Long-term Effect of Fertilization and Crop Rotation on Wheat Yields and on the Aggregate Size Distribution and Organic Matter Content of the Soil

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In the upper soil layer organic matter is constantly being created and decomposed. The humus pool of the soil is relatively stable (JENNY, 1941).

KEMENESY (1961) discriminated between humus-increasing and humus-decreasing crops, by means of which the soil organic matter pool can be maintained or increased. It was demonstrated by factor analysis in Martonvásár that the humus content of the soil is influenced by the soil tillage system, fertilization and crop rotation, in this order (GYŐRFFY, 1975).

Humus substances are well known to influence the physical condition of the soil indirectly through the water-air ratio and the water management of the soil (GYŐRI, 1984). Since the soil organic matter content may be affected to a certain extent by crop rotation, the physical parameters (macrostructure, aggregate size distribution) may also be affected. In soils with high organic matter contents the level of biological activity is also higher (TATE, 1987). Soil microorganisms produce secretions which stabilize the soil aggregates (COOK & ELLIS, 1987), though other authors warn against attaching too great importance to this phenomenon, because the effect of microorganisms on aggregate stability lasts for only a short time and cannot be regarded as permanent (DVORACSEK et al., 1957).

The effect of crop rotation has been studied in long-term experiments set up by the Department of Agronomy of the Georgikon Faculty of Pannon University, Keszthely. The investigations were supported by the National Scientific Research Fund (OTKA T 016469).

Materials and Methods

Data were processed from long-term crop rotation trials set up in Keszthely by Ernő Kemenesy in 1963. The bi-factorial trials were arranged in a randomized complete block design with four replications, applying mineral and

organic fertilizer treatments. For details of plot size, soil type and climate, see the authors' previous paper in this volume (KISMÁNYOKY & TÓTH, 1997).

The study was conducted on the wheat grown in two types of five-year crop sequences (winter wheat - alfalfa - alfalfa - winter wheat - maize; winter wheat - oats and vetch - winter wheat - maize - sorghum), thus involving four different forecrops (maize, alfalfa, oats and vetch, sorghum) and four fertilizer treatments (A: control; B: 520 kg NPK ha^{-1} 5 yr^{-1}; C: 2080 kg NPK ha^{-1} 5 yr^{-1}; D: 2080 kg NPK + 35 t farmyard manure ha^{-1} 5 yr^{-1}). The farmyard manure was applied before maize every fifth year.

Soil samples were collected in the winter wheat plots at a depth of 30 cm in May. The humus content was quantified by Tyurin's method, while the aggregate size distribution was determined by sieving. The aggregates were separated into three groups (<0.25 mm: dust; 0.25-10 mm: crumb; >10 mm: clod). Analysis of variance was used to test the statistical significance of the treatments.

Results

Winter wheat yield

The significant effect of the forecrops on the grain yield of wheat decreased at the highest nutrient level, but did not disappear completely (Figure 1).

In the unfertilized plots (treatment A) the effect of the forecrop can clearly be seen. This effect decreased at the high nutrient level, but did not disappear. Sudan grass (sorghum) proved to be the worst forecrop for winter wheat, and oats and vetch the best. In treatment B the yield increased significantly compared to the yield recorded in treatment A, but a further rise in the fertilizer rate (treatments C and D) did not lead to a further significant increase.

Oats and vetch resulted in a significantly higher yield when averaged over the treatments compared to the effect of the other three forecrops. The highest yields were registered in the crop rotation without alfalfa.

Humus content

The humus content was significantly higher after alfalfa than after Sudan grass and after oats and vetch. The humus-increasing effect of farmyard manure could be observed when wheat was grown after maize in the manured treatment. The soil organic matter content increased parallel with the rise in fertilizer rates (Figure 2).

Treatments C and D resulted in a significantly higher humus content compared to treatment A, while in treatment D the humus content was also significantly higher than in treatment B.

