The level of soil nitrate content at different management of organic fertilizers application

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ABSTRACT

Changes in N-NO_3^- content and N-NO_3^- increase after incubation were studied in 1992–1998 in soils of two farms situated in identical soil and climatic conditions (in spring and autumn seasons). The two farms produce sugar beet and grain crops, but since 1991 they have used different types of organic fertilizers. Farmyard manure has regularly been applied to root crops on Dobrá Voda farm; since Chvalina farm does not have animal production, green manure and plowing-in of beet tops and straw are used for organic fertilization. Soils with regular applications of farmyard manure show a trend of lower N-NO_3^- content than the soils of the farm without animal production. At Dobrá Voda N-NO_3^- content was about 12 ppm N in spring and 9 ppm N in the autumn season while the respective values for Chvalina were 14 and 10 ppm N. On the hand, N-NO_3^- increase after soil incubation (12–14 ppm N) was higher in Dobrá Voda soils than in soils from Chvalina farm (5–8 ppm N).

Keywords: organic fertilizers; N-NO_3^- content in soil; N-NO_3^- increase after incubation

The content of nitrogen forms in soils and their changes have been studied from different aspects, and with respect to possibilities of their utilization. Studies aimed at mineral forms of nitrogen and at readily mineralizable fractions of the organic component of soil organic matter have been published in recent years. It is intelligible because these forms of nitrogen substantially influence plant growth, product quality and environment, particularly surface water quality, and can be utilized for practical application of fertilizers (Rausch 1989, Kubát et al. 1999, Kolář et al. 2002, etc.).

Changes in mineral nitrogen in soils are influenced by many factors that can be affected by human activities to a larger or smaller extent. Besides weather and soil conditions and cropping system changes caused by soil tillage (Torbert et al. 1997) or fertilization (Apfelthaler 1977, Kubát et al. 1999, etc.) were investigated. Naturally, the time period of observations, i.e. duration of observations, and the time period of the effect of changed conditions are also important because changes are stabilized after a longer-time effect. This is the reason why data from long-term experiments are most valuable (Körschens 1997, Kubát et al. 1999, etc.).

MATERIAL AND METHODS

Changes in the content of mineral and mineralizable nitrogen were investigated in arable lands of two farms: at Dobrá Voda and at Chvalina localities that are situated in comparable soil and weather conditions, at a height of 260–265 m above sea level near the town of Hořice in Podkrkonoší region (at the foothills of the Krkonoše Mts.). Selected plots have loamy Luvisols with medium content of organic matters and good biological activity, neutral pH value and medium content of available P, K and Mg. Total N content was about 0.12%.

The two farms have used different farming systems since 1991. Farmyard manure has regularly been applied to root crops and cabbage on Dobrá Voda farm (40 t/ha); since Chvalina farm does not have any animal production sector, straw plowing-in, green manure and growing of legume crops have been used as sources of organic matters. Nitrogen rates in mineral fertilizers amounted to 105 kg N on Dobrá Voda farm and to 100 kg N/ha per year on Chvalina farm.

Six plots of the same site quality were selected on each farm from where soil samples were taken at regular intervals. The average area of plots at Dobrá Voda was 42 ha and at Chvalina 14 ha. Regular crop rotations (grain and root crops) were used on these plots. Average ratios of crops (%) are given in Table 1.

Table 1. Average ratios of crops (%)

Crops	Dobrá Voda	Chvalina
Winter crops	50	39
Spring crops	17	11
Sugar beet	28	28
Cabbage	5	–
Rape	–	5
Alfalfa and pea	–	17
Green manure (mustard)	–	22

