The Journal of Animal & Plant Sciences, 24(1): 2014, Page: 321-328
ISSN: 1018-7081

EFFECT OF SOIL ON UPTAKE AND UTILIZATION OF NITROGEN BY OAT (*Avena sativa* L.)

P. K. Ng`ang`a and K. M. Jezik

University of Natural Resources and Life Sciences, Vienna
Corresponding Author: kinotix@yahoo.com

ABSTRACT

Growers seeking an alternative to animal residue based organic nitrogen (N) fertilizers can select among a number of different plant- and industry processed organic fertilizers. However, the effect of soil properties on the N release of these fertilizers has not yet been studied. Therefore, three pot experiments were conducted to investigate the influence of different soils on the N utilization of these fertilizers. Grain legumes (unlabelled and ^{15}N labelled) and industry processed plant residues were applied as fertilizers to oat as a model plant, with the effects being evaluated by the calculation of the apparent N utilisation and, in one case, by the N use efficiency. The N release was influenced by the N content of the fertilizers, with the apparent N utilization and the N use efficiency increasing with increasing N content. In addition, soils modified N utilization by the plants, but this effect was dependent upon the N content of the fertilizers. When the N content was low (pea), the apparent N utilization by oat was significantly higher in the coarse textured soils as compared to the fine textured soils. However, when the N content of the fertilizer was higher, plant N uptake was unaffected by the soils. In an experiment conducted with a wider range of soils, the apparent N utilization of two fertilizers with a medium N content differed between the soils, although the differences were not obviously related to any of the soil texture, soil C_{org} content, or N mineralization of the unfertilized soil. However, a higher N mineralization from the unfertilized soils was associated with a higher N use efficiency of oat from all tested fertilizers, indicating a positive soil-fertilizer interaction in these soils. It is concluded that none of the soil parameters examined could account in isolation for the variations in the N utilization of the fertilizers in different soils. However, the use of fertilizers with a higher N content are generally recommended for achieving a high N utilization, especially for fine textured soils and soils with a high N release.

Key words: Oat, Grain legumes, Nitrogen, Soil

INTRODUCTION

Sources of nitrogen (N) for crop production which can be used for organic farming include N_2 fixation by legumes (Rahman *et al.*, 2013) and organic fertilizers such as farm yard manure and poultry manure (Mohsin *et al.,* 2012). As a result of the recent BSE-crisis, the use of grain legumes and organic fertilisers of industry processed plant residues has become increasingly common. More specifically, in the year of application, N availability from organic fertilizers determined as mineral fertilizers equivalents ranges widely from 10% (bio-compost) to 90% (urine). For fertilizers used in organic horticulture, these values typically vary between 30 -70% (Gutser *et al.*, 2005). Soil N supply – both initial levels, which can now be quantified quickly and cost effectively (Schmidhalter, 2005), and mineralizable soil N are important components in optimising N fertilizer application (Olfs *et al.,* 2005). It is documented that soil affects the N mineralization of incorporated material like crop residues or manure. Soils that were high in silt and clay immobilized more N from crop residues (1.3-2.8% N) than did sandy soils (Egelkraut *et al.,* 2000). Moreover, remineralization of immobilized N showed a greater delay in soils with higher clay content (Egelkraut *et al.,* 2000). It has also been suggested that fine textured soils tend to mineralize less N from crop residues and manure than do coarse textured soils (Thomsen *et al.,* 2003b). Thomsen *et al.,* (2001) showed that an increase in soil clay content from 10 to 40% decreased the net N mineralization of ^{15}N labelled oat by about 10%, whereas the addition of silt sized organomineral complexes did not affect net N mineralization. They hypothesized that soil texture has only a small effect on net N mineralization in soils with similar mineralogical compositions and cropping histories, and identical soil water matrix potentials. Pare and Gregorich (1999) reported that the effect of soil texture is dependent on the kind of crop residue used: N mineralization from maize (2.5% N) and soybean (1.7% N) was highest in fine textured soils, but was highest from alfalfa (3.4% N) in a sandy soil. Furthermore, alfalfa showed a positive "added nitrogen interaction" (ANI) in sandy soil and a negative ANI in more fine textured soils, whereas the ANIs of maize and soybean were negative for all soils. Only a few reports deal with the interaction of incorporated organic fertilizers and soil organic matter. In their recent review, Cabrera *et al.,* (2005) recommended that additional research on the effect of soil characteristics on net N mineralization should be conducted. Given that the body of evidence indicates that the N release of plant derived and industry processed organic N fertilizers may depend on soil properties, the objective of this study was to determine the influence of different soils on the N utilization of oat fertilized with plant (unlabelled and ^{15}N labelled) and industry processed organic fertilizers in pot experiments.

