SOIL FERTILITY DEPENDING ON ORGANIC AND MINERAL FERTILIZATION, IN A 46-YEAR LONG-TERM FIELD EXPERIMENT

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Increasing doses of farm-yard manure (FYM) or equivalent mineral NPK fertilizers and their combinations were analyzed in a crop rotation with potato, maize and winter wheat with special regard to their long-term influence on soil fertility. The yield-increasing capacity of FYM doses was only 82 %, as compared to the equivalent amount of mineral NPK. Fairly high N-release (50.9 kg ha^{-1}) could be observed on the unfertilized plots. Great differences in N-utilization developed depending on the form and dose of fertilizers. The average N-utilization from FYM was only 29.3 %, while that of equivalent fertilizer application was 49.8 %. The lowest soil reactions were observed both without fertilization and with the highest NPK doses. Negative N-balances generally resulted in low soil organic matter content. FYM and equivalent NPK fertilizers similarly influenced the ammonium-lactate-extractable (AL)-K_2O content of the soil. An increased AL-P_2O_5 content, however, could be observed in case of mineral fertilization.

Key words: crop yield, N-balance, N-utilization

Introduction

At present it is impossible to supply the world population the without mineral fertilization. The highest challenge for modern agriculture is to maintain soil fertility and to preserve the original condition of the natural environment besides increasing production as much as possible. Many factors contribute to the deterioration of the soil fertility (soil degradation, deterioration of the soil structure, acidification, salinization etc). Agriculture endangers the natural environment first of all through water pollution by nitrogen and phosphorus fertilization (*Csathó and Radimszky,* 2007). At the same time, these are the most effective factors of the efficient food production (*Tóth et al*., 2009). Therefore, it is a primary task to apply organic and mineral fertilizers as well as crop rotation properly (*Pepó*, 2007; *Árendás et al*., 2006) in order to realize sustainable agricultural development and to maintain productivity (*Jolánkai,* 2004).

The relationship between fertilization and soil fertility/productivity can not be reliably studied in the short turn and without proper documentation. Namely, the different processes in soil go on slowly and a longer period is necessary to determined their tendency and rate (*Körschens,* 2006). Long-term field fertilizer experiments, maintained for many decades, are the most suitable means for that purpose. Although these experiments were not originally set up to answer these new questions of the day, their nutrient treatments containing many different combinations, provide a reliably basis for studying these relationships;

furthermore, for forecasting the crop productivity and the future efficiency of production systems (*Berzsenyi,* 2009).

Furthermore, the results of a 46-year organic and inorganic fertilizer field experiment will be discussed. This long-term experiment was set up in 1963 when the efficiency of mineral fertilizers, compared to the farmyard manures applied almost exclusively in earlier years, was a basic issue.

Materials and methods

The long-term organic-mineral fertilizer experiment was set up on Ramann type brown forest soil (Eutric Cambisol) at Keszthely/Hungary with two crop rotations (/'A' and 'B') and different doses of (FYM) or equivalent NPK fertilizer and combined treatments of NPK fertilizer and FYM or straw manuring. Both rotations contained 15 treatments. The trials were carried out on plots of 98 m^2 (= 7 x 14), in randomized block design, in four replications. The crop rotations consisted of: 'A': potato (until 2002 sugar beet) - maize- maize – winter wheat- winter wheat (until 1985 red clover); 'B': potato - winter wheat winter wheat - maize - maize. For the present study of fertilizer effects, treatments of rotation '' modeling different nutrient supplying norms of today and reflecting also their efficiency and their long-term effect on soil fertility have been selected (Table 1). The FYM-doses were given in the first and third years, while the mineral fertilizer doses were distributed yearly.

Table 1. Selected treatments of the long-term experiment.

