International Journal of Agricultural Sciences
Volume **10** | Issue 2 | June, 2014 | 506-511
e ISSN–0976–5670 | Visit us | *www.researchjournal.co.in*

RESEARCH PAPER

Microbial biomass and total nitrogen as affected by organic and conventional farming systems in soils of southern Karnataka, India

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Abstract : In the past decade, there has been increased scientific interest in organic farming, especially in comparison with conventional agriculture. Many recent studies compare these two fundamentally different systems for soil properties, in different regions of the world. Soil samples from two depths (0-15 cm and 15-30cm) collected from 4 farmer's fields each under different periods of practicing of organic farming (0-3 years, 3-6 years and over 6 years) and same number of soil samples collected from neighboring conventional farming fields in central dry agro-climatic zone and southern dry agro-climatic zones of southern Karnataka during 2008 and 2009 were studied to determine the effects of these two agricultural systems on soil properties at the farm level. The fields under organic management showed significantly better soil nutritional and biochemical attributes; with increased level of total nitrogen, an increased microbial biomass content. Results of the study suggest that, over the period of organic management system strongly affects soil properties.

Key Words : Organic farming, Conventional farming, Soil microbial biomass, Total nitrogen

View Point Article : Malayanur, Vijay Sankar Babu, Ramakrishna, V.R. and Reddy, M. Vijaya Sai (2014). Microbial biomass and total nitrogen as affected by organic and conventional farming systems in soils of southern Karnataka, India. *Internat. J. agric. Sci.*, **10** (2): 506-511.

Article History : Received : 06.07.2012**; Revised :** 21.03.2014**; Accepted :** 06.04.2014

INTRODUCTION

Organic farming has gained ground worldwide and has expanded in the last decade due to environmental, economic and social concerns (Araujo *et al.*, 2008). Soil and crop management practices, including organic and conventional management, can influence soil biological activities through their effects on the quality, structure, and distribution of soil organic matter. Systems with high organic matter inputs tend to have higher microbial biomass contents and activities because they are preferred energy sources for microorganisms. The soil microbial biomass is involved in the decomposition of organic materials and thus, the cycling of nutrients in the soil. It is also frequently used as an early indicator of changes in soil chemical and physical properties resulting from soil management and environmental stress in agricultural ecosystems (Trasar-Cepeda *et al.*, 1998). Although the soil microbial biomass C (Cmic) constitutes only 1-3per cent of total soil C and the biomass N (Nmic) up to 5per cent of total soil N, they are the most labile C and N pools in soils (Jenkinson and Ladd, 1981; Saffigna *et al.*, 1989 and Bremner and Van Kessel, 1992). The objective of the present study was to determine the effect of different periods of organic over the adjacent conventional management systems on the microbial biomass carbon, microbial biomass nitrogen, and total nitrogen at two different soil depths in soils of central dry agro-climatic zone and southern dry agro-climatic zones of southern Karnataka during 2008 and 2009. The importance of micro-

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organisms in ecosystem functioning has led to an increased interest in determining soil microbial biomass (Azam *et al.*, 2003). According to Gosling and Shepherd (2005), the comparison of organically and conventionally managed systems is rather complicated and difficult due to the great overlap in management techniques.

MATERIAL AND METHODS

The study was conducted in the central dry and southern dry agro climatic zones of Karnataka, India. The central dry agro climatic zone consisting an area of 1.81 million hectares. The annual rainfall ranged between 454 and 718 mm, of which more than 55 per cent received during *Kharif* season. The elevation ranges between 450 and 900 m. The principal crops grown are ragi, sorghum, pulses and oil seeds. The southern dry agro climatic zone extends over an area of 1.74 million hectares covering the districts of Chamrajnagar, Mandya, and Mysore. The annual rainfall ranges from 671 to 899 mm. The elevation is 450-900 meters and the soils are red sandy loam in major areas. The principal crops are rice, ragi, pulses, sorghum, and oil seeds.Twenty four surface (0-15cm) and twenty four subsurface (15-30cm) soil samples with four samples each from 0-3 years, 3-6 years and > 6 years of organic farming practicing fields were collected in the central dry zone and southern dry zone of Karnataka during *Kharif* 2008 and early summer 2009. Same numbers of soil samples were collected from neighboring conventionally managed farms which were selected under similar soil type. Each pair of organic and conventional neighbours' was sampled consecutively on the same day.

