Journal of Agricultural Technology 2010 Vol.6(3): 599-606
Available online http://www.ijat-rmutto.com
ISSN 1686-9141

Soil microbial biomass responses to seasonal change, soil depth and tillage method

Zarea, M.J.* **and Rahshidi, Z.**

Faculty of Agriculture, Ilam University, Ilam, Iran.

Zarea, M.J. and Rahshidi, Z. (2010). Soil microbial biomass responses to seasonal change, soil depth and tillage method. Journal of Agricultural Technology 6(3): 599-606.

Although considerable literature exists on microbial and soil chemical changes under various tillage methods, little information exists on these changes under dry land farming conditions and different soil layer to a cessation in tillage. This experiment was conducted to determine the effects of three tillage systems on soil microbial biomass carbon (SMBC), soil microbial biomass N (SMBN) and Soil respiration (SR) during the wheat (*Triticum aestivum*) growing seasons on a clay-loam soil in the west region of Iran. The three tillage treatments were: (1) conventional tillage (CT), with moldboard ploughing followed by harrowing once with a springtine harrow; (2) reduced tillage (RTC), with ducksfoot cultivator with a springtine harrow, and (3) with moldboard ploughing with the moldboard detached (RT). Averaged between depths, SMB, SMBN and SR were not differing under NT compared with CT, while RTC and RT had greater SMB, SMBN and SR in spring. SMB, SMBN and SR showed a higher rate under CT in mid fall (Wheat tillering growth stage) but in spring, NT had the higher rate SMB, SMBN and SR in surface soils. Thus, SMB, SMBN and SR alteration response to tillage methods was depended on soil depth and seasonal change.

Key words: conventional tillage, reduced tillage, soil microbial biomass carbon, soil microbial biomass N, Soil respiration

Introduction

The semiarid region encompasses a wide variety of agricultural systems where water is probably one of the main keys to productivity. Yield of dryland semiarid crops is usually low and widely variable due to high seasonal variability of rainfall. Conventional tillage with mouldboard ploughing is commonly used in some semiarid region of undevelopment countries and developing countries. For example shallow and reduced tillage, which are practices often included under the broad terminology of ‘‘conservation tillage’’ (Sprague and Triplett, 1986), have lately been introduced in the Mediterranean regions northwest of Turkey (Ozpinar, 2006). Yet, and in Iran, prefer tillage is

*Corresponding author: Mohammad Javad Zarea; e-mail: mjzarea@ymail.com

commonly mouldboard ploughing. Major crop of dryland semiarid crops is usually Cereal grain. Cereal grain response to conservation tillage practices is variable (Rao and Dao, 1996). Higher yield is usually attributed to increased water conservation or utilization by the crop, especially in arid and semi-arid regions; lower yield is attributed to greater disease and weed infestations and N immobilization (Lo´pez-Bellido *et al.*, 1996; McMaster *et al.*, 2002). However, residue retention by conservation tillage such as shallow or reduced tillage practices can, over the long term, improves soil structure and nutrient cycling. These desirable outcomes of crop rotation with such tillage practices have been reported extensively for mainly temperate environments (Karlen *et al.*, 1994; Lal, 1989). May yield be equal or lower in conservation tillage than conventional poughing in short term but it can, over the long term, improve soil structure, nutrient cycling and soil biota. However, a deterrent for growers considering the transition to conservation tillage is the delay in soil response (e.g. increased soil carbon, efficient nutrient cycling, impacts on yield) associated with the equilibration of the soil food web (Phatak *et al.*, 1999; Simmons and Coleman, 2008) but subsurface can respond quickly to a cessation in tillage than surface soil (Simmons and Coleman, 2008). Also evidence indicate that belowground food webs can respond quickly to a cessation in tillage suggests that the delay in soil response may be due more to the time required to build organic matter than to a slow response by the biota (Simmons and Coleman, 2008).

The objective of this study that conducted under dryland semiarid crop was to determine the effect of minimum tillage (MT) and conventional tillage (CT) for 0–5 and 5–15 cm depths on soil microbial biomass carbon (SMBC), soil microbial biomass N (SMBN) and Soil respiration (SR) under the wheat (*Triticum aestivum* L vr. Sardari).