MATERIALS AND METHODS

Three sets of pot experiments were carried out to investigate the effect of soil on nitrogen utilization of oat (*Avena sativa* L.) from plant and industry produced organic nitrogen fertilizer varying in nitrogen content. The experiment was carried out at the University of Natural Resources and Life Sciences, Vienna, in 2012. In this set of experiments, the different types of soils which varied in texture and organic carbon were used. Both the fertilizers and soils were examined in accordance to the European Union Standards on organic production of agricultural products. Glasshouse and field soils obtained at (0-30 cm soil depth) for use in the experiments was collected and sieved to obtain particle size distribution within the range of (≤ 5 mm). The characteristic features of the fertilizer material used in the pot experiments are described in table 1. With regard to the characteristic features of the different types of soil used in the pot experiments, these are described under the respective pot experiments. Table 1 describes the % nitrogen content, % carbon content and C/N ratio of the fertilizers used in the three pot experiments.

Pot experiment 1: In the first pot experiment, coarse meal of each of pea (*Pisum sativum* L., 3.0% N), lupin (*Lupinus luteus* L., 3.4% N) and faba bean (*Vicia faba* L., 4.0% N); Maltaflor®- spezial (4.7% N); and Rizi-Korn (5.3% N) (Tab.1), were each tested in four different types of soils whose characteristics are described in table 2 below. Table 2 describes the characteristic features of soils used in the first pot experiment. Fertilizer in the amount of 800 mg N/pot (255 kg N/ha) was mixed into the upper portion of four types of soils and compared with a control treatment without fertilizer. Oat (*Avena sativa* L.; 1.5 g/pot) was sown one day after fertilizer addition. Pots were irrigated regularly with distilled water to achieve 60 % maximum water holding capacity. All pots were uniformly treated with 0.3 g potassium as K_2SO_4 one week after the first harvest. During the 13 weeks of cultivation, Oat was harvested three times. After each harvest, the plants were immediately kept in the oven for drying at 70 °C until constant weight. After drying, the N content of each harvest was analysed separately using an FP-328 Nitrogen/Protein Determinator (LECO CORPORATION, St. Joseph, Michigan, USA). The apparent N utilization was calculated from the total N uptake of all the three cuttings. Seeds of oat were sown in pots and placed in the glasshouse at the beginning of January (5th January, 2012) and the experiment was terminated at the beginning of April 2012 (4th April, 2012). Nine treatments (five fertilizers and four soil types) were laid out in a Randomized Complete Block Design (RCBD) with three replicates.

Pot experiment 2: In this pot experiment coarse meal of faba bean (*Vicia faba* L., 4.0 % N) and Maltaflor®-spezial (4.7% N) (Table 1), were investigated using eight different types of soils whose characteristics are shown in table 3. Table 3 describes the characteristics features of the soils used in the second pot experiment. 800 mg N/pot (255 kg N/ha) similar to the first pot experiment were mixed into the upper portion of the soil in three replicates and compared with a control treatment without fertilizer. Oat (*Avena sativa* L.; 1.5 g/pot) were sown two weeks after fertilizer addition. Pots were irrigated regularly with distilled water to achieve 60 % maximum water holding capacity. All pots received 0.2 g potassium which was applied one week before the first harvest and one week after the second harvest. Pots with Oat were left for 12-13 weeks during the cultivation period. During this period, plants were harvested four times. After harvesting they were dried by putting them into an oven at 70 °C until constant weight. After drying, the N content of each harvest was analysed separately using an FP-328 Nitrogen/Protein Determinator (LECO CORPORATION, St. Joseph, Michigan, USA) similar to pot experiment 1. The apparent N utilization was calculated from the total N uptake of all the four cuttings. Seeds of oat were sown in pots and placed in the glasshouse at the beginning of May (8th May, 2012) and the experiment was terminated at the end of July 2012 (30th July, 2012). Ten treatments (two fertilizers and eight soil types) were laid out in a Randomized Complete Block Design (RCBD) with three replicates.