Treatment		**Form and dose of fertilizer during 5 years**	**Active ingredients (kg year^{-1})**
No.	**characterization**		
1	**exhausting**	**unfertilized control (coded: no)**	**$N_0P_0K_0$**
2	**organic, low dose**	**1 FYM**	**$N_{44}P_{38}K_{49}$**
3	**organic, medium dose**	**2 FYM**	**$N_{88}P_{76}K_{98}$**
4	**organic, high dose**	**3 FYM**	**$N_{132}P_{114}K_{147}$**
5	**low input**	**1 eqv**	**$N_{44}P_{38}K_{49}$**
6	**integrated I**	**2 eqv**	**$N_{88}P_{76}K_{98}$**
7	**integrated II**	**3 eqv**	**$N_{132}P_{114}K_{147}$**
8	**intensive mineral**	**4 eqv**	**$N_{176}P_{152}K_{196}$**
9	**intensive combined**	**FYM+$N_{640}P_{360}K_{660}$ (coded: 1 FYM+NPK)**	**$N_{172}P_{110}K_{181}$**

Notes: 1 FYM= 35 t ha^{-1} farmyard manure (of analyzed NPK content) in 5 years, distributed in the first and third year,
eqv. = mineral NPK equivalent to 35 t ha^{-1} FYM in 5 years, distributed yearly

Mean annual temperature and precipitation (in years 1951-2000) were 10.4 °C and 654 mm, respectively. The original fertility of this nearly neutral sandy loam was poor for organic matter and phosphorus, medium for potassium content: Humus (H) % = 1.5-1.7%; pH_{KCl} = 7.1-7.3; AL-P_2O_5 = 27-60 mg kg^{-1}; AL-K_2O = 135-160 mg kg^{-1}. In the present study, crop yields, N-balance and N-utilization of winter wheat and maize of crop rotation "A" from the 1998-2008 period of the long-term field experiment are discussed. Some major soil parameters reflecting soil fertility are also reported.

Results and discussion

Effect of fertilizer forms and doses on the grain yields

The highest yields could be gained by high mineral fertilizer doses and with combined application of FYM and mineral fertilizer (Table 2). Mineral fertilizer treatment 2 eqv. ('integrated I') was already enough to achieve an economically optimal yield level under the given site conditions. Soil parameters presented hereafter show that these fertilizer doses can be reliably qualified as environmentally friendly. Much higher fertilizer doses can be reasonable only in the case of high-level agricultural technology and special quality purposes.

Table 2. Average yields expressed in cereal unit in years 1998-2008.

Treatments			Yields ($t\ ha^{-1}\ yr^{-1}$)
No.	**Characterization**	**Codes**	
1	**exhausting**	**no**	**3.313 a**
2	**organic, low**	**1 FYM**	**4.257 b**
3	**organic, medium**	**2 FYM**	**4.471 b**
4	**organic, high**	**3 FYM**	**4.958 c**
5	**low input**	**1 ekv.**	**4.873 c**
6	**integrated I**	**2 ekv.**	**5.971 d**
7	**integrated II**	**3 ekv.**	**5.944 d**
8	**intensive mineral**	**4 ekv.**	**6.071 d**
9	**intensive combined**	**1 FYM+NPK**	**6.359 d**
$LSD_{5\%}$			**0.690**

Yields gained with FYM doses, distributed in two portions for five years ('organic') were significantly lower than those achieved with mineral fertilizer doses of equivalent NPK content, but distributed yearly. The obvious reason for this is the less effective utilization of nutrients because of their inadequate release dynamic and the increased incorporation into the soil organic matter. However, it is suitable for organic farming, which strives for the enhancement of natural soil fertility. Consequently, this process meets its expectations, because the lower yield result can be compensated through a higher price. The fertilization had an equally positive effect on all tested crops. Averaged over the treatments, the effectiveness of FYM was about 82% as compared to the equivalent NPK fertilization.

Simplified N-balances of the tested treatments

Figure 1 shows the simplified N-balances in average of the test period. On the unfertilized control plot, the average N uptake amounted to 50.9 kg ha^{-1} yr^{-1}. This data shows well the considerable natural fertility of the soil, namely this N supply was experienced in spite of any fertilization for fast five decades. To some extent, the aerial deposition and non-symbiotic N_2-fixation can be a source of this N-supply, too. Because of the worst utilization, the N-content of FYM remained in the soil, its N-balance was positive even in case of the 'low organic dose'. On the contrary, the N-balance of mineral fertilization was negative even in case of the dose regarded as economically optimal.

