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Ecological and Agronomical Perspectives of Vermicompost Utilization in Mediterranean Agro-ecosystems

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ABSTRACT

Fields experiments were conducted to treat an agronomic soil using three types of fertilizers: organic (vermicompost), mineral, and a mixture of organic and mineral (vermicompost + NPK), added to soil with two N application doses (100 and 200 kg/ha). Vermicompost was obtained through aerobic stabilization of biological sludge, performed by earthworms (*Eisenia fetida*). The soil was cropped with maize (*Zea mays*) and sunflower (*Helianthus annuus*). Plant productivity and effects of treatments on soil chemical and biochemical properties were evaluated. Results showed an increase of plant productivity (expressed as kg of seeds produced per plot) in the treatment with vermicompost and mineral fertilizer, for both plant species and application rates. Mineral fertilization reduced soil microbial activity and increased the release of carbon and nitrogen soluble compounds suggesting a degradation of native soil organic matter and impacting on environmental quality.

Keywords: agrochemicals, maize, soil quality, sunflower

Abbreviations: Dh-ase, dehydrogenase activity; **EC**, electrical conductivity; **N-NO$_3$**, nitrates; **Pav**, available phosphorus; **Ph-ase**, phosphatase activity; **SOM**, soil organic matter; **TN**, total nitrogen; **TOC**, total organic carbon; **TP**, total phosphorus; **WSC**, water soluble carbon

INTRODUCTION

The decline in soil fertility and productivity due to excessive soil erosion, nutrient run-off, and loss of soil organic matter has stimulated interest in improving overall soil quality by the addition of organic matter (Senesi *et al*. 2007). Organic amendments (compost, green manure, animal manure, sewage sludge) applied to soil have long been employed to enhance favourable soil conditions (Wander *et al*. 2002; Sebastia *et al*. 2007), that is to maintain or improve the tilth, fertility, and productivity of agricultural soils. Soil quality is difficult to define and quantify, since it depends on the soil uses, management practices, and socio-economic and political pressures. Doran and Parkin (1994) suggested that the following aspect should be considered in the soil quality definition: 1) the capacity of a soil to sustain plant and biological production (productivity), 2) the ability of a soil to reduce the effects of environmental contaminants and pathogens (environmental quality), 3) the preservation of soil organic matter (SOM) functions in relation to plant, animal and human health (functionality).

The capacity of agronomic soils to sustain agronomic productivity and to develop the ecological function for the regulation of principal elements cycle, depends on type and intensity of the agronomic practices (Masciandaro 1997; Pajares *et al*. 2009).

The introduction of agricultural intensive practices using mineral fertilization (especially nitrogenous), contributes to raise productive profits, creating chemical-physical conditions unfavourable for microbial activity, and contributing to the reduction of SOM. Furthermore, also the reduction of the organic substance drastically reduces soil quality and fertility (Masciandaro and Ceccanti 1999). The organic matter, the principal responsible of soil quality and productivity, is often utilized for practices of soil regeneration and preservation (Ceccanti *et al*. 1994; Senesi *et al*. 2007). A great amount of organic materials is often used as organic substances and mineral nutrients source, available for cultivations. In particular, organic residues are considered as an alternative source of nitrogen (Sims 1995; Geisseler *et al*. 2009).

Vermicompost, derived from biological sludge throughout the combined action of earthworms (*Eisenia fetida*) and microorganisms could be considered as an organic nitrogenous fertilizer due to its high level of nitrogen content (3-4%), as well as the higher content of organic substances (> 50%) (Masciandaro *et al*. 1997). Therefore, vermicompost could be utilized for soil organic amendment practices, supporting soil mineral fertilization.

The main objective of this work was to evaluate the effects of organic and mineral fertilizer, mixed or used separately, on the agronomic productivity as well as on the preservation of SOM quality.

MATERIALS

Experimental set up, soil and vermicompost

Field experiments were carried out in Lucca Province (central Italy), in 2005 and consisted in plots of 80 m^2 (10 × 8m) with a space between the plots of 3 m. The design of the experiment consisted of a complete randomised block with three replicates per treatment.

The following fertilisation treatments were carried out: (1) natural soil (control); (2) soil + vermicompost (VC) from sewage sludge (obtained as reported in Masciandaro *et al*. 1997); (3) soil + mineral fertiliser (urea and ammonium phosphate; MF); and (4) soil + a mixture of VC and MF (VC+MF). Two doses of fertilisers were applied using the equivalent dose of 100 and 200 kg total N/ha (**Table 1**). The effect of each treatment on yield was checked

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Table 1 Different doses utilized in the experimentation.