Pot experiment 3: In this third pot experiment, the fate of N from ^{15}N labelled fertilizers derived from the coarse meal of a straw mixture from pea and faba bean (1.5% N), and a coarse meal of either pea (3.7% N) or lupin (4.6% N) (Table 1), was studied in each of the four soils used in pot experiment 1(Table 2). In this experiment, oat yields from the four cuttings grown for a period of 13 weeks were summed up. After drying in the oven at 70 °C until constant weight, N and ^{15}N content for each harvest was analysed separately using an ANCA-MS (EUROPA SCIENTIFIC SL 20-20, Crewe, GB). Nitrogen use efficiency was determined through calculation using the formula: N use efficiency = 100 x NdfF (g/pot) / total N applied (g/pot), where NdfF is N derived from fertilizer, which was calculated as: NdfF (g/pot) = NdfF (%) x N uptake (g/pot) NdfF (%) = atom

% ^{15}N excess of plant N / atom % ^{15}N excess of fertilizer N, where atom % ^{15}N excess was obtained by subtracting the abundance of the control sample (plant and soil respectively) from the measured value. Seeds of oat were sown in pots and placed in the glasshouse in mid-August, 2012 (13th August, 2012) and the experiment was terminated in mid-November, 2012 (12th November, 2012). Seven treatments (three fertilizers and four soil types) were laid out in a Randomized Complete Block Design (RCBD) with three replicates.

Statistical analyses: SAS Version 8.2 was used for all statistical evaluations. The results of both incubation and pot experiments were subjected to one-way analyses of variance with the significance of the means tested with a Tukey/Kramer HSD-test at $p \leq 0.05$. Regression and correlation analyses were calculated using the SAS procedures "proc reg" and "prog corr".

RESULTS

1.0 **Apparent nitrogen utilization:** The apparent N utilization of oat from the five plant and industry processed organic residues was influenced predominantly by the fertilizer used (F = 45.69), but also to a lesser degree by the soil (F = 10.93) (Tab. 6). An increase in fertilizer N content increased the apparent N utilization in each soil (Fig. 1), whereas the influence of the soil on the apparent N utilization was dependent on the fertilizer. No effect of the soil was observed when the N content of the fertilizers was high. By contrast, the apparent N utilization of oat grown in the sandy loam soils was significantly higher compared to the silt loam soils under the application of a fertilizer with a low N content (pea). Consequently, the decline in apparent N utilization from fertilizers of decreasing N contents was less significant in the coarse textured soils. To confirm the influence of soil texture on N utilization, a second experiment using a higher number of soils was conducted, but only two fertilizers (faba bean, Maltaflor®-spezial) with similar, intermediate values of N content were used. Their effect on the apparent N utilization was statistically still significant, although the probability value was higher compared to the previous experiment. Both the influence of the soils on the N uptake of the plants (F = 9.75) (Tab. 6) and the interaction between soils and fertilizers sandy loam silt loam sandy loam silt loam (F = 3.14) were significant (Tab. 6). Milled seeds of faba bean and Maltaflor®-spezial both showed a relatively high level of N utilization in all soils (Fig. 2), although specific values did vary from 60% (Maltaflor®-spezial for silty clay loam 6.6) to about 40% (faba bean for either silt loam 4.8 or loam 8.4). The N utilization of faba bean was equal to that of Maltaflor®-spezial, except for two soils (silt loam 4.8 and loam 8.4) where the N utilization of faba bean was significantly lower. In contrast to the first experiment, differences in the apparent N utilization between the fertilizers were not obviously related to the soil texture. For example, in the fine textured, silt soils, the apparent N utilization of Maltaflor®-spezial was both superior (silt loam 4.8, loam 8.4) or equal (silt loam 1.3, silty clay loam 6.6) to that of faba bean. For both fertilizers, the apparent N utilization tended to increase slightly in those soils with higher C_{org} contents. However, it was equally apparent, particularly for faba bean, that soils high in C_{org} (e.g., silt loam 4.8, loam 8.4) could not accommodate a high N utilization. Because these soils combine high C_{org} content with a silty, finer soil texture, we assumed that the turnover of organic substance might explain the observed differences in the N utilization between the soils.