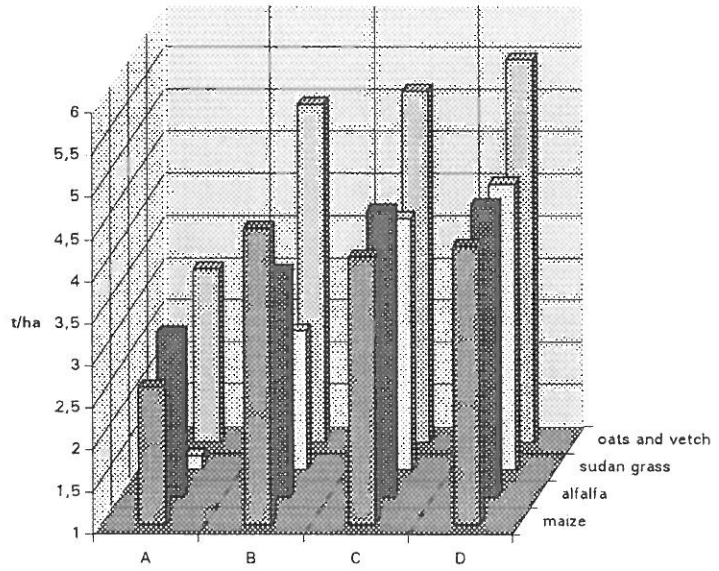

Figure 1
Yields of winter wheat plots as a function of forecrops and fertilizer rates (A-D)
$LSD_{5\%}$ between combinations: 1.6; between means: 0.8

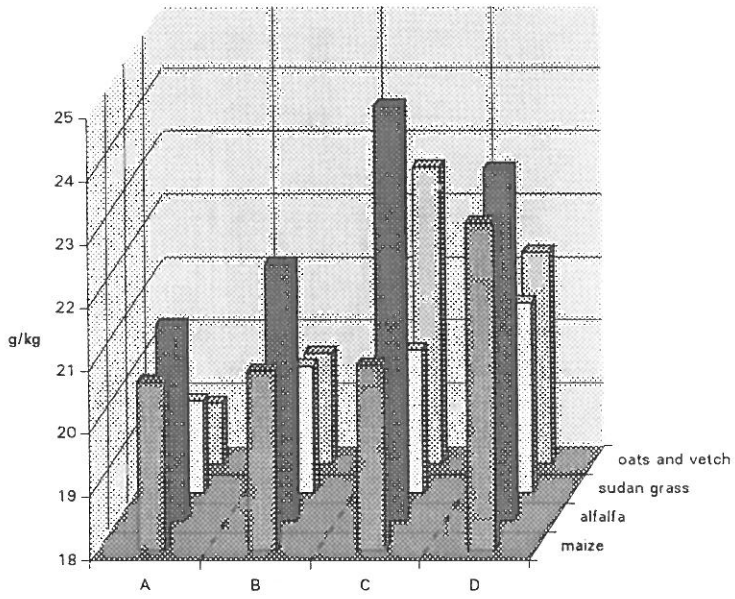

Figure 2
Humus content of soil as a function of forecrops and fertilizer rates (A-D)
$LSD_{5\%}$ between combinations: 3.06; between means: 1.53

