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Changes of the humus status of Pellic Vertisol (FAO) soil type under long-term growing of field crops in a stationary trial without fertilization

V. Koteva*, S. Kostadinova1

1Institute of Agriculture, 1 Industrialna, 8400 Karnobat, Bulgaria
2Department of Agrochemistry and Soil Science, Faculty of Agronomy, Agricultural University, 12 Mendeleev, 4000 Plovdiv, Bulgaria

Abstract. This investigation was aimed at determining the changes in the humus content of leached Pellic Vertisol under long-term growing of intensive field crops in crop rotation in a stationary field trial without fertilization. For this purpose agrochemical investigations were carried out in the 48-year-old stationary fertilizer trial maintained at the Institute of Agriculture, Karnobat, Bulgaria on Pellic Vertisol (FAO). The analyzed soil samples were taken from the 0-100 cm horizon of the stationary trial and from soil not subjected to anthropogenic influence (under forest vegetation and from virgin land). The total humus content was determined and the humus reserves and humus energy were calculated. It was found that the leached Pellic Vertisol subjected to long-term land use without introduction of fertilizers had humus content two times lower than the content in soil where natural soil formation processes occurred without anthropogenic influence (under forest vegetation and on virgin land). At 48-year growing of field crops without fertilization, humus content in the 40 cm soil horizon decreased with 5-7 relative percent. In the 40-100 cm horizon significant changes did not occur. High correlation was determined between the total humus reserves and the yield from the field crops (R from + 0.668 to + 0.724)

Keywords: Pellic Vertisol, humus, changes, fertilization, stationary trial

Introduction

It is an indisputable fact that humus content is at the basis of potential soil fertility. It is also an indisputable fact that it is formed under the influence of natural soil-formative processes which occur slowly, for centuries. However, in soils subjected to intensive agricultural cultivation, the natural humus content changes comparatively fast, not only the quantity but also the quality of humus changing in the process (Pachev, 1997). The opinions of the researchers on this problem are not unanimous. According to some authors the intensive agriculture factors (fertilization, soil tillage, crop rotations, irrigation, etc.) cause decrease of total humus (Kenenbayev and Kucherov, 1995; Artinova, 1995; Valev and Guchevilov, 1998). According to others it does not change (Mineev et al., 1986; Charkov, 1987; Martinovich and Martinovich, 1989; Saratov and Valev, 1990; Nankova and Kalinov, 1992). According to Martinovich and Martinovich (1989) and Panayotova (2005) it even increases. Analyzing the changes, researchers pay attention to both the total percent content of humus and to its reserves in the cultivated horizon, its energy content (Tvertin, 1984; Koteva, 1993; Artinova, 1995; Artinova, 2012). The total reserves are related to the productivity of the agricultural crops, and the energy reserve – to the balance of energy in agriculture (Raichev and Filcheva, 1989; Volodin, 1992; Klochkov and Klochkova, 1995).

The quantitative and qualitative changes in soil humus are determined by the relations between the processes of synthesis and decomposition of the organic matter. They are dynamic and are expressed specifically under particular soil and climatic conditions and systems of agriculture. These processes are best studied in long-term stationary trials. It is in such long-term field trials carried out on different soil types that the most thorough investigations on the changes of humus in Bulgaria have been done (Filipov, 1972; Artinova and Giurov, 1988; Nankova and Kalinov, 1992; Koteva, 1993; Filipov and Delchev, 2001; Panaiotova, 2003; Tomov and Artinova, 2005; Panaiotova, 2009).

In the trial field of the Institute of Agriculture, Karnobat, a stationary field trial has been maintained for 48 years on leached Pellic Vertisol. While investigating the condition of natural humus reserves and their changes, up to now in the stationary trial the main focus has been on humus changes under the effect of various norms of mineral fertilization. The dynamics of the humus status in soil under growing of crops without mineral or organic fertilization has not been studied.

Therefore we set the following goals: to find out the changes in the humus content of leached Pellic Vertisol under long-term growing of field crops in the crop rotation of a stationary field trial without fertilization; to compare the condition of humus under long-term growing of the crops without fertilization to their growing with “moderate” norms of nitrogen, phosphorus and potassium fertilization; to compare the natural humus status of the leached Pellic Vertisol in which no agricultural activity has been carried out (under forest vegetation and virgin land) to the humus content of soil subjected to intensive land use.

