀ (control); N₉₀₈P₆₀K₁₅; N₁₂₀₈P₈₀K₆₀; N₁₅₀P₁₀₀K₇₅; N₁₈₀P₁₂₀K₉₀.

In soil samples taken before seeding and after harvesting a content of total humus was estimated by the Tyurin method, and to characterize the humus composition we used the Tyurin method with modifications by Ponomaryeva and Plotnikova. A state of labile and inert humus was analyzed according to fractions of humic and fulvic acids.

The Tyurin method includes sulfur-chromium oxidizing of an organic matter. A fraction of organic carbon in the soil was corrected to humus content using a coefficient of 1.724 [11, 12].

When assessing the humus composition as in the modification by Ponomaryeva and Plotnikova, an alkaline extract was taken from a soil weighted sample and various fractions of organic matters were sequentially extracted from other weighted samples of the same soil type. Within this method it is possible to divide soil humus into three fractions of humic acids – HA (fraction HA-1 free and bound with non-silica sesquioxides; HA-2 calcium-related; HA-3 – with stable forms of sesquioxides and clay minerals), and four fractions of fulvic acids – FA (fraction FA-1a free and bound with non-silica sesquioxides or “aggressive”; FA-1 – bound with fraction 1 of humic acids; FA-2 – bound with fraction 2 of humic acids; FA-3 – bound with fraction 3 of humic acids) and humin (insoluble part) [11].

3. Results and discussion
Before rice seeding humus content in the plow layer of meadow and meadow-bog soils was as high as 3.70 and 3.90 %, respectively. The use of mineral fertilizers had a positive effect on the humus state of soils – at the end of a rice growing season a humus content increased by 0.08-0.14 % and by 0.10-0.17 %, respectively, as compared with the control data (Table 1-2).

An important characteristic of soil humus is its group and fraction composition. Studies with the focus on quality composition of soil humus in rice paddies are of theoretical and practical significance, contributing to the control of pedogenesis processes, which are relevant for the humus state.

A correlation between humic and fulvic acids in humus composition provides information on a humus-formation type, a resultant of natural factors and anthropogenous influence on soils. A content of carbon in humic acids is higher than that in fulvic acids in the group composition of meadow and meadow-bog soil humus. When a rice vegetation season was completed and irrigation water removed from paddy fields, a content of fulvic acids increased from 18.9 and 20.0 to 19.6-21.1 and 20.8-22.9 % vs. total carbon, respectively. The fertilization didn’t make a difference for a content of humic acids but a fraction of fulvic acids increased in the composition of humus. In addition, an increased use of fertilizers makes humus more fulvic, especially in meadow-bog soils, where humic type of humus alters to the fulvic and humic one. Meadow soil humus is humic (Cₗ₈: Cₗ₆ = 2.17-2.49), and that of meadow-bog soil – humic (Cₗ₈: Cₗ₆ = 2.10-2.28) or fulvic and humic (Cₗ₈: Cₗ₆ = 1.94-2.00). The latter correlation Cₗ₈: Cₗ₆ is narrower, indicating higher mineralization resistance of humus.

Humin characterizes the strength humus matters bind with a mineral soil element, i.e. its silt fraction; its hydrolysis and mineralization are hard. In soils of rice paddies under study a low amount of non-
hydrolyzed residue was detected. They display no significant differences. Fertilizers reduced an insoluble residue from 34.1-34.5 (control) to 32.4-33.8 % vs. C₁ on fertilized areas.

Transformations in humus and its growth are well characterized using labile forms of humus substances. These are “young” forms of humus with a high nitrogen concentration. They tend to quick mineralization, supplying nitrogen to plants. A ratio between labile and inert humus fractions in soils makes possible the estimation of humus content dynamics and its resistance to negative natural and anthropogenous factors, and their dehumification rates [13].

In contrast to meadow soils humus of meadow-bog soils is characterized with low lability, an inert part in its composition amounts to 91.7-94.6 % vs. total humus. This percentage in meadow soil is less significant, being 89.0-92.0 % of total humus (Table 1-2).