Material and methods

The field is located on the experimental farm of Ilam University at 31° 58′ N and 45° 24′ E. with a sandy loam texture. This soil is with approximately 356 mmannual precipitation. The rainfall is restricted to six months a year, from November to January, with negligible rainfall during spring and no rainfall in summer (May–August). The experimental design was a split-plot design with three randomized complete blocks, with the main plot treatments with three tillage practices implemented for one year under winter wheat were: (i) conventional tillage (CT), with moldboard ploughing to 25–28 cm depth followed by harrowing once with a springtine harrow to about 4–6 cm depth with wheat residue removed in the field; (ii) reduced tillage (RTC), with ducksfoot cultivator with a springtine harrow to 4 to 6 cm depth with 70%

wheat residue retained in the field, and (iii) with moldboard ploughing with the moldboard detached and 35% (RT) wheat residue retained in the field. Full fertility plots were fertilized according to soil test recommendations. Seed broadcasting and subsequence followed by harrowing to about 4–6 cm depth secondary tillage for seed incorporation into soil. To investigate the effects of treatments on soil biological activity, three times during the growing season (26 April–6 October) including before tillage practices (fall), wheat tillering growth stage (mid fall) and spring. Soil samples for microbial biomass (100–125 g) were taken from the 0-5 and 5–15 cm depths. For each soil sample, soil microbial C (SMBC) According to Horwath and Paul (Horwath and Paul, 1994) and soil microbial N (SMBN) were determined as in Brookes *et al.* (1985a) and Brookes *et al.* (1985b). Soil respiration (SR) measurements as described in Anderson (Anderson, 1982).

The analysis of variance (ANOVA) was based for a split-plot randomized complete block design. All measured variables were assumed to be normally distributed and statistical analysis by ANOVA was performed using SAS software (SAS, 1990). The significance of the differences between treatments was estimated using the LSD range test, and a main effect or interaction was deemed significant at $P < 0.05$.

Results

There was no significantly more SMBC, SMBN and SR under RT or RTC when compared with the conventional tillage except for spring that RTC had significantly more SMBC and SMBN (Table 1, 2 and 3). There was no significant more response of SR to tillage method (Table 3). However, SR was not significantly different, but greater amounts were seen in the spring compared to fall. The SMBC and SMBN were significantly greater in the spring compared with the fall. For 0-15 cm depth, SMBC, SMBN and SR were greater when compared to 0-5 cm depth for different times (Table 1, 2 and 3). Minimum and maximum rate of SMBC, SMBN and SR obtained from in the mid fall and spring treatments compared to the fall sampling, respectively. Averaged over locations and fall sampling times, SMBC, SMBN and SR in the 5- 15cm layer was significantly more under reduced tillage (RT or RTC) and CT compare to 0-5 cm layer (Table 4, 5 and 6).

At late fall, the effect of treatment on SMBC, SMBN and SR revealed some common patterns. The most significant more SMBC, SMBN and SR were in the 5- 15cm layer under reduced tillage (RT or RTC), except for CT that rate of SMBC, SMBN and SR were the equal for different soil depths (Table 4, 5 and 6). At spring result were versus the mid fall. At this time SMBC, SMBN and SR in the 5- 15cm layer was nearly constant under RT or

RTC from 0-5 and 5-15. SMBC, SMBN and SR were significant more for 5-15 compared with 0-5 cm layer (Table 4, 5 and 6).

Table 1. Soil microbial biomass C for 0–5 and 5–15 cm depths associated as affected by soil depth and tillage regime.

Treatment	Seasonal sampling		
	Autumn (before planting)	Autumn (Tillering)	Spring
CT	223.1	263.8	246.8
RTC	225.5	280.5	305.5
RT	215.6	225.4	247.4
0-5	209.4	246.2	241.2
0-15	233.3	266.9	291.9
LSD ($P < 0.05$)	<32.2 (tillage*); 14.73 (depth*)	<55.2 (tillage*); 3.44 (depth*)	<56.2 (tillage*); 4.87 (depth*)

CT = conventional tillage with moldboard ploughing, RTC = reduced tillage with ducksfoot cultivator, RT = moldboard ploughing with the moldboard detached, *significant effects at $P < 0.05$.

Table 2. Soil microbial biomass N for 0–5 and 5–15 cm depths associated as affected by soil depth and tillage regime.

