Crops use-efficiency of nitrogen from manures allowed for organic farming

M Ângelo Rodrigues, A Pereira, J E Cabanas, L Dias, J Pires and M Arrobas

Mountain Research Centre (CIMO) – E. S. Agrária; 5301-855 Bragança, Portugal

Telef. 00351 273303200; fax 00351273 325405; email angelor@ipb.pt

Abstract

The current increase in the organic agriculture sector has created a new market for fertilisers approved for organic farming. Off-farm N sources for organic farming are scarce considering the restriction on the use of chemical fertilisers. Thus, when some commercial products are allowed for organic agriculture, commercial opportunities became available. In this study we compare the behaviour of Vegethumus (Veg) and Phenix (Phe), which are two manures allowed for organic farming, with several other manures, ammonium nitrate (AN) and control treatments. A three year field trial and a pot experiment were carried out in order to estimate dry matter yield, N uptake, and N nutritional status of the crops, as well as soil N availability by using anion exchange membranes inserted into the soil. Apparent N recoveries in the field trial were 6.3 % and 58.2 % in Veg and AN plots, respectively, after the application of 380 kg N/ha in the previous 5 growing seasons. In the pot experiment the ANR of Veg and Phe were -5.0 % and 13.6 %, respectively, while in AN pots it was 37.1%. The other organic manures used in the pot experiment gave higher apparent N recoveries than Veg and Phe if their C:N ratios or inorganic-N contents were taken into account. This work stresses that the use of manures approved for organic farming must first be carefully considered by farmers, with reference to price and agronomic value.

Keywords: N management; commercial organic amendments; anion exchange membranes

1. Introduction

Over the last few decades, the world has witnessed a rapid development of the organic agriculture segment. Organic farming systems aim to produce safety food with the least harmful environmental impact by imposing severe restrictions on the use of synthetic agrochemicals. From the viewpoint of conventional agriculture, organic farming could mean extensive modifications in crop rotations and cropping systems. Regarding the restrictions on the use of chemical fertilisers, the principle challenge when converting a conventional farm to organic, is to provide N at rates and time to the crops which ensure acceptable yields.

Nitrogen management in agro-systems has been extensively studied due to the particular importance of this nutrient for crop yield and quality, and its potential negative impact in ecosystems. Diverse methodologies based on *in situ* and laboratorial incubations, chemical extractions and electro-ultrafiltrations have been made to improve the accuracy of N recommendation programs (Stanford and Smith, 1972; Németh, 1985; Gianello and Bremner, 1986; Bhogal et al., 1999) The greatest difficulty in N advisory systems is to quantify the rate and time at which the native soil organic matter release its N to the crops. When organic substrates are added to the soil the problem increases. The N mineralization-immobilization turnover depends on the nature of substrate and the ecological conditions of each agro-system. In this respect, some attempts to improve N recommendations have been made, such as the development of decay series for organic substrates (Pratt et al., 1976; Beauchamp, 1987), empirically crediting the N contributions of amendments and green manures to the next crop (Shepherd et al., 1996; Andreski and Bundy, 2002) or using N mineralization indices performed by similar laboratorial incubations and chemical extractions as referred for soils. However, the recommendation of precise N rates regarding crops needs still remains a very difficult task (Walley et al., 2002; Rodrigues, 2004b).

Splitting N fertilisers over the growing season improves the synchronization between soil available N and crop demand (Westermann et al., 1988). Nitrogen applications at sidedress should be based on pre-sidedress soil or plant tests as indicators of soil available N. The pre-sidedress soil nitrate test became well known after the work of Magdoff et al. (1984). Thereafter, many researchers included this soil N availability index in their studies. Crop N nutritional indices determined at pre-sidedress, such as petiole nitrate content, stem nitrate content and leaf greenness were also generalized (Blackmer and Schepers, 1994; Singh et al., 2002; Rodrigues, 2004a). These N indicators are used in N recommendation programs after the definition of threshold levels below which the crop needs to be supplemented with more N. However, the quantification of optimal sidedress N rates based upon crop N nutritional indices or pre-sidedress soil nitrate tests (Baethgen and Alley, 1989; Scharf, 2001; Rodrigues et al., 2005) is the final step in improving N use efficiency.

In organic farming systems there are two main ways to supply the crop N requirements: introducing or reinforcing legumes in crop rotations and/or using organic amendments allowed for organic agriculture. Legumes must be able to fulfil their own N needs, by fixing atmospheric N_2, and must supply enough N for the succeeding crops. However, in many farming systems legumes produce poor commercial returns unless they have a role as green manure. The organic amendments increase soil organic matter and also provide nutrients, including N, but many farms do not have supplies of manure due to the absence of livestock.

