Tropical Ecology **41**(1): 123-126, 2000
ISSN 0564-3295

Implications of tillage and residue management on soil microbial biomass, N-mineralization rate and available-N in a dryland agroecosystem

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Key words : Available-N, microbial biomass, N-mineralization rate, residue retention, tillage reduction

In dryland (rainfed) agroecosystems excessive tillage and crop residue removal leads to biological degradation of soil which in turn results in decreased crop production. In recent years interest in conservational tillage has increased because of the potential of this practice to reduce soil erosion, conserve soil moisture and improve soil fertility (CTIC 1994). Inputs of organic materials like crop residues offer sustainable and ecologically sound alternative for meeting the N requirement of crops. Presence of low quality crop residues often extends the time period of availability of soil N to the crop plants in dryland farming conditions through the initial immobilization of N in the microbial biomass. Acting as a reservoir of critical nutrients (Smith & Paul 1990), microbial biomass serves as a major determinant of nutrient availability and thereby of soil fertility. Under upland field conditions microbial biomass may practically act as slow release fertilizer. The suitability of crop residues as a source of N depends to a great extent on the mineralization of its N in relation to the crop demand. Crop productivity is strongly influenced by nutrient availability in soil and the N-mineralization rate is a crucial process of nutrient dynamics. There is a need to understand the impact of practices combining tillage and residue input variations on the biological processes involved in the maintenance of soil fertility in agroecosystems. This study assesses the impact of tillage reduction and crop residue retention on the levels of microbial biomass, N-mineralization rate and available-N in a tropical dryland agroecosystem. Such information is scarce in dryland agroecosystems in India, which account for ca. 70% of the cultivated land in the country.

The experiment was carried out at the Dryland Farm at the Institute of Agricultural Sciences, Banaras Hindu University (25°18 N lat. and 83°1 E long., above 76 m msl). The soil of study site is an inceptisol with a flat topography, pale brown colour, and sandy loam texture. The region has a tropical moist sub-humid climate, characterized by strong seasonality with respect to temperature and precipitation. The summer (April-June) is dry and hot with temperatures ranging between 35 to 45°C during the day. Warm conditions (25-35°C) and high relative humidity (70-91%) prevail during the rainy season (July-September). In the winter season (November-February) temperature falls between 10 and 25°C. Of the total annual rainfall during the study period (1287 mm) more than 85% occurred within the rainy season. The rainy and winter seasons are the major cropping seasons in this region where rice based crop rotation is most common.

The experiment was designed to vary the amount of organic input through crop residue retention from the previous crop to the next crop, and the soil disturbance in the form of different tillage practices (conventional-minimum - and zero tillage). Rice was grown during the rainy season in 1997, and at time of its harvest in November, six treatments with three replicates (each 9 m x 10 m plot size) were established in a randomized block design. A strip of 1 m was left to separate each treatment block. The treatments were : (a)

Conventional tillage (disked twice, cultivated once to 20 cm depth) and residue removed (CT-R); (b) Conventional tillage (as above) and residue retained (CT+R); (c) Minimum tillage (disked once, cultivated once to 10 cm depth) and residue removed (MT-R); (d) Minimum tillage (as above) and residue retained (MT+R); (e) Zero tillage (no cultivation other than the disturbance caused by the planting tines) and residue removed (ZT-R); (f) Zero tillage (as above) and crop residues retained (ZT+R). In the residue retained plots, harvesting of rice was done 20 cm above the ground leaving a portion of crop biomass standing in the plot. The rice biomass thus retained was incorporated in soil during the tillage operations (either conventional or minimum tillage) before sowing of barley (October 1997). In case of zero tillage the standing crop biomass left in the plot was chopped at the bottom at the time of first tillage operation in conventional and minimum tillage plots and the cut material was left on the soil surface. After harvesting barley in 1998, the same six treatments with barley shoot residue were again established for the succeeding rice crop. The amount of crop residue retained at the time of rice harvesting for barley crop period in all residue retained treatments (CT+R, MT+R, ZT+R) was 6825 358 kg ha^{-1}. At barley harvest the residue retained for the succeeding rice crop was 5831 495, 6687 308, and 3750 508 kg ha^{-1} in CT+R, MT+R and ZT+R treatments, respectively; these differences were due to the variation in the standing crop biomass. The composition of residues retained was : rice, C 49.1 0.52%, N 0.602 0.025%; barley, C 48.9 0.53%, N 0.622 0.020%. The NPK chemical fertilizer was applied in all treatments at the time of crop sowing (80 kg N ha^{-1}, 40 kg P ha^{-1} and 30 kg K ha^{-1} for rice and 60 kg N ha^{-1}, 40 kg P ha^{-1} and 30 kg K ha^{-1} for barley).

