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Nitrogen in Agriculture as Affected by the Kind of Fertilizer. II. Nitrogen in Soil and Plant

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Summary

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Since nitrogen is a main nutrient of plants thus representing a limiting factor to yield, an analytical method should be contrived to determine the adequate amount of fertilizer to be added to optimize production without harming the environment.

A plot-trial was established on an existing farming-site located near Vienna in an area called „Obere Lobau" to compare variants treated with compost, mineral-fertilizer and controls. Different forms of nitrogen in soil and plants (i.e. rye) were investigated. Samples were taken from 21/05/1997 to 02/07/1997 about every two weeks. The N_{min}-method is of little avail when organic manure is concerned due to the quick uptake of nitrate by the plants and the slow mineralization rate of the manure. An analytical method to estimate SRNH (soil-nitrogen soluble in hot dinatriumhydrogenphosphatebuffer) was established, which is believed to represent the potential amount of nitrogen available during the vegetation period. The investigations proved this farming-site to be well supplied with nitrogen, which entailed a luxurious consumption of nitrogen by the plants, especially in the plots with mineral fertilization. Compost showed a slow and longterm mineralization rate thus enabling the uptake of nitrogen according to need only in contrast to „force feeding" in conventional systems. Compost-manuring resulted in a higher content of total nitrogen and SRNH in the soil.

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Introduction

Nitrogen (N) exists in many different forms in soils, plants, animals and the atmosphere. These forms, such as ammonia (NH_3), ammonium (NH_4), nitrate (NO_3), nitrogen gas (N_2) and organic nitrogen compounds, undergo several transformations in the environment as part of the nitrogen cycle. Nitrogen is an essential nutrient element for plants because it is a major component of important plant compounds such as amino acids, nucleic acids, chlorophyll and enzymes. Without adequate nitrogen, plant growth is restricted. (MOTAVALLI & al. 2000). On the other hand, nitrogen can become an environmental problem, when applied in abundance (ANONYM 2001a, DER RAT DER SACHVERSTÄNDIGEN FÜR UMWELTFRAGEN 1985, SCHEFFER 1998). Furthermore, overloads of nitrogen may be financially disadvantageous to farmers (DIERCKS 1983). So there is a need to estimate the potential amount of N which can be supplied by the soil and the quantity which has to be added by fertilization. This can be easily done in conventional farming by using the N_{min}-method and mineral fertilizer (SCHEFFER 1998). In biological farming, only organic manure has to be used (ANONYM 2000). To optimize organic fertilizing, the mineralization rate of e.g. compost during the whole vegetation period has to be taken into account, because the mineralization rate of organic fertilizers is slow and relatively steady (AMLINGER 1993). The N_{min} - method is of no great use, since nitrate is immediately taken up by plants. Therefore an analytical method has been developed to estimate SRNH (soil-nitrogen soluble in hot disodiumhydrogenphosphate-buffer), which is believed to represent the amount of nitrogen being potentially mineralized (WENZL 1997). At the Ludwig Boltzmann Institute for Biological Agriculture and Applied Ecology a cheap analytical way easy to use has been standardized to estimate SRNH in soils based on the microwave/oxisolv digestion created by Merck for water and wastewater. It has been proved to work well within the usual limits of chemical analysis and can be used as a reference method for intended physical measurement of SRNH such as NIRA (Near Infra Red Absorption).

Material and Methods

Sampling sites

A plot-trial was installed in an area called „Obere Lobau" located on an existing farm near Vienna. This farm was converted to biological agriculture since 1978 step by step. The break, in which the field trial took place, was cultivated biologically since 1990. The crop rotation up to now existed of 80 % grain and 20 % potatoes. The soil management was done by plowing and harrowing, weed control by currying. As fertilizer, biological waste compost was used. The standing crop in 1996 was common oats. The size of the plots was 3x5m resulting in a net-plot of 2x4m thus pinpointing the effect of cultivation (Fig. 1).

Four variations of treatment were compared in three replications: O = no fertilization, BK = manured with compost (38t ha^{-1}), BR = fallow, N = amended with calcium ammonium nitrate 38 kg N ha^{-1}. The standing crop was rye (*Secale cereale ssp. L*). The soil of the experimental area is a calcaric fluvisol and a fine sandy silty loam with a pH of 7.4 and a CEC of 13.85 cmol kg^{-1}. The entire break was cultivated uniformly, including the plots: plowing at the end of September 1996, use of seedbed combination and sowing on 05/10/1996. The variants „BK“ were manured with compost as mulch on 30/04/1997, mineral fertilizer was applied on 16/05/1997 to the plots „N“.

