0.01 M $CaCl_2$ EXTRACTED NITROGEN FORMS IN THE SOILS OF HUNGARIAN LONG-TERM FERTILIZATION TRIAL NETWORK AND THEIR CORRELATION WITH WINTER WHEAT YIELDS

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Abstract

Soil nitrogen undergoes a series of chemical and biological transformations, which influence its availability to plant nutrition and the leaching losses. Methods for measuring various forms of nitrogen in soil are important in order to improve N management and to minimize losses of nutrients in soils. In the present study, 0.01 M $CaCl_2$ extraction was used to determine the concentrations of ammonium, nitrate and organic N nitrogen, as these are closely related to the N mineralization potential of the soil and play a major role in nitrogen uptake by plants. Improving the precision of nitrogen management is essential for increasing the efficiency of production and minimizing potential losses of nitrogen in agriculture. A better knowledge of 0.01 M $CaCl_2$ extracted nitrogen forms helps to improve the efficient use of fertilizers and organic manure.

The study aimed at the optimization of the fertilizer recommendation system by considering the organic N content of soil as a measurement of site-specific mineralization potential. The 0.01 M $CaCl_2$ extraction method measures amount of nitrate (NO_3^--N), ammonium (NH_4^+-N) and organic-N compounds that are related to the transformation of nitrogen in the soil. The amount of nitrate (NO_3^--N), ammonium (NH_4^+-N) and organic N were measured 9 experimental sites of Hungarian Long-Term Fertilization Trial Network and knowledge of 0.01 M $CaCl_2$ extractable nitrogen forms help environment friendly nitrogen fertilization. Based on the results of this paper, the introduction of 0.01 M $CaCl_2$ extraction method may improve the efficient use of fertilizers and organic manure, without negative effects on the yield or the quality of produced crops. Taking costs into consideration, the 0.01 M $CaCl_2$ extraction method is suitable for the routine analysis of measuring available nitrogen forms.

Key words: 0.01 M $CaCl_2$ extractable nitrogen, nitrogen fertilizer recommendation, wheat yield, Hungarian Fertilization Trial Network.

INTRODUCTION

Németh et al. (1988) showed that the organic nitrogen fraction extracted by EUF is a reliable indication of mineralization during the growing season. Appel and Mengel (1990) reported a close relationship between organic N content and the N mineralization potential. They also showed that the nitrogen mineralization potential can be characterized with sufficient accuracy by using organic N fractions. The $CaCl_2$ extraction was found to be more appropriate than EUF or the hot water extraction. Organic fractions extracted by 0.01 M $CaCl_2$ solution were more closely related to nitrogen mineralization than the other two inorganic fractions. Similar results were reported by Jászberényi et al. (1994), Loch and Jászberényi (1997), Houba and Novozamsky (1998) and Lazányi et al. (2002).

Dou et al. (2000) found a strong correlation between the EUF extractable total nitrogen and nitrogen extractable by 0.01 M $CaCl_2$ solution. In their study, representative Florida soils were sampled and the electro-ultrafiltration (EUF) technique was used to measure the concentrations of total EUF-extractable nitrogen, NH_4^+-N and NO_3^--N. The nitrogen concentrations in the EUF extraction were greater than those measured with the 0.01 M $CaCl_2$ extraction method. The N-organic fraction, estimated by the EUF method, ranged from 4.4 to 40.8 mg/kg soil, equivalent to 10 to 91 kg/ha nitrogen for the 0–15 cm soil depth and was in positive correlation with the total soil nitrogen determined by the Kjeldahl method.

Extraction with $CaCl_2$ has also provided promising results, with good correlation between this particular index and N uptake in pot (Appel, Mengel, 1993) and field experiments (Appel, Mengel, 1992; Groot, Houba, 1995). On the other hand, Houba et al. (1995) found that N extracted with $CaCl_2$ was a poor predictor of the fertiliser needs of sugar beet. Such inconsistency is a common feature to all extraction methods and is due to the diverse and variable nature of soils and to variable environmental conditions. It is unlikely that chemical extraction methods alone would provide a reliable index of soil N availability (Houba et al., 1993). Nonetheless, it has been suggested that data from extraction procedures might serve as simple input parameters in mathematical models that can account for other factors contributing to N availability, such as climatic conditions and previous management practices (Appel, Mengel, 1998). To study the relationships between these indices and the N cycle samples were collected evaluated from 9 experimental sites in the Hungarian Long-Term Fertilization Trial Network.