Single dose	Control (untreated soil)
(100 kg N/ha)	Vermicompost: 1VC
	Mineral fertilizer: 1MF
	Vermicompost + mineral fertilizer: 1VC+MF
Double dose	Vermicompost: 2VC
(200 kg N/ha)	Mineral fertilizer: 2MF
	Vermicompost + mineral fertilizer: 2VC+MF

Table 2 Main analytical characteristics of vermicompost and soil.

Parameters	**Unit**	**Vermicompost**	**Soil**
pH	-	7.2	6.5
TOC	%	31	0.95
TN	%	3.5	0.085
Cd	μg/g	4.2	0.6
Hg	μg/g	0.8	0.009
Ni	μg/g	46	14
Pb	μg/g	210	22
Cu	μg/g	575	33.5
Zn	μg/g	1830	40.3

on the same cultivated soil with maize (*Zea mays* – 'Cecilia HS') and sunflower (*Helianthus annuus* – 'Select').

Organic fertiliser (VC) was incorporated into the top 15 cm of soil by a mechanical rotary tiller 4 weeks before planting. Mineral fertilizer (MF) was applied to the soil surface 4 weeks after sowing; maize seeds were sown at a depth of 5 cm.

In **Table 2** are reported the main characteristic of the soil and vermicompost. Soil samples were collected after one year of maize and sunflower sowing and specifically after 32 weeks after harvesting. Three sub-samples were taken from the surface layer (0–15 cm) diagonally in each plot. These sub-samples were mixed (to have a single sample for each plot), air-dried, sieved (< 2 mm) and stored at room temperature for chemical analyses. Fresh soil samples were sieved for the biochemical analyses and stored at 4°C.

Vermicompost was obtained from the aerobic stabilization of biological sludge derived from civil and industrial (paper factories) wastewater treatment plants, due to earthworms (*Eisenia fetida*) activity (Masciandaro *et al.* 1997).

METHODS

Chemical analyses

Total organic carbon (TOC) and water-soluble carbon (WSC, extracted in water and determined throughout water extracts 1: 10 w/v, García *et al.* 1990) were determined by dichromate oxidation (Yeomans and Bremner 1988). Total nitrogen (TN) was determined by the Kjeldhal method (Jackson 1960) and nitrate ($N\text{-}NO_3$) analysis was performed in a DIONEX ion chromatograph, model 2000i (DIONEX corporation, California, USA), equipped with a Dionex AS4A 4-mm analytical column according to the methodology of the handbook instructions. Total and available phosphorus have been determinated by colorimetric method (Murphy and Riley 1962) after acid digestion with nitric-perchloric acids and extraction with ammonium acetate diethylenetriaminepentaacetic acid (DTPA), respectively.

Biochemical analyses

Dehydrogenase activity (Dh-ase) (E.C. 1.1.1) was determined by the method of Von Mersi and Schinner (1991) modified by Masciandaro *et al.* (2000) using INT chloride (2-(4-Iodophenyl)-3-(4-nitrophenyl)-5-phenyl-2H-tetrazolium chloride >97% BioChemika, Sigma-Aldrich n. 58030) as substrate. The product INTF (1-(4-Iodophenyl)-5-(4-nitrophenyl)-3-phenylformazan) was measured spectrophotometrically (λ = 490 nm). The calibration curve was prepared using INTF (Sigma-Aldrich n. I-7375).

Phosphatase activity (Ph-ase) (E.C. 3.1.3.2) was determined referring to the method reported in Tabatabai and Bremner (1969) using 0.115 M 4-nitrophenyl phosphate disodium salt hexahydrate (PNP >99% BioChemika, Sigma-Aldrich, n. 71768) as substrate and determining the 4-nitrophenol product (PNP) spectrophotometrically (λ= 398 nm). The calibration curve was prepared using PNP >95% (Fluka, Sigma-Aldrich, n. 73562).