Treatment	Seasonal sampling		
	Fall (before planting)	Autumn (Tillering)	Spring
CT	17.5	21.9	24.6
RTC	17.7	23.3	30.5
RT	16.9	18.7	24.7
0-5	16.4	20.5	24.1
0-15	18.3	22.2	29.1
LSD ($P < 0.05$)	<2.53 (tillage*); 1.16(depth*)	<4.6 (tillage*); 0.28 (depth*)	<5.52 (tillage*); 0.34 (depth*)

CT = conventional tillage with moldboard ploughing, RTC = reduced tillage with ducksfoot cultivator, RT = moldboard ploughing with the moldboard detached, *significant effects at $P < 0.05$.

Table 3. Soil respiration for 0–5 and 5–15 cm depths associated as affected by soil depth and tillage regime.

Treatment	Seasonal sampling		
	fall (before planting)	Mid fall (Tillering)	Spring
CT	0.17	0.25	0.23
RTC	0.17	0.31	0.22
RT	0.18	0.22	0.23
0-5	0.16	20.5	0.21
0-15	0.19	22.2	0.24
LSD (P < 0.05)	<0.025 (tillage*); 0.01(depth*)	<0.14 (tillage*); 0.28 (depth*)	<0.025 (tillage*); 0.008 (depth*)

CT = conventional tillage with moldboard ploughing, RTC = reduced tillage with ducksfoot cultivator, RT = moldboard ploughing with the moldboard detached, *significant effects at P < 0.05.

Table 4. Effect of tillage systems on soil microbial biomass C.

Depth (mm)	Fall (before planting)			Mid fall (wheat tillering growth stage)			Spring		
	CT	RTC	RT	CT	RTC	RT	CT	RTC	RT
0-5	212b	213b	202b	262.9a	263b	212.7b	203.9b	288a	231.7a
5-15	233a	238a	228a	264.6a	298a	238.1a	289.6a	323a	263.1a

CT = conventional tillage with moldboard ploughing, RTC = reduced tillage with ducksfoot cultivator, RT = moldboard ploughing with the moldboard detached, *significant effects at P < 0.05. data shows no changes that occurred after growing wheat under RT, RTC or CT.

Table 5. Effect of tillage systems on soil microbial biomass N.

Depth (mm)	Fall (before planting)			Mid fall (wheat tillering growth stage)			Spring		
	CT	RTC	RT	CT	RTC	RT	CT	RTC	RT
0-5	16.7b	16.7b	15.9b	21.9a	21.9b	17.7b	20.3b	28.8a	23.1a
5-15	18.3a	18.7a	18a	22a	24.8a	19.8a	28.9a	32.3a	26.3a

CT = conventional tillage with moldboard ploughing, RTC = reduced tillage with ducksfoot cultivator, RT = moldboard ploughing with the moldboard detached, *significant effects at P < 0.05. data shows no changes that occurred after growing wheat under RT, RTC or CT.

Table 6. Effect of tillage systems on soil respiration.

Depth (mm)	Fall (before planting)			Mid fall (wheat tillering growth stage)			Spring		
	CT	RTC	RT	CT	RTC	RT	CT	RTC	RT
0-5	0.16b	0.16b	0.17b	0.25a	0.29b	0.22b	0.21b	0.22b	0.22b
5-15	0.18a	0.19a	0.19a	0.25a	0.3a	0.23a	0.23a	0.24a	0.25a

CT = conventional tillage with moldboard ploughing, RTC = reduced tillage with ducksfoot cultivator, RT = moldboard ploughing with the moldboard detached, *significant effects at P < 0.05. data shows no changes that occurred after growing wheat under RT, RTC or CT.