Recent studies have shown that soluble organic nitrogen (SON) varied yearly between 8–20 kg/ha in coarse sand and 15–30 kg/ha in sandy loam Loch and Jászberényi (1997), Lazányi et al. (2002). Mengel et al. (2000) reported 35–45 kg/ha 0.01 M $CaCl_2$ extractable organic nitrogen. The minimum value was measured in winter; the maximum value in summer. Under continuous arable cropping Murphy et al. (2000) measured 7–18 kg/ha SON after 8 years of grass lay in the 0–25 cm soil layer, which accounted for 33–60% of the total soluble nitrogen. Even higher SON was measured in a soil profile of 0–90 cm after ploughing up a long-term experiment on grassland. Appel and Mengel (1992) and Nunan et al. (2001) found a correlation between SON and nitrogen mineralization, and suggested that SON extracted by 0.01 M $CaCl_2$ solution is a reliable indicator of organic N available for mineralization and plant uptake. Murphy et al. (2000) gave account of similar results in loamy sand with KCl extractable N-organic.

MATERIAL AND METHODS

In this paper the relationship between the winter wheat yield and 0.01 M $CaCl_2$ extracted NO_3^--N, NH_4^+-N, and organic N content of soils were studied in the Hungarian Long-Term Fertilization Trial Network. Samples were collected from top 0-30 cm soil layer of 9 experimental sites (Bicsérd (BI), Hajdúböszörmény (HA), Iregszemcse (IR), Karcag (KA), Keszthely (KE), Kompolt (KO), Mosonmagyaróvár (MO), Nagyhörcsök (NA), Putnok (PU) representing various ecological and soil conditions of Hungary. Selected NPK treatments include 000, 101, 111, 121, 201, 220, 221, 222, 331, 341, 421, 441, where N and P doze increase with 50-50 kg/ha increments and K doze with 100 kg/ha increments. Soil samples were collected in 27th and 28th years of treatment in the Hungarian Fertilization Trial Network in 4 replications. Cropping pattern is winter wheat (Triticum aestivum L.) maize (Zea mays L.) double cropping system in a four-year rotation and winter wheat yield data are from 23rd, 24th, 27th, 28th 31st years in the experiment. Mathematical statistical analysis of the experimental data was done by ANOVA and REGRESSION using of SPSS for Windows statistical program.

RESULTS AND DISCUSSION

In the Hungarian Long-Term Fertilization Trial Network, both yield and soil 0.01 M $CaCl_2$ extracted N forms were affected by fertilization and by the different soil and ecologic conditions. The amount of NO_3^--N was between the values of 2-30 mg/kg depending on the treatments and experimental sites (Figure 1). Correlation analysis was performed and close relationship was obtained for winter wheat yield and of nitrate nitrogen (Figure 3). Soil nitrate nitrogen measurements are most useful to evaluate N management. Nitrate remaining in the soil after harvest can leach during winter rains, contaminating surface and groundwater. For evaluating N management, residual soil NO_3^--N is considered medium 10–20 mg/kg and high 20–30 mg/kg. If residual nitrate levels are consistently high or excessive (>30 mg/kg) fertilizer N inputs should be reduce in future growing seasons.

The Nitrates Directive of EC (1991) aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices. Huge efforts are still needed in order to restore water to optimal quality across the EU, although farmers are becoming increasingly positive about environmental protection and exploring new techniques. Agriculture remains an important source of water-related problems, and farmers need to continue to adopt sustainable practices. The Nitrates Directive forms an integral part of the Water Framework Directive and is one of the key instruments in the protection of waters against agricultural pressures.