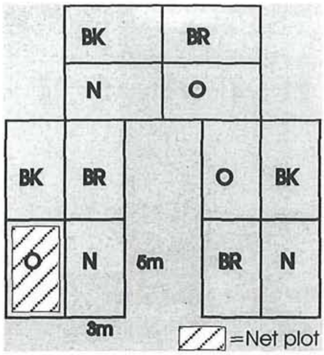

Fig. 1. Plot trial. The net plot for sampling on one plot is shown as an example.

Sampling and analysis

The soil samples were taken in a depth of 0-30 cm according to soil management practices with a sampler corresponding to PÜRCKHAUER (ANONYM 2001b) with an inner diameter of 1.5cm. 12 samples per net plot were taken evenly distributed. From 21/05/1997 to 02/7/1997 soil samples were taken four times. The fresh soil was sieved to 4 mm and analysed for total nitrogen (BREMNER & MULVANEY 1982), nitrate, ammonia (RUZICKA & HANSEN 1988) and SRNH. The method of analysis of SRNH was developed at the Ludwig Boltzmann Institute for Biological Agriculture and Applied Ecology based on a microwave/oxisolv-digestion created by MERCK. About 5g of fresh soil were extracted with 25ml cooking di-sodiumhydrogenphosphate buffer (0.1m, pH 7.00) for one hour under reflux and filled up to 250ml with aqua dest.. An aliquot was centrifugated at 6000 rmp for 10 minutes and 2ml of the extract were digested with two microspoons of oxisolv (Merck Nr.1.12936.0030) by microwave (450W, 70sec.) using 25ml teflonbombs converting the total nitrogen in the extract to nitrate. After that ammonium chloride buffer (7.5 % pH 8.5) was added to adjust pH about 7. Nitrate was analyzed with a continuous flow auto analyser (FIA, Cd-reduction method) (RUZICKA & HANSEN 1988).

Plant samples were taken 5 times in the period from 21/05/1997 to 02/07/1997. Evenly spread over the net plot, 32 ear-bearing stems were harvested and divided into ear, flag (leaf 1), the following leaves 2, 3 and 4 and stem. The tissue was freeze-dried and analysed for total nitrogen (BREMNER & MULVANEY 1982), nitrate and hot-water soluble nitrogen. According to the analysis of SRNH in soil, the method to estimate hot-water soluble nitrogen was established at the Ludwig Boltzmann Institute for Biological Agriculture and Applied Ecology. 0.2 – 0.5g of dry matter were mixed with 20ml hot aqua dest. and kept on the cooking water bath for one hour. Afterwards the extract was filled up to 50ml and filtered. The total nitrogen in hotwater extract was determined using the oxisolv digestion and FIA as described above.

Results

Soil

Total nitrogen

The total nitrogen content in soil did not show any seasonal dynamics, however, the organically fertilized plots proved to have a higher content of total nitrogen (Fig. 2).

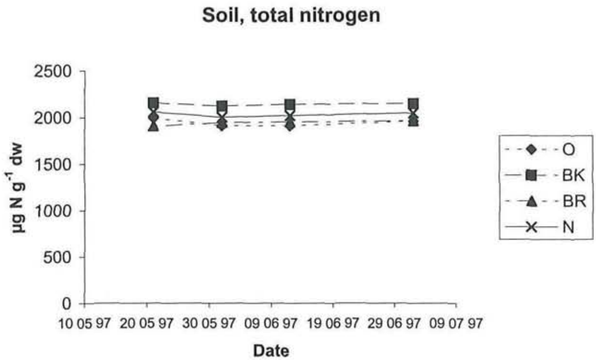

Fig. 2. Concentration of total nitrogen in the soil (µg N g^{-1} dw) from May to July 1997. O = no fertilization, BK = compost fertilization BR = fallow, N = mineral fertilization.

SRNH

The SRNH-content increased during the vegetation period, the highest amount was found in the manured plots followed by the mineral variant (Fig. 3).

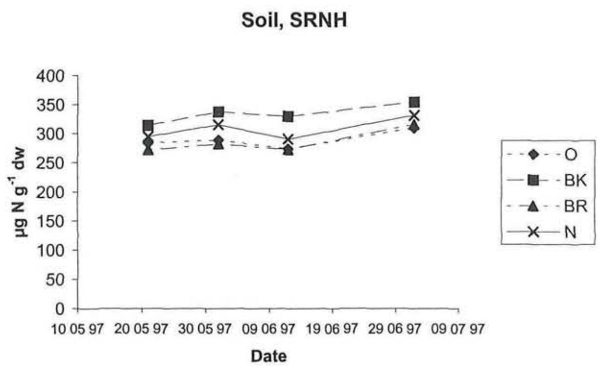

Fig. 3. Concentration of SRNH in the soil (µg N g^{-1} dw) from May to July 1997. O = no fertilization, BK = compost fertilization BR = fallow, N = mineral fertilization.

