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Research article

Evaluation of nitrogen fertilizing value of composted household solid waste under greenhouse conditions

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Abstract – Accumulation of municipal solid wastes, such as household solid waste, can be rated as a harmful, if not critical, pollution problem. However, if these wastes can be composted and the end product used as soil organic amendment or fertilizer, this may represent one of the alternatives for achieving the goal of ensuring integrated and sustainable waste management. The objective of the present work is to evaluate the nitrogen fertilizing value of household solid waste compost in two soils of Morocco with contrasting properties: a sandy soil and a loamy-clay soil. The compost used in this study was prepared by aerobic biodegradation using the organic fraction after its separation from the non-compostable materials. A study of nitrogen availability of the compost was carried out in a Soil – Compost – Crop system under greenhouse conditions using lettuce as a test crop. Four increasing compost rates of 0, 10, 20 and 30 tons/ha were applied to the soils. The recommended mineral fertilizer rate by the Agricultural Extension Service for lettuce and its half values constituted additional treatments. The results show a high stock of mineral nitrogen in the loamy-clay soil before crop installation. Unlike the loamy-clay soil, the sandy soil generated a better yield increase and a better response to mineral fertilizers. The effect of compost rate on nitrogen mineralization was significant in the two studied soils. The quantities of mineralized nitrogen of the compost varied between 15 and 24% of the compost total nitrogen applied to the sandy and the loamy-clay soils during the lettuce growing season. Therefore the use of household solid waste compost as soil amendment constitutes a beneficial alternative in Mediterranean soils because it permits the generation of a high nitrogen fertilizing value.

compost / lettuce / fresh matter / dry matter / nitrogen uptake / nitrogen supply

1. INTRODUCTION

The current development of composting practice allows an agricultural valorization of household solid waste. The composts have the advantage of keeping a stable composition and of being free from pathogenic germs and seed weeds. Compost valorization in agriculture is considered not only a sustainable and ecological practice because of the insertion of organic carbon in food chains, but it can be an alternative source to the costly imports of industrial organic amendments. Moreover, household solid waste compost valorization requires the evaluation of its fertilizing value and of the soil contamination risks engendered by metals or trace elements, which vary according to the nature of raw organic materials, the composting process and the compost maturity level.

The compost nitrogen contents are generally low (0.5 to 2%) and the release of mineral nitrogen to the crops is performed gradually during the years following its application (Karlen et al., 1995). According to Dick and McCoy (1993), nitrogen availability during the first year subsequent to compost application is approximately 25%. Regarding the annual nitrogen mineralization rate, it was reported that a compost of household refuse releases 5 to 20% of bio-available form from its organic nitrogen contents (Mustin, 1987; Rangarajan, 1998). Experiments conducted under field conditions showed that compost may represent a good source of available nitrogen, particularly if it is applied before seeding (Sanchez et al., 1997). Compared with conventional mineral fertilizers, compost improves nitrogen availability. However, according to a study carried out in 1990 after several years of annual applications of compost and mineral fertilizers on rice, the nitrogen uptake in the amended plots was higher than those receiving mineral nitrogen fertilizer (Suzuki et al., 1990).

The objective of the present study considers an evaluation of the compost nitrogen fertilizing value under greenhouse conditions. The three criteria used in the evaluation of the effects of the adopted treatment on yield and nitrogen utilization are (i) fresh matter; (ii) dry matter production at the end of the growing cycle and (iii) nitrogen uptake.

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Table I. Chemical characteristics of the compost used in the present study.