2.0 Nitrogen uptake from unfertilized soils: The turnover of the organic substance can be described by the amount of N uptake of plants from native, unfertilized soils. The N uptake by oat from unfertilized soils differed greatly between the different soils (Fig.3). Two soils in particular (sandy loam 3.4, silt loam 4.8) released high amounts of plant available N, whereas the N uptake from the remaining soils was much lower. The N release from a given soil was not obviously related to its C_{org} content. Moreover, no clear relationship existed between the N availability (Fig. 3) from a given, unfertilized soil and the apparent N utilization (Fig. 2). Soils with a high N release (sandy loam 3.4, silt loam 4.8) did lead to neither extremely high nor low fertilizer N utilization, but one of these soils (silt loam 4.8) showed distinct differences in the N utilization between faba bean and Maltaflor®-spezial. Moreover, soils with low or very low N release lead to any of high (silty clay loam 6.6), low (sandy loam 1.2, silt loam 1.3) or even fertilizer dependent (loam 8.4) apparent N utilization. Consequently, the turnover of soil organic matter determined as plant N uptake from native soils also could not account for differences in the apparent N utilization.

3.0 Nitrogen use efficiency: A further way to follow the fertilizer N turnover processes in more detail is the application of ^{15}N labelled material, which can help specify the interaction between soil and fertilizer through the proportion of fertilizer N in plant N uptake (= N use efficiency). In this experiment, the results were similar to those in the previous experiment: soil N release determined as plant N uptake from the unfertilized soils differed greatly, with both high (sandy loam 3.4, silt loam 4.8) and low (sandy loam 1.7, silt loam 3.0) values being observed (Tab. 3). The apparent N utilization increased when the N content of the plant-derived fertilizers was higher, and the overall influence of the fertilizers (F = 3800) was much stronger than that of either the soils themselves (F = 112) or of the interaction between fertilizers and soils (F = 38), although each effect was highly significant (Tab.6). Straw application immobilized

N which was more evident in the soils with higher N release. For these latter soils, the increase in the apparent N utilization with increasing fertilizer N content was more pronounced than for those soils demonstrating a low N release. These differences were not as obviously associated with the soil texture as was the case in the first experiment, although the role of soil N release became increasingly evident when the two groups of soil textures (sandy and silty soils) were considered separately. Then a relationship of soil N release with soil C_{org} content was observed. And in this case, straw immobilized more N and pea mineralized less N from soils with a high N turnover, whereas the apparent N utilization of lupin was higher in such cases. Generally, the soil dependent differences in the apparent N utilization were more obvious for the low N fertilizers than for those fertilizers with high N content. Similar to the apparent N utilization, N use efficiency increased when fertilizer N content was higher (Tab. 4), although the differences were less pronounced. Nitrogen was even taken up from straw and this was significantly higher in those soils higher in N release. The difference in the N use efficiency of higher N content fertilizers (pea, lupin) was less clearly related to this soil parameter. The N uptake from lupin was higher in soils with higher N releases, but N use efficiency for pea could not be attributed to either soil N release or to soil texture alone. However, subdividing the soils into two groups of similar soil texture again suggested that, within each of the groups of the sandy and the silty soils, N use efficiency of all tested fertilizers was superior in soils with a high N release.