Nitrate

Mineral fertilization resulted in a high nitrate-level in soil in spring and decreased to the levels of the other plots in June. At the end of the vegetation period the compost-treated variant showed a slightly increased nitratecontent (Fig. 4).

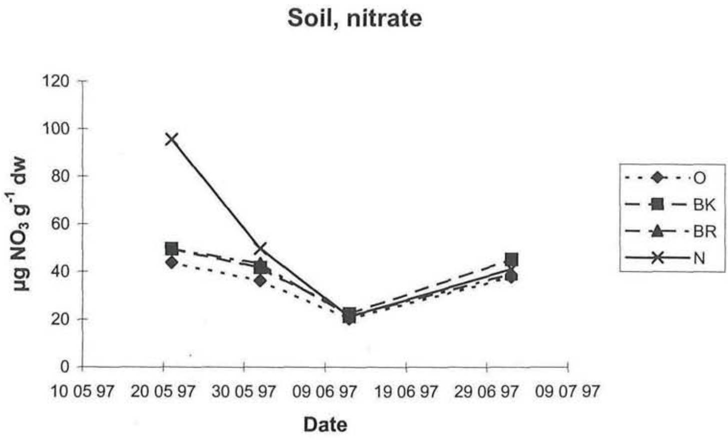

Fig. 4. Concentration of nitrate in the soil (µg NO_3 g^{-1} dw) from May to July 1997. O = no fertilization, BK = compost fertilization BR = fallow, N = mineral fertilization.

Plant

Total nitrogen

The nitrogen distribution was distinctly different between the single plant-fractions. The young and physiologically active parts such as leaf one and leaf two had a higher content of nitrogen than the older leaves, ear and stem. Within the development of plants mineral-fertilized rye exhibits a higher nitrogencontent, mostly in the plant fraction with high turnover (i.e. leaf one, the flag, and two) as compared to the other variants. Compost-amendment leads to higher N-concentrations in the leaves compared to the unfertilized variants (Fig. 5).

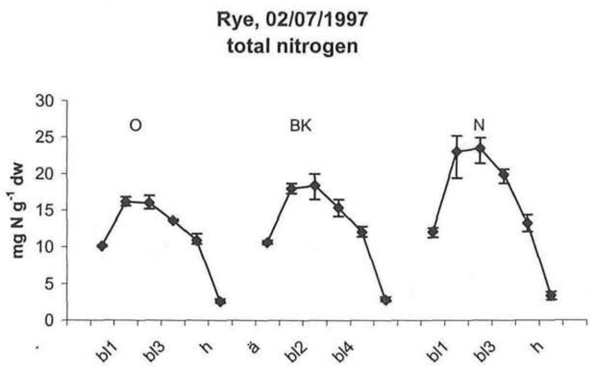

Fig. 5. Concentration of total nitrogen in different parts of the rye plants in mg N g^{-1} dw. O = no fertilization, BK = compost fertilization, N = mineral fertilization. ä = ears, bl1 = flag, bl2 = leaf 2 from the top, bl3 = leaf 3 from the top, bl4 = rest of the leaves, h = stem. Mean, minima and maxima of the three replications are plotted.

Hot water soluble nitrogen

This fraction is expected to represent an intermediate between nitrogenuptake in form of nitrate and incorporated total nitrogen in plants. Therefore the hot water soluble nitrogen content in ears is high at the beginning of the vegetation period and increasing in vegetative plantparts during growth. Since there were great variations of the values, no significant differences between distinguished fertilized plots could be detected.

Nitrate

Since rye - being a cereal - reduces nitrate mostly in the roots, the nitrate-content in the plants is very low. Nevertheless, higher values in minerally fertilized plants were found, especially in stems, the medium of transport (Fig. 6).

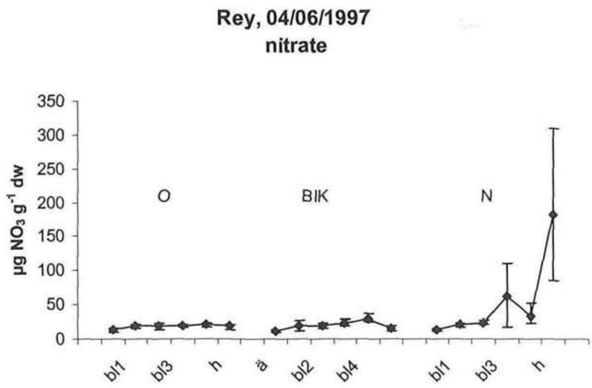

Fig. 6. Concentration of nitrate in different parts of the rye plants in µg NO_3 g^{-1} dw. O = no fertilization, BK = compost fertilization, N = mineral fertilization. ä = ears, bl1 = flag, bl2 = leaf 2 from the top, bl3 = leaf 3 from the top, bl4 = rest of the leaves, h = stem. Mean, minima and maxima of the three replications are ploted.