The Nitrates Directive (1991) aims to protect water quality across Europe by preventing nitrates from agricultural sources and by promoting the use of good farming practices. Within the national monitoring and reporting system, Member States are required to report on (i) nitrates concentrations in ground and surface waters; (ii) eutrophication of surface waters; (iii) assessment the impact of action programmes on water quality and agricultural practices; (iv) revision of Nitrate Vulnerable Zones and action programmes (v) estimation of future trends in water quality in every four years.

The amount of NH_4^+-N was between the values of 1-5 mg/kg soil depending on the treatments and experimental sites (Figure 2). Correlation analysis show less expressed relationship between winter wheat yield and ammonium-nitrogen (Figure 5). Ammonium-nitrogen does not accumulate in the soil, as soil temperature and moisture conditions suitable for plant growth are also ideal for conversion of NH_4^+ to NO_3^-. Ammonium-nitrogen concentrations of 2–10 mg/kg are typical in Hungary. Soil NH_4^+-N levels above 10 mg/kg may occur in cold or extremely wet soils, or if the soil contains fertilizer residue.

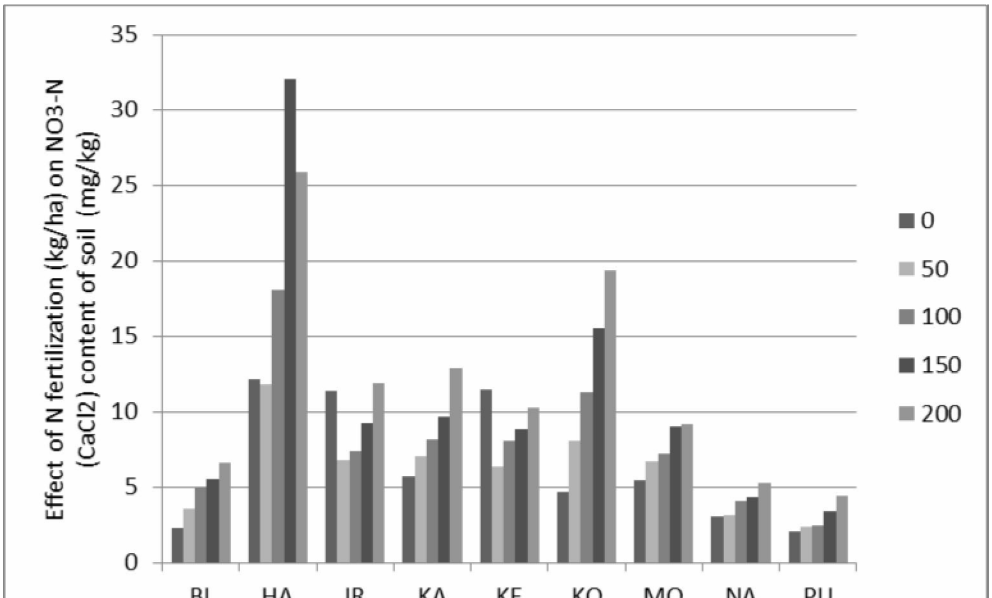

Fig. 1. Effect of N fertilization (kg/ha) on NO_3^--N ($CaCl_2$) content of soil in Treatment of Hungarian Fertilization Trial Network (mg/kg)