Organic Carbon (%)	12.62
Organic matter (%)	21.76
Total Nitrogen (%)	1.26
C/N ratio	10.02
Mineral Nitrogen ($NH_4^+ - N + NO_3^- - N$) ($mg \cdot kg^{-1}$)	1000.00
Electrical Conductivity 1/10 (mS/cm)	4.43
pH_{water}	8.75
Total Phosphorus (%)	3.04
Total Potassium (%)	3.88

2. MATERIALS AND METHODS

Two contrasting and representative soils were studied: a sandy soil and a loamy-clay soil. The texture has significant effects on the organic matter dynamics because of the interactions between clay and the organic components. The sandy soil is a red fersiallitic soil representative of the coastal area. It is characterized by a low organic matter content (0.85% of organic matter), a high proportion of sand, a low water holding capacity (9%) and low CEC (Cation Exchange Capacity) value. It contains 14 mg/kg of available phosphorus and 75 mg/kg of available potassium. The loamy-clay soil is representative of the Gharb irrigated alluvial plain. It contains 13% of calcium carbonates, 1.93% of organic matter, 33 mg/kg of available phosphorus and 149 mg/kg of available potassium, has a fine texture and a high water holding capacity of 25%.

In this study, the Batavia lettuce cultivar was selected for its short vegetative cycle and for its sensitivity to phyto-toxicity. The adopted experimental design was a randomized block with two main factors: the soil type and the compost application rate. The household solid waste compost came from the Sorting and Composting Unit situated in Salé Bab Lamrissa. The household solid wastes were collected from the city of Salé and submitted to a sorting operation of the organic fraction, representing between 50 and 70% of fresh weight. The sorting operation also allowed limiting the risks of contamination by trace elements. The composting system was based on windrows periodically turned (Mustin, 1987; Soudi, 2001) to achieve an optimal aeration and to expose the various parts of the pile at high temperatures (60–65 °C) during the thermophilic stage to ensure removal of the pathogenic germs and denaturation of weed seeds. An adjustment of moisture content was carried out to maintain it between 50 and 55%.

The mature compost used was 10 months old. Its chemical characteristics are reported in Table I.

The applied rates of compost were equivalent to 10, 20 and 30 tons fresh weight per hectare. These rates are ranged between those used in practice, which vary between 10 and 40 tons fresh weight per hectare. An additional treatment was adopted and consisted of applying a mineral fertilizer rate as recommended by the Agricultural Extension Service for lettuce fertilization. This mineral fertilizer was made up of 100 kg of N/ha in the forms $(NH_4)_2SO_4$, 250 kg of K_2O/ha and 50 kg of P_2O_5/ha. In total, 12 treatments were adopted for each soil: 3 treatments with increasing rates of compost only, referred to as C10 (10 tons fresh weight per hectare of compost), C20 (20 tons fresh weight per hectare of compost), and C30 (30 tons fresh weight per hectare of compost); 3 treatments with increasing rates of compost, supplemented with half of the indicated rates of mineral fertilizers, referred to as C10 + ½ MinF (10 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C20 + ½ MinF (20 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers), and C30 + ½ MinF (30 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); 3 treatments containing increasing rates of compost with 100% of the recommended rates of N, P_2O_5 and K_2O, referred to as C10 + MinF (10 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C20 + MinF (20 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers), and C30 + MinF (30 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers) and 3 treatments as controls: absolute control with soil without any amendment (0), control with half of the recommended mineral fertilizers (½ MinF) and control with 100% of the recommended rates of mineral fertilizers (MinF). All treatments were replicated 3 times.

The soil samples were dried and sieved (2 mm). Sub-samples of 5 kg each were put in a plastic cylindrical recipient with 20 cm diameter and 21 cm height. All the compost rates were closely mixed in soil samples to get a uniform and homogenous distribution. The mineral fertilizers were pulverized in soluble form on the soil samples.

For germination purposes, the lettuce seeds were put under a temperature of 20 °C in a potting mixture divided into boxes as if check – rowed. One grain was put in each box. Transplanting into the plastic cylindrical recipient containing soil was implemented 31 days after seeding. This stage corresponded to three or four leaves. The soil moisture content was continuously adjusted and maintained during the growing season at 80% of Water Field Capacity.

Crop harvest was realized 85 days after seeding for all the treatments. Fresh and dry matter were determined and nitrogen uptake was analyzed. The data were statistically evaluated by STATITCF software. In cases where the average values were significantly different, the NEWMAN and KEULS test was used. A probability level of 5% was adopted to reject or accept the averages equivalent hypothesis.