Statistical analysis

All results reported in the text are means of three sampling replicates data. Each soil sample (object) was considered as an assembly of 13 variables represented by parameters (chemical, biochemical and yield), treatment, dose and plant. These variables formed a data vector (objects × variables) which represented a soil sample. Data vector belonging to the same group (VC, VC+MF, MF, C, single and double dose, and plant) were analyzed. All numerical parameters before statistical analysis were normalized and autoscaled: the result for each variable is a zero mean and a unit standard deviation (Latorre *et al*. 1999). Analysis of variance (ANOVA) was used to evaluate the differences ($P < 0.05$) between treatment (VC, VC+MF, F), dose (single and double) and plant (maize and sunflower) and their interactions. Differences between treatments and control soil for each plant were tested using Dunnett's comparison test. A statistical correlation between the data was calculated. For each treatment a correlation among the parameters have been made. The reported significant levels ($P < 0.05$) are based on Student's distribution. Discriminant function analysis was used to determine which variable discriminates between the different treatments (VC, VC+MF, MF, C). In stepwise discriminant function analysis (Forward Stepwise Analysis), a model of discrimination is built step-by-step. Specifically, at each step all variables are reviewed and evaluated to determine which one will contribute most to the discrimination between groups. That variable will then be included in the model and the process starts again. The stepwise procedure is "guided" by the respective F to enter and F to remove values. The F-value for a variable indicates its statistical significance in the discrimination between groups. Discriminant analysis determine some optimal combination of variables so that the first function provides the most overall discrimination between groups, the second provides next most, and so on. A canonical correlation analysis was performing determining the two functions and canonical roots (Benitez *et al*. 2006). The STATISTICA 6.0 software (StatSoft Inc., Tulsa, Oklahoma, USA) was used for all statistical analysis.

RESULTS AND DISCUSSION

Productivity yields

Data referred to plants production are reported in **Table 3**. The data are expressed in kg of seeds produced per plot. The highest yields were obtained for both plant species for the mixture with vermicompost and mineral fertilizer (VC+MF). Beneficial effect of combined use of organic and inorganic materials in increasing crop yields as well as in maintaining soil health on long-term basis had been also reported by other authors (Ghosh *et al.* 2004; Rasool *et al.* 2008; Manivannan and Sriramachandrasekharan 2009).

Such an effect may be attributed to better availability of plant nutrients in mineral fertilizer (Nakano *et al.* 2001) and

Table 3 Productivity of soils under mineral and organic treatments, seeded with maize and sunflower. Values are mean of three replicates ± standard deviation.

Treatment	**Maize**		**Sunflower**	
	yield ($kg/80m^{2a}$)	**yield (%^{b})**	**yield ($kg/80m^{2a}$)**	**yield (%^{b})**
C	55.8 ± 9.0	100	6.7 ± 1.6	100
1VC	58.6 ± 4.5	105	9.7 ± 0.5	145
1VC+MF	72.3 ± 6.8*	130	12.2 ± 2.0*	182
1MF	66.0 ± 6.7	118	7.0 ± 0.8	105
2VC	64.3 ± 6.7	115	6.8 ± 2.6	102
2VC+MF	72.0 ± 4.3*	129	11.7 ± 0.8*	175
2MF	66.0 ± 6.5	118	7.0 ± 0.7	105

[a] parcel surface
[b] comparing with control
[*] Dunnett's test (p<0.05), comparing separately each treatment (and plants) with control

Table 4 ANOVA; effect of treatment, dose and plant in the chemical and biochemical parameters, and yield.

Effect	EC		TOC		TN		TP		Pav		WSC		NO_3		Dh-ase		Ph-ase		Yield	
	F	p	F	p	F	p	F	p	F	p	F	p	F	p	F	p	F	p	F	p
Treatment	35.0	0.00*	33.3	0.00*	67.0	0.00*	10.6	0.00*	431	0.00*	608	0.00*	143	0.00*	133	0.00*	107	0.00*	15.8	0.00*
Dose	128	0.00*	0.33	0.57	4.56	0.04*	1.34	0.26	96.6	0.00*	24.8	0.00*	107	0.00*	127	0.00*	4.68	0.04*	1.36	0.25
Plant	18.7	0.00*	19.2	0.00*	319	0.00*	14.4	0.00*	60.5	0.00*	118	0.00*	246	0.00*	271	0.00*	60	0.00*	1638	0.00*
Treatment*Dose	8.38	0.00*	2.11	0.14	0.46	0.63	0.15	0.86	11.0	0.00*	148	0.00*	26.0	0.00*	7.11	0.00*	1.90	0.17	0.99	0.39
Treatment*Plant	2.77	0.08	4.88	0.02*	3.91	0.03*	0.12	0.89	4.89	0.02*	7.15	0.00*	13.8	0.00*	1.61	0.22	6.32	0.01*	6.51	0.01*
Dose*Plant	0.09	0.77	17.2	0.00*	0.06	0.80	0.27	0.61	6.94	0.01*	128	0.00*	3.24	0.08	141	0.00*	136	0.00*	3.09	0.09
Treatment *Dose*Plant	21.6	0.00*	4.46	0.02*	0.35	0.71	0.09	0.91	1.47	0.25	11.9	0.00*	16.4	0.00*	5.82	0.01*	1.52	0.24	2.58	0.10