Discussion

Tillage practices did not affect SMBC as well as SMBN till spring. Lynch and Panting (Lynch and Panting, 1980; Lynch and Panting, 1982) showed that SMB in the surface layer (0–15 cm) under both direct-drilled (NT) and ploughed (CT) wheat (*Triticum aestivum* L.) was nearly constant from autumn to spring, and increased to a maximum during the summer, then declined to about the autumn concentration. At spring there was more SMBC and SMBN under RTC however indicated that the transition to conservation tillage is the delay in soil response (e.g. increased soil carbon, efficient nutrient cycling, and impacts on yield). Tillage had significant effects on SMBC and SMBN, with RTC having greater SMBC than CT. This may be that NT improved soil organic matter (data not shown) storage and hence it increases SMBC and SMBN levels of soils. Agricultural practices such as CT have been shown to increase decomposition when compared with NT systems (Guggenberger *et al.,* 1999). However, tillage had no significant effects as SMBC and SMBN till spring. Another reason to increase on SMBC and SMBN under RTC combined with crop residue retention on the soil surface, may can related to improve moisture infiltration and greatly reduce erosion and enhance water use efficiency compared to CT (Johansson *et al.,* 2004; Shaver *et al.,* 2002). Previous research indicated that microbial biomass would be greatest in the spring, due to increased soil carbon and residue from the winter cover crop exploited by microbes (Adl *et al.,* 2006). Crecchio *et al.* (2007) argue that microbial response to tillage is minimal and that incorporation of residues is sustainable practice.

Result showed more SMBC, SMBN and SR in the 5- to 15-cm layer compared with 0- to 5-cm layer. Precipitation was an important factor in evaluating SMBC and SMBN under dryland regions. In this area surface layer prone to evaporation and it may prevents to create a suitable climate for evolution of SMBC, SMBN under surface layer. At fall (before tillage practices), SMBC, SMBN and SR were greater at 5-15 cm under reduced tillage (RT or RTC) or CT may due to undisruption nich or habitat of microorganism. At mid fall, after tillage practices, layers of 0-5 cm and 5-15 cm had nearly the same pattern on SBMC, SBMN and SR distribution in soil profile. When the surface soil of this semiarid region that is not richer of microorganism incorporated into the soil by plowing and replaced with the subsurface soil cause to a regular distribution pattern on SMBC, SMBN and SR at soil layers.

At spring under RT or RTC, SMBC and SMBN were similar for different soil depths that indicated by supporting higher soil water content and organic matter compared to CT (data not shown), a new nich for microorganism is created. This experiment showed that conservational tillage under semiarid regions that plants subjected to several limited factor such as water and nutrient, affected soil biological according to the depth of soil. Results showed that subsurface can respond to a cessation in tillage than surface soil. This evidence indicated that surface layer can create a new nich under RTC that is respond to a cessation in tillage. However it may need more to the time required to build organic matter than to a slow response by the biota. Semi-arid and arid regions imply prolonged dryness, and are used with respect to the climate itself, and the land below it. In such regions the ability to produce agricultural crops is restricted. Usually on semiarid lands the potential evaporation of water from the land is high and soil prone erosion. Because of the low rainfall and consequently reduced plant growth, organic material is produced slowly. Yet, again because of low rainfall, it may be broken down slowly as well. Tillage results in soil erosion, loss of organic matter, decreased water infiltration, loss of soil structure, decreased soil fertility and a reduction in overall soil quality due to the destruction of soil aggregates and structure (Nyakatawa *et al.*, 2007) that can more under dry land farming. Tillage increases decomposition of crop residues and changes the structure of the soil food web by relocating food resources and exposing protected carbon (Wardle, 1995; Six *et al.*, 2002). However mostly studies indicated there is long term response of soill to conservation tillage but it seems that this response are more complication. Some responses as subsurface are quickly to tillage accessing (Simmons and Coleman, 2008) and others take a long term. In this study response of soil microbial that is important engine of soil depended on soil layer and season.

References

Adl, S.A., Coleman, D.C. and Reed, F. (2006). Slow recovery of soil biodiversity after 25 years of no-tillage management. Agric. Ecosyst. Environ. 114: 323–334.

Anderson, J.P.E. (1982). Soil respiration. In: Page, A.L. (Ed.), Methods of Soil Analysis, Part 2, Chemical and microbiological properties. Agronomy Monograph No. 9, 2nd Edition. ASA-SSSA, Madison, WI.

Brookes, P.C., Kragt, J.F., Powlson, D.S. and Jenkinson, D.S. (1985a). Chloroform fumigation and the release of soil nitrogen: the effects of fumigation time and temperature. Soil Biol. Biochem. 17: 831–836.

Brookes, P.C., Landman, A., Pruden, G. and Jenkinson, D.S. (1985b). Chloroform fumigation and the release of soil nitrogen: a direct extraction method to measure microbial biomass nitrogen in soi. Soil Biol. Biochem. 17: 837–842.