Soil organic matter content was determined by the Walkley and Black method based on dichromate oxidation (Allison, 1965; Nelson and Sommers, 1982). Mineral nitrogen extracted with 0.01 M $CaCl_2$ was determined by steam distillation in the presence of MgO to displace NH_4^+ ions, and in the presence of Deverda's alloy to reduce NO_3^- ions (Bremner, 1965; Keeney and Nelson, 1982). Available phosphorus (extracted with 0.5 M $NaHCO_3$, pH 8.5) was determined according to Olsen's method (Olsen et al., 1954) and available potassium (extracted with 0.1 M NH_4Ac) by flame photometry. Total nitrogen was determined, in the soil, plant and compost, by wet digestion (Kjeldahl method). Total phosphorus and total potassium, in the plant and compost, were determined in the extract obtained from the sulfuric/ hydrogen peroxide digestion of the products.

Table II. Lettuce fresh and dry matter yields, and terms of the nitrogen balance.

Soils	Treatments	Fresh matter yields g/pot	Dry matter yields g/pot	Nitrogen uptake mg·kg^{-1} of soil	Initial soil mineral nitrogen mg·kg^{-1} of soil	Mineral nitrogen applied mg·kg^{-1} of soil	Residual mineral nitrogen mg·kg^{-1} of soil	Nitrogen released from the soil mg·kg^{-1} of soil
	0	33.30 f	4.23 f	9.56 h	2.82	0.00	5.72 g	12.46 e
	½ MinF	96.70 d	8.88 d	32.50 g	2.82	20.83	22.75 a	31.60 abcd
	MinF	138.66 ab	11.56 b	51.10 e	2.82	41.67	26.48 b	33.09 abcd
	C10	70.13 e	7.47 e	25.40 g	2.82	4.17	5.67 g	24.08 d
	C20	76.50 e	7.71 e	30.84 g	2.82	8.33	6.44 g	26.13 cd
Sandy	C30	95.50 d	9.83 cd	43.26 f	2.82	12.50	2.10 h	30.04 bcd
soil	C10 + ½ MinF	101.57 d	9.28 cd	47.14 ef	2.82	25.00	12.72 d	32.04 abcd
	C20 + ½ MinF	108.83 cd	9.51 c	51.36 e	2.82	29.16	15.45 c	34.83 abc
	C30 + ½ MinF	123.67 bc	10.43 b	60.92 d	2.82	33.33	12.97 d	37.74 ab
	C10 + MinF	141.90 ab	12.50 ab	69.00 c	2.82	45.84	13.23 d	33.57 abcd
	C20 + MinF	151.47 a	12.85 ab	77.10 b	2.82	50.00	11.55 e	35.83 abc
	C30 + MinF	156.03 a	13.60 a	90.58 a	2.82	54.17	7.77 f	41.36 a
	0	126.37 ab	8.52 d	38.68 f	39.2	0.00	27.28 j	26.76 d
	½ MinF	140.37 ab	10.22 bcd	50.08 ef	39.2	19.23	41.88 g	33.53 cd
	MinF	146.07 ab	11.99 ab	63.54 cd	39.2	38.46	49.12 d	35.00 bcd
	C10	105.23 c	9.78 cd	46.94 ef	39.2	3.85	38.66 i	42.55 abc
	C20	122.00 bc	9.95 bcd	54.12 de	39.2	7.69	39.88 h	47.11 ab
Loamy-clay	C30	127.77 abc	10.17 bcd	58.18 de	39.2	11.54	43.47 f	50.91 a
soil	C10 + ½ MinF	119.20 bc	10.43 bc	57.16 de	39.2	23.08	50.63 c	45.51 ab
	C20 + ½ MinF	131.45 abc	11.45 abc	74.66 bc	39.2	26.92	42.14 g	50.68 a
	C30 + ½ MinF	145.57 ab	11.72 ab	80.16 ab	39.2	30.77	43.21 f	53.40 a
	C10 + MinF	143.97 ab	10.79 abc	65.60 cd	39.2	42.31	63.93 a	48.02 ab
	C20 + MinF	154.20 a	11.10 abc	78.36 b	39.2	46.15	59.97 b	52.98 a
	C30 + MinF	156.43 a	12.52 a	98.16 a	39.2	50.00	47.57 e	56.53 a

