Nitrogen release from plant-derived and industrially processed organic fertilizers used in organic horticulture

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Summary

As a consequence of the BSE crisis, alternatives for fertilizers derived from animal residues are being sought for use in organic horticulture. Grain legumes (milled seeds of pea, yellow lupine, and faba bean) and organic fertilizers of industrially processed plant and microbial residues (Maltaflor®-spezial, Phytoperls®, Agrobiosol®, Rizi-Korn) were investigated as to their suitability as a replacement fertilizer. With four soils, incubation studies were conducted to determine net N mineralization of the organic fertilizers, and pot experiments were used to measure the apparent N utilization by perennial ryegrass. The objectives of this study were (1) to determine simple fertilizer characteristics that describe their N release and (2) to compare the suitability of both experimental setups to predict fertilizer N release.

At the end of all experiments, net N mineralization and apparent N utilization from Rizi-Korn was highest compared to all the other organic fertilizers, while pea performed relatively poor. This differentiation between the fertilizers developed during the first 2 weeks. Nitrogen release from the organic fertilizers as described by net N mineralization or apparent N utilization was significantly related to the N content of the fertilizers. Different soils modified this relationship. Two industrially processed fertilizers (Phytoperls®, Agrobiosol®) could not be included into a generalized relationship because N release from these fertilizers was low compared to their N content. It is discussed that the quality of fertilizer C and N affected the N release from the fertilizers. Both experimental setups, incubation and pot experiments, were suitable to describe the release of plant-available N from the organic fertilizers. However, N release of fertilizers with a low net N mineralization in the incubation experiments was underestimated compared to plant N uptake of ryegrass in the pot experiments. It is concluded that the N content of organic fertilizers indicates, but not predicts their N release.

Key words: apparent N utilization / C : N ratio / N content / net N mineralization / nitrogen fertilizer

1 Introduction

Vegetable crops usually have a high nitrogen (N) requirement. Therefore, N fertilizers used for organic vegetable production should ensure high N turnover, fast N availability, and continuous N supply. Most organic-vegetable growers provided in the past N through organic fertilizers, which predominantly contained animal residues such as horn, blood, or meat meal. However, caused by the BSE (*Bovine Spongiform Encephalopathy*) crisis, animal residues are mostly forbidden as fertilizers in organic agriculture (*Schmitz* and *Fischer*, 2003). Therefore, milled seeds of grain legumes and organic fertilizers of industrially processed plant and microbial residues are used as substitutes. Many different types of these fertilizers are already available, and newly formulated industrial fertilizers are frequently placed on the market. This implies a great variety in fertilizer composition. Moreover, fertilizers like grain legumes strongly vary in response to genotype and growing environment (*e.g.*, *Bhardwaj* et al., 1998). For all these plant-derived and industrially processed organic fertilizers, the N release should be known. Although these fertilizers differ markedly in N mineralization (*Schmitz* and *Fischer*, 2003), little is known regarding possible reasons for this.

By contrast, the N turnover of crop residues and green manures is described frequently. Experimental results from warm climatic conditions such as the tropics are partly transferable to infer N release under glasshouse conditions. When crop residues are added to soil, a rapid initial N mineralization was observed after which the rate of mineralization decreased (*Müller* and *Sundman,* 1988; *De Neve* and *Hofman*, 1996; *Thönnissen* et al., 2000; *Khalil* et al., 2005). In numerous studies, a relation between N mineralization and the biochemical characteristics of crop residues was shown. Frequently, either N content (*Iritani* and *Arnold*, 1960; *Frankenberger* and *Abdelmagid*, 1985; *Trinsoutrot* et al., 2000; *Mendham* et al., 2004) or C : N ratio (*Vigil* and *Kissel*, 1991) were strongly correlated to the N release of crop residues. However, other factors such as polyphenol content (*Constantinides* and *Fownes*, 1994) or a combination of, *e.g.*, (lignin + polyphenol) : N ratio (*Fox* et al., 1990; *Handayanto* et al., 1994) was revealed to be more important in some studies. Recently, *Khalil* et al. (2005) proposed the inexpensive option of indexing organic-matter (OM) quality using pH and the C : N ratio of the organic residues of plant and animal origin in order to quantify decomposition rate and N mineralization.

The aim of the study was to investigate whether the N release of plant-derived and industrially processed organic fertilizers can be explained by similar characteristics as for crop residues. Due to the great diversity of these fertilizers, simple, cheap, and fast measurements are required. Consequently, N and C content were selected to be most promising. Therefore, we tested whether the N release of milled grain legumes and organic fertilizers of industrially processed plant and microbial residues can be predicted by their N content or C : N ratio. Question arises, whether incubation or pot experiments with plants are more suitable to describe potentially plant-available N from organic fertilizers. Therefore, both an incu-

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bation and a pot experiment with perennial ryegrass were set up to compare milled seeds of three grain legumes and three organic fertilizers of industrially processed residues with the commonly used fertilizer "Rizi-Korn".