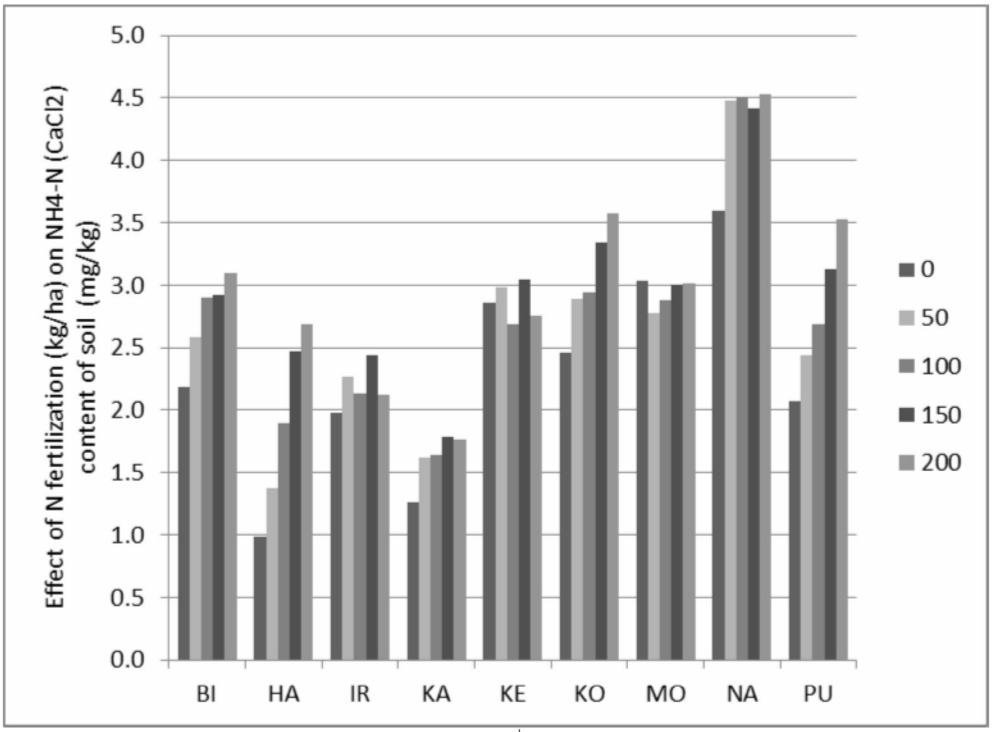

Fig. 2. Effect of N fertilization (kg/ha) on NH_4^+-N ($CaCl_2$) content of soil in Treatment of Hungarian Fertilization Trial Network (mg/kg)

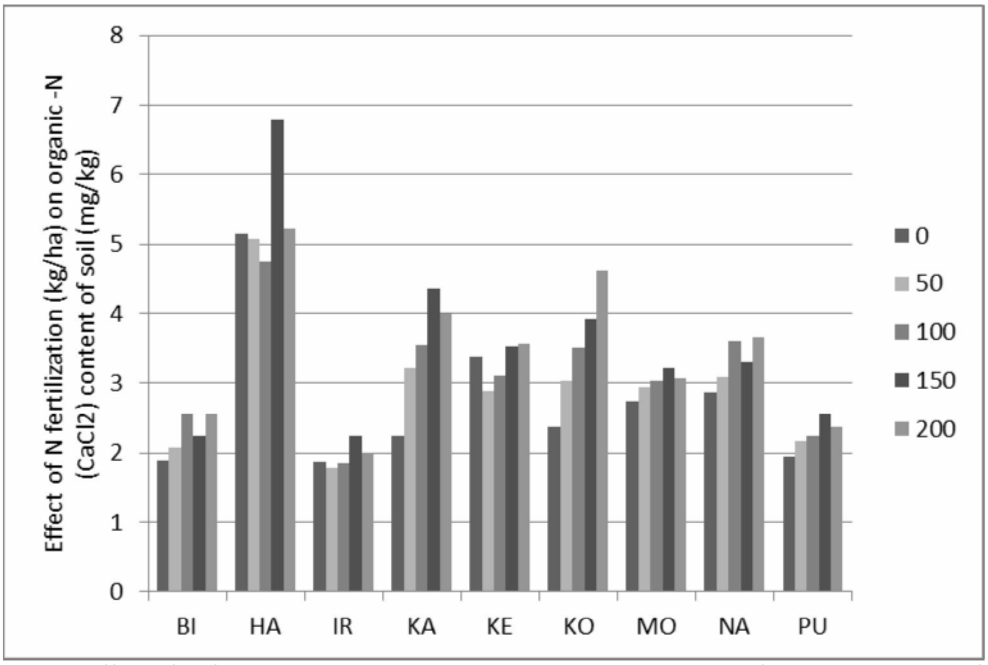

Fig. 3. Effect of N fertilization (kg/ha) on organic N ($CaCl_2$) content of soil in Treatment of Hungarian Fertilization Trial Network (mg/kg)

Although the organic fraction obtained by a 0.01 M $CaCl_2$ solution represents only about 1% of the total organic nitrogen, it still has a major impact on plant nutrition and nitrogen cycling. The amount of organic-N was between the values of 2-6 mg/kg depending on the treatments and experimental sites (Figure 3). This method measures soluble organic nitrogen compounds, which are expected to be closely related to the mineralization of organic nitrogen in the soil (Appel, Mengel, 1998). Correlation analysis show well expressed relationship between winter wheat yield and organic nitrogen (Figure 6) at many experimental sites. Organic N in the soil becomes available for plants after mineralization into inorganic forms that are related to microbial activity. Mineralization considerably depends on the decomposability and the C/N ratio of the soil organic matter.