a, b, c, d, e… the values followed by the same letter in the same column are not significantly different at the 0.05 probability level;
0 (absolute control with soil without any amendment); ½ MinF (50% of recommended mineral fertilizers); MinF (100% of recommended mineral fertilizers);
C10 (10 tons fresh weight per hectare of compost); C20 (20 tons fresh weight per hectare of compost); C30 (30 tons fresh weight per hectare of compost);
C10 + ½ MinF (10 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C20 + ½ MinF (20 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C30 + ½ MinF (30 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers);
C10 + MinF (10 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C20 + MinF (20 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C30 + MinF (30 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers).

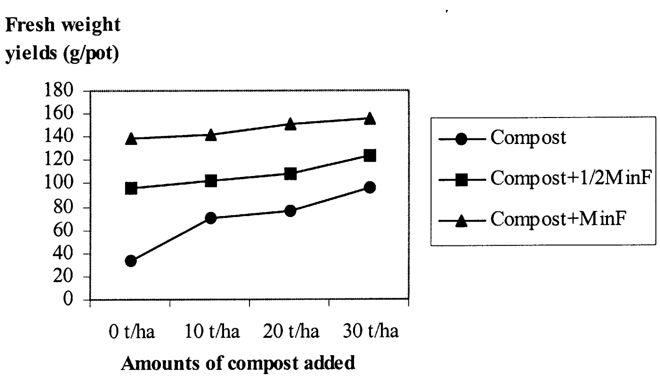

Figure 1. Effects of the various treatments on lettuce fresh weight yields in the sandy soil. ½ MinF (50% of recommended mineral fertilizers); MinF (100% of recommended mineral fertilizers).

3. RESULTS AND DISCUSSION

3.1. Fresh matter production

Statistical analysis showed that the soil type and compost and/or fertilizer applications had a significant effect on the fresh matter production. The fresh matter production varied in the two studied soils and the tested treatments (Tab. II). The effect of soil amendment was significantly different in the studied soils. In the sandy soil, the fresh matter was significantly different from the absolute control (0) for all treatments. The fresh matter decreased following the treatment sequence: C30 + MinF, C20 + MinF, C10 + MinF, MinF, C30 + ½ MinF, C20 + ½ MinF, C10 + ½ MinF, ½ MinF, C30, C20, C10, 0. The highest yield corresponds to the C30 + MinF treatment and the lowest was observed for the C10 treatment after the absolute control. The effect of compost application rate on fresh matter yield was clearly expressed (Fig. 1). However, the yield increase is less than 6.4 g/pot in terms of absolute value and

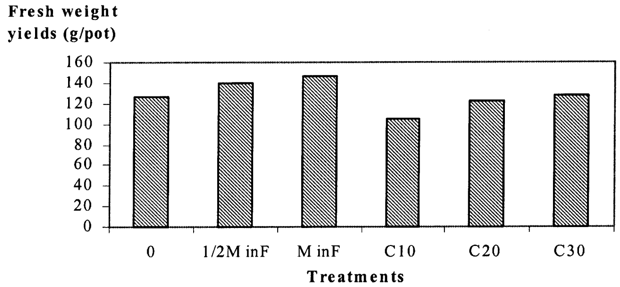

Figure 2. Compost in various amounts and mineral fertilizer dressings: effects on lettuce fresh weight yields in the loamy-clay soil. 0 (absolute control with soil without any amendment); ½ MinF (50% of recommended mineral fertilizers); MinF (100% of recommended mineral fertilizers); C10 (10 tons fresh weight per hectare of compost); C20 (20 tons fresh weight per hectare of compost); C30 (30 tons fresh weight per hectare of compost).