Nitrogen management in organic farming systems is complex (Pang and Letey, 2000; Delden, 2001). The use of organic amendments approved for organic farming as N source could not necessarily ensure an adequate synchronization of available N and crop demand. The balance of the mineralization-immobilization process of organic residues is highly unpredictable, even when N indicators of manure composition, such as N content and C/N ratio were used (Geypens and vandendriessche, 1996). Thus, in organic farming we could have under N supplying crops, perhaps the most common situation, but even an over N supply. Since organic-N could not be easily split it is questionable if organic farming can prevent N losses through nitrate leaching, denitrification or ammonia volatilization. The introduction of catch crops could mitigate N losses from soils (Martinez and Guiraud, 1990; Vos and Putten, 2001), but during the year there are always fallow periods or low crop growth phases where N is not taken up by plants (Rodrigues, et al., 2002). On the other hand, the progressive accumulation of soil organic matter could increase the risk of soil N losses (Lewan, 1994; Aronsson and Torstensson, 1998).

The development of the organic agriculture segment has led to the emergence of new markets for commercial amendments approved for organic farming. Taking into account the relatively high prices of some of these products it is essential to look into their fertilising value. In this study, the agronomic behaviour of organic amendments was compared to that of synthetic N fertilisers and control treatments. Field trial results are presented, which include silage-triticale as winter crop and silage-maize as summer crop, where N nutritional indices, N uptake and dry matter yields were recorded. A pot experiment with maize as summer crop and turnip and rye as winter crops was carried out to obtain supplemental information about the effect of each N fertilization strategy, by using anion exchange membranes to recover the soil available nitrates.

2. Material and methods

2.1. Field experiment

The field trial took place on Sta Apolónia experimental farm located in Bragança, NE Portugal (41º48'N, 6º44'W), with silage-maize (*Zea mays* L.) and silage-triticale (*Triticosecale* Wittm.). The region benefits from a mediterranean climate. Mean annual records of precipitation and temperature are 743 mm and 12.2 ºC. The soil is a Eutric Cambisol loamy textured with 66 % of sand, 18 % silt and 16 % clay. In October 2002, soil organic matter was 11.5 mg kg^{-1}, $pH(H_20)$ 6.0 and extractable soil P and K (ammonium lactate and acetic acid) were very high 119 and 186 mg kg^{-1}, respectively. Thus, P and K fertilisers were not applied during the study.

Maize and triticale were inserted into a quadrennial rotation with two crops per year, where maize and potatoes were grown as summer main crops (Jun to Sep) and triticale as winter crop (Oct to May). The data recorded for that study are taken from the italicized part of the entire crop rotation: Potato/Triticale-Maize/*Triticale-Maize/Triticale-Maize/Triticale*. The field trial started in Oct 2002 and finished in May 2005. Triticale was sown on Oct 29 (2002), Oct 22 (03) and Oct 27 (04) and cut on May 27 (03), May 18 (04) and May 18 (05), respectively in the three consecutive seasons. Maize was sown on Jun 12 (03) and Jun 9 (04) and cut on Sep 18 (03) and Sep 23 (04). Maize was sprinkle-irrigated during the growing season. The depth and timing of irrigations were determined in accordance with FAO guidelines (Allen et al., 1988).

Five treatments were arranged in a completely randomized design with four replications. The experimental setup included two rates of N as Vegethumus, a commercial organic amendment allowed for organic farming, similar N rates as ammonium nitrate and the control treatment (without N). In order to evaluate the residual effect of the continuous N applications, in the last growing season of triticale (2004/05) no AN or Veg were applied (table 1). Vegethumus was incorporated in the soil before the seed was sown, whereas most of AN was applied at sidedress. Ammonium nitrate and Veg were applied in variable weights depending on its dry matter % and N content, in order to apply the N rates shown in table 1.

Table 1. Nitrogen applied as ammonium nitrate (AN) and Vegethumus (Veg). 1 and 2 represent simple and double N rates.