Generally proteins are more easily decomposed than other nitrogen compounds. According to Groot and Houba (1995) the soluble organic nitrogen extracted with 0.01 M $CaCl_2$ solution is an index for the N mineralization capacity of soils. In their experiment the organic nitrogen fraction extracted by 0.01 M $CaCl_2$ solution correlated well with the nitrogen uptake of ryegrass. Net mineralization was also tested in Mitscherlich pot experiments with three treatments; (1) fallow soil without N fertilizer, (2) soil cultivated with ryegrass without N fertilizer, (3) soil cultivated with ryegrass with fertilizer. The highest proportion of nitrogen in the extract was amino acids and peptides, amounting to approximately 60% of the total nitrogen extracted by 0.01 M $CaCl_2$ solution.

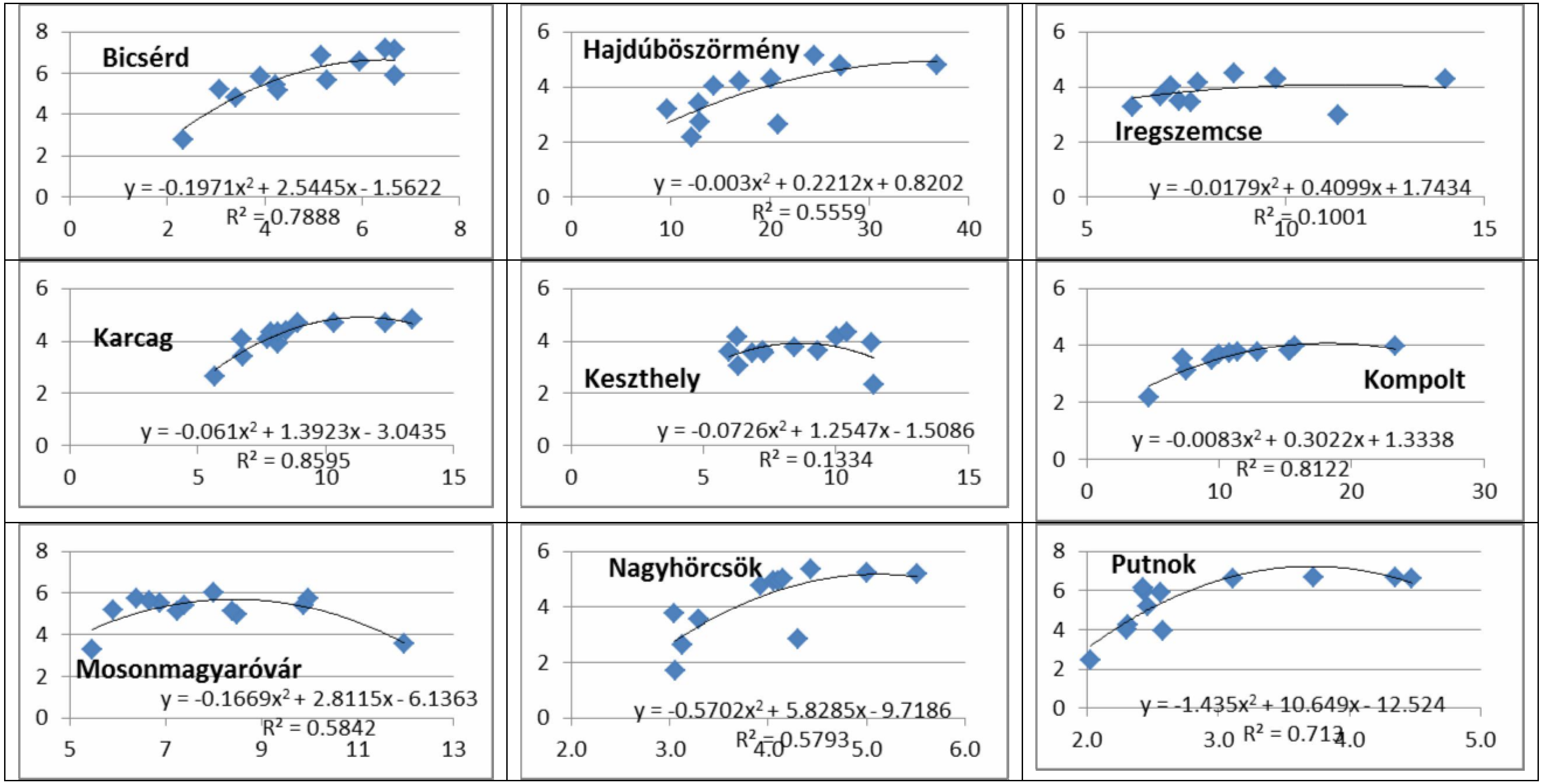

Fig. 4. Relationship between winter wheat yields (t/ha) and NO_3^--N ($CaCl_2$) content of soil (mg/kg)