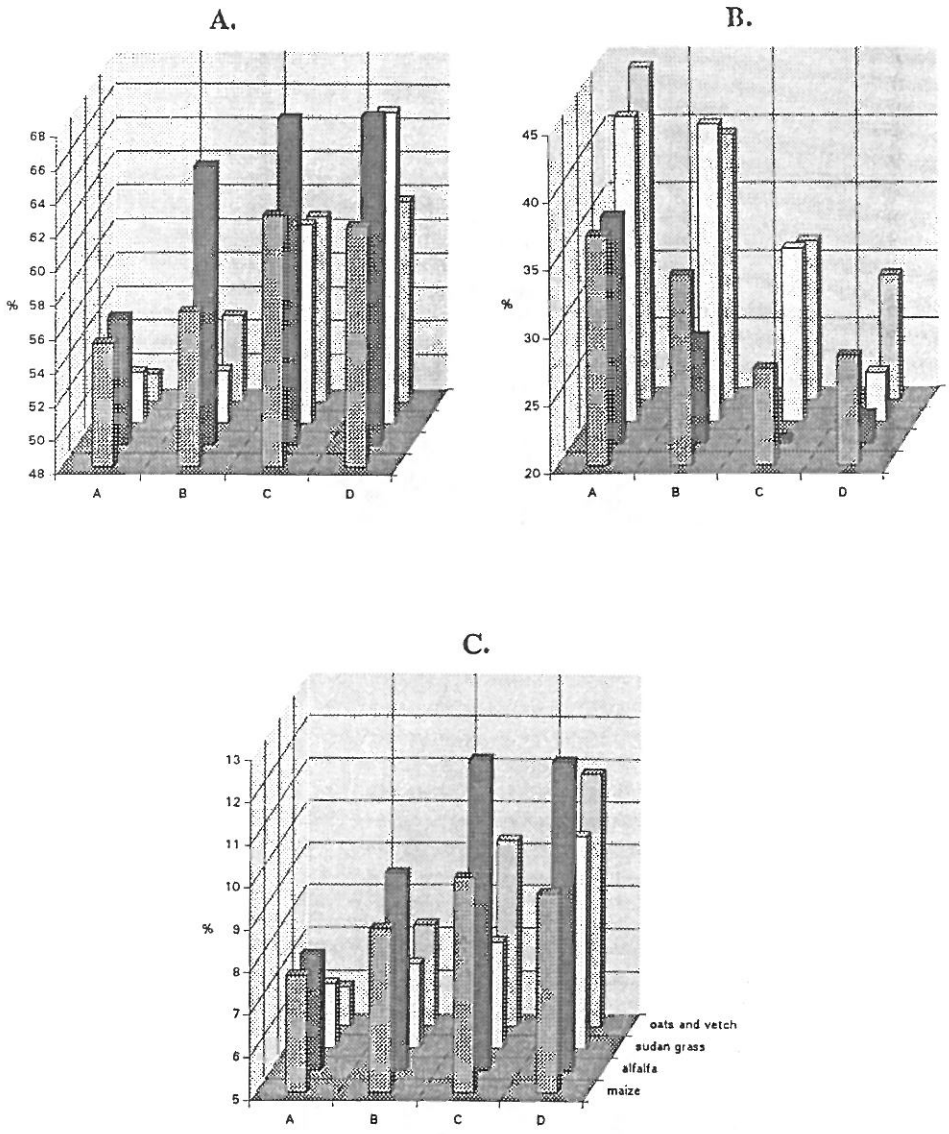

Figure 3
Aggregate size distribution (A. >10.0 mm; B. 0.25-10.0 mm; C. <0.25 mm) as a function of forecrops and fertilizer rates. $LSD_{5\%}$ between combinations: A. 10.54; B. 8.80; C. 2.69. $LSD_{5\%}$ between means: A. 5.27; B. 4.40; C. 1.34

Aggregate size distribution

The proportion of the undesirable clod fraction (>10 mm) decreased with a rise in the fertilizer rates, while that of the desirable crumb fraction (0.25-10 mm) increased. The proportion of the dust fraction (<0.25 mm) also increased, but not to such a great extent.

In treatments C and D the proportions of the crumb and dust fractions were significantly larger, while the proportion of the clod fraction was significantly smaller than in treatments A and B.

Alfalfa as a forecrop had a significant positive effect on the aggregate size distribution compared to the other three crops. The proportion of the clod fraction decreased and that of the crumb fraction increased after alfalfa, but it should be noted that the dust fraction also increased, presumably due to the intensive soil tillage after alfalfa (Figure 3A,B,C).

Summary

The long-term effects of fertilization and crop rotation on winter wheat yields and on changes in soil humus content and aggregate size distribution were studied in a long-term two-factor crop rotation experiment involving mineral and organic fertilization treatments, set up in 1963.

It can be seen from the trends that fertilization, soil humus content and aggregate size distribution are correlated with each other. As a consequence of optimal fertilization the physical conditions of the soil improves. This process is influenced by the crops grown.

The significant effect of the forecrops on the grain yield of wheat decreased at the highest nutrient level, but did not disappear completely.

The humus content of the soil increased parallel with the rise in fertilizer rates in the crop sequences. Alfalfa and farmyard manure had a positive effect on the humus content of the soil and the aggregate size distribution also improved when alfalfa was the forecrop.

It was found that the soil structure did not deteriorate when high rates of fertilizer were applied in a crop rotation, in fact some improvement could be observed, presumably as a result of larger root mass.

References

COOK, L. R. & ELLIS, B. G., 1987. Soil Management. John Wiley & Sons, Inc. New York, USA.

DVORACSEK, M., DI GLÉRIA, J. & KLIMES-SZMIK, A., 1957. Soil Physics and Soil Colloidics. (In Hungarian) Akadémiai Kiadó. Budapest.

GYŐRFFY, B., 1975. Crop rotation - crop sequence - monoculture. (In Hungarian) Agrártud. Közlem. 34. 61-90.

GYŐRI, D., 1984. The Fertility of Soil. (In Hungarian) Mezőgazdasági Kiadó. Budapest.

JENNY, H., 1941. Factors of Soil Formation. McGraw-Hill Co. New York - London.

KEMENESY, E., 1961. The Principles of Agriculture. (In Hungarian) Akadémiai Kiadó. Budapest.

KISMÁNYOKY, T. & TÓTH, Z., 1997. Role of crop rotation and organic manure in sustainable land use. Agrokémia és Talajtan. 46. 99-106.

TATE, R. L., 1987. Soil Organic Matter. John Wiley & Sons, Inc. Toronto.