EC. Electrical conductivity; TOC. Total Organic Carbon; TN. Total Nitrogen; TP. Total phosphorus; Pav. available Phosphorus; WSC. Water Soluble Carbon; NO_3. Nitrates; Dh-ase. Dehydrogenase; Ph-ase. Phosphatase

* Multifactorial ANOVA ($p<0.05$)

Table 5 Chemical results for soils seeded with maize and sunflower, at the end of the first cultivation cycle. Values are mean of three replicates ± standard deviation.

Treatment	Maize					Sunflower				
	EC (µS/cm)	TOC (%)	TN (mg/kg)	TP (mg/kg)	Pav (mg/kg)	EC (µS/cm)	TOC (%)	TN (mg/kg)	TP (mg/kg)	Pav (mg/kg)
C	27.0 ± 2.2	0.90 ± 0.04	793 ± 34	315 ± 18	1.80 ± 0.10	28.0 ± 2.2	0.95 ± 0.06	900 ± 48	301 ± 14	1.20 ± 0.10
1VC	51.3 ± 4.1*	1.02 ± 0.02*	943 ± 34*	373 ± 23*	2.57 ± 0.20*	46.7 ± 3.7*	1.16 ± 0.06*	1360 ± 44*	402 ± 19*	3.20 ± 0.21*
1VC + MF	35.7 ± 3.0*	1.02 ± 0.01*	862 ± 27*	347 ± 15	4.26 ± 0.23*	41.7 ± 3.3*	1.14 ± 0.05*	1152 ± 50*	375 ± 15*	5.75 ± 0.33*
1MF	45.7 ± 4.1*	0.98 ± 0.01*	805 ± 20	339 ± 18	2.77 ± 0.13*	39.3 ± 2.6	0.98 ± 0.03	1018 ± 43	367 ± 14*	2.99 ± 0.11
2VC	68.7 ± 5.5*	1.06 ± 0.04*	998 ± 33*	388 ± 21*	2.90 ± 0.14*	60.0 ± 5.0*	1.06 ± 0.01*	1403 ± 76*	404 ± 27*	3.20 ± 0.16*
2VC + MF	53.0 ± 4.4*	1.07 ± 0.03*	888 ± 26*	358 ± 17	5.93 ± 0.41*	41.7 ± 3.8*	1.07 ± 0.02*	1240 ± 96*	388 ± 24*	6.76 ± 0.41*
2MF	57.0 ± 4.17*	1.00 ± 0.01*	812 ± 12	346 ± 25	3.60 ± 0.22*	59.5 ± 5.4*	1.00 ± 0.02	1040 ± 113	366 ± 18*	3.84 ± 0.24*

EC. Electrical conductivity; TOC. Total Organic Carbon; TN. Total Nitrogen; TP. Total phosphorus; Pav. available Phosphorus

* Dunnett's test ($p<0.05$), comparing separately each treatment (and plants) with control

to the slow-release nutrients, plant growth regulators and humic acid in vermicompost, which are due to the increased activity of microorganisms (Arancon *et al.* 2004).

Referring to vermicompost treatment (VC) and mineral fertilizer treatment (MF), a tendency of productivity increasing has been observed (**Table 3**). Moreover no significant differences were observed between the two doses in the same treatment (**Table 4**), indicating that a higher fertilizer dose did not give higher plant yields and that the lower dose is preferred also to avoid negative environmental impact.

Effects on soil

Referring to data reported in **Table 5**, TOC, TN and TP resulted significantly higher in VC treatments (VC and VC+MF) with respect to controls and MF treatments for both maize and sunflower (**Table 4**). Organic management systems maintained soil organic matter and nutrient content at higher level than inorganic fertilization and no amended soil (Melero *et al*. 2006; Fließbach *et al*. 2007; Azarmi *et al.* 2008; Purakayastha *et al*. 2008).

This increase in C in the VC+MF-treated plots resulted from increased yields of roots and plant residues, and the application of organic C through vermicompost (Kundu *et al.* 2002). Apart from that, organic amendments are known to have a high humification coefficient that leads to greater C-sequestration in soil (Beri *et al.* 1995). The benefits of sequestering C to sustain crop productivity by applying organic amendments have been well documented in temperate regions (Aulakh *et al.* 2001). In all VC treatments (VC and VC+MF) positive correlations between TOC and TN ($P < 0.05$; $0.90 \leq r \leq 1.00$) were observed. In the VC+MF treatments, statistical analysis also showed the influence of soil N nutrients on plant productivity, being correlated with N-NO_3 ($P < 0.05$; $0.93 \leq r \leq 0.96$) and TN ($P < 0.05$; $0.96 \leq r \leq 1.00$).