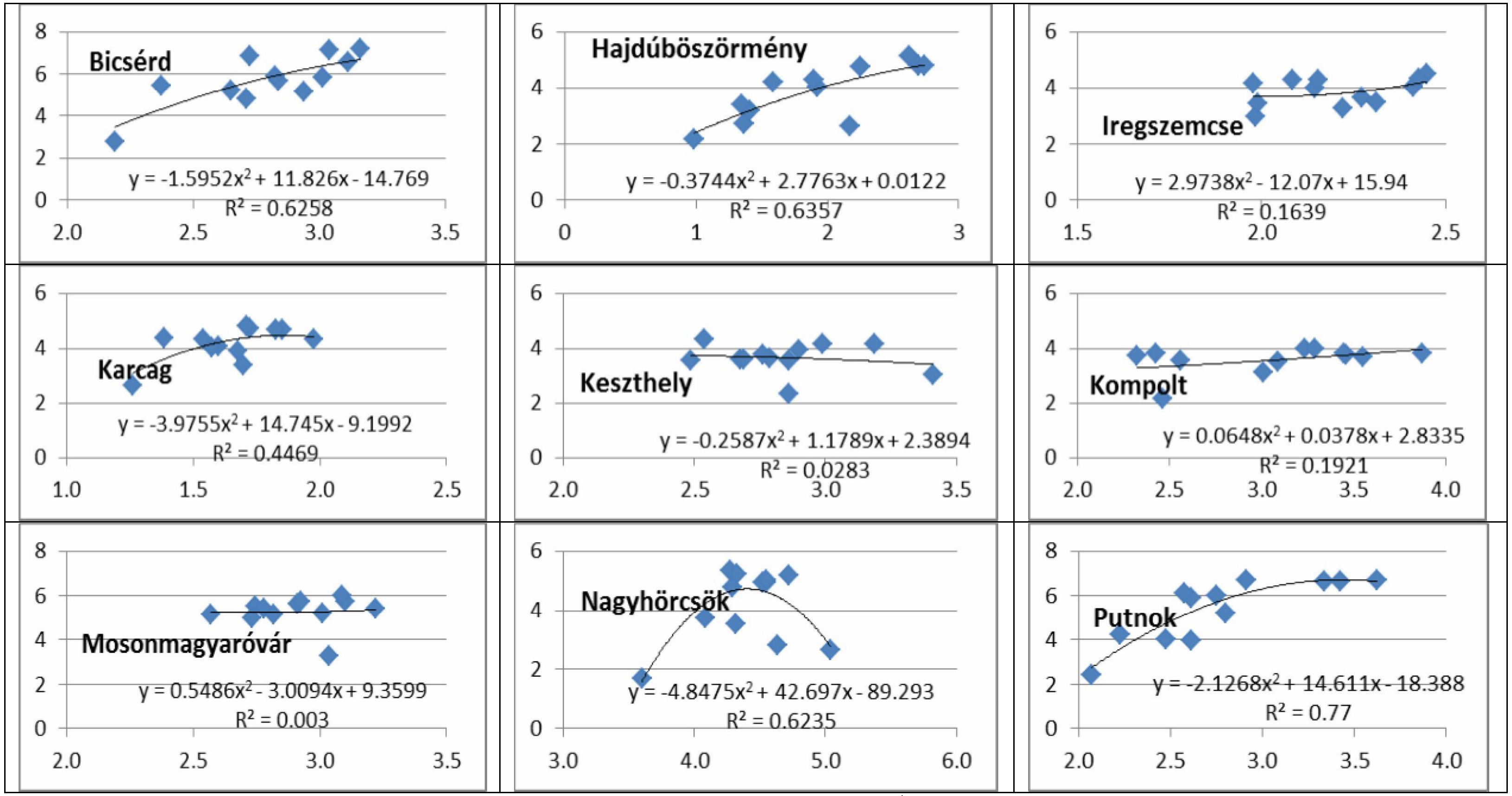

Fig. 5. Relationship between winter wheat yields (t/ha) and NH_4^+-N ($CaCl_2$) content of soil (mg/kg)