The soil samples were immediately packed in polyethylene bags loosely tied and covered with wet cotton to ensure sufficient aeration and to prevent moisture loss and was stored at 4°C for estimating biochemical activities. Soil microbial biomass was estimated by fumigation and extraction method as proposed by Carter *et al.* (1999). Ninhydrin reactive N released during the fumigation of the soil was determined by using ninhydrin reagent and was used as a measure of microbial biomass. For total nitrogen, the soil samples were digested using concentrated H_2SO_4 and digestion mixture containing K_2SO_4, $CuSO_4$ and selenium (100:20:1). Nitrogen in the digest was estimated by distillation in an alkaline medium as per standard procedure (Piper, 1966). The results were analyzed by ANOVA, with organic and conventional farming as the independent variables. All statistical analyses were performed with the program SPPS 11.0 for Windows (SPSS, 2001). All values are expressed as mean values. Significant statistical differences between treatments were established by the Tukey's test at $p < 0.05$.

RESULTS AND DISCUSSION

The soil samples collected from organic and conventional farming systems under central dry and southern agro climatic zones of Karnataka recorded higher organic carbon, available N, P_2O_5, K_2O and micronutrient content in organic farming fields compared to their conventionally managed nearby fields of different periods (0-3, 3-6 and >6 years) of organic farming practice (Table 1). The results of the present study indicated that the organic carbon, available N, P_2O_5, K_2O content of soils increased due to organic matter additions in all the zones irrespective of cropping systems compared to conventional farming. Several authors namely Mathur (1997), Andrews *et al.* (2002) and Melero *et al.* (2006) also found higher available nutrients in soils treated with organics. The trends were similar in respect of the contents of DTPA extractable Fe Mn, Zn and Cu in organic and conventional farming systems over three different periods practice. The soils under organic farming recorded much higher concentration of micronutrients than soils under conventional farming. Addition of large quantities of organic manures every year under organic farming practice was the cause for such marked increase in the DTPA-extractable micronutrients. In the present study, the addition of organic amendments influenced the distribution of Cu, Mn, Fe and Zn in the different fractions by moving from the less soluble fractions to more plant-available forms .The results of the present study suggest that by yielding soluble complexes, the supply of organic composts could give rise to a more Cu, Mn, Fe and Zn after 3-6 years, and over 6 years period, the OM primarily promotes the most stable complexes. These results were in close agreement with the findings of Herencia *et al*. (2008).

Soil microbial biomass :

The soil microbial biomass carbon (SMB-C) of surface soils sourced from organic farming system under central dry agro-climatic zone ranged from 329 (0-3 years) to 487 $\mu g\ g^{-1}$ (over 6 years) during *Kharif* 2008 and 297 to 530 $\mu g\ g^{-1}$ during summer 2009, where as in conventional farming system it ranged from 176 (3-6 years) to 273 $\mu g\ g^{-1}$ (over 6 years) during *Kharif* 2008 and 118 (3-6 years) to 153 (0-3 years) $\mu g\ g^{-1}$ during summer 2009 (Table 2). An increasing trend was noticed in soil microbial biomass nitrogen (SMB-N) from 0-3 years (38.0 $\mu g\ g^{-1}$) to over 6 years (62.6 $\mu g\ g^{-1}$) of organic farming practice in central dry zone and from 0-3 years (37.5 $\mu g\ g^{-1}$) to over 6 years (154.6 $\mu g\ g^{-1}$) in soils collected from southern dry agro-climatic zone. SMB-C and SMB-N contents were relatively high in soils sampled from fields under organic farming practices than in soils sampled from conventional system during 3-6 and >6 years of practice in both central dry and southern dry agro-climatic zones of Karnataka at two depths (0-15 and 15-30cm) during *Kharif* 2008 and early summer 2009. SMB-C and SMB-N contents increased in soils of organic farming system with time of practice, but were not the same in case of conventional farming system indicating that organics stimulated greater microbial growth. The microbial biomass

Table 1 : Soil properties as influenced by organic and conventional farming systems over the years in Southern Karnataka