### Table 1. Total, labile, and inert humus in the meadow soil

| Variant | Determination period | Total humus (%) | Labile humus (%) | Inert humus (%) | Labile vs. total (%) |
|---------|---------------------|----------------|-----------------|----------------|---------------------|
| N₀P₀K₀  | prior rice seeding  | 3.70           | 0.34            | 3.36           | 9.19                |
| N₀P₀K₄₅ | after harvesting    | 3.64           | 0.29            | 3.35           | 7.97                |
| N₁₀₀P₀K₄₀ | after harvesting  | 3.66           | 0.38            | 3.28           | 10.38               |
| N₁₀₀P₁₀₀K₆₀ | after harvesting | 3.78           | 0.38            | 3.40           | 10.05               |
| N₁₈₀P₁₀₀K₇₅ | after harvesting | 3.78           | 0.40            | 3.38           | 10.58               |
| N₁₈₀P₁₂₀K₉₀ | after harvesting | 3.72           | 0.41            | 3.31           | 11.02               |

In labile humus of meadow soil fulvic acids prevail over humic acids in a ratio HA-1: FA (1a+1), equal to 0.71-0.89. Importantly, a content of humic and fulvic acids was equal before flooding: HA-1: FA (1a+1) = 0.10.

Labile humus of meadow-bog soil contains more fulvic compounds with a ratio HA-1: FA (1a+1) = 0.38-0.55, what indicates the considerable predominance of fulvic acids. Before flooding a concentration of labile humus was low with dominating fulvic acids: HA-1: FA (1a+1) =0.50.

In inert humus of meadow soil calcium-related fractions are most important (34.7-37.8 %) in a ratio HA-2: FA-2 = 7.67-8.75, as well as humin in a percentage of 32.8-34.6 % of total humus. Fractions of clay minerals and stable forms R₂O₃ are least important with a share of 18.6-21.0 % in total humus. Fulvic acids prevail there with a ratio HAK-3: FA-3, equal to 0.82-0.96.

Inert humus in meadow-bog soil is similar to that of meadow soil. Calcium-related fractions are in a percentage of 35.1-39.0 % (HA-2: FA-2 = 4.73-5.83), non-hydrolyzed residue amounts to 32.3-34.4 %; fractions of clay minerals and stable forms R₂O₃ – 21.3-24.0 % of total humus (HA-3: FA-3 = 1.00-1.12).

### Table 2. Total, labile, and inert humus in the meadow-bog soil

| Variant   | Determination period | Total humus (%) | Labile humus (%) | Inert humus (%) | Labile vs. total (%) |
|-----------|---------------------|----------------|-----------------|----------------|---------------------|
| N₀P₀K₀    | prior rice seeding  | 3.90           | 0.21            | 3.69           | 5.38                |
| N₀P₀K₄₅  | after harvesting    | 3.82           | 0.21            | 3.61           | 5.50                |
| N₁₀₀P₀K₄₀ | after harvesting    | 3.92           | 0.26            | 3.66           | 6.63                |
| N₁₀₀P₁₀₀K₆₀ | after harvesting | 3.99           | 0.29            | 3.70           | 7.27                |
| N₁₈₀P₁₀₀K₇₅ | after harvesting | 3.96           | 0.33            | 3.63           | 8.33                |
| N₁₈₀P₁₂₀K₉₀ | after harvesting | 3.93           | 0.32            | 3.61           | 8.14                |

The use of mineral fertilizers raised a share of labile humus in soils. Before rice seeding and flooding of paddies its amount was 0.34 in meadow and 0.21 % in meadow-bog soils, on vegetation completion – 0.29 and 0.21 % (control) and 0.38-0.41 and 0.26-0.33 % on fertilized areas, respectively. The increased usage of fertilizers N₁₈₀P₁₀₀K₇₅ and N₁₈₀P₁₂₀K₉₀ contributed to the enrichment of soils with
labile humus. At the end of rice cultivation period its content in total soil humus was as high as 10.58 and 11.02 % in meadow and 8.33 and 8.14 % in meadow-bog soil, respectively (Table 1-2).

To summarize, mineral fertilizers raise an amount of newly formed humus substances, which are immediate reserves of fertilization elements for plants and microorganisms. Therefore, the total humus content and its labile part represent most important indicators of the humus state in rice paddy soils.

4. Conclusion
When growing rice, fulvic acids increased in meadow and meadow-bog soils owing to dominant reduction processes and oxidative degradation of humic acids. The use of mineral fertilizers contributed to humus preservation in soils. In humus of soils under consideration compounds of humic acids or substances related to fulvic and humic acids dominate. An increase of fertilizers makes humus more fulvic. A labile fraction in total humus amounts to 7.97-11.02 % in meadow and 5.38-8.33 % in meadow-bog soil, respectively. In labile humus of meadow soil fulvic acids prevail over humic acids (HA-1: FA (1a+1) = 0.71-0.89). Humus of meadow-bog soil is more fulvic (HA-1: FA (1a+1) = 0.38-0.55). Fertilizers contribute to the development of “young” labile humus substances. The increased usage of fertilizers N₁₅₀P₁₀₀K₇₅ and N₁₉₀P₁₂₀K₉₀ intensify processes of humus formation.

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