	N applied (kg/ha)

Growth season	Control	Veg1	Veg2	AN1	AN2
	-----------------------------------	basal + sidedress		-------------------------------------	
Triticale 02/03	0+0	40+0	80+0	0+40	30+50
Maize 03	0+0	60+0	120+0	0+60	40+80
Triticale 03/04	0+0	30+0	60+0	0+30	0+60
Maize 04	0+0	60+0	120+0	0+60	40+80
Triticale 04/05	0+0	0+0	0+0	0+0	0+0
Total N (kg/ha)	0	190	380	190	380

Dry matter yield, N uptake, leaf greenness (SPAD-502 Chlorophyll meter) and stem nitrate concentration were used to compare the different treatments. Dry matter (DM) yields were recorded from 1 and 2 m^2 field samples for triticale and maize, respectively. Sub-samples with approx. 1000 g were dried to obtain dry matter %. Thereafter, the sub-samples were ground and its N content measured by steam distillation and acid titration in a Kjeltec Autoanalyser 1030. In maize, chlorophyll-SPAD values were obtained from thirty readings made on the newest fully expanded leaf when the leaf collar is exposed. Within the leaf, the readings were taken from a point one-half the distance from the leaf tip to the collar and halfway between the leaf margin and the leaf midrib (Peterson et al., 1993). For triticale, despite the differences in leaf morphology, a similar procedure was followed. Stem nitrate concentrations were obtained from thirty tillers of triticale and six plants of maize randomly chosen from each plot and cut at 5 cm above ground level. The lower 15 cm of the stems were separated from nodes being the fresh tissues macerated and boiled for 15 min with ≈ 100 ml of distilled water. After cooling, final volumes of 200 ml were made up and nitrate concentrations in extracts determined using the RQflex reflectometer (MERCK) (Rodrigues, 2004a).

2.2. Pot experiment

The pot experiment was conducted between May 18, 2004 and April 20, 2005. The soil was loamy textured with 65 % of sand, 19 % silt and 16 % clay. Soil organic matter was 6.9 mg kg^{-1}, pH($H_2$0) 6.0 and extractable soil P and K were 18 and 60 mg kg^{-1}, respectively. The soil was screened (6 mm mesh) and air dried. The pot experiment included eight fertilization treatments. Four commercial organic amendments, Veg, Phenix (Phe) Nutrisoil (Nut) and Beiraadubo (Bei), the two former allowed for organic farming, composted cattle (*Bos taurus*) manure (CM), a farm product, chestnut bark (CB), a by-product of removing the skins of chestnut fruit, AN and the control. Some characteristics of the organic amendments are shown in table 2. Each pot received a mixture of 10 kg of soil and 1.5 g of N, varying the weight of amendments and fertiliser with their dry matter % and N content. Six pots per treatment (6 replications) were used in the experiment.

Table 2. Selected characteristics of the organic amendments used in field and pot experiments.

	Dry matter (%)	TOOC[2] $g\ kg^{-1}$	Nitrogen $g\ kg^{-1}$	C:N	NH_4^+ $g\ kg^{-1}$	NO_3^- $g\ kg^{-1}$
Nutrisoil	85.9	458.1	144.2	3.2	45.20	13.07
Phenix	95.3	484.5	64.3	7.5	4.30	2.60
Vegethumus[1]	77.1	590.7	22.8	25.9	0.19	4.84
Beiraadubo	61.1	542.1	29.5	18.4	1.14	6.01
Cattle manure	24.7	533.7	22.3	23.9	0.11	4.69
Chestnut bark	61.0	571.5	5.9	96.9	0.09	5.33

[1]Mean values of samples from two different Veg lots (2002 and 04).
[2]Total oxidizable organic C (2 hours hot digest with sulphuric acid and K-dichromate).

Three seeds of maize per pot were sown on Jun 5, 2004, followed by the first irrigation with 1800 ml of distilled water per pot. After emergence, the plants were thinned to 1 plant per pot. During the growing season the soil was maintained at a moisture status that allows for adequate crop development. The volumes of water of each irrigation varied among pots, taking into account the different transpiration rates of plants grown under different fertilization treatments. Dishes under the pots prevented water losses and nitrate leaching. A nutrient solution without N was added to all pots shortly after crop emergence.

During the growing period N released from fertilisers and manures was monitored by recovering the NO_3^- adsorbed in 1 x 2 cm strips of an anion exchange membrane (AEM) inserted directly into the soil with the help of a thin spatula. SPAD readings were also recorded on Jul 8 and Aug 2, 2004, 33 and 58 days after the maize had been sown, following a similar methodology as referred to the field trial. The AEM were buried in the soil on Jun 16 and Jul 29 and removed on Jun 23 and Aug 5, respectively. The AEM strips were tied with a fishing line allowing for easy removal from the soil. The AEM strips removed from soil were washed with distilled water to remove soil particles and NO_3^- eluted in flasks containing 20 ml of 0.5 *M* HCl (Qian and Schoenau, 1995). Nitrate concentrations in the extracts were determined by UV/visible spectrophotometry. The strips were regenerated in $NaHCO_3$ before being reused.