2 Materials and methods

2.1 Fertilizers

Milled seeds of three grain legumes (pea, *Pisum sativum* L.; yellow lupin, *Lupinus luteus* L.; fababean, *Vicia faba* L.), organic fertilizers of industrially processed residues from plants (Maltaflor®-spezial and Phytoperls®) and microorganisms (Agrobiosol®), and Rizi-Korn as one of the most commonly used fertilizers in organic vegetable production were investigated in both incubation and pot studies. These fertilizers were selected to obtain a wide range in N content and C : N ratio (Tab. 1). The N content of grain legumes ranged between 3.0% and 4.0%, whereas the range of N contents for organic fertilizers of industrially processed residues was much higher. The C content of the investigated organic fertilizers did not vary much. Hence, the C : N ratio was mainly determined by the variation in N content, resulting in higher ratios for the grain legumes than for the organic fertilizer of industrially processed residues.

Table 1: N and C content and C : N ratio of plant-derived and industrially processed organic fertilizers used in the experiments.

Fertilizer	N content (%)	C content (%)	C : N ratio
Grain legumes			
Coarse meal (1.5 mm) of pea	3.0	40	13.3
Coarse meal (1.5 mm) of yellow lupin	3.4	41	12.0
Coarse meal (1.5 mm) of fababean	4.0	40	9.9
Organic fertilizers of industrially processed residues			
Maltaflor®-spezial [(a)]	4.7	38	8.0
Agrobiosol® [(b)]	7.2	40	5.6
Phytoperls® [(c)]	8.5	43	5.0
Rizi-Korn [(d)] (reference fertilizer)	5.3	46	8.6

[(a)] maltgerms from malted barley mixed with vinasse
[(b)] fungal biomass of *Penicillium chrysogenum* (residues of penicillin production)
[(c)] fermentation residue of corn after withdrawal of corn germs, extraction of starch and sugar
[(d)] residues from castor-oil production mixed with vinasse

In order to minimize particle-size effects in our experiments, the investigated grain legumes were coarsely milled to pass through a 1.5 mm sieve (shear-mill, Brabender, Duisburg, Germany), and the organic fertilizers of industrially processed residues were sieved to pass through a 2.0 mm sieve after crushing.

2.2 Soils

Two sandy and two loamy soils, each differing in the organic-matter content, were selected for this investigation (Tab. 2). The four greenhouse soils (0–20 cm, ≤5 mm) were obtained from organic-vegetable growers.

2.3 Incubation experiments

Two incubation experiments were conducted. For the first experiment, soil 1 and seven plant-derived and industrially processed organic fertilizers were used. In the second experiment, three of the seven organic fertilizer were selected and incubated in four soils. Forty milligrams fertilizer N were mixed with 150 g dry soil and incubated in 500 mL polyethylene flasks at 20°C. The amount of applied organic fertilizer corresponded to 200 kg N ha^{-1}. A treatment without added fertilizer was included as a control. Each treatment was repeated four times (first experiment) or three times (second experiment). All samples were adjusted to a soil water tension of $\Psi_m = -0.016$ MPa. This corresponded to 9.4% or 10.5% gravimetric soil water content for soil 1 (first or second experiment), to 19.0% for soil 2, to 25.0% for soil 3, and to 39.0% for soil 4. The flasks were covered with cling film to prevent water loss.

Samples were taken at day 0, 4, 8, 15, 22, 29, 36, and 43 of the first experiment and at day 0, 4, 8, 22, and 36 of the second experiment. After incubation, the whole soil sample was extracted for nitrate (0.01 M $CaCl_2$, 1:2 soil-to-extraction ratio)

Table 2: Characteristics of the greenhouse soils used for the experiments.

Soil name	Soil horizon	Clay	Silt	Sand	Organic horticulture	Experiment	C_{org}	N_t	C : N	pH $CaCl_2$	P CAL	K CAL
		%			years in cultivation		%				mg (100 g dry soil)$^{-1}$	
Soil 1	mollic [(a)]	9	26	65	2	Incubation + Pot [(b)]	1.4	0.11	12.8	7.1	11	16
Soil 2	hortic [(a)]	12	18	70	32	Incubation	2.3	0.20	11.7	7.4	9	27
						Pot	3.1	0.28	11.1	7.5	17	43
Soil 3	hortic [(a)]	23	56	21	13	Incubation	1.6	0.16	9.7	7.2	15	24
						Pot	1.9	0.23	8.4	7.1	17	22
Soil 4	hortic [(a)]	24	53	23	16	Incubation	4.5	0.41	10.9	7.2	26	22
						Pot	–	0.50	–	7.0	26	38

