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Short Communication

Short-Term Contribution of Mineral N from Soil Organic Matter during the Rainy Season in a Vertisol of the Semi-Arid Tropics of Sudan

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ABSTRACT

This study was conducted to monitor the effect of tillage on potentially mineralizable nitrogen during the growing season of rain-fed sorghum (*Sorghum bicolor*). Two sites (with conventional tillage & traditional tillage) located southern central clay plain were selected. Auger soil samples were taken from the 0-30 and 30-60 cm soil depths every two weeks during the rainy season. Results showed that content of total mineral nitrogen (NH^{+}_{4}-N+NO^{-}_{3}-N) in traditional tillage was significantly higher than that obtained under conventional tillage. Accordingly, mineral nitrogen under traditional tillage determined after 2, 4, 6, 8 and 10 weeks were 366.2, 217.78, 206.12, 202.86, 189.8 kg ha^{-1}, respectively. Respective values for conventional tillage were 139.01, 160.34, 166.13, 177.18, 212.08 kg ha^{-1}. This possibly reflects the effects of accumulation of undisturbed crop residues in traditional tillage, thereby, securing more N. Therefore, traditional tillage system is characterized by fewer chances of leashing of NO^{-}_{3}-N. It could be concluded that less soil disturbance with traditional tillage provides the subsequent crop with substantial amounts of mineral N during the growing season, unlike conventional tillage where NO^{-}_{3}-N was leached down beyond the rooting zone. This should also be taken into consideration during establishment of N fertilization budget.

Key Words: Central clay plain; Potentially mineralizable N; Rain-fed; Sudan; Tillage

INTRODUCTION

Tillage can act a major new control on soil biogeochemical cycles by making available previously protected soil organic matter (SOM), which changes net N mineralization and gross N immobilization (Ladd *et al.*, 1994). Loss of soil organic matter (SOM) has been associated with tillage intensity. However, SOM loss due to tillage can be expected to be a function of soil type, climate and cropping practice (Lal *et al.*, 1998). A better understanding of SOM is vital for development of effective soil conservation practices. Recent concern for global climate change emphasizes the importance of conservation tillage and how it can be implement in many soils to help reduce organic matter (OM) losses and hence increase SOM. Conservation tillage has a potential for converting many soils from source to sinks of atmospheric N (Kern & Johnson, 1993).

In Sudan, soils are known for their poor organic matter content. Most agricultural soils in Sudan are fine textured soils that have a greater potential for gains in SOM as reported in arid regions (McConkey *et al.,* 2003). The evaluation of changes in SOM and N content due to land use and management is needed to identify adequate strategies to increase agricultural production without soil degradation and without increasing emission of green house gases (CO_2, CO, N_2O & NH_4). Tillage was reported earlier to enhance N mineralization due to removal of physical protection (Grace *et al*., 1993; Reicosky *et al*., 1997; Calderon *et al*., 2000; Dharmakeerthi *et al*., 2004). However, López-Bellido *et al*. (1997) and Iqbal *et al.* (2005) reported that the tillage method did not influence the organic matter or N_{min} contents of the soil. Later, Fu *et al*. (2000) observed that the soil respiration was significantly higher under no till than that under conventional tillage. They reported that a longer period may have been required for differences between management systems to be observed owing to the small amount of crop residue that is returned to soil under rain-fed conditions of semi-arid climates. Also, Organic matter content in vertisols gradually decreases throughout the profile in relation to other soil types (Probert *et al*., 1987). Cropping usually lowers the organic matter content in vertisols, yet its influence on physical conditions is less significant than in soils with lower clay content. Rain-

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fed vertisols can lose substantial amounts of NO^-_3-N within the first 10 cm of the profile in a relatively short time.

In Sudan, all published studies on land use effects on soil quality did not report their impact on N mineralization and concentrated on other soil properties (Mubarak *et al.*, 2005). Therefore, the main objective of this study was to determine the effect of soil tillage on N mineralization from SOM under rain-fed vertisols.

MATERIALS AND METHODS

Study site. The site selected for this study is located in Sinnar State (Latitude 13′33°N & Longitude 33′37°E), which belongs to the southern central clay plain (about 280 km southern Khartoum State). The climate of the area is a semi-arid with hot summers and dry cold winters. The total annual rain fall is about 188.2-410.1 mm year^{-1} and mostly falls between May and October. The maximum mean annual temperature ranges between 33.5°C in January and 44.1°C in May, while the minimum mean temperature ranges between 14.0°C in January and 22.5°C in May. The relative humidity values are low during most months of the year and ranges between 30% in May and 48% in October (Metrogical Department of Sudan in 1997-2003). Two farms (traditional rain-fed, TRF & conventional rain-fed, CRF) were selected for conducting the experiment. The first farm site was located in Wad-Hashem, south east Sinnar State, which is usually, cultivated using subsoiler, smoothing by disk harrowing, leveling and ridging, representing conventional tillage. The second farm site was located in eastern Sinnar, representing traditional cultivation by hoe and sowing stick (locally known as Hashashah & Saloka cultivation). Farmers of both the sites cultivate sorghum (*Sorghum bicolor*) and sunflower (*Helianthus annuus*) for more than 25 years during the rainy season and with no supplementary irrigation. Under the CRF, farmers prepare their lands by disc ploughing and ridging, while in TRF, seeds are sown directly in holes, made by local hand driven implements known as "saloka" and seeds are buried by foot pressing.