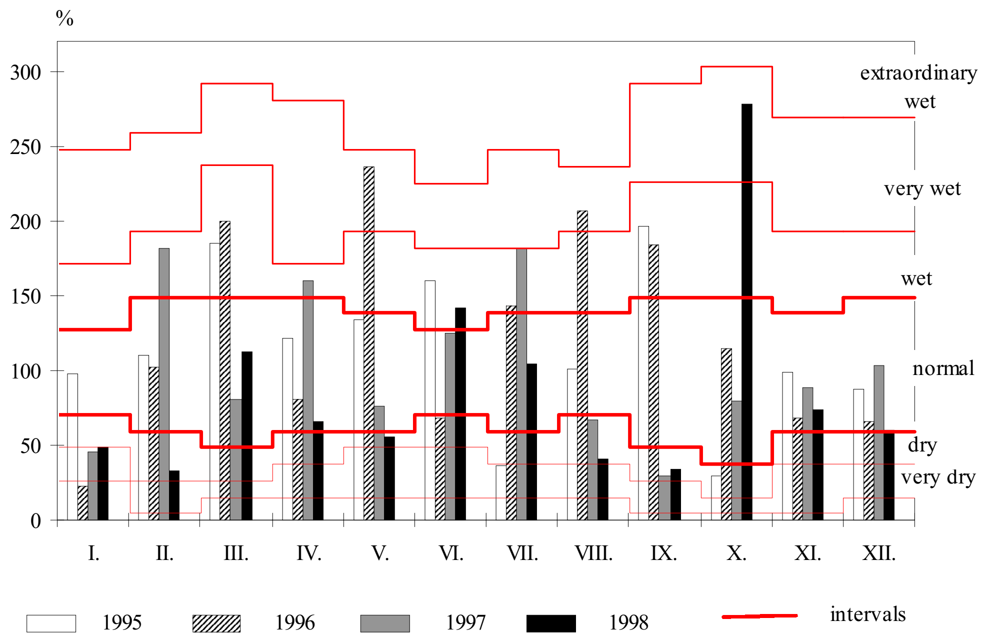

Figure 1. The average monthly precipitation in 1995–1998 (the classification of months according to the percentage of the long-term averages 1950–1990)

Data from the nearest meteorological station at Holovousy (1–4 km) were used to characterize weather conditions. Average annual temperature is 8.1°C, and 14.3°C in the growing season; annual precipitation sum amounts to 654 mm, and to 376 mm in the growing season. The characteristics of weather conditions in 1995–1998 are represented in graphs: precipitation (% of long-term average) in Figure 1 and temperatures (deviations from long-term average) in Figure 2 (Kožnarová and Klabzuba 2002). It is obvious that marked differences occurred in 1996, when after the cold off-season period (months XI and XII in 1995 and II and III in 1996) the growing season had normal temperatures but it was wet or very wet, and in 1998, when the warm winter was followed by summer months with normal temperatures and precipitation. The evaluated data were not influenced by high precipitation amounts in October.

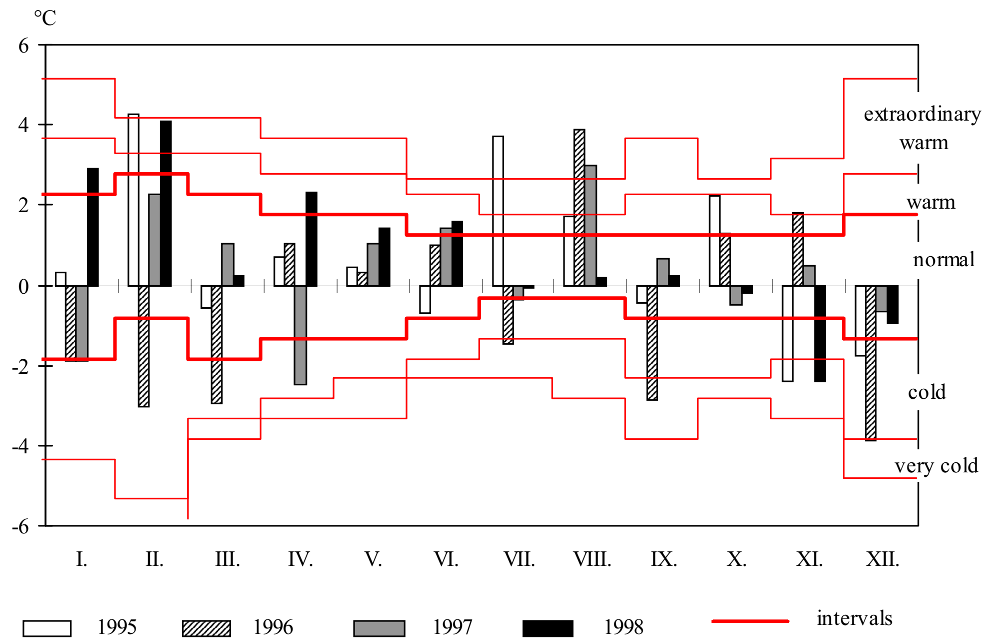

Figure 2. The average monthly temperatures in 1995–1998 (the classification of months according to the divergences from long-term averages 1950–1990)