Table 1: Nitrogen contents %, Carbon content % and the C/N ratio of the Fertilizer used in the pot experiments

Name of the Fertilizer	Nitrogen Content (%)	Carbon Content (%)	C/N Ratio
Coarse meal of straw from pea and fababean (c)	1.4	44	30.1
Coarse meal of pea (a)	3.0	40	13.3
Coarse meal of lupin (a)	3.4	41	12.0
Coarse meal of pea (c)	3.7	44	11.7
Coarse meal of fababean (a, b)	4.0	40	9.9
Coarse meal of lupin (c)	4.6	46	9.9
Maltaflor®-spezial (a, b)	4.7	38	8.0
Rizi-Korn (a)	5.3	46	8.6

(a) Fertilizers used in the first pot experiment
(b) Fertilizers used in the second pot experiment
(c) Fertilizers used in the third pot experiment with ^{15}N labelled fertilizers

Table 2: Characteristic features of soils used in the first pot experiment

Soil type	% Organic Carbon	% Total Nitrogen	C/N Ratio
Sandy loam	1.4	0.11	12.8
Silt loam	1.9	0.23	8.4
Sandy loam	3.1	0.28	11.1
Silt loam	8.0	0.50	15.9

Table 3: Characteristic features of soils used in the second pot experiment

Soil type	% Organic Carbon	% Total Nitrogen	C/N Ratio
Sandy loam	1.2	0.12	9.2
Silt loam	1.3	0.13	10.2
Sandy loam	1.7	0.14	12.4
Silt loam	3.0	0.27	11.1
Sandy loam	3.4	0.31	10.8
Silt loam	4.8	0.39	12.4
Silty clay loam	6.6	0.64	10.3
Loam	8.4	0.63	13.3

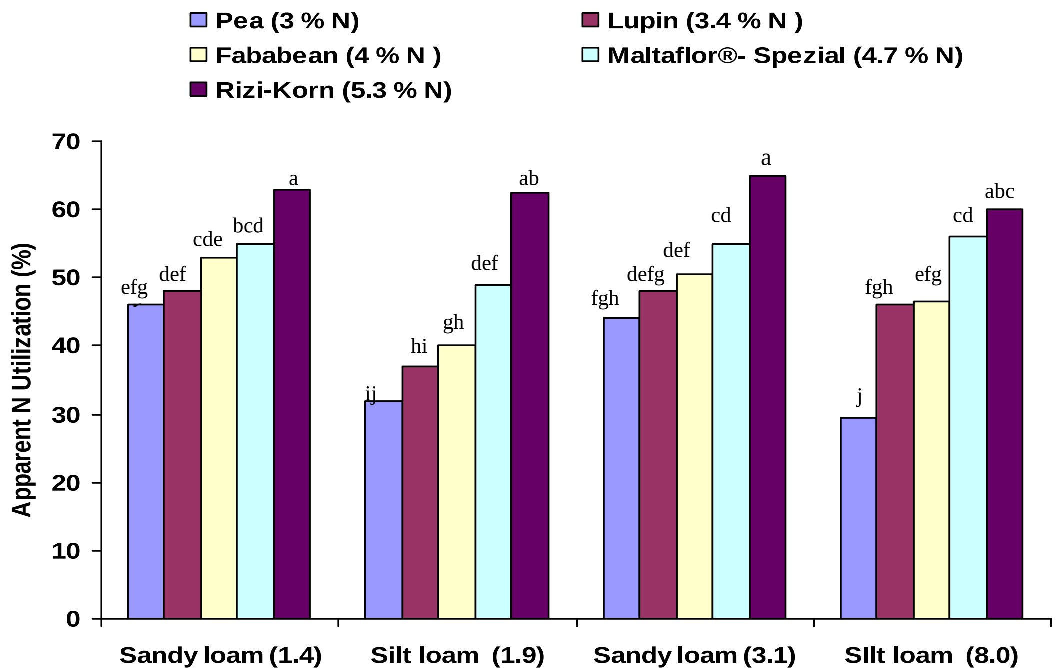

Figure 1: Apparent N utilization of oat from plant and industry processed organic N fertilizers in four different soils after 91 days

Different letters indicate statistically significant differences (LSD, $p \leq 0.05$).
subscript denotes C_{org} content