Soil parameter	*Management	Central Dry zone						Southern Dry zone					
		< 3 years		3- 6 years		> 6 years		< 3 years		3- 6 years		> 6 years	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Bulk density (g cm^{-3})	ORG	1.08-1.20	1.14	1.08-1.24	1.16	1.11-1.31	1.21	1.16-1.26	1.21	1.11-1.25	1.18	1.11-1.24	1.18
	CON	1.15-1.33	1.24	1.09-1.37	1.23	1.24-1.36	1.30	1.16-1.27	1.21	1.21-1.37	1.29	1.27-1.39	1.33
pH (1:2.5)	ORG	6.8-8.6	7.7	7.8-8.6	8.2	7.1-8.5	7.8	6.4-8.2	7.3	6.8-8.2	7.5	7.4-8.4	7.9
	CON	6.6-8.5	7.6	8.1-8.5	8.3	7.9-8.2	8.1	7.4-8.6	8.0	6.5-8.5	7.5	7.4-8.9	8.2
Organic Carbon (%)	ORG	0.8-1.0	0.9	1.0-1.4	1.2	1.4-1.8	1.6	0.6-1.8	1.2	1.3-1.7	1.5	1.7-1.9	1.8
	CON	0.2-0.8	0.5	0.5-0.7	0.6	0.6-1.0	0.8	0.6-1.0	0.8	0.5-1.4	0.9	0.7-1.1	0.9
Avail. N (Kg ha^{-1})	ORG	252-291	271.5	316-398	357	401-479	440	261-335	298	390-505	447.5	492-531	511.5
	CON	188-215	201.5	191-228	209.5	201-263	232	192-275	233.5	234-266	250	201-246	223.5
Avail. P (Kg ha^{-1})	ORG	9.5-17.9	13.7	10.3-15.2	12.8	15.9-30.3	23.1	8.3-27.5	17.9	13.2-26.6	19.9	18.1-27.6	22.9
	CON	4.7-18.4	11.6	4.5-9.5	7.0	4.2-6.1	5.2	5.0-21.2	13.1	10.8-15.5	13.2	10.4-15.6	13.0
Avail. K (Kg ha^{-1})	ORG	138-281	209.5	211-440	325.5	293-408	350.5	170-193	181.5	218-315	266.5	334-482	408
	CON	110-243	176.5	175-252	213.5	160-245	202.5	129-182	155.5	169-195	182	134-192	163
Avail. Zn (ppm)	ORG	0.3-0.44	0.37	0.23-1.18	0.71	0.82-1.35	1.09	0.3-0.46	0.38	0.45-0.75	0.60	0.7-2.23	1.47
	CON	0.3-0.51	0.40	0.09-0.38	0.24	0.25-0.55	0.40	0.2-0.48	0.35	0.21-0.29	0.25	0.25-0.51	0.38
Avail. Fe (ppm)	ORG	5.2-7.41	6.3	5.34-7.4	6.4	7.85-8.21	8.0	5.59-7.29	6.4	7.93-14.5	11.2	10.7-17.3	14.0
	CON	5.0-5.2	5.1	4-6.6	5.3	2.8-6.3	4.6	5.0-6.4	5.7	4.2-5.6	4.9	3.9-6.4	5.2
Avail. Cu (ppm)	ORG	1.0-1.87	1.44	1.86-2.72	2.29	2.36-4.36	3.36	1.34-2.38	1.86	1.34-4.09	2.72	2.93-4.58	3.76
	CON	1.2-1.9	1.56	1.1-1.5	1.3	1.1-2.5	1.8	1.4-2.2	1.8	0.9-2.7	1.8	0.8-2.5	1.7
Avail. Mn (ppm)	ORG	10.3-24.3	17.3	13.4-32.3	23.1	32.1-44.9	38.5	9.34-24.1	16.7	31.1-57.0	44.1	31.4-36.5	33.9
	CON	7.3-24.4	15.8	9.6-14.6	12.1	11.5-32.7	22.1	7.5-21.9	14.7	10.8-18.8	14.8	6.6-9.4	8.0

*ORG: Organic farming CON: Conventional farming contained in the organic amendments and addition of substrate-C accounted for increase in microbial biomass observed in organically fertilized soils over the years. This dual effect of organic amendments has also been reported by other authors (Schjonning *et al.,* 2002 and Melero *et al.,* 2006). Furthermore, the increase of soil microbial biomass in organically-fertilized soils could also be related to the capacity of organic matter to protect microbial biomass (Bhattacharyya *et al.,* 2005 and Cong *et al.,* 2006).