[(a)] soil horizon (*FAO*, 1998)
[(b)] same soil in incubation and pot experiments

and ammonium (2 M KCl, 1:2 soil-to-extraction ratio). After filtration of the soil extracts (589/2 ½ Schleicher & Schüll, Dassel, Germany), the filtrates were stored frozen until analytical determination. Nitrate was analyzed photometrically after separation by HPLC (Uvikon® 720 LC micro, Kontron Instruments, Au i.d. Hallertau, Germany) according to *Vilsmeier* (1984), and ammonium was analyzed photometrically at 667 nm (Fa. Perkin Elmer, UV/VIS Spectrometer Lambda 20, Neuried, Germany) after formation of a complex with salicylate (*Mulvaney*, 1996).

The net N mineralization was calculated as:

Net N mineralization (%) = (A – B) / C × 100,

A: Soil mineral N of the fertilized treatment at sampling in mg flask^{-1},

B: Soil mineral N of the control treatment at sampling in mg flask^{-1},

C: N fertilized (= 40 mg flask^{-1}).

2.4 Pot experiments

Four soils were used in separate pot experiments (Tab. 2) with 5 L Mitscherlich pots. Eight hundred milligrams of organic fertilizer N, equivalent to 255 kg N ha^{-1}, were mixed into the upper half of the soil in the pots in four replicates. A control treatment without fertilizer was also included. Perennial ryegrass seeds (*Lolium perenne,* L. cv. Lifloria; 1.5 g) were sown after the addition of the fertilizer. The pots were covered with a lid until germination of ryegrass and were regularly watered with distilled water to achieve 60% maximum water-holding capacity, equivalent to 16% (soil 1), 19% (soil 2), 18% (soil 3), 34% (soil 4) gravimetric soil water content. All pots received 0.3 g potassium (as K_2SO_4) one week after the first harvest.

During 13 weeks of cultivation, ryegrass was cut three times to 1.5 cm stubble height. Ryegrass was oven-dried for 24 h at 105°C to determine the dry-matter content. Samples were milled to pass through a 1 mm sieve (Micro-mill, Culatti AG, Zurich, Switzerland), and their N content was determined (FP-328 Nitrogen/Protein Determinator, LECO Corporation, St. Joseph, Michigan, USA).

After final harvest, soil was sampled for mineral-nitrogen analyses as mentioned above.

The apparent N utilization was calculated as:

Apparent N utilization (%) = (D – E) / F × 100,

D: Cumulative N uptake of fertilized ryegrass shoots at harvest in mg pot^{-1},

E: Cumulative N uptake of unfertilized ryegrass shoots (control) at harvest in mg pot^{-1},

F: N fertilized (= 800 mg pot^{-1}).

Residual soil mineral nitrogen after harvest was not included.

2.5 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".

3 Results

3.1 Incubation experiments

During the first incubation experiment (soil 1, seven organic fertilizers), net N mineralization differed among the fertilizers. Rizi-Korn reached the highest net N mineralization (70%) of all the fertilizers at the end of the incubation period and was one of the most rapidly mineralizing fertilizers as well (Fig. 1). At the beginning of the incubation, high net–N mineralization rates were also observed for the industrial fertilizers Maltaflor®-spezial, Agrobiosol®, and Phytoperls®, and for milled seeds of fababean. But after 43 d, these fertilizers were significantly less mineralized as compared to Rizi-Korn. For milled seeds of lupin and pea, a "lag phase" of net N mineralization was observed until day 4. The total net N mineralization for these fertilizers was lower than for the other organic-fertilizer treatments throughout the whole incubation period. Net N mineralization of the tested organic fertilizers, except pea, occurred primarily within the first 15 d (about 70% of the total net N mineralization). Maximum amount of net N mineralization seemed to be largely attained after 4 weeks of incubation.

In the second incubation experiment, net N mineralization of three selected organic fertilizers was again determined for soil 1 and additionally examined in three other soils. Net N mineralization of Rizi-Korn, fababean, and pea in soil 1 had the same characteristic as in experiment one, and this was principally found for the other three soils as well (Fig. 2). The

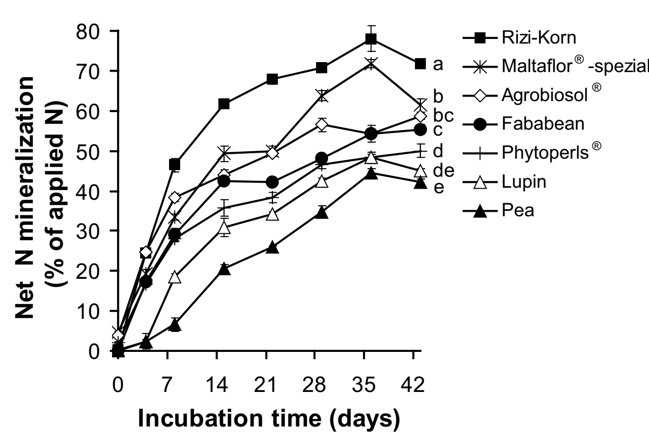

Figure 1: Time course of net N mineralization of plant-derived and industrially processed organic fertilizers applied to soil 1 during 43 d of incubation at 20°C and Ψ_m = –0.016 MPa. Letters indicate significant differences at the end of the incubation period (HSD, $p \leq 0.05$). Error bars indicate standard deviations and are hidden by the symbol if not indicated.

