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Corn management: can compost help to substitute mineral fertilizers?

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Riassunto
La capacità del compost di sostenere la produzione di mais e di incrementare la sostanza organica del suolo è stata valutata in una sperimentazione di campo presso due siti con diverse condizioni pedoclimatiche (Torino e Napoli). Due livelli di fertilizzazione del mais con compost sono stati confrontati con altri trattamenti finalizzati all'incremento della s.o. del suolo: sovescio di veccia e minima lavorazione. Fertilizzazione con urea o assenza di fertilizzazione sono stati introdotti come controllo. I trattamenti fertilizzati hanno ricevuto 130 kg ha^{-1}di N (260 per il livello alto di compost). La lenta mineralizzazione del compost ha favorito l'incremento del C e N del suolo, mantenendo bassi livelli di N minerale, ma ne ha ridotto la disponibilità per la coltura soprattutto a Napoli, dove la mineralizzazione era lenta. Il compost si è dimostrato capace di incrementare la fertilità a lungo termine del suolo, ma una ridotta efficienza di uso dell'N deve essere tenuta in considerazione dagli agricoltori e deve essere valutata nel lungo periodo.

Summary
The potential of compost to sustain corn production and to increase soil organic matter were evaluated in a field trial in two contrasting Italian environments (Torino and Napoli). Compost fertilization of corn at two levels was compared with other treatments aimed at increasing the soil organic matter: vetch green manuring and minimum tillage. A treatment fertilized with urea and one without N additions were used as controls. All fertilized treatments received a total nitrogen amount of 130 kg ha^{-1} (260 in the high-level compost treatment). Slow mineralization of compost increased soil organic C and N, maintained low soil mineral N contents, but reduced mineral N availability to corn especially in Napoli, were soil organic N mineralization was slow. Compost showed the ability to increase long term soil fertility with positive environmental effect, but the low fertilizer N use efficiency found in the first years of application needs to be considered by farmers and evaluated in the long term.

1. Introduction

An increase in the soil organic carbon (SOC) content has well acknowledged positive effects on the soil chemical, biological and physical fertility. Recent global warming concerns have recommended maintaining and restoring soil carbon as a measure to mitigate rising atmospheric carbon dioxide (CO_2) concentration. Organic fertilization is one of the most diffused practices that increase the SOC content while potentially reducing non CO_2-GHG emissions [1,2]. In fact, energy needs per unit of nutrient available for crop uptake and N_2O emissions after soil incorporation can be lowered by organic fertilizers application. Composting park

and urban wastes has become in Italy an important mean to recover organic matter and an essential disposal method [3,4]. The use of compost as a field crop fertilizer could be a viable way to improve soil fertility, SOC sequestration and GHG emissions, and to recycle nutrients available for plant growth. However, its adoption is subject to the achievement of yield levels comparable to the commonly used mineral fertilizers. Soil and climatic conditions are known to influence organic matter mineralization rates. Thus, effects of compost utilization could vary among different pedoclimatic and agronomical conditions.
The objective of this paper was to assess the potential of compost fertilizer addition to influence corn yields and soil carbon sequestration in comparison with urea. Green manuring and minimum tillage were evaluated as well. Soil and climate influences were explored comparing two different Italian pedoclimatic conditions. Preliminary results are here discussed.