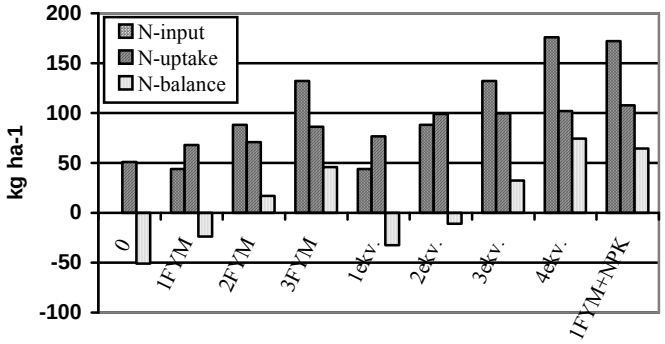

Figure 1. Simplified N-balances as a result of different mineral and organic fertilizer treatments (1998-2008)

Utilization of fertilizer-N

The utilization of fertilizer-N was calculated after the deduction of the N-uptake in the control plot (Table 3). High differences could be detected depending on the fertilizer forms and their active ingredient amounts. As it also follows from the results discussed earlier, the average N-utilization of FYM doses was much lower (29.3%) than that of the equivalent mineral fertilizer doses (49.8%). The well-known tendency, namely the decrease in the utilization with increasing N-doses, irrespective of the fertilizer form, could be observed in our experiment, too.

Table 3. Utilization of fertilizer-N (1998-2008).

Treatment code	N-utilization (%)
1 FYM	**38.4**
2 FYM	**22.7**
3 FYM	**26.7**
average FYM	***29.3***
1 eqv.	**58.2**
2 eqv.	**54.7**
3 eqv.	**36.4**
average eqv.	***49.8***
4 eqv.	**28.9**
1 FYM + NPK	**33.0**

Effect of long-term manuring and mineral fertilization on the main soil parameters

Table 4 shows the measured soil parameters. As opposed to mineral fertilization, FYM tendentiously increased the pH_{KCl} of the soil; the difference between the averaged pH values of the fertilizer forms amounted to 0.2. The highest dose of long-term mineral fertilization (4 eqv.) resulted in the lowest pH value. However, the pH_{KCl} value measured in the control plots shows, that non-fertilization (qualified as exhausting treatment) also influences the soil acidity negatively.

Table 4. Main soil characteristics affected by long-term fertilization (2007).

Treatment code	pH_{KCl}	Humus (%)	AL-P_2O_5 (mg kg^{-1})	AL-K_2O (mg kg^{-1})
control	6.3	1.40 [1]	58.0 [2]	156.0 [3]
1 FYM	6.7	1.47 [1]	58.2 [2]	163.5 [3]
2 FYM	6.8	1.53 [2]	79.7 [2]	178.7 [3]
3 FYM	6.6	1.74 [2]	133.5 [4]	163.0 [3]
average FYM	**6.7**	**1.58 [2]**	**90.5 [3]**	**168.4 [3]**
1 eqv.	6.5	1.56 [2]	68.1 [2]	165.0 [3]
2 eqv.	6.4	1.40 [1]	94.8 [3]	169.0 [3]
3 eqv.	6.5	1.61 [2]	172.0 [4]	184.0 [4]
average eqv.	**6.5**	**1.52 [2]**	**111.6 [3]**	**172.7 [3]**
4 eqv.	6.1	1.56 [2]	217.0 [5]	275.0 [4]
1 FYM + NPK	6.8	1.60 [2]	147.0 [4]	216.0 [4]

Notes: official soil fertility categories in Hungary: [1]very low, [2]low, [3]medium, [4]good, [5]very good

It is well-know that the organic matter content of the soil changes slowly. Considerable differences could not be measured in our experiment either.

Fertilization resulted in an improvement of at least one degree in the state of the supply. Organic fertilization was favorable, the highest FYM dose increased the H % to the greatest extent (by 0.24%). However, H% did not considerably differ from the control value even in treatments with negative N-balance. Equivalent mineral fertilizer doses increased the AL-P_2O_5 content of the soil to a higher degree than FYM doses. The highest nutrient supply resulted in a 'good' or 'very good' organic matter status in the soil, which might have even undesirable environmental consequences. Practically no differences could be measured between the effects of the two fertilizer forms on the AL-K_2O content in the soil. Only the highest doses could improve the originally medium K-supply.

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