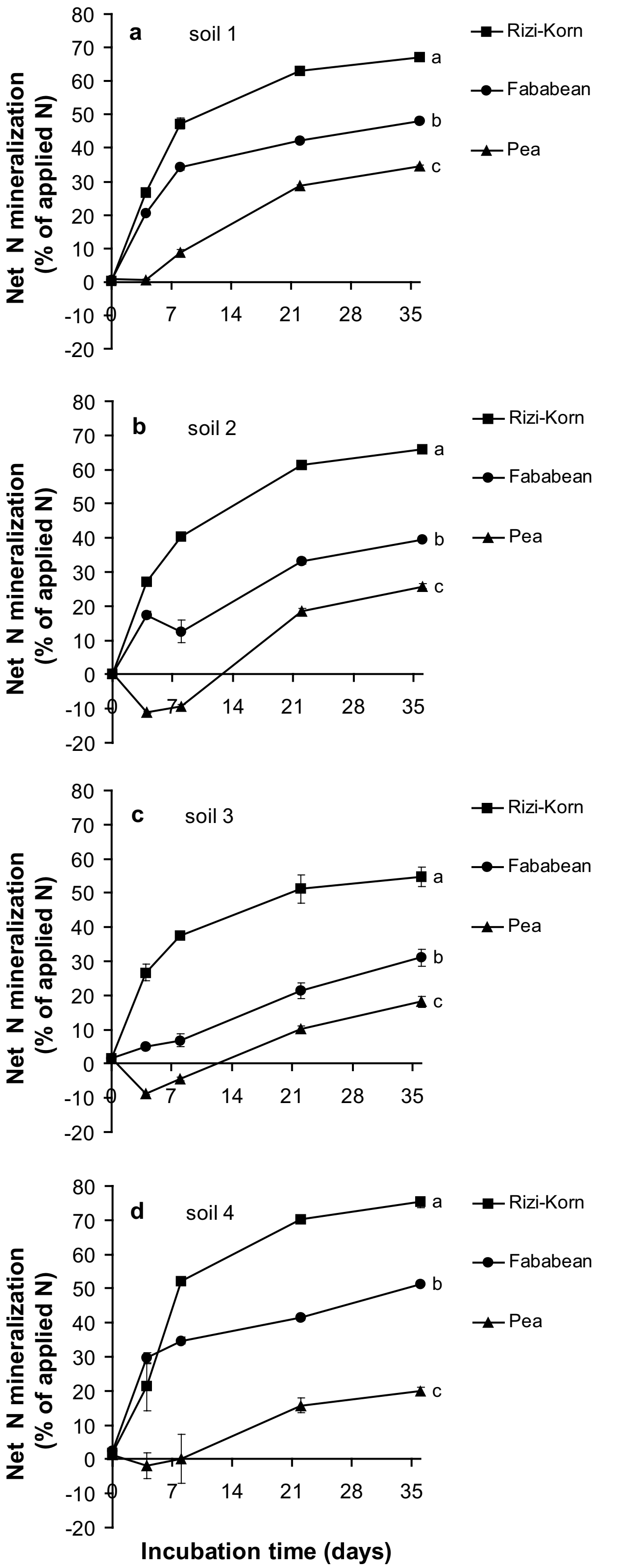

Figure 2: Time course of net N mineralization of plant-derived and industrially processed organic fertilizers applied to all four soils during 36 d of incubation at 20°C and Ψ_m = –0.016 MPa. Letters indicate significant differences at the end of the incubation period (HSD, $p \leq 0.05$). Error bars indicate standard deviations and are hidden by the symbol if not indicated.