Total N :

The total nitrogen content of soils under central dry zone of Karnataka (Table 3) differed significantly in organic and conventional farming in all the three different periods of practice and in two depths during *Kharif* 2008 and summer 2009. The total-N content in surface soils of organic farming system ranged from 0.75 (0-3yrs) to 1.28 g kg^{-1} (> 6yrs) during *Kharif* 2008 and 0.74 (0-3yrs) to 1.21 g kg^{-1} (>6yrs) in summer 2009, whereas in conventional farming it ranged from 0.52 (3-6yrs) to 0.57 g kg^{-1} (> 6yrs) during *Kharif* 2008 and 0.44 (3-6yrs) to 0.51 g kg^{-1} (> 6 yrs) during summer 2009. An increasing trend was observed in total nitrogen content from 0-3 yrs to > 6yrs of organic farming, and it not so with the conventional farming in both the depths and in both the seasons. During both the seasons, the total nitrogen content in soils of southern dry zone of Karnataka differed significantly in organic and conventional farming systems. Total-N content increased from 0-3yrs to > 6yrs of organic and conventional farming and it was significantly higher in organic farming than in conventional farming. The surface soils under organic farming practice recorded higher total-N compared to conventional farming irrespective of the zone. Drinkwater *et al.* (1998) and Fliessbach *et al.* (2006) compared organic and conventional farming for different soil parameters and also found that the soil organic matter and total N contents were higher due to organic practices than conventional farming practices. An increasing trend was observed in soil total nitrogen from 0-3 yrs to > 6yrs of organic farming, and the same was not the case due to conventional farming at both depths and seasons. Several soil fertility-related factors may contribute to the control of soil borne diseases, including increased soil microbial activity, leading to increased competition, parasitism and predation in the rhizosphere (Knudsen *et al.,* 1995).

Table 2 : Soil microbial biomass carbon and nitrogen (μg g^{-1}) content of soils as influenced by organic and conventional farming systems in Southern Karnataka

			Soil microbial biomass carbon (μg g^{-1})				Soil microbial biomass nitrogen (μg g^{-1})			
			Central dry zone		Southern dry zone		Central dry zone		Southern dry zone	
Periods (P)	Season	Depth (cm)	F_1:ORG #	F_2: CON	F_1:ORG #	F_2: CON	F_1:ORG #	F_2: CON	F_1: ORG #	F_2:CON
P_1	*Kharif*	D_1	329	197	283	244	38.0	34.1	37.5	31.7
(0-3 years)	'2008	D_2	227	161	208	159	24.8	29.4	27.0	22.4
	Summer	D_1	297	153	253	178	35.4	16.4	33.2	19.4
	' 2009	D_2	221	137	201	137	23.1	13.6	23.6	15.4
P_2	*Kharif*	D_1	381	176	483	319	49.4	26.6	86.3	35.4
(3-6 years)	'2008	D_2	239	121	332	231	33.9	21.7	48.1	28.1
	Summer	D_1	390	118	494	196	52.7	14.7	90.8	20.8
	' 2009	D_2	266	102	422	188	34.4	13.9	59.0	17.1
P_3	*Kharif*	D_1	487	273	623	389	62.6	39.1	154.6	46.6
(>6 years)	'2008	D_2	363	170	455	291	44.6	27.8	111.8	33.5
	Summer	D_1	530	152	510	205	65.6	24.9	166.8	34.9
	' 2009	D_2	356	133	495	202	47.5	19.0	124.4	30.2

	Kharif' 2008			*Kharif'* 2008			*Kharif'* 2008			*Kharif'* 2008		
	F	P	D	F	P	D	F	P	D	F	P	D
F-test	*	*	*	*	*	*	*	*	*	*	*	*
S.E. ±	10.8	13.2	10.8	10.8	13.2	10.8	1.3	1.7	1.3	4.2	5.1	4.2
C.D. (P=0.05)	31.1	38.1	31.	31.1	38.1	31.1	4.0	4.9	4.0	12.1	14.8	12.1
	Summer'2009			*Summer'2009*			*Summer'2009*			*Summer'2009*		
F-test	*	*	*	*	*	*	*	*	*	*	*	*
S.E. ±	8.4	10.3	8.4	8.48	10.3	8.4	1.4	1.7	1.4	3.4	4.2	3.4
C.D. (P=0.05)	24.4	29.9	24.4	24.4	29.9	24.4	4.1	5.01	4.1	9.9	12.1	9.9