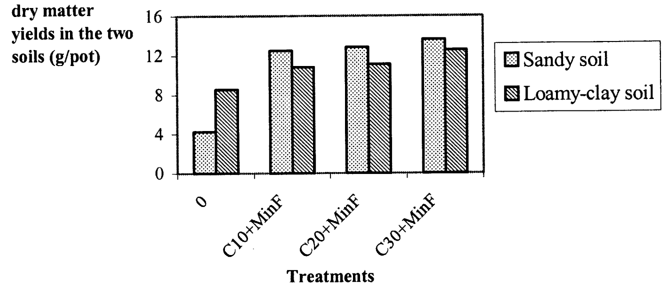

Figure 3. Compost in various amounts plus recommended mineral fertilizer dressing: effects on the lettuce dry weight yields in the two soils. 0 (absolute control with soil without any amendment); C10 + MinF (10 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C20 + MinF (20 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C30 + MinF (30 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers).

9 g/pot in terms of relative value for the increasing compost rate from 10 to 20 tons/ha. When the compost application increased from 20 to 30 tons/ha, fresh matter yield reached 19 g/pot which corresponded to the percentage increase of 25%. The first rate application of 10 tons/ha generated an increase of 111%.

Also, the fresh matter yield increases with the mineral fertilizer rate. This treatment generated the highest yield, which was equivalent to that observed in the case of the compost rate of 30 tons/ha. Compared with the compost application alone, the yield increased when half of the recommended rate of mineral fertilizer was added. Only the compost rate of 30 tons/ha was equivalent to the ½ MinF treatment.

The mineral fertilizer supplement generated proportionally increasing yields with the compost rate. In so doing, the (Compost + MinF) treatment generated the highest yield, which amounted to twice the yield obtained in the control. The intermediate yield value was obtained in the ½ MinF treatment. The treatment sequence of the increasing yield was as follows: Compost alone ≤ ½ MinF < Compost + ½ MinF ≤ MinF < Compost + MinF.

Under the study conditions, the results indicated that the best yield was obtained when the compost was combined with the mineral fertilizers. From the cost effectiveness viewpoint, one can conclude that the Compost + ½ MinF was the most appropriate treatment for the sandy soil. This treatment permitted the maximization of crop production and minimization of groundwater pollution risks.

Fresh matter yield in the loamy-clay soil was not significantly different in the treatments compared with the absolute control (Fig. 2). The highest yields were obtained in the cases of the MinF, C30 + MinF and C30 treatments. All the rates using the MinF treatment caused depressive effects on the crop. Similar yields were noted in the two studied soils for the following treatments: C10 + MinF, C20 + MinF and C30 + MinF. Yields for the other treatments were greater in the loamy-clay soil than in the sandy soil.

3.2. Dry matter production

Statistical analysis showed that the soil type and the treatment had a significant effect on dry matter production (Tab. II). In the case of the sandy soil, the effect of all the tested treatments on dry matter production was significantly different from the control. Data analysis showed the decrease in dry matter production according to the following sequence: C30 + MinF, C20 + MinF, C10 + MinF, MinF, C30 + ½ MinF, C30, C20 + ½ MinF, ½ MinF, C20 + ½ MinF, C20, C10, 0.

For treatments corresponding to the compost application, the effect of the compost rate was significant. The optimal yield (9.83 g/pot) was obtained for the 30 tons/ha rate. At the compost rate of 30 tons/ha, the yield increase was 5.6 g/pot, which corresponded to 132% of the yield obtained at the equivalent rate of 0 tons/ha. This increase exceeded 0.24 g/pot (6%) when the compost rate went up from 10 tons/ha to 20 tons /ha.