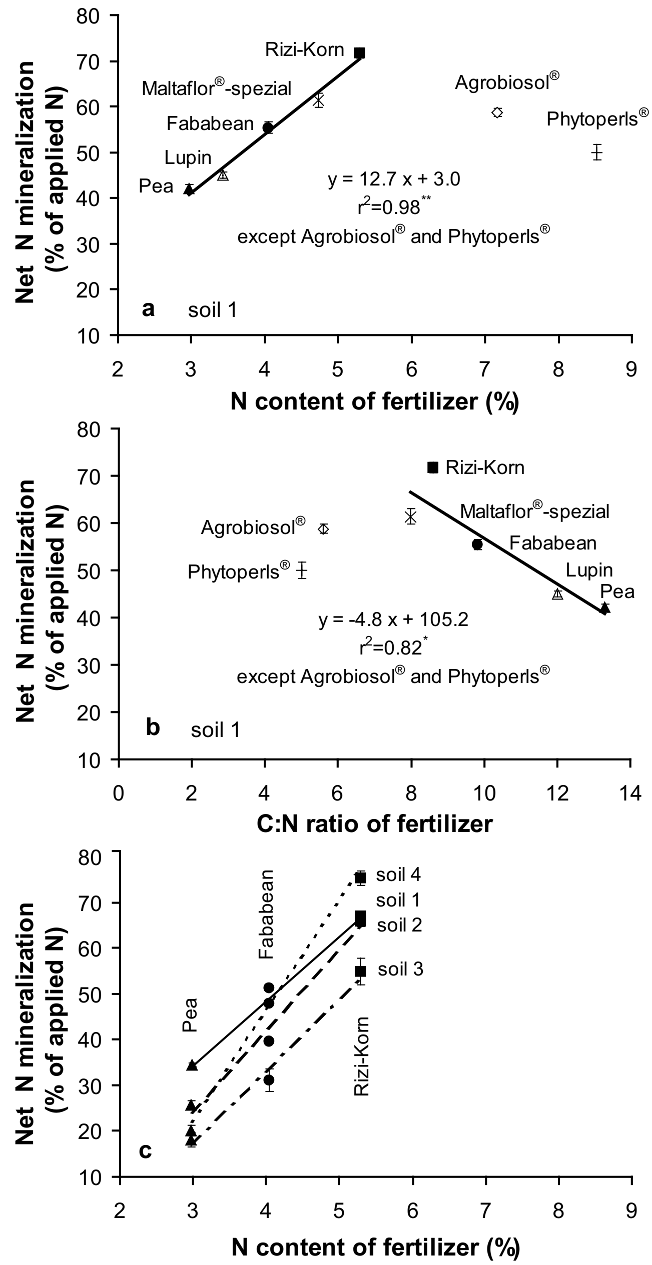

Figure 3: Relationship between net N mineralization and N content (a, c) or C : N ratio (b) of plant-derived and industrially processed organic fertilizers applied to soil 1 after 43 d of incubation (a, b) or to all four soils after 36 d of incubation (c) at 20°C and Ψ_m = –0.016 MPa.

distinct differences between the organic fertilizers at the end of the incubation period were similar in all soils. However, for pea not only a "lag phase" of net N mineralization was observed in soil 1 and soil 4, but even a strong net N immobilization occurred in soil 2 and soil 3. In these latter two soils, net N mineralization of faba bean was delayed as compared to soil 1 and soil 4. However, the time course of net N mineralization from Rizi-Korn was similar in all four soils.

To describe the relative differences in the N release between the organic fertilizers, net N mineralization was related to the

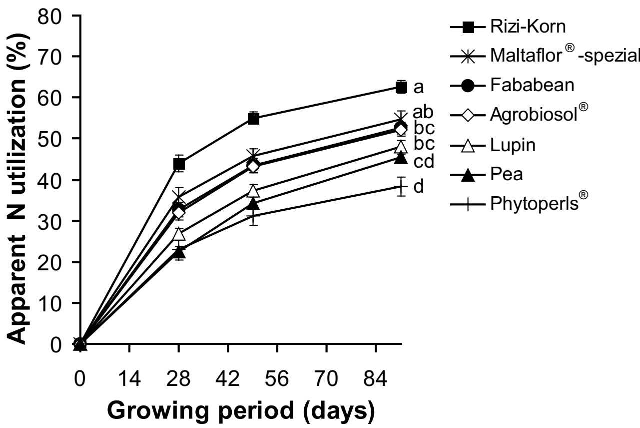

Figure 4: Apparent N utilization of plant-derived and industrially processed organic fertilizers by perennial ryegrass during the pot experiment with soil 1. Ryegrass was grown 91 d at 60% maximum water-holding capacity, and shoots were harvested three times. Letters indicate significant differences at the end of the experiment (HSD, $p \leq 0.05$). Error bars indicate standard deviations and are hidden by the symbol if not indicated.

N content of the fertilizers or to their C : N ratio. In the first incubation experiment, a significant relationship ($r^2 = 0.98^{**}$) between the N content of the organic fertilizers and their net N mineralization was found except for Agrobiosol® and Phytoperls® (Fig. 3a). In relation to their N content, net N mineralization from Agrobiosol® and Phytoperls® was clearly lower as compared to the other tested organic fertilizers. These two fertilizers were characterized by high N contents and very narrow C : N ratios. With the exception of Agrobiosol® and Phytoperls®, the relationship between net N mineralization of the organic fertilizers and their C : N ratio was statistically significant ($r^2 = 0.82^*$; Fig. 3b), as well.