Soils and samples collection. According to the Soil Survey Staff (1996), the soil of this site belongs to the order vertisols (Table I), which are cracking clays during the summer and winter, while cracks close during the rainy season. Soil samples (0-30 & 30-60 cm) were collected from the two farms (0.8 ha each) during the rainy season (August 3 to October 15. 2005) using an auger of 5 cm ∅. Samples (in quadruplicate) were taken at an interval of 0, 2, 4, 6, 8 and 10 weeks and kept frozen until analysis. Mineral N (NH_4^+-N & NO^-_3-N) was determined by extraction of 10 g soil with 40 mL of 2 M KCl and N was collected in 20 mL of boric acid indicator after distillation using MgO (for determination of NH_4^+-N) and Deverda's alloy (for NO^-_3-N) (Keeney & Nelson, 1982). Mineral N was presented as either in kg NH_4^+-N, NO^-_3-N ha^{-1} or total NH_4^+-N+ NO^-_3-N kg ha^{-1} using bulk density of 1.33 tm^{-3}.

Statistics. The t-test of SAS (1985) was used to determine statistical variations between management systems (in NH_4^+-N, NO^-_3-N & total mineral N). Each week of sampling was compared separately.

RESULTS AND DISCUSSION

Mineral N in the 0-3 cm depth. At the start of the rainy season, NH_4^+-N in the 0-30 cm soil depth determined in the TRF farm was significantly ($P \leq 0.005$) higher than that under CRF (Table II). Accordingly, NH_4^+-N released during the first two weeks was almost double that from CRF (198.8, 143.96 Vs 96.64, 64.43 kg N ha^{-1}) for TRF and CRF, respectively. Thereafter NH_4^+-N, though higher in TRF, was not significantly different between TRF and CRF. The peak of accumulation was found to be earlier in the season. The content of NH_4^+-N, then after started to decrease gradually reaching the lowest level after 6 weeks.

The NO^-_3-N accumulated at the onset of the rainy season and after 2 and 6 weeks of the TRF plots (304, 248 & 235 kg N ha^{-1}, respectively) were significantly ($P \leq 0.005$-0.04) higher than that determined in CRF (182, 150 &161 kg N ha^{-1}, respectively). With the exception of the 10th week, NO^-_3-N in this depth was consistently higher in the TRF as compared to the CRF (Table II). These results appeared to be however, not in line with many previous findings showing the enhancement of tillage to mineralization of soil organic matter (e.g., Grace *et al.*, 1993; Reicosky *et al.*, 1997; Dharmakeerthi *et al.*, 2004; Zhang *et al.*, 2008). This might possibly be due to some reasons, firstly, the fact that traditional farmers leave tremendous amount of stubble in the field, not deliberately, but because they do not afford renting labors to collect all stubble. This stubble would be available for mineralization in the field. Secondly, the disc plough in the CRF seemed to be not enough to break the physical protection of organic matter and this operation resulted in big clods especially when practiced in heavy clay soils. Thirdly the possibility of

Table I. Some selected soil (0-30 cm) chemical and physical properties of the study site

Tillage type	pH	EC_e (dS m^{-1})	N (%)	Na (meq L^{-1})	O.M (%)	Ca+Mg (meq L^{-1})	SAR	CEC (cmol 100 g^{-1})	$CaCO_3$ (%)	Sp (%)	B.D (tm^{-3})	Particle size distribution (%)			Texture
												Clay	Silt	Sand	
TRF	7.90	0.4	0.2	2.2	0.1	1.7	3.0	56.4	1.6	62.8	1.3	49.5	12.4	38.1	Clay
CRF	8.00	0.4	0.2	1.5	0.1	2.5	1.3	59.2	1.5	66.8	1.3	52.7	11.1	36.1	Clay