We decided to end the maize cycle in the vegetative phase (6 to 8 leaves), on Aug 20, since in some treatments, mainly in CB and control, the plants showed severe N-deficiency symptoms and started to senesce. The decision for an early cut of plants was made in order to avoid N losses by NH_3 volatilisation from canopy (Wetselaar and Farquhar, 1980). After the maize had been harvested the soil was kept moist to stimulate microbial activity. On Sep 9, the AEM were inserted into the soil again and removed on Sep 14.

The trial continued during the winter with turnip (*Brassica campestris*) and rye (*Secale cereale*). The six pots used for maize were randomly divided for turnip and rye, following the experiment with three replications per crop. Sowing of rye and turnip took place on Sep 23. Shortly after the crops' emergence, on Oct 13, a nutrient solution without N was added again. An excess of seed was sown in each pot but after emergence only 20 turnip and 20 rye plants were kept. The growth of the winter crops was very poor due to the soil N exhaustion by maize. The turnip was cut on Mar 10, 2005, when a lot of plants began to show senescent leaves and the rye was cut on Apr 12, 2005. The samples of maize, turnip and rye were dried and ground for determination of dry matter and N content.

Data analysis was carried out using JMP 5.1 software. After ANOVA examination, the means with significant differences ($\alpha < 0.05$) were separated by Tuker-Kramer HSD test. The apparent N recovery (ANR) and N use efficiency (NUE) were estimated according to the following equations:

ANR = (N uptake on fertilized plots - N uptake on control)/N applied as fertiliser * 100;

NUE = (DM yield on fertilized plots - DM yield on control plots)/N applied as fertiliser.

3. Results

3.1. Field experiment

In the first growing season, AN led to significant ($\alpha < 0.05$) increases of triticale dry matter yield and N uptake in comparison with control and Veg (table 3). Vegethumus applied at an amount equivalent to 80 kg N/ha (Veg80) led to significantly lower dry matter yield than control. Mean triticale N uptake in Veg80 was also slightly lower than that in Veg40 and control. On March 17, before the sidedress AN applications, SPAD values were similar among all treatments. After the sidedress N application, AN40 and AN80 showed SPAD values significantly higher than that of Veg and control treatments. Forty nine days after the sidedress, high stem nitrate contents persisted in only AN80 plots. The results of the first growing season of triticale (Oct 2002 to May 2003) showed that Veg did not release N to the crop. On the other hand, the use of higher rates of AN led to higher values of dry matter yield, N uptake and N nutritional indices.

Table 3. Triticale N uptake, dry matter yield and N nutritional indices as a function of the rate and the source of N.

N applied, kg/ha (basal+sidedress[1])	SPAD[1]	SPAD[2]	Stem-NO_3[(3)] ($mg\ kg^{-1}$)	N uptake[4] (kg/ha)	DM yield[4] (Mg/ha)
Control (0+0)	41.8 a†	36.6 b	Not detected	53.0 b	7.2 b
Veg40 (40+0)	41.5 a	36.3 b	Not detected	51.3 b	6.3 bc
Veg80 (80+0)	41.3 a	37.2 b	Not detected	49.4 b	5.8 c
AN40 (0+40)	42.3 a	49.9 a	11.1	74.7 a	10.4 a
AN80 (30+50)	42.5 a	50.3 a	121.2	87.2 a	11.4 a
Anova (P)	0.918	0.000	----	0.000	0.000

†Means with the same letter in columns are not different by Tukey-Kramer HSD test ($\alpha < 0.05$).
[1]March 17, Zadoks 31; [2]April 10, Zadoks 32; [3]May 5, Zadoks 55; and [4]May 27, Zadoks 75.

Table 4 shows maize results, the second crop of the study. We can observe a similar pattern of the previous year among the different treatments. The N applied as inorganic source improved dry matter yield, N uptake and N nutritional indices above the control, whereas Veg did not. Stem nitrate content before sidedress N applications was higher in AN120 plots (with 40 kg of N applied on sowing) than that on the other treatments. After sidedress, SPAD values and stem nitrate content were higher in AN120 and AN60 than that in Veg and control. After 80 (triticale) + 120 (maize) kg N/ha had been applied in the same plot as Veg no positive effect on crop growth resulting from organic manuring was observed.