The linear relationship between net N mineralization and N content of the organic fertilizers that was observed in the first incubation experiment was confirmed for the other soils with selected organic fertilizers (Fig. 3c).

3.2 Pot experiments

Pot experiments were conducted to determine the availability of organic-fertilizer N to ryegrass. In the experiment with soil 1, the time course of the apparent N utilization of ryegrass differed strongly depending on the organic fertilizer used (Fig. 4). Most of the N was already released until the first cut (about 60% of the total N uptake) except for pea and lupin. Thereafter, the increase in the apparent N utilization was markedly lower. The cumulative fertilizer-N uptake of ryegrass was highest from Rizi-Korn and lowest from Phytoperls®. A medium apparent N utilization of ryegrass was achieved for the other organic fertilizers, with a relatively good performance of Maltaflor®-spezial and with pea at the lower end of this group. For the other three soils, the time course of apparent N utilization by ryegrass was principally the same. A similar ranking of the fertilizers was found with the exception of pea and Phytoperls® that changed their positions (data not shown). At the end of the pot experiments, ryegrass had taken up almost all of the plant-available fertilizer N, because less than 0.8% of the applied N still remained as mineral N in the soils (data not shown). Therefore, in the pot experiment the cumulative fertilizer-N uptake of ryegrass that is calculated as apparent N utilization can describe the potentially plant-available fertilizer N.

In each soil, the apparent N utilization of ryegrass was significantly related to the N content of the organic fertilizers (Fig. 5), however, the regression on the C : N ratio was only significant for soil 4 ($r^2 = 0.81^*$; data not shown). Just as in the incubation experiment, Agrobiosol® and Phytoperls® had to be excluded for regression analysis.

3.3 Comparison of the incubation and the pot experiments

In both the incubation and the pot experiment, almost the same ranking of the tested organic fertilizers was found. If both experimental setups describe plant availability of organic-fertilizer N similarly, a 1:1 relationship between the apparent N utilization of ryegrass in the pot experiment and the net N mineralization in the incubation experiment is expected. Indeed, a strong correlation between both measurements was found, if Phytoperls® was excluded (Fig. 6a). For some organic fertilizers, net N mineralization and apparent N utilization are similar. However, for all fertilizers the correlation indicates a systematic divergence from the expected 1:1 relationship. The apparent N utilization of ryegrass from fertilizers with a high net N mineralization was distinctly lower than expected. In contrast, the apparent N utilization of fertilizers was slightly higher than expected when net N mineralization of the fertilizers was low. Consequently, the difference between the fertilizers was markedly higher for the net N mineralization (42%–72%) than for the apparent N utilization (46%–63%). This effect was found for all investigated soils, confirming the systematic divergence of the experimental setups for the description of the plant availability of organic fertilizer N (Fig. 6b).

4 Discussion

In all incubation and pot experiments, net N release from the organic fertilizers was almost completed by the end of the experiments. At the end of all experiments, net N mineralization and apparent N utilization from Rizi-Korn was highest compared to all the other fertilizers, while pea performed relatively poor. A high net N mineralization of Rizinus, a residue of castor-oil production and main constituent of Rizi-Korn, was also demonstrated by *Braun* et al. (2000), *Schmitz* and *Fischer* (2003), and *Müller* and *von Fragstein und Niemsdorff* (2006). In our incubation experiments, the differentiation between the fertilizers developed during the first 2 weeks. Within this period, high or low net-mineralization rates were typical for fertilizers with a high or low total net N mineralization. Different net–N mineralization rates can be explained by the proportion of carbon readily available for microbial transformation processes, supposed that the availability of the protein N of these fertilizers is rather similar. Therefore, the extraction of oil from castor bean will markedly reduce the