Discussion

Composted organic wastes are increasingly pointed out as alternative to chemical fertilizers for crop production (RODRIGUES & al. 1996). On the other hand, nutrients from organic fertilizers applied to soil, such as nitrogen, are slowly mineralized and there is little experience of providing plants with nitrogen by compost (DIEZ & KRAUSS 1997). So some of the efforts to estimate the potential of soil, amended in different ways, to mineralise nitrogen and make it available for plants were conducted by WENZL & al. 1987. Also APPEL & MENGEL 1998, KÖRSCHENS & al. 1990 and MENGEL & al. 1999 presented some investigations on soluble nitrogen in soil to predict the mineralizable nitrogen in soil. To accomplish experiments which are developing a NIRA-analysis of soil (WENZL 1996), recording the potential nitrogen supplement for crop, there was established a so called wet-chemical analysis method at the Ludwig Boltzmann Institute for Biological Agriculture and Applied Ecology as a reference required for the calibration of NIRA-spectroscopy (CAPRIEL & al. 1999). It is based on a microwave-digestion of the soil-sample extract with Oxisolv and the final photometrical determination of nitrate (ZIMMERMANN 1996, RUZICKA & HANSEN 1988). This method has proved to work well within a coefficient of variation beyond 2 % for a sieved (4mm) and well mixed soil-sample. As a benefit of this described analytical method it can be pointed out, that there is no interference with the extraction medium as shown in the method according to Dumas (SCHELLER 1993) and, contrary to Kjeldahl-analysis, the total nitrogen in the soil-extract can be determined (BREMER & MULVANEY 1982). Phosphate-buffer was chosen as extraction medium, because the results are more stable as compared to hot-water- and $CaCl_2$- extraction and in addition to fast mineralizable nitrogen slowly mineralizable nitrogen is included as well (WENZL & SOBOTIK 2001).

FREI MING & al. 1997 and VANDRE 1994 report, that compost-nitrogen applied to soil is incorporated mostly in humus and therefore not available for plants, therefore no higher yields could be found. It has even been demonstrated, that compost can lead to an immobilisation of nitrogen in soil (BRANDT & WILDHAGEN 1999). On the other hand, RODRIGUES & al. 1996 describes the potential of compost to provide nutrients to plants in a balanced way, providing high yields. Also ABIGAIL & al. 2000 achieved higher yields of onions on compost-amended plots in comparison to unamended soil. JOHNSTON & al. 1989 reported a long-term increase of total nitrogen in soil when compost was distributed. Due to our experimental design the consideration of crop-yield was not possible, but it can be seen, that total nitrogen of soil is raised by compost-distribution and the content of total nitrogen in plants is increased by fertilization in the order of O<BK<N according to WILDHAGEN & al. 1987. As reported in the cited investigation, higher N-content of cereals corresponds with a higher yield, a fertilization-effect of compost can be expected in our trial. This assumption is fortified by a higher content of extractable nitrogen in compost-amended soil corresponding to the work of HARTL & WENZL 1997, which is believed to represent the ability of soils to release nitrogen (KÖRSCHENS & al. 1990, MENGEL & al. 1999, APPEL & MENGEL 1998). In contrast to RODRIGUES & al. 1996 and according to PARKINSON & al. 1996 compost-distribution did not raise the value of soil-nitrate as mineral fertilization did in the beginning of the vegetation-period. As described by VOGTMANN & al. 1993 for some vegetables, minerally fertilized rye showed higher levels of nitrate-content than non-treated and compost-amended plants, especially in stems, indicating a luxury consumption of nitrogen of the minerally fertilized rye and a balanced supply of nutrients by compost.

Conclusions

Compost-manuring influenced the content of total nitrogen in soil in a positive way. Also SRNH as the potential available nitrogen in soil showed higher values. Mineral fertilization resulted in a significantly higher content of nitrate after application. Crop (i.e. rye) reacted with a higher content of total nitrogen, hot water soluble nitrogen and especially nitrate in plants, total nitrogen mostly in the anabolically active parts of the plants. This may be due to a sufficient nitrogen-availability in the untreated soil and/or to the slow and steady mineralization of organic nitrogen. However it could be assumed that this place was well supplied with nitrogen and mineral fertilization led to luxury consumption of nitrogen by crop, whereas in the variant fertilized with compost the plants were not forced to an extreme uptake of nitrogen.

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