Table 4. Maize N uptake, dry matter yield and N nutritional indices as a function of the rate and the source of nitrogen.

N applied, kg/ha (basal+sidedress[1])	SPAD[1]	Stem-NO_3[1] ($g\ kg^{-1}$)	SPAD[2]	Stem-NO_3[2] ($g\ kg^{-1}$)	Nuptake[3] (kg/ha)	DM yield[3] (Mg/ha)
Control (0+0)	47.0 a	6.3 c	44.5 b	0.6 b	106.5 b	18.8 bc
Veg60 (60+0)	47.7 a	13.8 b	42.2 b	0.3 b	105.0 b	17.6 c
Veg.120 (120+0)	47.6 a	14.2 b	42.7 b	0.2 b	102.4 b	18.2 bc
AN60 (0+60)	48.2 a	6.3 c	49.0 a	7.3 a	177.8 a	21.4 ab

AN120 (40+80)	49.1 a	26.3 a	50.2 a	5.8 a	186.9 a	22.7 a
Anova (P)	0.167	0.000	0.001	0.001	0.000	0.040

[1]July 17, 6-8 leaf stage; [2]July 29, 8-10 leaf stage; [3]September 18, Full Dent stage.

In the second growing season of triticale (Oct 03 to May 04), Veg maintained mean SPAD values, N uptake and dry matter yields similar or even slightly lower than control (data not shown). Three growing seasons after the trial start, Veg still did not release any N to the crop. When using AN, just 30 kg N/ha were needed to significantly improve N uptake and SPAD values over the control. The higher AN rate (60 kg N/ha) significantly increased N uptake and SPAD values in comparison with all the other treatments.

The performance of Veg seems to be slightly different in the second maize growing season in comparison with the three previous crops. Mean dry matter yield and mean N uptake were significantly higher in Veg than in control plots (table 5). SPAD readings followed the same pattern. Thus, after 4 seasons of continuous Veg applications in the same plots, in a total amount of 380 kg N/ha, some N seemed to be available to the crop. Ammonium nitrate applied in this season (AN120) produced higher means dry matter yield and N uptake than that of Veg. Chlorophyll-SPAD readings taken after the sidedress N application stressed also the difference between AN and Veg. The SPAD readings were taken 12 days after the sidedress application of 80 kg N/ha of AN, which promoted the greenness of the leaves.

Table 5. Maize N uptake, dry matter yield and SPAD values as a function of rate and type of N fertilization source

N applied, kg/ha (basal+sidedress[1])	SPAD[1]	SPAD[2]	N uptake[3] (kg/ha)	DM yield[3] (Mg/ha)
Control (0+0)	34.3 b	31.5 c	76.2 c	10.1 d
Veg60 (60+0)	39.9 a	34.2 bc	105.8 b	14.3 bc
Veg120 (120+0)	42.9 b	35.6 bc	99.3 b	14.9 b
AN60 (0+60)	33.9 b	37.7 b	96.8 b	12.9 c
AN120 (40+80)	39.9 a	43.8 a	138.0 a	18.3 a
Anova (P)	0.003	0.012	0.000	0.000

[1]July 23, 6-8 leaf stage; [2]Aug 4, 8-10 leaf stage; [3]September 18, Full Dent stage.

In the 5th growing season no N was applied in the experiment. Triticale dry matter yield and N uptake were recorded to evaluate the residual effect of previous N applications. None of the treatments produced significantly higher mean dry yields and

N uptake than control. However, the higher mean dry matter yield and N uptake were recorded in Veg380 treatment (6.0 Mg DM/ha and 57.2 kg N/ha) and the lower values in control (4.3 Mg DM/ha and 43.0 kg N/ha).

Total dry matter yields and N uptake during the five growing seasons as well as the apparent N recovery (ANR) and N use efficiency (NUE) were used to compare the final performance of Veg, AN and control treatments in the field trial (table 6). The analysis on these parameters stresses the inefficacy of Veg to supply N to the crops. Vegethumus applied in rates of 380 kg N/ha led to total DM yields of 3.7 Mg/ha above the control and 18.1 Mg/ha below AN applied at similar N rates. In Veg plots, the ANR were only 6.3 and 14.7 % of applied N when 380 and 190 kg N/ha were used, respectively. If AN is the N source, applied at the same rates as Veg, the ANR were 58.2 and 67.1 %, respectively. The NUE varied from 9.7 to 12.6 kg DM/kg N when 380 and 190 kg N/ha were applied as Veg. With AN as fertiliser the NUE varied from 57.4 to 57.9 kg DM/kg N for AN380 and AN190, respectively.