Moreover, plant productivity was often positively correlated with phosphatase (**Table 4**), independently of the type of cropping, treatments and doses ($P < 0.05$; $0.84 \leq r \leq 0.98$).

The statistical relationship between phosphatase and plant yield has also been found in other studies (Melero *et al.* 2006), meaning the significant influence of P cycle on the agronomic productivity. Phosphatase is an hydrolytic enzyme linked to phosphorous cycle that catalyzes the transformation of organic phosphorous compounds into mineral phosphorous (phosphate), available for plants. The use of hydrolytic enzyme activities as an index of soil fertility was discussed since the 1980's (Skujins 1978). Nannipieri *et al.* (1990) suggested to test different enzymatic activities for the evaluation of soil global metabolism and to calculate some fertility indexes (Perucci 1992), also linked to plant production (Dick 1992).

Obviously, the addition of organic and mineral fertilizer to soil let increase agronomic yields, due to the presence of nutritional elements both in slow and quick release forms. In fact, slow-release nutrients mainly conditioned microorganism development and activity, while fast-release nutrients influenced firstly plants nutrition and productivity.

The increase of plant productivity is not always associated to an activation of microbial biomass (Dick 1992). In fact, in the presented agro-ecosystem, other factors could influence the relation between soil biological activity and plants production. Surely, microbial biomass activity is influenced by the treatments using organic substances in soil. Therefore, dehydrogenase activity, considered as a microbial activity index in soil (García *et al.* 1997; Taylor *et al.* 2002), showed the highest value in treatments with only vermicompost (**Fig. 1A, 1B**).

Organic amendments contain substrate capable of activating autochthonous biomass (Gaind and Nain 2007), supplying microorganisms and intra- and extracellular enzymes (Pascual *et al.* 1998). Also Marinari *et al.* (2000) showed that in a sandy loam soil cultivated with maize, mineral N fertilization had weaker effects on dehydrogenase activity, comparing to organic manuring.

Ecological aspects

The use of nitrogen-mineral fertilizer in soil let increase N and C turnover (Kuzyakov *et al.* 2000). A great numbers of field experiments showed that intensive cultivations using mineral fertilizer did not contribute to organic C and N accumulation, but reduce native soil organic matter during time (Li *et al.* 2007). This is due to the alteration of equilibrium between organic matter mineralization and immobilisation processes, favouring the mineralization. Therefore, the potential mineralization activity increases within the ap-