For the loamy-clay soil, data analysis showed that the difference in dry matter production was not significant between the tested treatments. This result could be attributed to the high concentrations of nitrogen, phosphorus and potassium initially available in the soil. Similar observations showed that there was no yield increase if the soil was initially rich in mineral nitrogen (Paul and Beauchamp, 1993). The comparison between the two studied soils (Fig. 3) showed that the dry matter production obtained in sandy soil was greater for the treatments supplemented with MinF. However, dry matter production was greater than the control in the loamy-clay soil. Similar yields were obtained in the two studied soils for the treatments with half of the recommended rate of mineral fertilizers**,** the treatments with 100% of recommended mineral fertilizers, treatments with compost and treatments with compost supplemented with half of the recommended rate of mineral fertilizers.

The relative dry matter yield increase for the two soils and for all the tested treatments was calculated on the basis of the yield obtained in the absolute control.

$$\Delta R = ((Y_a - Y_c) / Y_c) \times 100$$

where ΔR: Relative yield increase (%); Y_a: Yield obtained in amended soil with compost and/or mineral fertilizers); Y_c: Yield obtained in the absolute control.

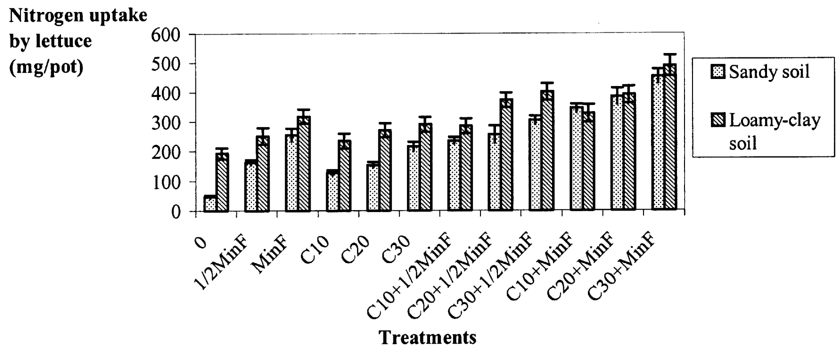

Figure 4. Total nitrogen uptake by lettuce in relation to the various treatments. 0 (absolute control with soil without any amendment); ½ MinF (50% of recommended mineral fertilizers); MinF (100% of recommended mineral fertilizers); C10 (10 tons fresh weight per hectare of compost); C20 (20 tons fresh weight per hectare of compost); C30 (30 tons fresh weight per hectare of compost); C10 + ½ MinF (10 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C20 + ½ MinF (20 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C30 + ½ MinF (30 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C10 + MinF (10 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C20 + MinF (20 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C30 + MinF (30 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizer).

Table III. Relative increase in lettuce dry matter yield (%) as compared with the absolute control.

Treatment	½ MinF	MinF	C10	C20	C30	C10 + ½ MinF	C20 + ½ MinF	C30 + ½ MinF	C10 + MinF	C20 + MinF	C30 + MinF
Sandy soil	110	173	77	82	132	119	125	147	196	204	222
Loam-clay soil	20	41	15	17	19	22	34	38	27	30	47

½ MinF (50% of recommended mineral fertilizers); MinF (100% of recommended mineral fertilizers);
C10 (10 tons fresh weight per hectare of compost); C20 (20 tons fresh weight per hectare of compost); C30 (30 tons fresh weight per hectare of compost);
C10 + ½ MinF (10 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C20 + ½ MinF (20 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C30 + ½ MinF (30 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers);
C10 + MinF (10 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C20 + MinF (20 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C30 + MinF (30 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizer).

The ΔR values, reported in Table III, varied with the soil type and the amendment rate. It was low for the loamy-clay soil land and did not exceed 47% for the treatment C30 + MinF. The maximal value of ΔR (222%) was obtained in the sandy soil.

Globally, organic amendment generated more crop response in the sandy than in the loamy-clay soil. For the compost, the ΔR was 77% at the compost rate of 10 tons/ha and increased to 132% at the rate of 30 tons/ha for sandy soil. The ΔR values were 15% and 19% for the 10 and 30 tons/ha rates in the loamy-clay soil, respectively. This was attributed to the high initial value of mineral nitrogen in the loamy-clay soil and the low mineral nitrogen supply in the sandy soil.