Table 6. Total dry matter yield, total N uptake, ANR and NUE after the five growing seasons of triticale and maize.

Total N applied (kg/ha)	Total DM yield (Mg/ha)	Total N uptake (kg/ha)	ANR (%)	NUE (kg DM/kg N)
Control (0)	46.8	326.6	----	----
Veg ½ rate (190)	49.2	354.6	14.7	12.6
Veg full rate (380)	50.5	350.4	6.3	9.7
AN ½ rate (190)	57.8	454.1	67.1	57.9
AN full rate (380)	68.6	547.7	58.2	57.4

3.2. Pot Experiment

A pot experiment with maize followed by two winter crops, rye and turnip, was conducted in the summer season of 2004 and winter season of 2004/05. The winter crops were grown without N application to allow for the complete exhaustion of the nutrient. Early in the season, 33 days after the maize had been sown, the plants grown in CB pots showed an evident chlorosis, a symptom of a marked N deficiency. Mean SPAD value was 20.0, which is a significantly lower value than that registered in control pots (table 7). Vegethumus presented mean SPAD values slightly lower than control. Ammonium nitrate and the organic amendments with high N contents, such as Nut (14.4 % N) and Phe (6.4 %), gave the higher mean SPAD values. On the second

SPAD readings, 58 days after showing, the behaviour of the different treatments was not much different. However, Bei exchanged its position with Phe. The former seems to release more N later in the growing season. At 58 days after sowing Veg presented slightly higher SPAD values than control but the means are not statistically different.

N uptake was higher in Nut pots (table 7). A slightly lower value was recorded with AN fertiliser. Beiraadubo seems to release more nitrogen as the growing season progresses. The nitrogen uptake by maize was significantly higher on Bei than that in Phe, CM and Veg pots. Mean N uptake in Veg pots was lower than that in control, while N uptake on CM pots was slightly higher than that in control. Chestnut bark yielded very low values when compared with all the other treatments. As expected, there was a clear relationship between N uptake and above ground dry matter yield. The plants in treatments that uptake most N generally produced higher dry matter yields (table 7).

Table 7. SPAD-values, N uptake and dry matter yield of maize in pot experiment.

	SPAD[1]	SPAD[2]	N uptake[3] (mg/pot)	DM Yield[3] (g/pot)
Control	32.5 cd	22.8 c	292.6 d	50.7 cd[3]
Chestnut bark	20.0 e	21.5 c	86.5 e	13.2 e
Vegethumus	29.3 d	25.9 bc	235.7 d	39.5 d
Cattle manure	37.4 abc	30.5 b	359.8 cd	51.9 bcd
Beiraadubo	36.5 bcd	37.3 a	651.9 b	66.9 ab
Phenix	42.6 ab	28.4 b	478.6 c	64.9 abc
Nutrisoil	44.1 a	41.1 a	856.0 a	73.6 a
Ammonium nitrate	44.0 a	37.9 a	812.6 a	79.5 a
Anova (P)	0.000	0.000	0.000	0.000

[1]Jul 8, 2 leaf stage; [2]Aug 2, 6 leaf stage; [3]Aug 20, 8 leaf stage.

Soil N availability measured by nitrate adsorbed in AEM allows the clarification of some aspects of maize N uptake, dry matter yield and SPAD values (table 8). The application of CB reduced the available inorganic-N in soil, by microbial immobilization, restricting maize growth. The AEM results confirmed that Bei released N in lower amounts than CM and Phe in the first weeks after sowing, but as the growing season progressed the net N mineralization rates in Bei pots significantly increased. With AEM results we could confirm that Nut provide more N than AN, justifying the slightly higher values of N taken up by the maize (table 7). After the end of the maize growing cycle, in the fallow period (Aug 20 to Sep 14), soil nitrate availability levels were not much dissimilar than that in the previous AEM extraction. However, CM, Phe and Nut were the materials that showed higher soil nitrate levels on this sampling date.

Table 8. Nitrates recovered by the anion exchange membranes used in pot experiment.