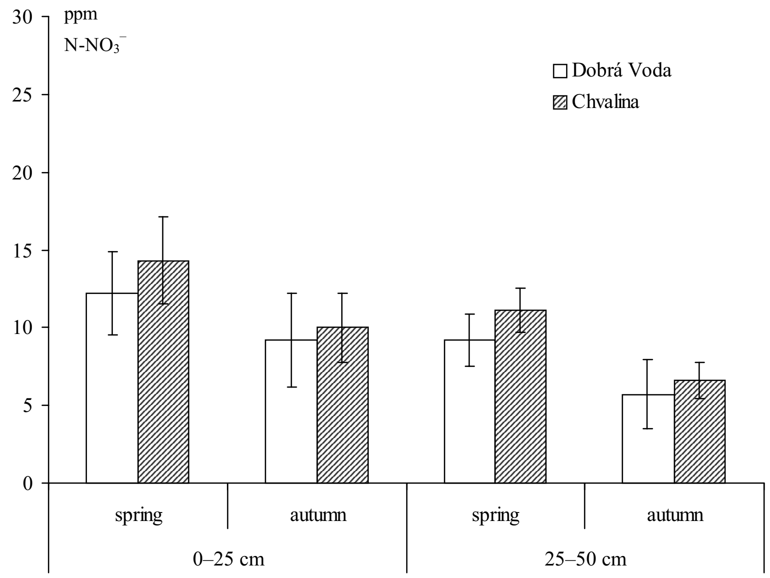

Figure 3. The average content of N-NO_3^- [ppm] in the soils (in depths 0–25 and 25–50 cm)

Soil samples were taken regularly in the spring season (mostly in March) and after crop harvest, most frequently at the end of September and at the beginning of October, always before fertilization. Two average samples were taken from each plot, and they were analyzed separately. Soil samples were dried at 40°C, and after crushing they were sieved on a 2mm-mesh screen. Fine soil was used for analyses.

N-NO_3^- and N-NH_4^+ contents were determined colorimetrically in an extract of 1M KCl on a SKALAR automatic analyzer. Bremner's (1965) method was used for soil incubation: a mixture of soil and sand (1:1) is incubated at a temperature of 30°C for 7 days and the content of mineral N is determined also in an extract of 1M KCl. In our observations this method showed very good correlations with the method of plant samples (Pavlíková et al. 1992). The values are given in ppm.

The main objective was to determine the effect of different farming systems, particularly of applied organic fertilizers (traditional application of farmyard manure on Dobrá Voda farm vs. green manure and plowing-in of beet tops and straw on Chvalina farm), on dynamics of changes in mineral and mineralizable nitrogen in soils. The investigations were carried out in the spring season on order to apply the results to specification of spring doses of N fertilizers, and in the autumn season so as to determine residual mineral N in soils and to specify N dose in this season.

RESULTS AND DISCUSSION

The evaluation of a large set of data from the analyses of mineral N content in soils from two sites indicates that the values for each site (its particular plots) that are in-

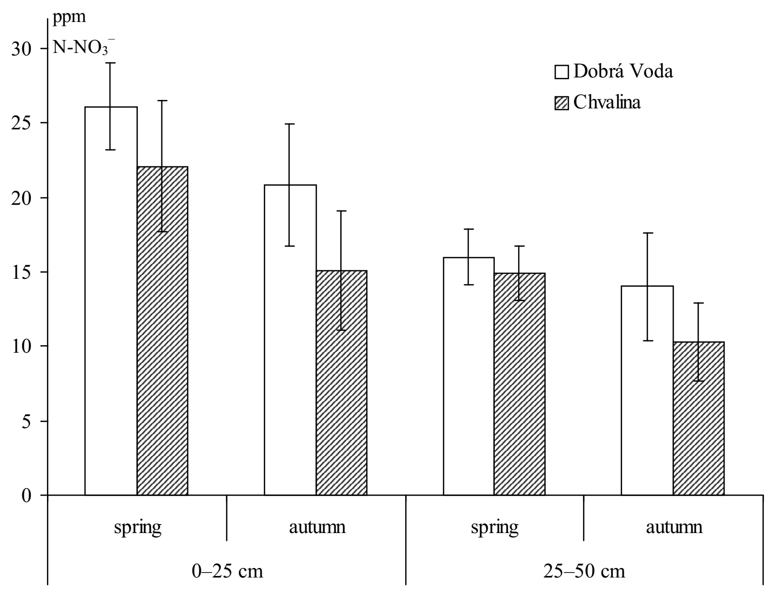

Figure 4. The content of N-NO_3^- [ppm] after incubation of soils (in depths 0–25 and 25–50 cm)