3.3. Nitrogen uptake

Statistical analysis showed a significant effect of the tested treatments and their interaction on nitrogen quantity mobilized by the lettuce crop. In the case of the absolute control (without amendment), the nitrogen uptake was 23 kg and 71 kg de N/ha for the sandy and loamy-clay soils, respectively. This observation confirmed the results related to dry matter production attributed to the high initial concentration of mineral nitrogen in the loamy-clay soil and to low nitrogen mineralization in the sandy soil.

For all the treatments in the two studied soils, the nitrogen uptake was greater than in the absolute control (Tab. II, Fig. 4). The nitrogen uptake originated from three sources: added mineral nitrogen fertilizer, the mineralization of the native organic mineralizable nitrogen in the soil fraction and the mineralization of a proportion of the organic nitrogen of the applied compost. The maximal value of nitrogen uptake was obtained in the C30 + MinF treatment. Other observations confirmed that the increase in nitrogen uptake in this case was not only attributed to the mineral nitrogen applied as fertilizer but to the positive priming effect of mineral nitrogen on soil and compost organic nitrogen mineralization (Chalk et al., 1990; Azam et al., 1992).

3.4. Nitrogen mineralization evaluation

The global mass balance of nitrogen in the soil – plant system was established to assess the nitrogen mineralization rate. The nitrogen mass balance included all the transfers and transformations

Table IV. Effect of various treatments on the mineral nitrogen released by the two soils in mg/kg.

Treatments	Sandy soil	Loamy-clay soil
0	12.46 e	26.76 d
½ MinF	31.60 abcd	33.53 cd
MinF	33.09 abcd	35.0 bcd
C10	24.08 d	42.55 abc
C20	26.13 cd	47.11 ab
C30	30.04 bcd	50.91 a
C10 + ½ MinF	32.04 abcd	45.51 ab
C20 + ½ MinF	34.83 abc	50.68 a
C30 + ½ MinF	37.74 ab	53.40 a
C10 + MinF	33.57 abcd	48.02 ab
C20 + MinF	35.83 abc	52.98 a
C30 + MinF	41.36 a	56.53 a

a, b, c, d, e… the values followed by the same letter in the same column are not significantly different at the 0.05 probability level.
0 (absolute control with soil without any amendment); ½ MinF (50% of recommended mineral fertilizers); MinF (100% of recommended mineral fertilizers);
C10 (10 tons fresh weight per hectare of compost); C20 (20 tons fresh weight per hectare of compost); C30 (30 tons fresh weight per hectare of compost);
C10 + ½ MinF (10 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C20 + ½ MinF (20 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers); C30 + ½ MinF (30 tons fresh weight per hectare of compost + 50% of recommended mineral fertilizers);
C10 + MinF (10 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C20 + MinF (20 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizers); C30 + MinF (30 tons fresh weight per hectare of compost + 100% of recommended mineral fertilizer).

of nitrogen and input and output of nitrogen in the soil – plant system. Some assumptions were made before implementing calculations: (i) nitrate leaching was neglected because the moisture content was maintained during the growing season at its optimal level corresponding to 80% of water holding capacity; (ii) the volatilization process was neglected for the sandy soil and estimated to be 10% of MinF in the clay soil because of its high pH.

The mass balance equation was:

$$N_0 + N_a + N_{ss} = N_u + N_r \qquad (1)$$

where N_0: Initial mineral nitrogen (mg/kg);

N_a: Applied nitrogen in mineral fertilizer form (mg/kg);

N_u: Nitrogen uptake (mg/kg);

N_r: Residual mineral nitrogen after harvest (mg/kg);

N_{ss}: Mineral nitrogen supplied by soil by mineralization process (mg/kg).

The individual contribution of each term in the balance depends on its role and its relative importance.