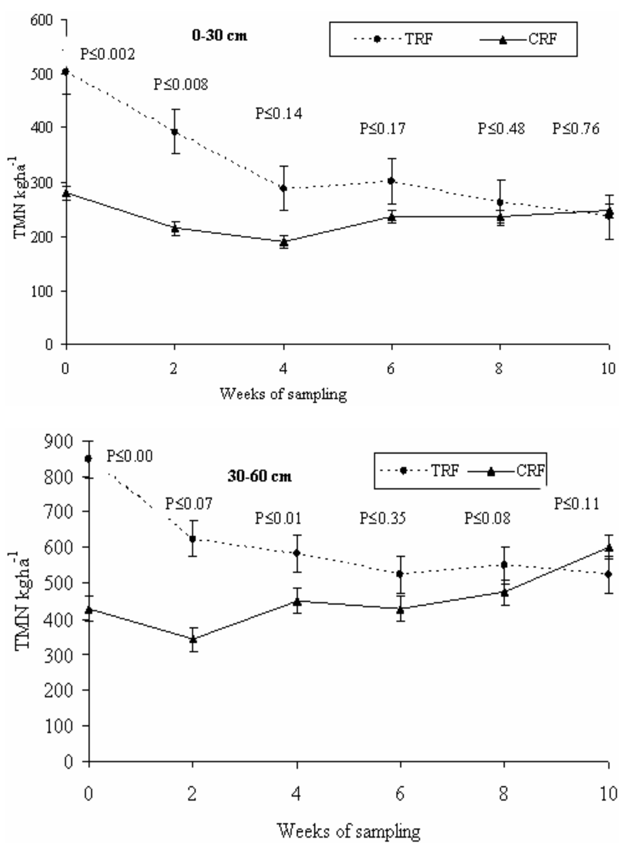
A: Represent traditional tillage, B: Represent conventional tillage, Sp: Saturation percentage, EC_e: Electric conductivity of the saturation extract, SAR: Sodium adsorptions ratio, CEC: Cation-Exchange-Capacity, O.M: Organic matter, B.D: Bulk density

Table II. Effect of tillage on mineral N accumulation during the rainy season

Tillage Type	Sampling period (weeks) 0		2		4		6		8		10	
	Mineral N (kg ha^{-1})											
	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-
0-30 cm												
TRF	198.83±26	302.62±26	143.96±26	248.66±26	91.61±26	196.31±23	65.44±24	235.57±30	78.52±30	183.22±30	78.53±30	157.05±12
CRF	96.64±21	182.55±21	64.4324	150.33±24	50.74±23	139.59±22	75.17±19	161.o7±21	75.17±41	161.07±21	64.43±24	182.55±21
SE	14.00	15.64	11.73	22.64	24.81	23.83	13.89	23.04	21.54	23.04	27.51	10.74
P ≤	0.005	0.005	0.007	0.02	0.19	0.09	0.53	0.04	0.89	0.41	0.64	0.09
30- 60 cm												
TRF	344.63±53	503.69±33	280.85±61	359.9±31	185.57±53	397.65±53	157.05±60	366.44±60	183.22±52	366.44±60	157.05±23	366.44±60
CRF	128.86±49	300.67±49	94.79±37	246.48±37	128.86±49	322.15±42	128.86±49	300.68±43	150.33±42	322.15±31	107.38±23	493.96±42
SE	45.6	45.7	54.50	82.2	23.64	39.29	39.09	55.02	4.69	25.00	25.00	25.00
P ≤	0.01	0.02	0.04	0.26	0.09	0.15	0.52	0.14	0.006	0.17	0.14	0.01

TRF: Traditional tillage, CRF: conventional tillage; SE: Standard error; P: Probability

Fig. 1. Total mineral N (kg ha^{-1}) under rain-fed traditional agriculture (RFT) and conventional rain-fed tillage (CRF) of the 0-30 cm and 30-60 cm depth



downwards movement of mineral N in CRF supported by tillage. These findings were in line with Fu *et al.* (2000) and López-Bellido *et al.* (1997).

Mineral N in the 30-60 cm depth. The NO_3^--N accumulated in the TRF ranged from 359 kg N ha^{-1} (after 2 weeks) to 503 kg N ha^{-1} (after the onset of the rainy season). Under CRF, the maximum amount was found to be at the end of the rainy season (493 kg N ha^{-1}). Interestingly, TRF retained significantly ($P \leq 0.01$) higher NO_3^--N only at the onset of the rainy season, whereas CRF retained significantly ($P \leq 0.01$) higher NO_3^--N levels towards the end of the rainy season (Fig. 1). The general trend of the accumulation of NO_3^--N was consistently decreasing in the case of TRF, while it was consistently increasing in the case of CRF. Therefore, TRF acts similar to no tillage in removing NO_3^--N from the soil (Bhat *et al.,* 2004; Mkhabela *et al*., 2008).

In both depths, total mineral N accumulated under TRF was significantly higher during the first four weeks from the start of the rainy season. However, the content later in the season was kept also higher than that determined under CRF, though statistically not significant. The study showed clearly that the accumulation of the NO_3^--N in the CRF was consistently increasing. This revealed that the effect of tillage on enhancement of N mineralization through disruption of aggregates is much seen after the rainy season advances when water percolates downwards this depth causing aggregates to disintegrate easily thereby, releasing physical protection of the organic matter. The study also showed that NO_3^--N accumulated in the subsoil compared to the plough layer indicating downwards movement depending on the intensity of the rains (Stenberg *et al*., 1999).

CONCLUSION

TRF agriculture made available ample amounts of mineral N made available at the onset of the rainy season. This N was consistently decreased when the rainy season advanced thereby reducing chances of pollution of the underground water. On the other hand, tilling the vertisols was found to have no effects on availability of mineral N during the growing season. There was a trend of building up mineral N during the season, a phenomenon that endangers the quality of underground water.

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