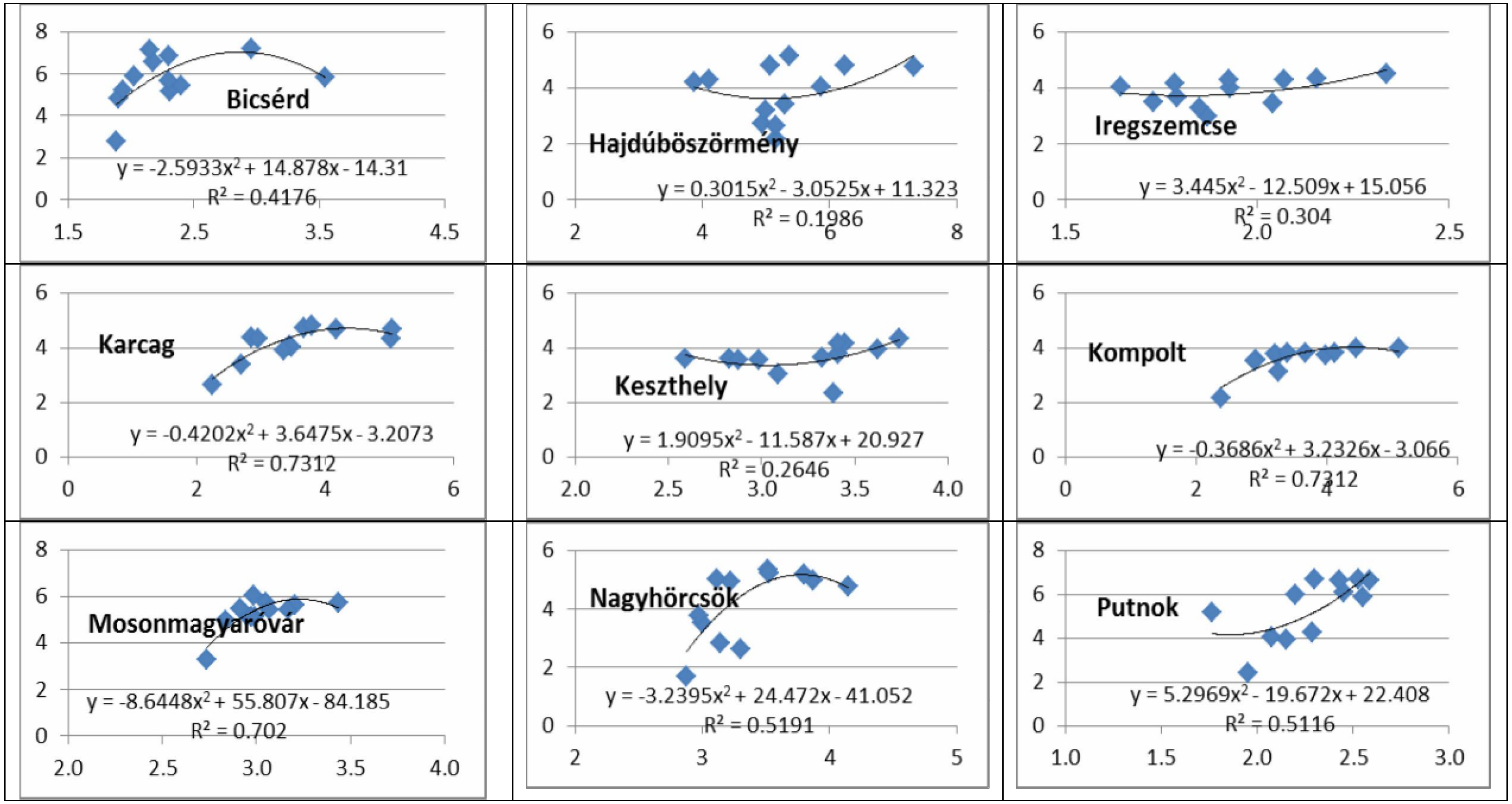

Fig. 6. Relationship between winter wheat yields (t/ha) and organic-N ($CaCl_2$) content of soil (mg/kg)

CONCLUSIONS

Nitrogen is often the growth-limiting nutrient in agricultural ecosystems. The nitrogen taken up by crops can range between 100 and 300 kg/ha annually. Nitrogen is derived from a number of sources, particularly from synthetic fertilizers, biological N fixation, and mineralization of soil organic matter, crop residues and manures. The contribution of mineralization to N supply range from less than 20 kg/ha to more than 100 kg/ha depending on the quantity and quality of organic N in the soil. Environmental conditions control the rate of mineralization and the estimation of N supply of soil is of considerable importance to maximize agricultural N use efficiency and to minimize environmental losses.

Nitrogen losses from soils to the environment occur in the form of NH_3 due to volatilization, in the form of N_2O, NO or N_2 produced during denitrification and in the form of NO_3^- due to leaching. The contribution of these N losses to eutrophication, ground water quality and global warming are of great concern to our environment policy and a series of governmental policies and measures have been implemented at both national and international levels. Recent surveys show that these measures have already had a positive effect on NO_3^- levels in numerous water courses (European Commission, 2007) and led to a reduction in the use of commercial inorganic N fertilizer in most European countries. Balanced and sustainable N management can significantly reduce N leaching losses to the environment, as agriculture still accounts for significant N emissions and yearly losses.