Microbial biomass C and N, available-N and N-mineralization rate were estimated six times, once during seedling, grain-forming, and maturity stages of barley as well as rice crops. Three subsamples of soil (0-10 cm depth) from each replication plot were collected, sieved (2 mm mesh), composited and analysed separately. Microbial biomass carbon (MBC) and nitrogen (MBN) were measured by Chloroform Fumigation Extraction Method (Vance *et al.* 1987; Brookes *et al.* 1985). Fresh field moist and sieved (2 mm) samples were used for the determination of available-N (nitrate-N and ammonium-N) concentrations. Nitrate-N was measured by the phenol disulphonic acid method, using CaSO$_4$ as the extractant (Jackson 1958). Ammonium-N was extracted by 2 M KCl and analysed by the phenate method (APHA 1995). N-mineralization rate was measured by buried bag technique (Eno 1960). Statistical analysis was done using SPSS/PC$^+$. Treatment means were compared using the LSD range test procedure at the 5% level of significance.

The levels of soil microbial biomass responded rapidly to various treatments. Soil MBC ranged 226-395 and 245-460 g g^{-1} in different treatments in barley and rice crop, respectively (Fig. 1). In both crops minimum MBC was recorded in CT-R (control) and the maximum in MT+R treatment. Incorporation of residue in the soil with conventional tillage (CT+R) increased the levels of MBC about 47% over control in both crops. Tillage reduction in association with incorporation of retained residue in soil (MT+R) increased MBC 75% and 88% over control in barley and rice, respectively. However, tillage reduction in association to surface application of retained residue (ZT+R) increased MBC by only 35-37% over control. In both crops minimum increases (13-22% over control) in the levels of MBC were recorded in treatments comprising of tillage reduction alone (MT-R, ZT-R). These enhancements in the MBC obtained may be compared with 77% increases of MBC in straw+fertilizer and 51% increase in straw treatment under reduced tillage in a dryland agroecosystem reported by Singh & Singh (1993). In an Australian vertisol, Saffigna *et al.* (1989) reported 15-27% increases in the levels of MBC following straw incorporation alone and along with zero tillage. The differences in decomposition rates of crop residue were responsible for the variation in the levels of microbial biomass (Schnurer *et al.* 1985).

Soil MBN levels in different treatments ranged 23-45 and 25-53 g g^{-1} in barley and rice, respectively (Fig. 1). In both crops the minimum levels of MBN were recorded in CT-R treatment and maximum in MT+R treatment. In both crops incorporation of retained residue with conventional tillage (CT+R) increased the levels of MBN in the soil by 59-61% over control. Tillage reduction with residue incorporation (MT+R) resulted in the maximum increase (92-112% over control) in the levels of MBN. Zero tillage with surface application of retained residue (ZT+R) showed lesser increase (28-31% over control) in MBN. In both crops mini-

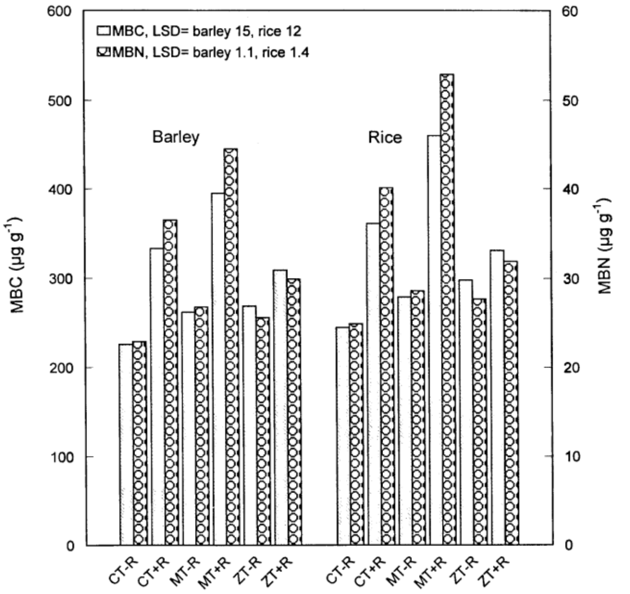

Fig. 1. Variations in the mean levels of soil microbial biomass C and N (g g^{-1}) in barley and rice under different tillage and residue treatments; values are mean of three samplings; LSD shown at 5% level of significance.

mum enhancements (11-17% over control) were recorded with tillage reduction alone (MT-R, ZT-R). Singh & Singh (1993) reported 77% and 84% increases in the levels of MBN under straw+ fertilizer and straw treatments, respectively, in a dryland agroecosystem. Much lesser increase (18-22%) in MBN was reported by Saffigna *et al.* (1989) in treatments involving straw or straw input plus zero tillage in an Australian vertisol.