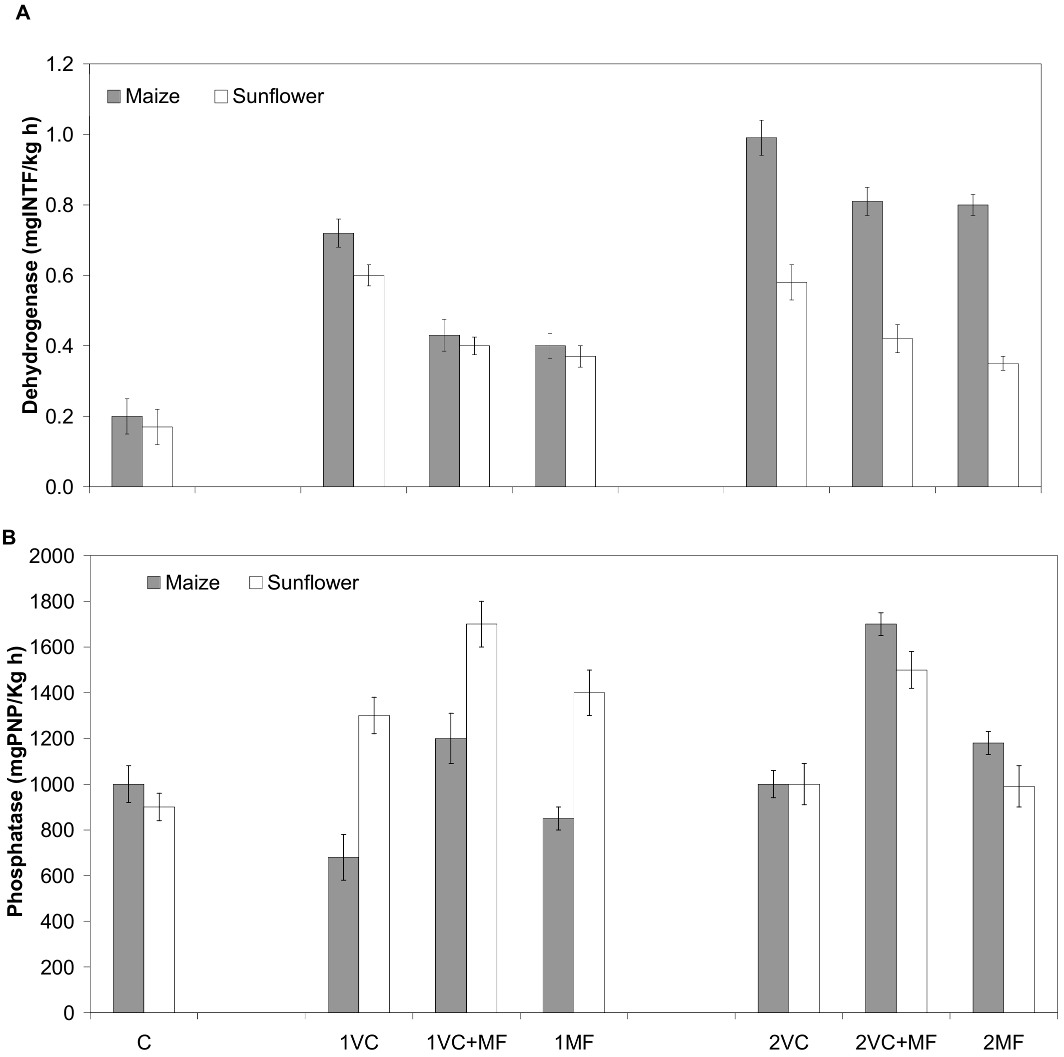

Fig. 1 Behaviour of dehydrogenase activity (A) and phosphatase activity (B), in the treated soil seeded with maize and sunflower. The error bars represent the standard deviations.

plication of mineral fertilizers, causing a sort of "priming" effect, releasing available and soluble mineral N forms (Kuzyakov *et al.* 2000; Marinari *et al.* 2000). In fact, as expected, great concentrations of C water soluble compounds (WSC) and of N water soluble compounds (N-NO_3) were found in treatments that use only mineral fertilizer (single and double dose), for both plant species (maize and sunflower), as reported in **Fig. 2A, 2B**.

The high concentrations of WSC and N-NO_3 could represent an ecological problem, because other than altering soil chemical-physical composition, these two compounds are considered potential contaminants for surface groundwater.

Discriminant and canonical analysis

For the discriminant analysis of the different treatments (VC, VC+MF, MF, C) without taking into account plant species, the following variables were determined: EC, TOC, WSC, TN, N-NO_3, TP, Pav, Dh-ase, Ph-ase, and plant yield. **Table 6** shows the results from applying the algorithm for selecting variables according to treatments (VC, VC+MF, MF, C) with different doses.

The variables with the greatest discriminating power were WSC, EC, Ph-ase, followed by nutrient content (Pav, TP, TN, TOC, N-NO_3), Dh-ase activity and plant yield. Surprisingly, the fit between the soils belonging to each treatment and those predicted by the discriminant model resulted in 100% (**Table 7**). Each sample is represented according to the values of the variables acquired after the discriminant analysis, which gave rise to two canonical functions (**Table 8**). In function 1 (root 1) (77%) WSC, Ph-ase activity, EC and plant yield were selected as the variables that produced the best classification of the samples between the different treatments; while in function 2 (root 2) (13%) the best variables were TN, TP and Dh-ase activity. **Fig. 3** presents the results for the canonical analysis of the soils according to the two discriminating functions created taking into account the used treatments (VC, VC+MF, MF, C). Function 1 was capable of discriminating the different treatments VC, VC+MF and MF with respect to the control. Moreover, function 1 seemed to discriminate mostly between single dose and double dose in all treatments (means of the canonical variables: VC -4.97 and -26.20; VC+MF -3.28 and -26.32; MF 23.50 and 30.41). On the contrary, function 2 seemed to not discriminate between doses in VC and VC+MF treatments (VC 11.10 and 12.13; VC+MF -10.03 and -10.04). The closeness within each group suggested that both plants behave similarly in the different treatments. Moreover, along the function 1 the MF treatments at both doses were clearly discriminated with respect to the VC treatments (VC and VC+MF), probably due to the higher soluble nutrient forms when mineral fertiliser was added. On the other hand, the strong discrimination between VC and VC+MF along the function 2 seemed to be influenced by the higher Dh-ase activity found in the treatments with only VC.