F: Farming systems (2) | P: Years (3) | D: Depth (cm) (2)
F_1- ORG: Organic farming | P_1 :0-3 Years | D_1 : 0-15
F_2- CON: Conventional framing | P_2 : 3-6 Years and P_3: > 6 Years | D_2 : 15-30
:Mean of 4 farmers | * : Significant (P=0.05) | NS: Non significant

Table 3 : Soil total N (g kg^{-1}) content of soils as influenced by organic and conventional farming systems in Southern Karnataka

			Soil total N (g kg^{-1})					
Periods (P)	Season	Depth (cm)	Central dry zone			Southern dry zone		
			F_1:ORG #		F_2: CON	F_1: ORG #		F_2: CON
P_1	*Kharif'* 2008	D_1	0.75		0.54	0.74		0.63
(0-3 years)		D_2	0.49		0.44	0.54		0.44
	Summer' 2009	D_1	0.74		0.47	0.69		0.49
		D_2	0.44		0.40	0.47		0.34
P_2	*Kharif'* 2008	D_1	0.97		0.52	1.64		0.69
(3-6 years)		D_2	0.67		0.42	0.96		0.56
	Summer' 2009	D_1	1.00		0.44	1.73		0.56
		D_2	0.66		0.36	0.9		0.45
P_3	*Kharif'* 2008	D_1	1.28		0.57	2.04		0.93
(>6 years)		D_2	0.87		0.52	1.22		0.67
	Summer' 2009	D_1	1.21		0.51	1.89		0.81
		D_2	0.85		0.44	1.18		0.57
			Kharif' 2008			*Kharif'* 2008		
			F	P	D	F	P	D
F-test			*	*	*	*	*	*
S.E.±			0.02	0.03	0.02	0.07	0.09	0.07
C.D. (P=0.05)			0.08	0.09	0.08	0.22	0.27	0.22
			Summer' 2009			*Summer'* 2009		
F-test			*	*	*	*	*	*
S.E.±			0.02	0.03	0.02	0.08	0.09	0.08
C.D. (P=0.05)			0.08	0.10	0.08	0.23	0.28	0.23

F: Farming systems (2) P: Years (3) D: Depth (cm) (2)
F_1- ORG: Organic farming P_1 :0-3 years D_1:0-15
F_2- CON: Conventional framing P_2: 3-6 years and P_3: > 6 years D_2: 15-30
:Mean of 4 farmers * : Significant (P=0.05) NS: Non-significant

Conclusion :

We found that the Microbial biomass C and Total N showed significant responses to organic and conventional farming systems. Soil microbial biomass can be regarded as a sink and source of plant nutrients. Organic systems supported a higher microbial biomass level than conventional and systems. Soil microbes from organic farming systems utilize the available resources more efficiently in terms of microbial growth rather than for maintenance. The differences in chemical analysis of variance showed that microbial biomass, and total N values were significantly (> 0.05) affected by organic and conventional management. The highest microbial biomass and Total N values were found in plots of over 6 years of organic farming practice followed by 3-6 years. The lowest Cmic and Total N values were recorded under conventional farming system and 0-3 years of organic farming practice. The current results suggested that 3 years of organic management may be a minimum to significantly and consistently enhance microbial biomass and activities that support nutrient supply for crops in the varied climatic and soil conditions and suggests that there is a biological basis to the recommended 3-year transition requirements for certification, in addition to providing consumer confidence in organic produce.

Acknowledgement :

Senior author wishes to acknowledge the financial help given by Acharya N.G. Ranga Agricultural University, Hyderabad, Andhra Pradesh, India in the form of deputation to do research on organic farming as part of his Ph.D. work at G.K.V.K, University of Agricultural Sciences, Bangalore, Karnataka, India. We also thank the farmers, NGOs, State Agriculture Department of Karnataka for their outstanding help and co-operation and for allowing us to take the soil samples from the organic farming practicing fields.

REFERENCES

Andrews, S.S., Mitchell, J.P., Mancinelli, R., Karlen, D.L., Hartz, T. K., Horwarth, W.R., Pettygrove, G.S., Scow, K.M. and Munk, D.S. (2002). On-farm assessment of soil quality in California's Central Valley. *Agron. J.*, **94** : 12-23.