Material and methods

To realize the above goals, agro-chemical investigations were done in a long-term stationary trial initiated in 1963 at the Institute of Agriculture, Karnobat on soil type Pellic Vertisol (FAO). The crop-rotation of the trial included maize, wheat, sunflower and barley, which were alternated in time and place. The crops were treated with conditionally designated “low”, “moderate” and “high” N-P-K norms (Koteva, 1993). A check variant without treatment was used for comparison. The design of the trial and the levels of the fertilization norms of the respective crops have already been described in our
variants. It is evident that the sharpest decrease in the untreated twice richer in humus in comparison to the soil from the same region of Gorni Dabnik (30-year stationary trial) was by 11% (Valev There are interesting data from the analysis of the samples from the stationary trial, samples taken from the same horizons of the leached *Pellic Vertisol* under forest deciduous vegetation (forest shelter belt) and virgin land (field boundary) situated about 500 m from the stationary trial were also analyzed. Total humus was determined from these samples according to Tyurin (1965). The same method was applied to determine humus prior to the initiation of the trial. Based on the established total humus content and the volume weight of soil in the respective horizon determined in a previous investigation (Koteva, 1993), the total humus reserves were calculated (t/ha). Using the methodology of Orlov and Grichina (1981), the humus energy was determined (MKJ/ha).

## Results and discussion

The analysis on the soil samples from the 0 – 20 cm horizon investigated on the 48th year from the initiation of the trial showed that the initial total humus content of 2.48 – 2.53% decreased to 2.36% under growing of crops without fertilization (Table 1). The above decrease, comprising 4.8 – 6.7% of the total humus, is alarming for the relatively short period of the study. During the same period, the long-term “moderate” N-P-K fertilization increased total humus to 2.74% and stabilized it within the range of 2.62 – 2.79%. The increase comprised about 5.7 – 10.3 relative percent according to the initial humus level. A number of Bulgarian researchers have reported significantly higher increase of the total humus in the arable areas of different soil types where field crops were grown without fertilization. Misas (2003) found out that after 40-year growing of field crops without fertilization, the total humus in the cultivated horizon of alluvial meadow soil in the region of Plovdiv decreased by 22% according to the initial level. The decrease of humus in the leached *Pellic Vertisol* under the same conditions of land use (40-year stationary trial) in the region of Chirpan was by 14% (Panayotova, 2005), and the decrease of humus in the leach chernozem soil in the region of Gorni Dabnik (30-year stationary trial) was by 11% (Valev and Gushelev, 1998).

Table 1 presents long-term data on the total humus content in the surface soil layer of the untreated and “moderately” treated variants. It is evident that the sharpest decrease in the untreated check variant occurred after the first rotation (7.5%). After the second rotation and during the 6–12th rotations humus slightly increased and stabilized at levels 2.36 – 2.40%. During the same period the “moderate” mineral fertilization preserved the initial humus content in the first and second rotation, then gradually enhanced it and stabilized it at levels 2.73 – 2.79%.

The investigations on the distribution of humus down the soil profile revealed differences between the untreated and the “moderately” treated variants only in the 0 – 20 cm and 20 – 40 cm horizons (Table 2). Down the profile, from 40 cm to 100 cm, the humus content became equal and was not affected by the way of land use. It can be assumed that this is, on the one hand, a consequence from the long-term growing of the crops in the stationary trial, the roots of which are located mainly in the horizon with depth up to 40 cm, and on the other hand – a consequence from the soil tillage incorporating the post harvest residues to the same depth. The biomass of roots and the post harvest residues compensated to some extent the mineralization of humus in this very horizon.

There are interesting data from the analysis of the samples from the leached *Pellic Vertisol* which was not subjected to anthropogenic activity and situated under deciduous forest vegetation and under virgin land. Under such conditions the 60 cm soil horizon was almost twice richer in humus in comparison to the soil from the same

### Table 1. Total humus content in the 0 – 20 cm soil horizon, %

<table>
<thead>
<tr>
<th>Period</th>
<th>Without fertilization</th>
<th>With “moderate” N-P-K fertilization</th>
<th>Data on humus investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962 (prior to trial initiation)*</td>
<td>2.48 – 2.53</td>
<td>2.36 – 2.40</td>
<td>2.36 – 2.48</td>
</tr>
<tr>
<td>1 rotation (1963 - 1966 )*</td>
<td>2.34</td>
<td>2.36 – 2.47</td>
<td>2.36 – 2.47</td>
</tr>
<tr>
<td>2 rotation (1967 – 1970)*</td>
<td>2.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 rotation (1971 – 1974)</td>
<td>2.36</td>
<td>2.47 – 2.47</td>
<td></td>
</tr>
<tr>
<td>4 rotation (1975 - 1978)</td>
<td>2.36</td>
<td>2.73 – 2.79</td>
<td></td>
</tr>
<tr>
<td>5 rotation (1979 – 1982)</td>
<td>2.36</td>
<td>2.73 – 2.79</td>
<td></td>
</tr>
<tr>
<td>6 rotation (1983 – 1986)**</td>
<td>2.36</td>
<td>2.73 – 2.79</td>
<td></td>
</tr>
<tr>
<td>7 rotation (1987 – 1990)**</td>
<td>2.36</td>
<td>2.73 – 2.79</td>
<td></td>
</tr>
<tr>
<td>8 rotation (1991 – 1994)**</td>
<td>2.40</td>
<td>2.73 – 2.79</td>
<td></td>
</tr>
<tr>
<td>9 rotation (1995 – 1998)**</td>
<td>2.36</td>
<td>2.73 – 2.79</td>
<td></td>
</tr>
<tr>
<td>10 rotation (1999 – 2002)**</td>
<td>2.39</td>
<td>2.73 – 2.79</td>
<td></td>
</tr>
<tr>
<td>11 rotation (2003 – 2006)**</td>
<td>2.38</td>
<td>2.73 – 2.79</td>
<td></td>
</tr>
<tr>
<td>12 rotation (2007 – 2010 )**</td>
<td>2.36</td>
<td>2.74 – 2.79</td>
<td></td>
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</tbody>
</table>