Experimental sites of Hungarian Long-Term Fertilization Trial Network are suitable to study effects the long-term fertilisation, and the laboratory procedures proposed by Houba et al. (1986) is suitable to study plant available quantities of nutritional elements. The introduction of 0.01 M $CaCl_2$ extraction method can result in a more environment friendly fertilization, without negative effects on the yield or the quality of produced crops. In the Hungarian Fertilization Trial Network, both yield and soil 0.01 M $CaCl_2$ extracted N forms were affected by N fertilization and by the different soil conditions. The amount of nitrate (NO_3^--N), ammonium (NH_4^+-N) and organic-N were measured and a close correlation was found between 0.01 M $CaCl_2$ extracted nutrients and N fertilizer rates. The potential effect of sustainable fertilizer management on N losses is large and the introduction of 0.01 M $CaCl_2$ extraction method will possibly result in a more environment-friendly N fertilization without negative effects on the yield or quality of crops. The 0.01 M $CaCl_2$ extraction method is suitable for routine analysis and can be used widely for measuring different plant available forms of soil nitrogen at a low costs.

Nitrogen fertilizer recommendations in Hungary are based on soil organic matter content. The goal of testing nitrate (NO_3^--N), ammonium (NH_4^+-N) and organic-N compounds is to provide farmers with a fertilizer recommendation. Based on the results of this paper, the introduction of 0.01 M $CaCl_2$ extraction method may improve the efficient use of N fertilizers, without negative effects on the yield or the quality of produced crops. Taking costs into consideration, the 0.01 M $CaCl_2$ extraction method is suitable for the routine analysis 0.01 M $CaCl_2$ extracted nitrogen forms.

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