The results related to the absolute controls (Tab. IV) showed that the nitrogen mineralization capacity of the two soils during the growth period of the lettuces was different. The highest level was observed in the loamy-clay soil. The initial concentration of mineral nitrogen found in the two soils might explain this difference in capacity, since the existing mineral nitrogen stock, before plantation, might increase rapidly during the plant growth period. Indeed, in the loamy-clay soil the initial mineral nitrogen content was 39.2 mg/kg (102 kg/ha), while in the sandy soil there was only 2.82 mg/kg (7 kg/ha).

Regarding the mineral fertilizers supplied to the soils, a negative priming effect was observed for the clay soil exhibiting a strong nitrogen mineralization capacity, while the opposite was noticed for the sandy soil characterized by low nitrogen mineralization capacity. Other research studies reported that mineral fertilizer application might lead to a negative effect on soils' ability to mineralize their organic nitrogen (Broadbent and Nakashima, 1965; Soudi, 1988). The isotopic technique using N^{15} is recommended to quantify the relative contribution of the applied mineral fertilizers and the mineral nitrogen released by the mineralization of native soil organic nitrogen to the total nitrogen mobilized by the crop.

The mineral nitrogen released through compost nitrogen mineralization is calculated using the following relation:

Mineralized nitrogen = Mineral nitrogen released in amended soil – Mineral nitrogen released in absolute control by the mineralization process. (2)

Mineralized nitrogen depended on the soil's nature and its biological activity, and on the quantity and quality (maturity) of compost supplied. The highest level of mineralization was reached in the clay soil for all the treatments. The maximal value was obtained for 30 tons/ha of compost.

The evaluation of the annual rate of compost decomposition consisted of estimating the first value of a decay series. This value was calculated by establishing a ratio between mineralized nitrogen, obtained from equation (2) and total organic nitrogen supplied by the compost. The resulting mineralization rate values are presented in Table V. However, these values should be taken as indicative only.

4. CONCLUSION

The results show that compost application increased fresh and dry matter production, and nitrogen uptake by lettuce in the studied soils. Compost application had a significant effect on plant dry matter production and on its nitrogen uptake. Compared with sandy soil, a moderate effect was noticed for the loamy-clay

Table V. Net mineralized nitrogen production and the compost organic nitrogen mineralization rate calculated for the two soils.

		Mineralized nitrogen $mg \cdot kg^{-1}$ of soil	Organic nitrogen applied $mg \cdot kg^{-1}$ of soil	Mineralization rate
	C10	11.62	52.5	22
Sandy soil	C20	13.62	105.01	13
	C30	17.58	157.51	11
	C10	15.79	48.46	33
Loamy-clay	C20	20.35	96.92	21
soil	C30	24.15	145.38	17

C10 (10 tons fresh weight per hectare of compost);
C20 (20 tons fresh weight per hectare of compost);
C30 (30 tons fresh weight per hectare of compost).

soil, characterized by a higher mineralization capacity and a more significant initial mineral nitrogen content.

The quantities of mineralized nitrogen from the compost were different in the two soils, and turned out to be more significant with the increase in the compost rate. The mineralized nitrogen quantities available for the lettuce crop represented from 11 to 22% and 17 to 33% of the organic nitrogen supplied by the compost, for the sandy and the loamy-clay soils, respectively. Mineralized nitrogen decreased with the increase in applied compost rates. These may be equated with the first value of a decay series or, in the case of the lettuce growth cycle, with the compost annual mineralization rate.

These results show that the nitrogen contained in the compost, which is 92% organic, is weakly mineralized. Therefore, it can still be rated as an interesting organic amendment since it has a strong humification potential, but it does not present the disadvantage of releasing too much nitrogen. The results obtained from compost and mineral fertilizer combination suggest the prospect of reducing chemical fertilizers, when compost is able to provide part of the mineral nitrogen needed by the lettuce crop. The same observation has been made by other researchers (Mesquitas Dos Santos et al., 1996; Sikora and Enkiri, 1999; Soudi, 2001).

A final point of crucial importance pertains to weeds and pathogenic germs. Their presence was not noticed during the whole course of the experimental study. Therefore, it might be worthwhile concluding that the compost used can be rated as free of weeds and pathogens.

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