Note: * Investigations by Filipov (1972); **Own investigations

### Table 2. Total humus content in the 100 cm soil horizon under different systems of land use and without anthropogenic influence in 2011, %

<table>
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<tr>
<th>Horizon, cm</th>
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<th>Under deciduous forest vegetation</th>
<th>Under virgin land</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 20</td>
<td>2.36</td>
<td>2.74</td>
<td>5.01</td>
<td>4.31</td>
</tr>
<tr>
<td>20 – 40</td>
<td>1.31</td>
<td>1.43</td>
<td>2.41</td>
<td>2.92</td>
</tr>
<tr>
<td>40 – 60</td>
<td>0.86</td>
<td>0.88</td>
<td>1.94</td>
<td>1.97</td>
</tr>
<tr>
<td>60 – 80</td>
<td>0.71</td>
<td>0.57</td>
<td>0.61</td>
<td>0.64</td>
</tr>
<tr>
<td>80 – 100</td>
<td>0.51</td>
<td>0.49</td>
<td>0.55</td>
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The reserves of humus and energy in humus of the 20 cm soil horizon under different systems of land use

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<th>Rotation (periods)</th>
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<td></td>
<td>Humus reserves, t/ha</td>
<td>Humus energy, MKJ/ha</td>
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<tr>
<td>7 rotation (1987 – 1990)</td>
<td>59</td>
<td>739</td>
</tr>
<tr>
<td>9 rotation (1995 – 1998)</td>
<td>61</td>
<td>739</td>
</tr>
<tr>
<td>10 rotation (1999 – 2002)</td>
<td>62</td>
<td>754</td>
</tr>
<tr>
<td>11 rotation (2003 – 2006)</td>
<td>59</td>
<td>744</td>
</tr>
<tr>
<td>12 rotation (2007 – 2010)</td>
<td>61</td>
<td>739</td>
</tr>
</tbody>
</table>

horizons which was subjected to intensive land use both with and without mineral fertilization. Down the soil profile, below 60 cm, the humus content of all four variants became practically equal.

The humus reserves in the untreated variant remained similar to the initial condition and were relatively constant during the last 28 years of the stationary trial, with slight variation within 59–62 t/ha (Table 3). The difference between the soil without introduction of mineral fertilizers and the soil with annual application of “moderate” N-P-K norms was significant. In the second variant the leached Pellic Vertisol contained considerably higher humus reserves which increased with each successive rotation and for 48 years fertilization gradually increased the initial humus reserves by 23 t/ha.

In accordance with the humus reserves, the reserves of energy in the humus were also calculated: The humus of the untreated soil contained 54-99MKJ/ha less energy in comparison to the “moderately” fertilized soil. The modified solar energy accumulated in the soil humus is an invaluable source of viability of the microorganisms in the soil and the various biological transformations. Therefore, it plays an important role in the management of the soil processes. The indicated lower energy accumulated in the untreated soil is probably due to the lower biological activity in this variant as determined in a previous microbiological investigation in the same stationary trial (Koteva, 2002).

In the database of the stationary trial the annual grain yield from the crops grown in the rotation (maize, wheat, sunflower and barley) were pointed out. The data on the yield and the humus condition of the crops grown in the rotation (maize, wheat, sunflower and barley) were processed with correlation analysis. It was found that the correlation of yield with the humus reserves represented as t/ha, was higher (R from + 0.610 to + 0.700) than the correlation of yield with total humus represented as % (R from +0.485 to +0.520).

Conclusion

The leached Pellic Vertisol subjected to long-term land use without introduction of fertilizers had two times lower humus content (2.36%) than the humus content in the soil with natural soil-formative processes without anthropogenic influence under deciduous forest vegetation and virgin land (respectively 5.01 and 4.31%). Humus content in the 20 cm soil horizon decreased by 4.8 – 6.7 relative percent at 48-year annual growing of the field crops without fertilization. After 48 years, in the 40 – 100 cm horizon significant changes did not occur. The high correlations (R from + 0.688 to + 0.724) of the total humus reserves (t/ha) with the grain yield from the field crops (kg/ha) grown in the crop rotation of the stationary trial allowed considering this index sufficiently significant and suitable for characterization of the potential fertility of the leached Pellic Vertisol soil type.

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