N-mineralization rate in different treatments ranged 13.3-17.5 and 15.3-19.9 g g^{-1} month^{-1} in barley and rice, respectively (Fig. 2). In both crops minimum N-mineralization rates were recorded in ZT-R treatment and maximum in MT+R treatment. In both crops incorporation of retained crop residue in the soil with conventional tillage (CT+R) increased the rate of N-mineralization in barley and rice crops (16-24% over control, respectively). Tillage reduction in association with soil incorporation of retained crop residue (MT+R) increased (by 28-39% over control) the rate of N-mineralization. However, tillage reduction with surface application of retained crop residue (ZT+R) decreased (12% relative to control) N-mineralization rate in barley period, but only marginally increased (3% over control) the same during rice period. In both crops ZT-R treatment significantly decreased (by 23-24% relative to control) the rate of N-mineralization. It has been reported that incorporated crop residue shows 1.5 times faster decomposition rates than surface applied crop residues, and the residue incorporated in soil immobilizes less and mineralizes more nutrients compared to surface placed residue (Douglas & Rickman 1992). In zero tillage accumulation of crop residue and nutrients such as N at or near the soil surface restricts N-mineralization rate in the soil (Chamen & Parkins 1995).

The levels of soil available-N in different treatments ranged 7.8-15.6 g g^{-1} in barley and 7.8-16.6 µg g^{-1} in rice (Fig. 2). Minimum available-N values corresponded to ZT-R and the maximum to MT+R treatment. Generally the soil available-N concentrations followed the same pattern as of N-mineralization rate.

The retention of crop residue in all tillage conditions showed significant positive correlations of both MBC and MBN contents with N-mineralization rate and with available-N content (Table 1). In sharp contrast, these relationships in residue removed treatments were non-significant. Notable were the high correlations between MBN and N-mineralization rate (r = 0.94-0.95). These observations evidently show the direct effect of the previous crop residue on the enhanced microbial biomass status and N cycling processes of the succeeding crop. In the rice based dryland

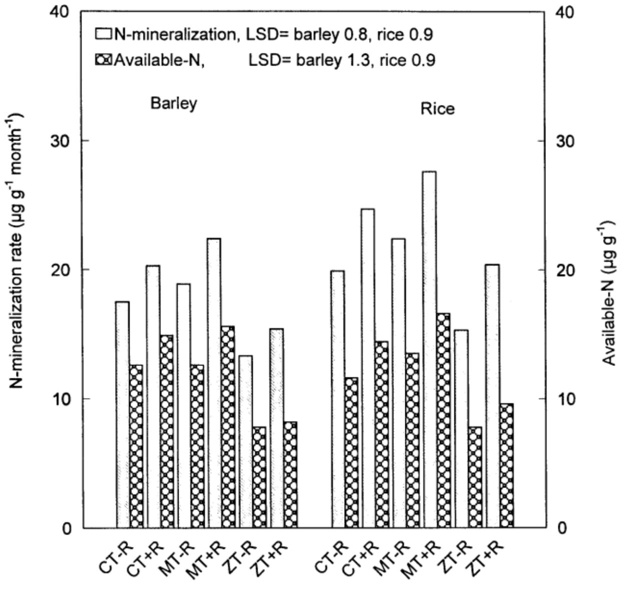

Fig. 2. Variations in the mean N-mineralization rate (g g^{-1} month^{-1}) and mean available-N (g g^{-1}) levels in soil in barley and rice under different tillage and residue treatments; values are mean of three samplings; LSD shown at 5% level of significance.

Table 1. Correlation and regression analyses contents (based on 3 treatments and 3 replicates, n = 9) reflecting relationships of soil MBC and MBN with N-mineralization rate and available-N in residue retained and removed conditions of different tillage systems in a tropical dryland agroecosystem.

Parameters		Residue retained			Residue removed		
x	y	a	b	r	a	b	r
Barley							
MBC^1	N-mineralization^2	-5.30	0.07	0.87**	28.36	-0.05	0.38^{NS}
MBN^1	N-mineralization^2	2.10	0.46	0.94**	15.69	0.04	0.01^{NS}
MBC^1	Available-N^1	-11.20	0.69	0.74*	26.51	-0.06	0.56^{NS}
MBN^1	Available-N^1	-5.11	0.48	0.86*	15.59	-0.19	0.14^{NS}
Rice							
MBC^1	N-mineralization^2	5.68	0.05	0.89**	37.41	0.07	0.50^{NS}
MBN^1	N-mineralization^2	10.92	0.33	0.95**	14.86	0.15	0.08^{NS}
MBC^1	Available-N^1	-4.19	0.50	0.86*	25.64	-0.05	0.48^{NS}
MBN^1	Available-N^1	0.24	0.32	0.93**	7.18	0.14	0.09^{NS}

^{1} expressed as g g^{-1}; ^{2}expressed as g g^{-1} mo^{-1}.

* significant at P>0.05; **significant at P>0.001; ^{NS} not significant.

agroecosystem studied, post-harvest retention of about 20 cm shoot biomass of the previous crop and its incorporation in soil through minimum tillage in the succeeding crop may be suggested as an ecological approach towards maintaining high soil fertility.

Acknowledgements

We thank the Head and the Programme Coordinator, Centre of Advanced Study in the Department of Botany, for providing laboratory facilities, and Prof. S.R. Singh, Institute of Agricultural Sciences, B.H.U. for providing experimental plots and other field facilities in the Dryland Farm.

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