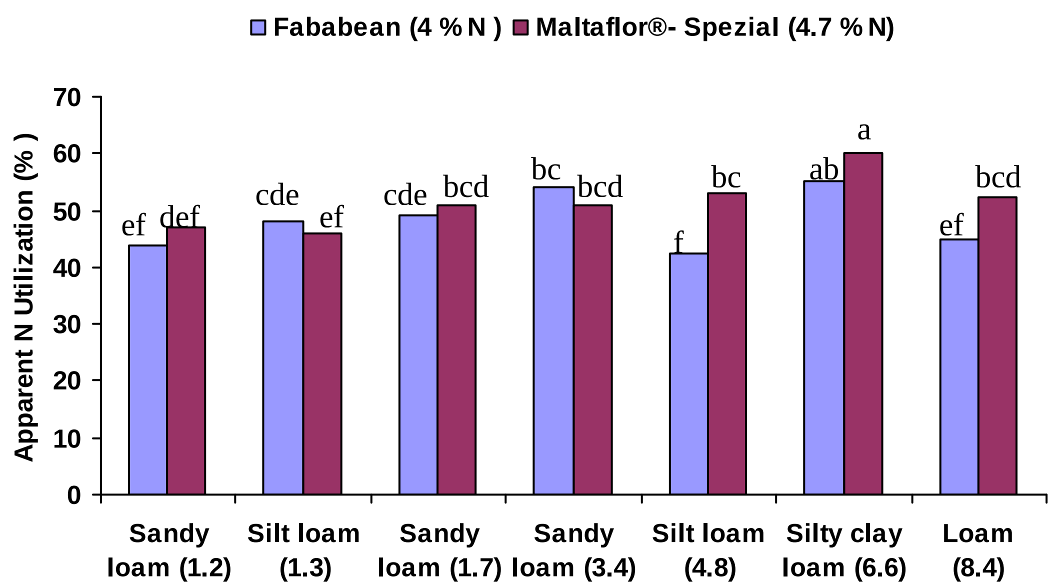

Figure 2: Apparent N utilisation of oat from fababean and Maltaflor®-spezial in seven different soils after 84 days

Different letters indicate statistically significant differences (LSD, $p \leq 0.05$).
subscript denotes C_{org} content

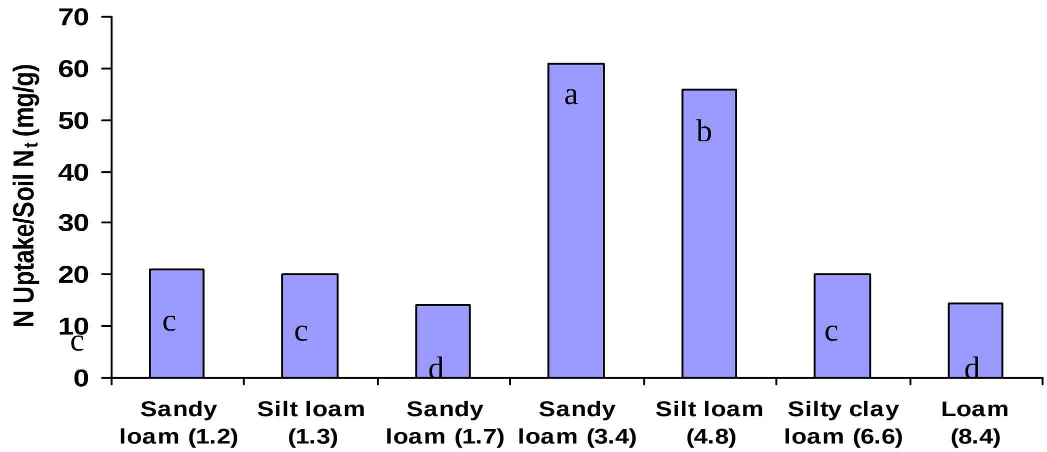

Figure 3: N uptake of oat related to total soil N in seven unfertilized soils after 84 days

Different letters indicate statistically significant differences (LSD, p ≤0.05).
subscript denotes C_{org} content

Table 4: N uptake of oat from unfertilized soils and apparent N utilization of oat from plant N fertilizers in four different soils after 91 days

Soil type	N - uptake/soil - Nt (mg/g)	Straw (1.5% N)	Pea (3.7% N)	Lupin (4.6% N)
Sandy loam 1.7	17 c	-1 a	45 a	49 ab
Sandy loam 3.4	64 a	-15 c	33 b	53 a
Silt loam 3.0	14 d	-7 b	34 b	41 c
Silt loam 4.8	60 b	-22 d	24 c	47 b