2. Materials and Methods

A field trial was established in 2006 in two contrasting environments in Italy: Torino (TO) and Napoli (NA), in the framework of the F.I.S.R. MESCOSAGR project. The site of Torino was located in the north-western Po Plain, while the site of Napoli was in the Sele Plain. The TO site was characterized by a temperate sub-continental climate (mean temperature: 11.9 °C; mean annual rainfall: 734 mm), while at NA site the climate was Mediterranean (mean temperature: 15.5 °C; mean annual rainfall: 908 mm). The soil at TO was sandy-loam, whit a bulk density of 1.4 g cm^{-3}, a soil organic carbon content of 11.4 g kg^{-1}, and a C:N ratio of 12.1. The soil at NA was clay loam, whit a bulk density of 1.3 g cm^{-3}, a soil organic carbon content of 10.6 g kg^{-1}, and a C:N ratio of 9.7.
Treatments included in the experiment were: UR (reference treatment, with plowing at 30 cm and mineral fertilization with urea); MT (minimum tillage –rotary harrow- with fertilization as in UR); LGM (fertilization by soil incorporation of winter leguminous green manure cover-crop (*Vicia villosa* L.) coupled with plowing at 30 cm); COM1 and COM2 (urban waste compost supplied at two different levels and soil incorporation by plowing at 30 cm); 0N (non N fertilized check treatment ploughed at 30 cm).
All fertilized treatments received 130 kg N ha^{-1}, except COM2 that received 260 kg N ha^{-1}. LGM plots were supplied with 130 kg of urea-N ha^{-1} in 2006 only, at both sites, owing to the poor growth of the vetch, while in 2007 and 2008 the atmospheric fixed N supply was 151 and 173 kg ha^{-1}, considering N-fixation as 58% of the uptake [5]. Phosphorus and K were supplied via mineral fertilizer (100 kg ha^{-1} of P_2O_5 and 200 kg ha^{-1} of K_2O) to all treatments. Corn was chosen as the most widespread crop in non-zootechnical farms (where the use of compost could be potentially more interesting). Corn was planted on the same day the plots were fertilized and ploughed. At harvest plants were completely removed from the field in order to prevent any possible effect of residue and to stress treatment influence. Total biomass yields are here presented. Plots were 48 m^2 at the TO site and 30 m^2 at the NA site, with a completely randomized design with 4 replicates.
The main properties of compost are shown in Table 1.
The main measurements carried out were:
- crop harvest and C and N analysis of tissues;
- soil mineral nitrogen content (SMN) during crop cycle: at 4 different dates (before-fertilization, ten leaves, flowering, and harvest) soil samples were taken from each plot from 3 different layers (0-15, 15-30, 30-60 cm);
- soil organic C and N (SON): soil from the 0-30 cm layer was sampled each year before planting and after corn harvest;
- phytotoxicity test: toxicity of added compost was tested on both soils [6].

	Compost		
	2006	2007	2008
Dry matter, %	43.1	61.0	61.6
Organic C, % dm	30.2	25.6	22.7
Total N, % dm	1.3	2.1	2.3
C:N	23.2	12.2	9.8

Table 1 – *Main properties of compost and green manure.*

Potential soil organic N mineralization (PONmin) was estimated as N uptake + SMN at harvest – SMN at sowing [7]. Gaseous losses and leaching were assumed null. Fertilizer N use efficiency (FNUE) was calculated as the percent ratio between corn N uptake and total fertilizer N applied to the soil. Total available N use efficiency (ANUE) was calculated as the ration between corn N uptake and the available N, defined as the sum of fertilizer N and PONmin. The effect on corn N uptake of both the total available N and of fertilizer N following compost application compared to urea were calculated as the ratio between ANUE of compost and of UR, and as the ratio between FNUE of compost and of UR, respectively.
Analysis of variance was used to determine differences among treatments, location, and year in corn total biomass production and N uptake, three years average SMN at harvest in the 0-60 cm soil layer, and SOC and SON in the 0-30 cm soil layer. When significant, means were separated using a Sidak post-hoc test.

3. Results and discussion

Corn yields and N uptake were significantly affected by treatments ($P<0.01$). However, both experimental pedoclimatic conditions and repeated application influenced the treatment effects on the crop response ($P<0.01$). Corn biomass and N uptake were lower at NA than at TO ($P<0.01$) and decreased from 2006 to 2008 ($P<0.01$), following a progressive depletion of soil fertility determined by the chosen N fertilization rate lower than the crop uptake (Fig. 1 and 2). Fertilization with compost in COM1 and COM2 lowered corn production and N uptake in both locations. At NA, the negative effect was the highest in the first year (average COM1 and COM2 harvested biomass was 37% than that in UR), with values significantly lower than 0N. In 2008 the negative effect was lower (COM1 and COM2 average harvested biomass was 52% than in UR), probably as a consequence of the repeated compost additions. At TO, the effect of compost was similar, but of a much lower extent. Crop production and N uptake in COM1 and COM2 were never significantly lower than in UR, and just showed a tendency toward lower values. 0N showed a N uptake significantly lower than UR only in 2008, probably as a consequence of a higher soil organic matter mineralization rates and the consequent ability of the soil to support high crop production levels. In fact, calculated PONmin were higher at TO (2006: 235 kg N ha^{-1}; 2007: 146 kg N ha^{-1}; 2008: 114 kg N ha^{-1}) than at NA (2006: 173 kg N ha^{-1}; 2007: 50 kg N ha^{-1}; 2008: 69 kg N ha^{-1}), and decreased with the progress of the trial.
Minimum tillage and fertilization by leguminous green manure incorporation did not affect corn biomass and N uptake in comparison with urea in both locations. This results show the viability of the substitution of plowing with minimum tillage, and of urea with a leguminous green manure as a good source of N to corn.