	Nitrate concentrations in extracts (mg/l)		
	Jun 16-23	Jul 29 – Aug 5	Sep 9-14
Control	78.9 cd	17.9 bc	14.5 bc
Chestnut bark	18.3 d	12.9 c	9.7 c
Vegethumus	56.2 cd	17.8 bc	13.6 bc
Cattle manure	116.9 bc	21.7 bc	51.0 a
Beiraadubo	52.0 cd	52.3 a	44.4 ab
Phenix	221.2 a	21.7 bc	32.4 abc
Nutrisoil	225.2 a	35.6 ab	58.6 a
Ammonium nitrate	239.3 a	28.9 bc	37.9 abc
Anova (P)	0.000	0.000	0.000

The amendments used in the maize crop did not provide enough N to allow for a successful growth of winter crops. The N reserves seem to have been used close to exhaustion by maize. However, the pots that presented high residual soil nitrates in September allow for slightly better winter crops growth. Chestnut bark and Veg always gave lower mean N uptake and dry matter yield of cover crops than control (table 9). The final result of Veg, two growing seasons after its application to the soil, seems to be net N immobilization. Nutrisoil showed ANR higher than AN, meaning that almost all its N was available for crops in a period shorter than one year. Beiraadubo showed also a high ANR taking into account its N content. Phenix, despite its high total- and inorganic-N content, showed a poor result when evaluated by the ANR at the end of pot experiment. Regarding the winter crops, rye grew better in N depleted soils than turnip, recovering more N and producing higher DM levels.

Table 9. Dry matter yield and N uptake of turnip and rye and total ANR.

	Turnip DM (g/pot)	Turnip N uptake (mg/pot)	Rye DM (g/pot)	Rye N uptake (mg/pot)	ANR[1] (%)
Control	0.9 b	17.7 b	4.2 bcd	47.9 bc	----
Chestnut bark	0.7 b	12.5 b	2.0 d	23.7 c	-15.4
Vegethumus	0.9 b	14.6 b	2.7 cd	30.8 c	-5.0
Cattle manure	3.5 ab	62.9 ab	7.8 abc	86.1 abc	7.0
Beiraadubo	5.1 a	97.0 a	8.4 ab	96.3 ab	27.2
Phenix	2.3 ab	38.1 ab	6.1 abcd	66.4 abc	13.6
Nutrisoil	4.6 a	84.5 a	10.8 a	125.0 a	42.7

Ammonium nitrate	4.4 a	74.0 ab	7.9 abc	85.0 abc	37.1
Anova (P)	0.000	0.001	0.000	0.001	

[1]Total ANR was determined by adding N uptake of both maize and rye crops (rye was the cover crop that recovered more N).

4. Discussion

Maize and triticale are crops with a high demand for N. The application of N at levels not excessive to crop needs causes significant increase in dry matter yield and N nutritional indices. Thus, from this viewpoint, the field trial showed an expected result when AN and control treatments were compared.

Ammonium nitrate applications in the first 4 seasons did not lead to significant residual effects on triticale dry matter yield and N uptake grown in the 5th season. Similar results were reported by Paul and Beauchamp (1993) using urea as N source. Nitrogen not recovery in the season of application seems to be lost from soil not giving any benefits to the succeeding crop.

Vegethumus is a composted and pelleted commercial organic amendment with a C:N ratio of 25.9 (table 2). In the first three growing seasons, triticale-maize-triticale, 260 (80+120+60) kg N/ha were applied in the Veg treatment of higher N rate. In this period, triticale and maize dry matter yields and N uptake by the crops were lower in Veg than in control. Douglas and Magdoff (1991), working with 19 different organic residues, concluded that organic substrates with C:N ratios between 11 and 25 are usually found to result in net N mineralization. Other studies have shown that apparent N recovery from manures is usually low (Beauchamp, 1986; Paul and Beauchamp, 1993; Fauci and Dick, 1994; Rodrigues et al., 2001). However, Veg showed a long period of apparent net N immobilization which is not usual.

Castellanos and Pratt (1981) consider that composting produces materials of high stability of both C and N, that is independent of total C and N, reducing odours and creating better physical properties. On the other hand, they showed that composting dramatically reduces the value of manures as an N source. Vegethumus performance seems to be in accordance with the results reported by Castellanos and Pratt (1981). In the 4th growing season, after 380 kg N/ha applied, the mean dry matter yield of maize and crop N uptake were higher in Veg, but not significantly different than that in control plots. In Veg plots, significant higher SPAD values were found only on the first SPAD reading date. In the 5th growing season, Veg did not produce any significant residual effect on dry matter yield and N uptake in comparison with the control.

The field methodologies used in this study were not able to explain the fate of N applied as Veg and not recovered by the crop. Organic manuring could promote N losses by denitrification (Smith and Chambers, 1993) and ammonia volatilization (Holding, 1982) compared to plots receiving inorganic-N. Part of the N applied could also remain immobilized in the soil organic matter or fixed in clay minerals. However, it is unquestionable that there was a huge difference in dry matter yield of Veg380 (50.5 Mg DM/ha) and AN380 (68.6 Mg DM/ha) if the 5 growing seasons were taken into account.