Different letters indicate statistically significant differences among soils for each fertiliser (LSD, p≤0.05)
Subscript denotes C_{org} content

Table 5: N use efficiency of oat from plant-derived fertilizers in four different soils after 91 days

Soil type	Straw (1.5% N)	Pea (3.7% N)	Lupin (4.6% N)
Sandy loam 1.7	4 c	38 b	39 c
Sandy loam 3.4	14 a	42 a	47 a
Silt loam 3.0	3 c	30 c	34 d
Silt loam 4.8	10 b	37 b	41 b

Different letters indicate statistically significant differences among soils for each fertilizer (LSD, p≤0.05).
Subscript denotes C_{org} content

Table 6: ANOVA:Effect of fertilizers, soils and their interaction on the apparent N utilization and N use efficiency

Description	Main Effects + Interactions	DF	F-Value	Pr >F
Effect of fertilizers, soils and their interaction on the apparent N utilization	Fertilizer	4	45.69	<0.0001
	Soil	3	10.93	<0.0001
	Soil X Fertilizer	12	1.56	0.1276
Effect of fertilizers, soils and their interaction on the apparent N utilization	Fertilizer	1	9.26	0.0051
	Soil	6	9.75	<0.0001
	Soil X fertilizer	6	3.14	0.0176
Effect of fertilizers, soils and their interaction on the apparent N utilization	Fertilizer	2	3800	<0.0001
	Soil	3	112	<0.0001
	Soil X fertilizer	6	38	<0.0001
Effect of fertilizers, soils and their interaction on the N use efficiency	Fertilizer	2	9131	<0.0001
	Soil	3	561	<0.0001
	Soil X fertilizer	6	20	<0.0001

DISCUSSION

In this study, N utilization of plant and industry processed organic N fertilizers was significantly correlated with the N content of fertilizers. Across the whole range of fertilizers with their differing N contents (ranging from low in straw at 1.5% N to high in Rizi-Korn at 5.3% N), soil dependent differences in the apparent N utilization were less pronounced at higher fertilizer N contents. However, the apparent N utilization for fertilizers with a medium N content (Faba bean, Maltaflor®-spezial) might also be significantly affected by soil properties. Fertilizers with a lower N content (straw, pea) generally released less N or even immobilized more N in the silty soils as compared to the sandy soils, although in one experiment (straw and pea 3.7% N) this was only true within the two groups of soils that were similar in the N turnover of organic substance. A lower N utilization of organic fertilizers on silty soils is supported by the majority of related studies in the literature. Crop residues and manure, both of which had a low N content, tended to result in a lower or slower N mineralization in finer textured soils as compared to coarser ones (Egelkraut *et al.*, 2000; Thomsen *et al.*, 2003b). However, our results indicated that the apparent N utilization of fertilizers was less determined by soil texture if the N content of the former is medium or higher. Soil texture was therefore not the only factor affecting the apparent N utilization. When soils are subdivided into two groups of similar texture (i.e., sandy versus silty soils) it was indicated that soil C_{org} content within each group might play a certain role for the apparent N utilization. This finding was the most obvious for straw (1.5% N) and pea (3.7% N), where the N immobilization of straw and the lower apparent N utilization of pea were more pronounced in the higher C_{org} content soils. However, this trend may also be restricted to fertilizers with lower N contents and, in some cases it was not possible to relate observed differences in apparent N utilization to soil C_{org} contents. Apart from soil C_{org} content, the turnover of the organic substance might affect the N utilization of fertilizers on different soils. In two of the soils investigated in present study (sandy loam 3.4, silt loam 4.8), the OM turnover as determined by the N uptake of plants from native, unfertilized soils significantly exceeded those of the remaining soils. This N release by the two soils was also not obviously related to their soil C_{org} contents. The high N mineralization observed in both the sandy loam 3.4 and silt loam 4.8 can easily be explained by the fact that at low OM contents, the mineralization rate is high, but less N is available due to low contents of organic N. Soils high in Nt and C_{org} has low mineralization rates which consequently results in low amounts of mineralized N as well. The mineralization in these soils was markedly superior to those of all other soils, regardless of whether their C_{org} contents were higher or lower. Our studies indicated that soils with a high N release will not necessarily result in a high apparent N utilization of the fertilizers. However, the N release from unfertilized soils was still a suitable indicator for the gross N turnover of fertilizers, particularly within the same soil texture. The fertilizer N use efficiency was significantly higher on soils with high soil N release (sandy loam 3.4, silt loam 4.8). In these soils, oat took up markedly more fertilizer derived N and this was true for all three tested fertilizers. However, when soils were grouped according to a similar level of N release, the role of soil texture for the N turnover becomes more visible. In this case, apparent N utilization and N use efficiency were always higher in the coarse textured soils regardless of the fertilizer applied. This may indicate that OM is less stable in the coarser textured soils and consequently less of the fertilizer N is incorporated into the soil OM. Nevertheless, the uniformity of the relationship between the N release and N use efficiency cannot explain the observed soil dependent differences in the apparent N utilization. The results of the present study showed that soils affected the apparent N utilization, and therefore it can be concluded that the influence of the fertilizers with different N contents was greater than that of the soils. However, there was no single clear indicator that explained the role of soil properties. Soil texture, C_{org} or soil N turnover could all affect the apparent N utilization, although there were also soils that deviated from a more general principle.