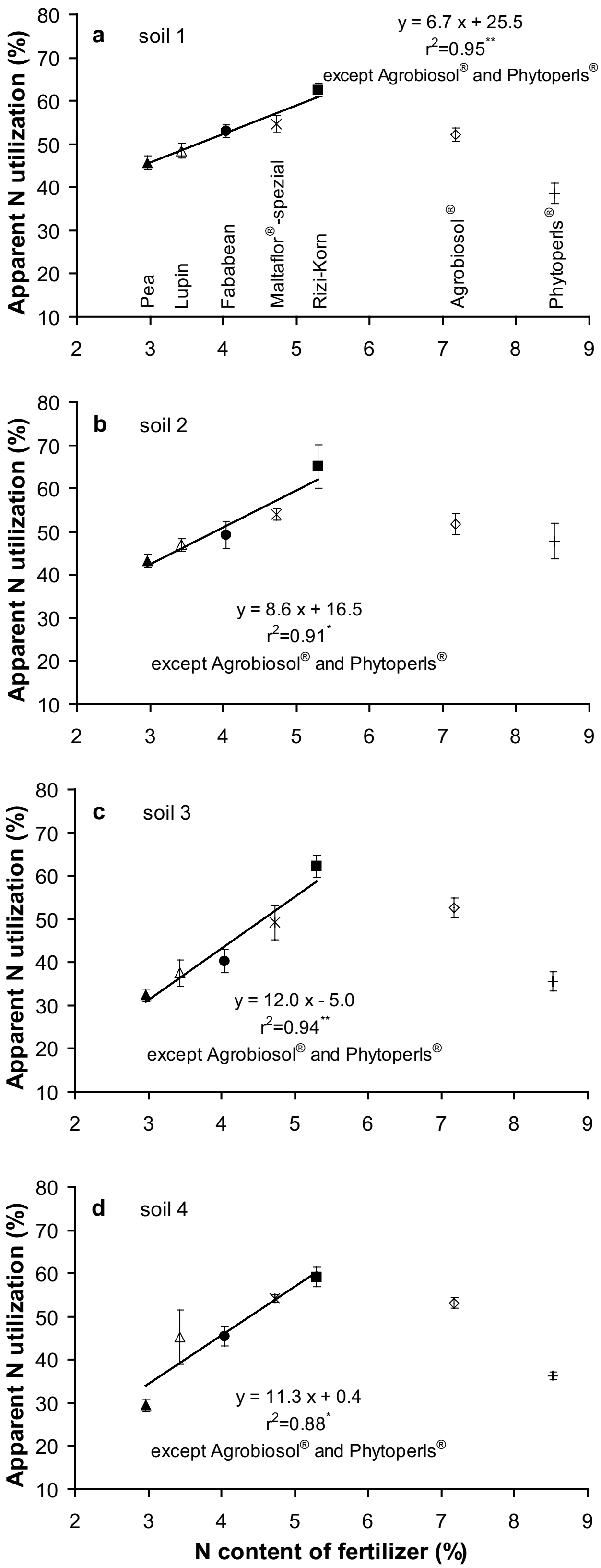

Figure 5: Relationship between apparent N utilization of perennial ryegrass and N content of plant-derived and industrially processed organic fertilizers without Agrobiosol® and Phytoperls® as found with all four soils. Apparent N utilization was calculated based on the cumulative N uptake (three cuts) during 91 d of growth.

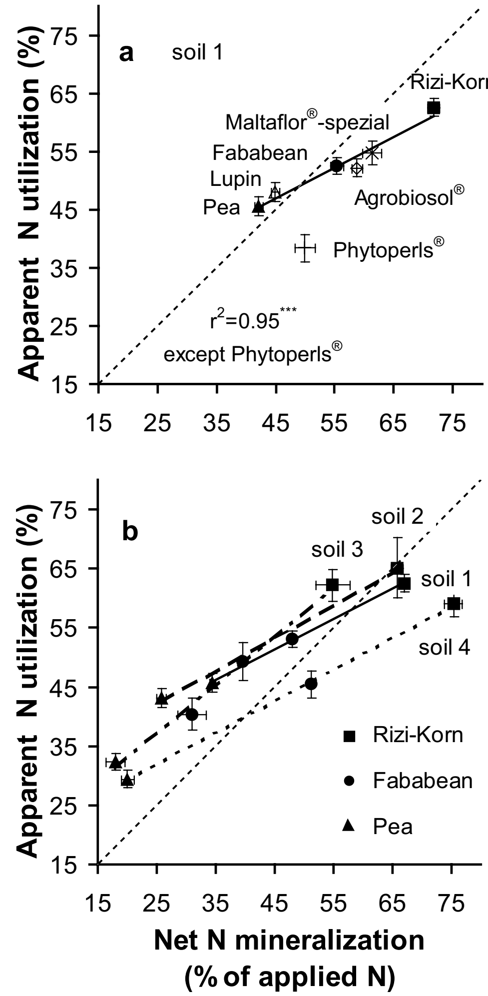

Figure 6: Relationship between apparent N utilization measured at the end of the pot experiment (91 d) and net N mineralization measured at the end of the incubation experiments (a: 43 d, b: 36 d) as obtained for soil 1 (a) and for all four soils (b).

N-immobilization potential of its residue that is the main constituent of Rizi-Korn. By contrast, a fertilizer low in N and high in carbohydrate content like pea may increase N immobilization and resulted even in a net N immobilization depending on the soil used (soil 1 and soil 4 compared to soil 2 and soil 3). A similar effect of these soils on net–N mineralization rates was also observed for fababean. Depending on the soil, net–N mineralization rates of fababean were similar or much lower than those of Rizi-Korn. After this first period, net–N mineralization rates were largely similar for all organic fertilizers, which may indicate that the surplus of carbon was depleted.