Crecchio, C., Curci, M., Pellegrino, A., Ricciuti, P., Tursi, N. and Ruggiero, P. (2007). Soil microbial dynamics and genetic diversity in soil under monoculture wheat grown in different long-term management systems. Soil Biol. Biochem. 39: 1391–1400.

Guggenberger, G., Frey, S.D., Six, J., Paustian, K. and Elliot, E.T. (1999). Bacterial and fungal cell-wall residue in conventional and no-tillage agroecosystems. Soil Sci. Soc. Am. J. 63: 1188–1198, Horwath, W.R. and Paul, E.A. (1994). Microbial biomass. In: Weaver, R.W., Angle, J.S., Bottomley, P.S. (Eds.), Methods of Soil Analysis, Part 2: Microbiological and Biochemical Properties", Soil Science Society of America, Madison, pp. 753–771.

Johansson, J.F., Paul, L.R. and Finlay, R.D. (2004). Microbial interactions in the mycorrhizosphere and their significance for sustainable agriculture", FEMS Microbiology Ecology 48: 1–13.

Karlen, D.L., Varvel, G.E., Bullock, D.G. and Cruse, R.M. (1994). Crops rotations for the 21st century. Adv. Agron. 53: 1–45.

Lal, R. (1989). Agroforestry systems and soil management of a tropical alfisol. IV. Effects of soil physical and soil mechanical properties", Agrofor. Syst. 8: 197–215.

Lo´pez-Bellido, L., Fuentes, M., Castillo, J.E., Lo´pez-Garrido, F.J. and Fernandez, E.J. (1996). Long-term tillage, crop rotation, and nitrogen fertilizer effects on wheat yield under Mediterranean conditions. Agron. J. 88: 783–791

Lynch, J.M. and Panting L.M. (1980). Cultivation and the soil biomass", Soil Biol. Biochem. 12: 29–33.

Lynch, J.M. and Panting, L.M. (1982). Effects of season, cultivation and nitrogen fertilizer on the size of the soil microbial biomass. J. Sci. Food Agric. 33: 249–252.

McMaster, G.S., Palic, D.B., Dunn G.H. (2002). Soil management alters seedling emergence and subsequent autumn growth and yield in dryland winter wheat-fallow systems in the central Great Plains on a clay loam soil. Soil Till Res. 65: 193–206.

Nyakatawa, E.Z., Reddy, K.C. and Mays, D.C. (2000). Tillage, cover cropping and poultry litter effects of cotton II Growth and Yield parameters. Agron. J. 92: 1000–1007.

Ozpinar S. (2006). Effects of tillage on productivity of a winter wheat-vetch rotation under dryland Mediterranean conditions. Soil & Tillage Research 89: 258–26.

Phatak, S.C., Reed, R., Fussell, W., Lewis, W.J. and Harris, G.H. (1999). Crimson clover cotton relay cropping with conservation tillage system. In: Hook, J.E. (Ed.), Proceedings of the 22nd", Annual Southern Conservation Tillage Conference for Sustainable Agriculture, Tifton, GA, pp. 184–188.

Rao, S.C. and Dao, T.H. (1996). Nitrogen placement and tillage effect on dry matter and nitrogen accumulation and redistribution in winter wheat, Agron. J. 88: 365–371.

SAS. (1990). SAS Procedure Guide. Version 6, 3rd Edition. SAS Institute, Cary, NC, 705 pp.

Shaver, T.M., Peterson, G.A., Ahuja L.R., Westfall D.G., Sherrod L.A., Dunn G. (2002). Surface soil properties after twelve years of dryland no-till management. Soil Sci. Soc. Am. J. 66:1292–1303.

Simmons, B.L., Coleman, D.C. (2008). Microbial community response to transition from conventional to conservation tillage in cotton fields. Applied soil ecology 40:518-528.

Six, J., Feller, C., Denef, K., Ogle, S.M., de Moraes Sa, J.C., Albrecht, A. (2002). Soil organic matter, biota and aggregation in temperate and tropical soils—effects of notillage", Agronomie 22:755–775.

Sprague, M.A. and Triplett, G.B. (1986). No Tillage and Surface -Tillage Agriculture, Wiley, New York, NY.

Wardle, D.A. (1995). Impacts of disturbance on detritus food webs in agro-ecosystems of contrasting tillage and weed management practices. Adv. Ecol. Res. 26: 105–185.

(Received 29 September 2009; accepted 12 May 2010)