Conclusion: The N utilization of plant and industry processed organic N fertilizers was affected greatly by the N content of fertilizers and also by the soils, albeit to a lesser degree. The soil-dependent variations could not be clearly explained by any of the investigated soil parameters (texture, C_{org} or soil N release). Differences in apparent N utilization between the soils were lower when fertilizer N contents were high. At low fertilizer N contents, however, N utilization on fine textured soils could be low and this effect was even more pronounced when the N release of these soils was high. Consequently, fertilizers with a higher N content are to be recommended for fine textured soils. In such cases, where the soils release a high amount of N, only fertilizer with a high content of readily degradable N will maintain a high N supply to the plants

REFERENCES

Cabrera, M.L., D.E. Kissel, and M.F. Vigil (2005). Nitrogen mineralization from organic residues: Research opportunities. J. Environ. Qual. 34, 75-79.

Egelkraut, T.M., D.E. Kissel, and M.L.Cabrera, (2000). Effect of soil texture on nitrogen mineralized

from cotton residues and compost. J. Environ. Qual. 29, 1518-1522.
Gutser, R., Ebertseder, T., Weber, A., Schraml, M., Schmidhalter, U. (2005). Short term and residual availability of nitrogen after long-term application of organic fertilizers on arable land. J. Plant Nutr. Soil Sci. 168, 439-446.
Mohsin, A.U., J. Ahmad, A.U, H. Ahmad, R.M.Ikram, and K. Mubeen. (2012). Effect of nitrogen application through different combinations of urea and farmyard manure on the performance of spring maize (*Zea mays* L.) The J. Anim. Plant Sci., 22 (1):195 - 198.
Olfs, H.-W., K. Blankenau, F. Brentrup, J. Jasper, A. Link and J. Lammel (2005). Soil and plant-based nitrogen-fertilizer recommendations in arable farming. J. Plant Nutr. Soil Sci. 168, 414-431.
Pare, T. and E.G. Gregorich, (1999). Soil textural effects on mineralization of nitrogen from crop residues and the added nitrogen interaction. Commun. Soil Sci. Plant Anal. 30, 145-157.
Rahman, M.M., M. Sofian-Azirun, and A.N. Boyce (2013). Response of nitrogen fertilizer and legume residues on biomass production and utilization in rice- legumes rotation. The J. Anim. Plant Sci., 23(3): 900 - 905.
Schmidhalter, U. (2005). Development of a quick on-farm test to determine nitrate levels in soil. J. Plant Nutr. Soil Sci. 168, 432- 438.
Thomsen, I.K., P. Schjonning, J.E. Olesen, and B.T. Christensen, (2003). C and N turnover in structurally intact soils of different texture. Soil Biol. Biochem. 35, 765-774.
Thomsen, I. K., J.E. Olesen, P. Schjønning, B. Jensen, and B.T. Christensen, (2001). Net mineralization of soil N and ^{15}N-ryegrass residues in differently textured soils of similar mineralogical composition. Soil Biol. Biochem. 33, 277-285.