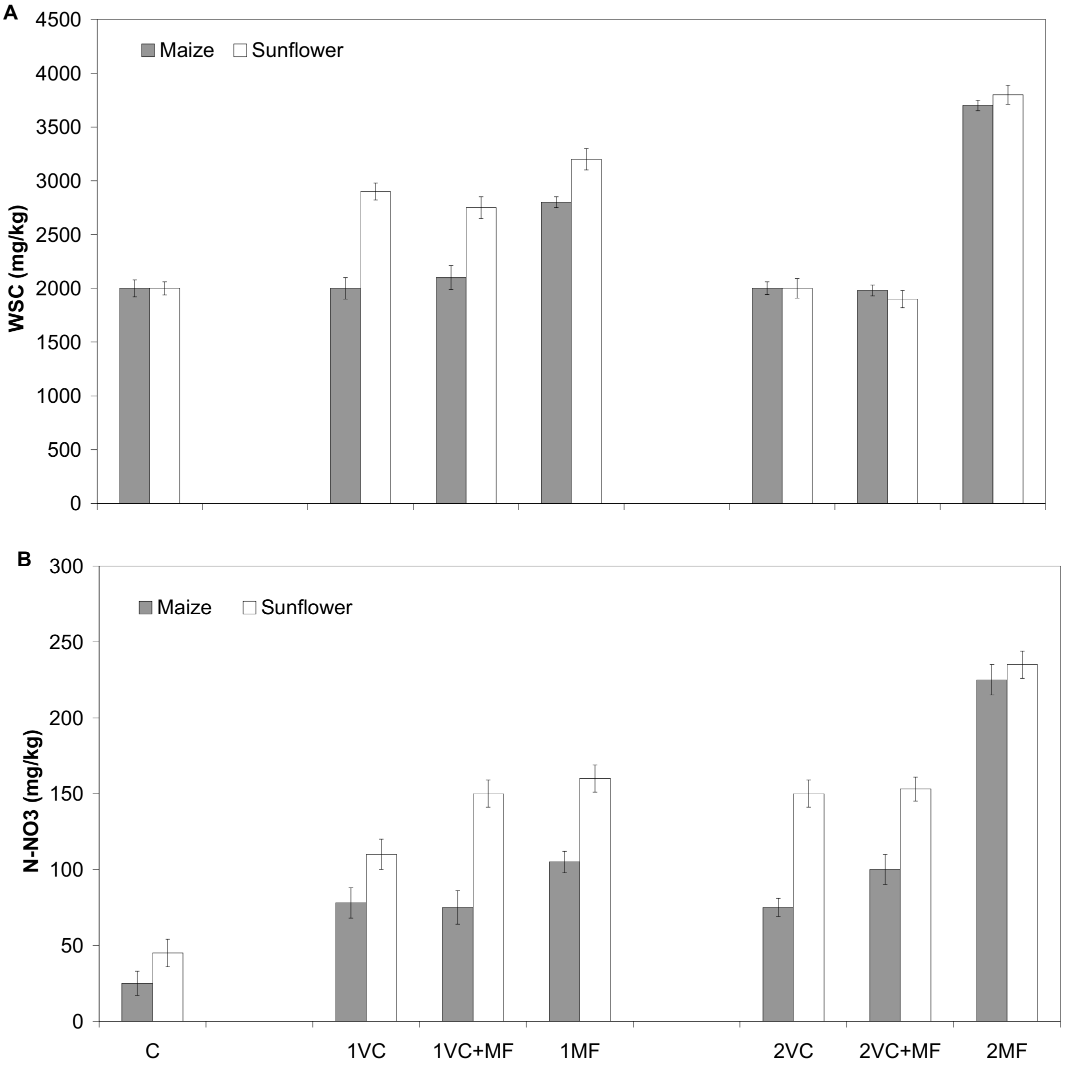

Fig. 2 Behaviour of water soluble carbon (WSC) (A) and nitrates (N-NO$_3$) (B), in the treated soil seeded with maize and sunflower. The error bars represent the standard deviations.

Table 6 Discriminant function analysis; summary of soil under different treatments (VC, VC+MF, MF, C) and dose (single and double).