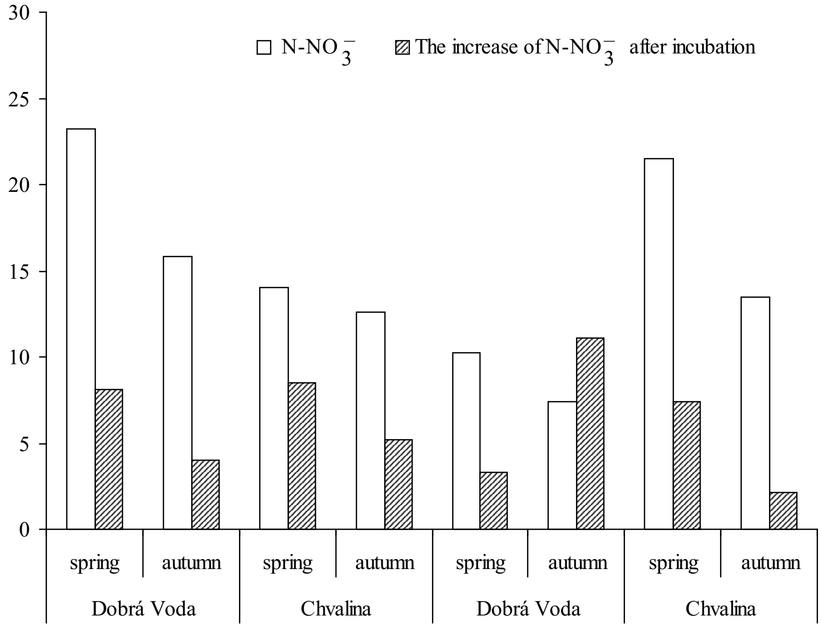

Figure 5. The content of N-NO$_3^-$ [ppm] in topsoil and the increase of N-NO$_3^-$ after incubation determined twice in 1996 and 1998

fluenced by weather conditions, crops and type of organic fertilizers are quite uniform, as also reported by several authors (Rausch 1989, Vaněk et al. 1995, 1997, etc.). Hence the evaluations are site-related (results from six plots). As N-NH$_4^+$ content in the soils under study does not vary very much and N-NO$_3^-$ content is most important for plant nutrition and can substantially influence the environment, the paper deals with the latter form of nitrogen.

Average contents of N-NO$_3^-$ for the period of observations are represented in Figure 3. The graph confirms the fact that N-NO$_3^-$ content is usually higher in the spring season than in autumn, and in topsoil (0–25 cm) than in the horizon of 25–50 cm. The values indicate a trend of higher N-NO$_3^-$ content in soils from Chvalina farm (in topsoil about 14 ppm N in spring and 10 ppm N in autumn while the respective values for Dobrá Voda are 12 and 9 ppm N). The higher N-NO$_3^-$ content in soils at Chvalina site may be a result of faster decomposition and mineralization of more readily decomposable organic materials such as green manure and beet tops, and of legume crop growing. It is to note straw plowing-in did not cause a marked and longer-term decrease in N-NO$_3^-$ content in soils.

The graph in Figure 4 shows that after soil incubation N-NO$_3^-$ content is higher in Dobrá Voda soils. It implies that the soils at this site have a higher amount of readily hydrolyzable organic compounds of nitrogen, so their ability to supply nitrogen to plants during vegetation is higher (under hydrothermic conditions favorable for mineralization). It can be expected that a large portion of farmyard manure and other postharvest residues undergoes slow mineralization, complementing or slightly increasing the proportion of readily hydrolyzable nitrogenous organic matters that can be mineralized in a later period. It is evident that after the application of high-quality manure the biomass of microorganisms markedly increases as a result of the incorporation of substrate and specific microflora (Apfelthaler 1977, Kubát et al. 1999, etc.). After extinction this biomass is a very rich source of nutrients, particularly nitrogen. It is so called reactive part of the soil organic component that is mineralized within several weeks or months under favorable conditions. This consideration is correct because N-NO$_3^-$ content in the soil does not mostly increase after manure application, on the contrary, the content of mineral N frequently decreases – that means immobilization occurs as it was also observed at other sites (Vaněk et al. 1995). It is only in spring months of the subsequent years after manure application when N-NO$_3^-$ content in soils slightly increases and can be utilized by plants during vegetation. The amount of N-NO$_3^-$ released by incubation is lower in soils from Chvalina site, equaling about the half values for Dobrá Voda soils (in topsoil 12–14 ppm N at Dobrá Voda and 5–8 ppm N at Chvalina). A moderate increase was observed after legume crops. The increase in N-NO$_3^-$ amount after incubation is higher at both sites in spring than in autumn.