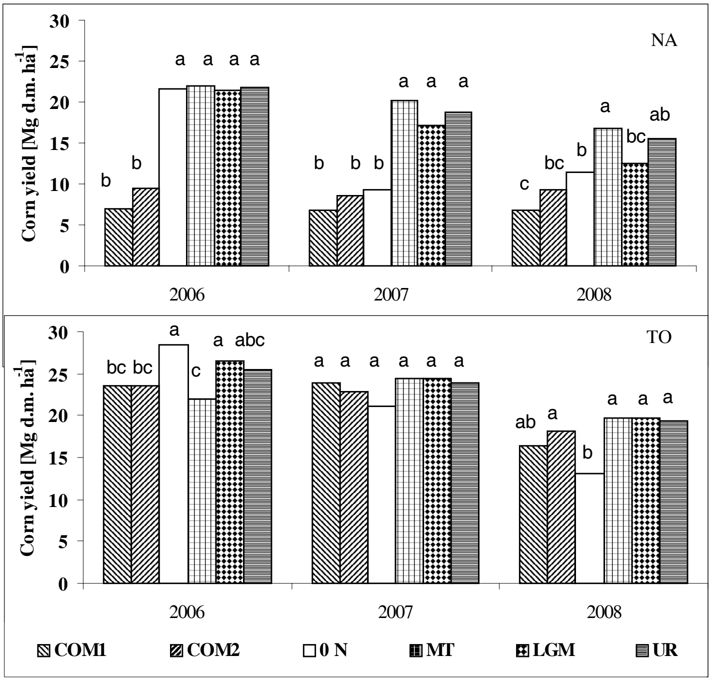

Fig. 1 – *Corn yields at NA and TO experimental sites. Letters in each graph separate significantly different averages among treatments at each location and for each year.*

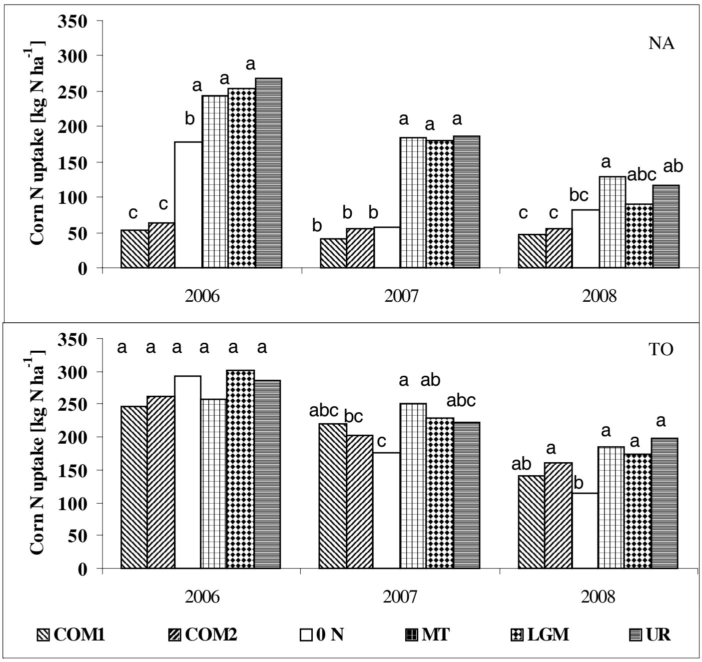

Fig. 2 – *Corn N uptake at NA and TO. Letters in each graph separate significantly different averages among treatments at each location and for each year.*

The observed depleting effect of compost addition on corn production at NA was probably the consequence of both soil mineral N immobilization and low organic N mineralization rates. A phytotoxicity test clearly showed the absence of any significant response of the test crop to the increasing compost addition (data not shown), indicating both the absence of a toxic effect of the compost, and very low N mineralization rates of the compost. Moreover, as already reported, no difference was found between COM1 and COM2 corn yields and N uptake, and the difference of these treatments respect to UR decreased with time while COM2 tended to increase its production levels. At TO, a significant compost effect was not found probably as a consequence of a PONmin sufficient to support corn N needs. PONmin was on average 70 % of the N uptake in UR (while in NA it was 50 %).
Soil mineral N monitoring further confirmed low compost mineralization rates. Treatments fertilized with compost showed the lowest SMN at harvest ($P<0.01$). Also, at NA, COM2 showed the lowest values, suggesting soil mineral N immobilization by the added organic matter. The three year average SMN at harvest (Fig. 3) was significantly higher in NA than in TO, indicating that organic matter mineralization was probably delayed. The NH_4^+N/NO_3^--N ratio was on average 10 times higher in NA than in TO (data not shown), probably indicating more anoxic condition contributing to slow N mineralization. Thus, mineral N was probably available to crop when corn N uptake was already subsiding, contributing to the higher differences observed at NA.
Similarly to the corn total harvested biomass and N uptake, SMN at harvest in LGM and MT was not significantly different from UR.