	Wilks' Lambda*	Partial Lambda**	F-remove (-6.26)	p-level
WSC	0.00	0.02	252.14	0.00
EC	0.00	0.07	59.40	0.00
Ph-ase	0.00	0.08	47.12	0.00
Pav	0.00	0.17	21.85	0.00
TP	0.00	0.21	16.46	0.00
TN	0.00	0.23	14.20	0.00
Dh-ase	0.00	0.26	12.54	0.00
TOC	0.00	0.26	12.46	0.00
N-NO$_3$	0.00	0.30	10.35	0.00
Yield	0.00	0.43	5.82	0.00

In the first column, selected variables according to their discriminant power in the model.

* Wilks' Lambda for the overall model that resulted after removing the respective variable; 0 (perfect discrimination). 1 (no discrimination).

** Wilks' Lambda associated with the unique contribution of the respective variable to the discriminatory power of the model.

WSC. Water Soluble Carbon; EC. Electrical conductivity; Ph-ase. Phosphatase; Pav. available Phosphorus; TP. Total phosphorus; TN. Total Nitrogen; Dh-ase. Dehydrogenase; TOC. Total Organic Carbon; N-NO$_3$. Nitrates

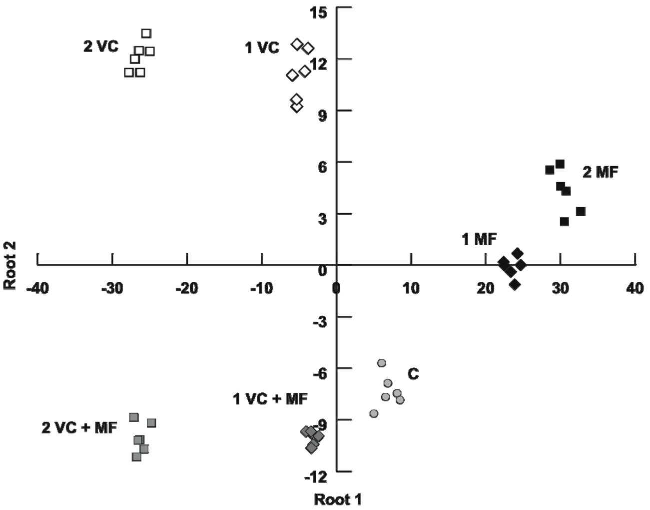

Fig. 3 Canonical analysis (root 1vs root 2) of soil under different treatments (VC, VC+MF, MF, C) and doses (single and double).

CONCLUSIONS

The use of a mixed fertilizer, constituted by mineral and organic compounds, increases productive yields if compared with the vermicompost or mineral fertilization. The agronomic productivity was statistically correlated to the phosphatase activity suggesting the involvement of P cycle in plant growth and activity. The treatment with only mineral fertilizer decreased soil microbial biomass activity (expressed as dehydrogenase activity), and released water soluble nitrogen and carbon compounds affecting native soil organic matter. Finally, high concentrations of N and C soluble compounds could also represent an ecological problem.

Table 7 Classification matrix after the discriminant analysis of soil under different treatments (VC, VC+MF, MF, C) and dose (single and double).

Group	**Classification matrix; rows: observed classifications and columns: predicted classifications**							
	Percent Correct	**1VC p=.1428**	**1VC+MF p=.1428**	**1MF p=.1428**	**2VC p=.1428**	**2VC+MF p=.1428**	**2MF p=.1428**	**C p=.1428**
1VC	100	6	0	0	0	0	0	0
1VC+MF	100	0	6	0	0	0	0	0
1MF	100	0	0	6	0	0	0	0
2VC	100	0	0	0	6	0	0	0
2VC+MF	100	0	0	0	0	6	0	0
2MF	100	0	0	0	0	0	6	0
C	100	0	0	0	0	0	0	6
Total	100	6	6	6	6	6	6	6

Table 8 Standardized coefficients for Canonical Variables.

	Root 1	**Root 2**
Pav	0.158	-1.455
WSC	7.125	1.418
TOC	-0.782	-1.391
Ph-ase	-5.256	-1.953
EC	-3.063	0.756
TP	-2.287	2.166
Dh-ase	-0.958	2.551
TN	-1.562	3.909
N-NO_3	1.644	-0.665
Yield	2.300	0.781

Pav. available Phosphorus; WSC. Water Soluble Carbon; TOC. Total Organic Carbon; Ph-ase. Phosphatase; EC. Electrical conductivity; TP Total phosphorus; Dh-ase. Dehydrogenase; TN. Total Nitrogen; N-NO_3. Nitrates

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