Araujo, A.S.F., Santos, V.B. and Monteiro, R.T.R. (2008). Responses of soil microbial biomass and activity for practices of organic and conventional farming systems in Piaui state, Brazil. *European J. Soil Biol.*, **44** : 225-230.

Azam, F., Farooq, S. and Lodhi, A. (2003). Microbial biomass in agricultural soils-determination, synthesis, dynamics and role in plant nutrition. *Pakistan J. Biol. Sci.,* **6** : 629–639.

Bhattacharya, P., Chakrabarti, K. and Chakraborty, A. (2005). Microbial biomass and enzyme activities in submerged rice soil amended with municipal solid waste compost and decomposed cow manure. *Chemosphere,* **60** : 310-318.

Bremner, E. and Van Kessel, C. (1992). Plant-available nitrogen from lentil and wheat residues during a subsequent growing season. *Soil Sci. Soc. Am. J.,* **56**: 1155-1160.

Carter, M.R., Gregorich, E.G., Angers, D.A., Beeare, M.H., Sparling, G.P., Wardle, D.A. and Voroney, R.P. (1999). Interpretation of microbial biomass measurements for soil quality assessment in humid regions. *Can. J. Soil Sci.,* **79** : 507-520.

Cong, T.U., Jean Ristaino, B. and Shuijin, H.U. (2006). Soil microbial biomass and activity in organic tomato farming systems: Effects of organic inputs and straw mulching. *Soil Biol. Biochem.,* **38** : 247-255.

Drinkwater, L.E., Wagoner, P. and Sarrantonio, M. (1998). Legume based cropping systems have reduced carbon and nitrogen losses. *Nature,* **396** : 262-265.

Fliessbach, A., Oberholzer, H.R., Gunst, L. and Ma¨der, P. (2007). Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. *Agric. Ecosys. Environ.,* **118** : 273-284.

Gosling, P. and Shepherd, M. (2005). Long - term changes in soil fertility in organic arable farming systems in England, with particular reference to phosphorus and potassium. *Agric., Ecosys. & Environ.,* **105** : 425-432

Herencia, J.F., Ruiz-porras, J.C., Morillo, E., Melero, S., Villaverde, J. and Maqueda, C. (2008). The effect of organic and mineral fertilization on micronutrient availability in soil. *Soil Sci.,* **173** : 69-80.

Jenkinson, D.S. and Ladd, J.N. (1981). *Microbial biomass in soil; measurement and turnover.* In: Paul, E.A., Ladd, J.N. (*eds*) Soil biochemistry, 5. Decker, New York, pp. 415-417.

Knudsen, I.M.B., Debosz, K., Hockenhull, .J., Jensen, D.F. and Elmholt, S. (1995). Suppressiveness of organically and conventionally managed soils towards brown foot rot of barley. *Appl. Soil Ecol.,* **12** : 61-72.

Mathur, G.M. (1997). Effect of long-term application of fertilizers and manures on soil properties and yield under cotton-wheat rotation in north-west Rajashtan. *J. Indian Soc. Soil Sci.,* **45** : 288-292.

Melero, S., Ruiz porras, J.C., Herencia, J.F. and Madejón, E. (2006). Chemical and biochemical properties in a silty loam soil under conventional and organic management. *Soil Tillage Res.,* **90**:162-170.

Saffigna, P.G., Powlson, D.S., Brookes, P.C. and Thomas, G.A. (1989). Influence of sorghum residues and tillage on soil organic matter and soil microbial biomass in an Australian Vertisol. *Soil Biol. Biochem.,* **21**: 759–765.

Schjonning, P., Elmholt, S., Munkholm, L.J. and Debosz, K. (2002). Soil quality aspects of humid sandy loams as influenced by organic and conventional long-term management. *Agric. Ecosyst. Environ.,* **88**:195-214.

SPSS. (2001). SPSS for Windows, Rel. 11.0.1. SPSS, Chicago.

Trasar-Cepeda, C., Leiros, C., Gil- Sotres, F. and Seoane, S. (1998). Towards a biochemical quality index for soils: an expression relating several biological and biochemical properties, *Biol. Fertile. Soils,* **26** : 100-106.