In the pot experiment, Veg gave rise to slightly lower maize dry matter yields and N uptake than control. The nitrate adsorbed by AEM and SPAD readings in Veg and control pots were similar during the entire growing season. Results of Veg were not better in the winter season with turnip and rye, and confirmed how poor Veg was as N source even if their C:N ratio and N content were taken into account. The results were lower compared with several conventional manures used in other studies (Pratt et al., 1976; Baldock and Musgrave, 1980; Beauchamp, 1986; Bitzer and Sims, 1988; Paul and Beauchamp, 1993).

Nutrisoil led to maize dry matter yields in pot experiment similar to AN, giving even slightly higher N recovery by the crop. The SPAD values, the nitrate extracted by AEM and the residual N effect on winter cover crops were similar when we compared Nut and AN treatments. If both maize and rye results were added together, Nut led to slightly higher ANR than AN. The effect of Nut seems to persist for a longer period than that of AN, when we take into consideration the time evolution of SPAD readings and nitrate levels in AEM extracts. Nutrisoil results allow us to speculate on some stimulus on soil microbes promoting a priming effect, or added N interaction, (Jenkinson et al., 1985; Schnier, 1994; Blackmer and Green, 1995) which could increase the N release from native soil organic matter.

Phenix produced lower dry matter yield than AN in the pot experiment, although the mean difference did not have statistical significance. The N uptake by maize was significantly lower on Phe than that on AN pots. SPAD values and soil nitrate content were high on the first determination date, but as the growing season progressed, SPAD readings and nitrate recovery in AEM showed a clear decrease. Total (maize + rye) ANR of Phe was only 13.6 %, a very low value if its C:N ratio and total- and inorganic-N content are taken into account. Phenix is a composted and pelleted commercial organic amendment and composting seems to could reduce its value as N source, as was discussed for Veg. The use of AEM showed that a proportion of Phe-N became available early in the season, with the remainder seeming to persist hidden for a long period of time.

Beiraadubo produced maize dry matter yields in pot experiment similar to Phe, but the apparent N recovery was higher. SPAD readings and nitrate concentrations in AEM extracts showed that this amendment releases its N later in the season but at a time appropriate to produce acceptable maize yields and with high N recovery. The net N mineralization persists over the winter period and dry matter yield and N uptake of cover crops were the highest among all the N sources. Beiraadubo is a composted manure but with a high moisture content. Fresh manures seem to release more N than older manures which are highly composted, pelleted and dried.

Cattle manure showed slightly higher values of dry matter yield and N uptake than control. The positive effect of CM increased in the winter crops, seeming to act as a very slow release N source. In comparison with AN, the CM showed a complete incapacity to provide enough N for maize, the first crop after manure application in the pot experiment. Low apparent N recoveries of farmyard manures are the results usually found in previous studies (Rodrigues et al., 2001; Paul and Beauchamp, 1993; Beauchamp, 1986; Baldock and Musgrave, 1980; Fauci and Dick, 1994).

Chestnut bark produces an expected result. The C:N ratio of this product is very high. It should not be used directly in a field crop. During all the pot experiment CB showed a complete incapacity to promote crop growth. Soil available N indicators presented low levels during all the growing seasons. There are no reasons to suspect phytotoxic effects, but only a high demand for soil inorganic N reserves during the mineralization process. Microorganisms are very competitive for inorganic N when an energetic source is available (Allison, 1966; Zaccheo et al., 1993). Thus, net N immobilization would persist over the entire trial period.

The results of field and pot experiments confirmed the difficulty in managing organic N sources as referred in previous studies. Crop N recovery from organic N sources was usually low and the timing and amount of N which is released to the crop is very difficult to predict. In addition, we could not split organic material over the growing season, one of the best strategies to improve N use efficiency when we use inorganic N sources. In this study, it has been shown that organic amendments allowed for organic farming do not have better fertilizing value than other organic materials. We could also conclude that organic farming, with specific regard to N management, is not necessarily more environmentally friendly than conventional farming, as was previously reported by Sileica and Guzys (2003). Commercial organic amendments allowed for organic farming are often expensive and could have misleading marketing strategies that promote fertilising properties that the amendments do not have. In addition, if the crops have high demands for N, dry matter yield could be severely reduced. This fact must be carefully considered by farmers and technical advisers because it could jeopardize both the profitability and sustainability of the farming system.

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