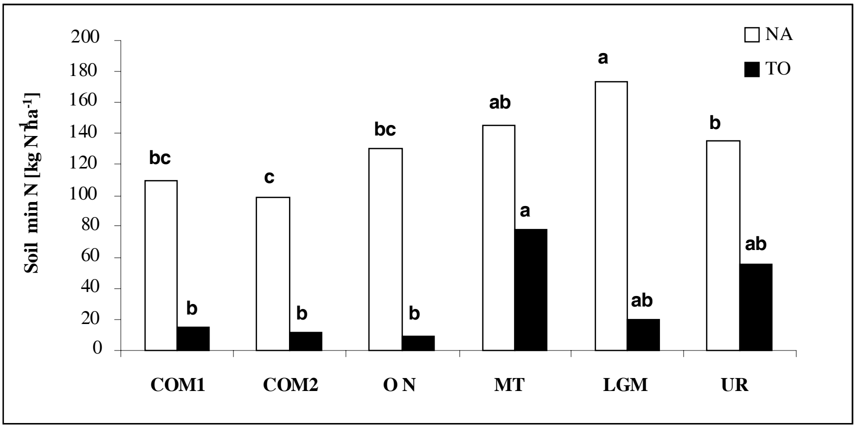

Fig. 3 – *Three year average soil mineral N content at harvest in the 0-60 cm soil layer in the different treatments at NA and TO.*

To evaluate the viability of the compost to substitute mineral fertilizers, FNUE and ANUE indicators were calculated. Values for COM1 are reported in Table 2. These indicators were not calculated for LGM and MT as their N uptake was not significantly different from UR. Both indicators clearly evidenced a reduced N fertilization effect of compost in comparison with urea, further stressing the strong importance of the pedoclimatic conditions in determining compost effect.

		ANUE	FNUE	UAE	UFE
		[kg N uptake/kg fertilizer N]	[kg N uptake/kg fertilizer N]	[%]	[%]
TO	compost	0.3	1.4	75	87
	urea	0.4	1.6	-	-
NA	compost	0.1	0.4	25	33
	urea	0.4	1.2	-	-

Tab. 2 – *Fertilizer N use efficiency (FNUE), available N use efficiency (ANUE), urea available N equivalents (UAE), urea fertilizer N equivalents (UFE) at the two locations.*

The compost effect on corn N availability was reflected in the SOC and SON evolutions from 2006 to 2008 (data not shown). AT NA, SOC increased following the addition of the stable compost organic matter, but no effect was found with the leguminous green manure probably as a consequence of a higher susceptibility of its organic matter. A similar increase was achieved with the tillage reduction in MT. Similar, SON decreased with time in UR, but remained stable in COM1, COM2 and MT.

2. Conclusions

The use of compost to fertilize corn was evaluated. Results showed that compost application could be a viable way to increase soil organic C and N contents and to improve long term soil fertility. The increase in soil organic N is the consequence of reduced mineralization rates of applied organic matter and probably of immobilization of N. As a consequence, N availability to the fertilized crop is reduced, especially in low fertility and poorly-aerated soils. Nitrogen use efficiency of added compost resulted to be variable from 87 to 33 % depending on the pedoclimatic conditions. However, it is possible that the observed reductions in corn yields and N uptake could reduce with time following the progressive increase in SON. Slow compost mineralization maintained low mineral N content in the soil similar to a slow N release fertilizer, contributing to protect ground water quality.
In contrast to compost, urea substitution with a leguminous green manure and the reduction of tillage did not influence crop growth. LGM did not contribute to store neither SOC nor SON while minimum tillage actively contribute to SOC and SON sequestration.
We conclude that compost showed the ability to increase soil fertility with positive environmental effect, but the low fertilizer N use efficiency found in the first years of application needs to be considered by farmers and evaluated in the long term.

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