At the end of both incubation and pot experiments, net N mineralization and apparent N utilization of the investigated organic fertilizers were significantly related to their N content. A less close relationship was found for the C : N ratio. In both cases, two fertilizers, Agrobiosol® and Phytoperls®, had to be excluded from the relationships. A close relationship between N release of organic material and their N content or C : N ratio was also found for crop residues. In these studies, N mineralization is more closely correlated to the N content than to the C : N ratio (*Iritani* and *Arnold*, 1960, 0.9%–4.0% N: r = 0.93, C : N = 10–48: r = –0.80; *Frankenberger* and *Abdelmagid*, 1985, 1.3%–5.9% N: r = 0.93***, C : N = 7–34: r = 0.88***; *De Neve* et al., 1994, 1.6%–3.3% N: R^2 = 0.86***, C : N = 10–26: R^2 = 0.78***; *Trinsoutrot* et al., 2000, 0.3%–4.5% N, r = 0.88***, C : N = not specified: r = –0.73***). According to *Constantinides* and *Fownes* (1994), the N content of the crop residues was closely related to the net N mineralization for each of the sampling dates from week 2 to week 16 of the incubation period. This is confirmed by our observations. The ranking of the organic fertilizers according to their N release that was related to the fertilizer N content at the end of the experiments was similar at each sampling date in the incubation and pot experiments.

The N release from the two fertilizers Agrobiosol® and Phytoperls® was neither explained by the described relation to the N content nor to the C : N ratio. In relation to these simple parameters, their N release was relatively lower as compared to the N release of the other fertilizers. These two fertilizers were characterized by unusually high N contents that also account for the narrow C : N ratios. This is a result of their composition and manufacturing process. Agrobiosol® is entirely made up of fungal biomass from *Penicillium chrysogenum* (Stattmann, 2006, personal communication), an ascomycete. The cell walls of these fungi contain chitin, a structural polysaccharide, which is characterized by a markedly lower degradability as compared to protein (*Li* and *Brune*, 2005). About 20% of the total N of Agrobiosol® is chitin (Stattmann, 2006, personal communication). Therefore, related to the N content or the C : N ratio, the N release from Agrobiosol® is lower than from most of the tested organic fertilizers. Phytoperls® is the fermentated residue of corn after the withdrawal of the corn germs and the extraction of starch and sugar. The knowledge about the manufacturing process does not explain the low N release from this fertilizer.

Related to the C : N ratio, the N release of Rizi-Korn is relatively high. This also indicates that the extraction of oil from castor bean may result in a shortage of easily degradable carbon and in consequence in a reduction of the immobilization potential of this fertilizer.

Altogether, compared to the C : N ratio, the N content of organic fertilizers is a more suitable indicator for predicting the N release of plant-derived material as well as for some industrially processed fertilizers. The close relationship between N content and N release was confirmed for each of the investigated soils. However, when the relation between the N content of the fertilizers and the apparent N utilization is compared for the different soils, different slopes are observed. This demonstrates that the soil will modify this relationship, which is in line with observations of *Bending* et al. (2002).

If all tested organic fertilizers are compared, the ranking of the fertilizers with respect to their net N release was the same in both experimental setups, incubation and pot experiments. In spite of this, for fertilizers with a low net N mineralization, N uptake by ryegrass was distinctly higher than was expected from the incubation experiment. Obviously, the growing plant promotes N release from these fertilizers. Therefore, the prediction of potentially plant-available N is better described by plant uptake than by chemical extraction of mineral N. However, a ranking of the N release can be measured with both experimental setups which confirms earlier findings of *Iritani* and *Arnold* (1960) and *Kuo* and *Sainju* (1998), who state a generally close relationship between N mineralization and N utilization from crop residues.

For one of the poorer mineralizing fertilizers, Phytoperls®, the apparent N utilization by ryegrass was even lower than the net N mineralization during incubation. This highlights a possibly unusual N-release characteristic of Phytoperls®, which is supported by conflicting reports in the literature. Data from *Schmitz* and *Fischer* (2003) show a relatively poor N mineralization of Phytoperls®, while *Heuberger* et al. (2005) reported a high N uptake of basil from this fertilizer.

5 Conclusion

With some exceptions, the N content of plant-derived and industrially processed organic fertilizers is a good indicator for their N release. It was clearly shown that a partially restricted availability of fertilizer N or C for transformation processes interferes with the close relationship between fertilizer N content and its N release. Obviously, soils will affect N release from the fertilizers without altering the close relationship between N content and N mineralization.

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