The results demonstrate advantages of farmyard manure and legume crops, which apparently supply to the soil more stabilized components with slow mineralization that will renew or increase soil productivity. As stated by Kubát et al. (1999), nitrogen cannot be accumulated in soils in other than organic form. Therefore mineral nitrogen must be consumed by plants or by microorganisms; otherwise there is a risk of its losses. From this aspect, the most efficient measure for the environment conservation is adequate crop production and creation of conditions for the formation of stable organic components in soil.

Most researchers who study the problems of organic matter in soils agree that marked and permanent changes in its content and quality can be expected after a long-time effect. So the cycles of soil nitrogen and carbon should be studied in long-term experiments (Peschke et al. 1987, Körschens 1997, Kubát et al. 1999, etc.) when the whole system that can be described by current methods and analyses is stabilized after a definite period. From this aspect, our results are considered as a trend showing potential changes.

Weather conditions substantially influence the dynamics of changes in mineral and mineralizable N. Identical trends of the effect that basically correspond to average values of the sites were mostly observed at both sites in the particular years (Figures 3 and 4). But the results for the sites were different in 1996 and 1998. In 1996 N-NO_3^- content in soils was high and N-NO_3^- increase was lower after incubation of soils from Dobrá Voda site similarly like at other sites (Němeček 2002) but soils from Chvalina site showed an opposite trend. N-NO_3^- contents were different also in 1998 – lower in soils from Dobrá Voda and higher from Chvalina (Figure 5). These differences are difficult to explain. It is true that trends in the horizon of 25–50 cm were similar to those in topsoil. Apparently, even though identical trends of the effect of weather conditions can be assumed at particular sites, some differences can be expected. Nevertheless it is to conclude that trends of mineral N content on plots typical of a region can be applied to adjacent plots where no analyses are performed.

The sum of mineral and mineralizable nitrogen was demonstrated to be a constant value at a given site. The higher the content of mineral N, the lower the amount of potentially releasable N, and vice versa. The knowledge of both values will help optimize applications of nitrogen fertilizers. Naturally, greater changes are caused by many factors whose identification (or identification of their combinations) is difficult, hence it is difficult to determine the trend of their effects. This is the reason why the informative value of single analyses is low.

Taking into account the above-mentioned facts it is obvious that the data on mineral and mineralizable N content in soils, particularly if they come from a longer time series and if other information such as data on weather conditions, forecrops, fertilization and common cultural practices is available, can be used to optimize applications of organic and mineral nitrogenous fertilizers. Such optimization will create conditions for better exploitation of the site productive potential, maintenance of soil productivity, higher effectiveness of cultural practices and environment conservation.

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ABSTRAKT

Obsah nitrátového dusíku v půdě při rozdílném systému organického hnojení

V letech 1992–1998 byly sledovány změny obsahu N-NO_3^- a přírůstek N-NO_3^- po inkubaci v půdách (v jarním a podzimním období) dvou farem, hospodařících ve stejných půdně-klimatických podmínkách. Farmy jsou zaměřeny na produkci cukrovky a obilí a od roku 1991 se liší v použití organických hnojiv. Farma Dobrá Voda pravidelně hnojí okopaniny hnojem a Chvalina hospodaří bez živočišné výroby a k organickému hnojení používá zelené hnojení a zaorávku chrástu a slámy.

V půdách pravidelně hnojených hnojem se ukazuje trend nižšího obsahu N-NO_3^- oproti půdám z farmy bez živočišné výroby. V Dobré Vodě se pohyboval obsah N-NO_3^- okolo 12 ppm N v jarním a 9 ppm v podzimním období, zatímco ve Chvalině činil 14 a 10 ppm N. Naopak půdy z Dobré Vody vykazovaly vyšší přírůstek N-NO_3^- po inkubaci zemin (12–14 ppm N) oproti půdám z farmy Chvalina (5–8 ppm N).

Klíčová slova: organická hnojiva; obsah N-NO_3^- v půdě; zvýšení obsahu N-NO_3^- po inkubaci

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