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Tillage and fertility management effects on soil organic matter and sorghum yield in semi-arid West Africa

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Abstract

Whether it is traditional, modern or "sustainable" agriculture, soil organic matter plays a key role in sustaining crop production and in preventing land degradation. A field experiment was conducted on a Ferric Lixisol at Gampela (Burkina Faso) in 2000 and 2001 to carried out the effects of tillage, fertilisation and their interaction on soil organic carbon (SOC) (0–10 cm), crop performance and microbial activities. Maize straw or sheep dung were applied separately or combined with urea in a till or no-till systems and compared with urea only and a control treatment. Sampling was done each year at 2 months after sowing and at harvest. SOC was increased in the tillage treatments in 2000 by 35% but only with 18% in 2001 suggesting reduced carbon accumulation in the absence of organic and mineral restitution. Ploughing in maize straw under conditions of N deficiency led to a drastic decrease in SOC due microbial priming effect that, was not observed when ploughing in sheep dung. In no-till system, losses, organic amendment N concentration and the soil N status determined the impact on SOC and crop productivity. The negative effect on SOC in the tillage treatment with maize straw (4.1 g kg^{-1}) was less when maize straw was combined with urea (6.2 g kg^{-1}). It is concluded that in semi-arid West Africa, without both organic resource and N inputs, soil organic matter "pays" for crop N nutrition. Increasing SOC accumulation while improving crop yield may be conflicting under low-input agricultural systems in semi-arid West Africa. Therefore, optimum soil organic carbon and crop performance results from a judicious combination of organic resources and inorganic N mediated by microbial activity.

Keywords: Crop performance; Fertiliser; Organic amendments; Soil carbon; Tillage

1. Introduction

Soil organic matter (SOM) plays a key role in the improvement of soil physical, chemical and biological properties. Many studies have shown that the addition of organic material improves soil physical properties, which enhance root development, resistance to erosion, soil porosity and water infiltration and decrease soil crusting (Mando and Miedema, 1997; Fernandes et al., 1997).

SOM is a source of nutrients and energy for the decomposer community and a source of nutrients for plant growth (Paul and Clark, 1996). Application of organic resources leads to the improvement of crop yields as a result of improved soil properties (Ouédraogo et al., 2001; Scholes et al., 1997; Mando, 1998). However, continuous cultivation in conjunction with residue

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removal, fertiliser application and tillage are often mentioned as causing rapid mineralisation of SOM within the first few years of cultivation (Woomer and Swift, 1994; Scholes et al., 1997). Doran et al. (1998) showed that no-till management resulted in the lowest loss of SOC and N in the topsoil over time as compared to tilled soils. However, under semi-arid conditions, hard data to clearly establish the role of the quality of organic inputs, tillage and N fertiliser application on SOM accumulation and decomposition are scarce. Combining organic resources and mineral fertiliser has been recommended to increase not only the total above ground biomass but also the below ground biomass production (roots) which can result in an increase of soil organic matter (Bationo and Burkert, 2001). An important issue is whether combining two technologies (here tillage and fertilisation) gives only additive benefits (i.e., the benefit of the combined application is equal to the sum of the benefits from the two technologies when applied in isolation) or truly leads to a positive or negative interaction (Iwuafor et al., 2002).

This paper investigates the impact of organic resource quality, fertiliser and tillage and their interactions on SOC and crop performance in semi-arid West Africa during two consecutive year cropping. We hypothesise that combining organic resources with N fertiliser may mitigate SOC loss in cropping systems.

2. Methodology

2.1. Site description

The study was conducted in 2000 and 2001 at Gampela, a village located in the central plateau of Burkina Faso between 12°25′N and 1°21′W. The climate is Sudano-Sahelian. Rainfall is monomodal and typically occurs for 4 months from June to September. It is irregularly distributed in time and space. The mean annual rainfall is 773 mm (based on 97 last years). The dominant soils are Lixisols. Table 1 presents the characteristics of the topsoil (0–10 cm).

Table 1
Characteristics of the top soil (0–10 cm) of a Ferric Lixisol at Gampela, Burkina Faso

Soil properties	Values (±standard deviation)
Clay (g kg^{-1})	60 ± 18
Silt (g kg^{-1})	420 ± 24
Sand (g kg^{-1})	520 ± 37
Carbon (g kg^{-1})	4.7 ± 0.5
Nitrogen (g kg^{-1})	0.4 ± 0.1
Phosphorus (mg kg^{-1})	55 ± 12
Potassium (mg kg^{-1})	304 ± 23
Exchangeable calcium (μmol kg^{-1})	0.87 ± 0.21
Exchangeable magnesium (μmol kg^{-1})	0.43 ± 0.06
Exchangeable potassium (μmol kg^{-1})	0.17 ± 0.09
Exchangeable sodium (μmol kg^{-1})	0.06 ± 0.01
pH (H_2O)	6.6 ± 0.3
pH (KCl)	4.9 ± 0.3

2.2. Experimental design

The experiment was a split plot randomized block design with three replicates. Tillage and no-till were the main treatments. The sub-plots consisted of C, control (0 N); U, urea (40 kg N ha^{-1}); U80, urea (80 kg N ha^{-1}); SD, sheep dung (40 kg N ha^{-1}); SD + U, sheep dung (40 kg N ha^{-1}) + urea (40 kg N ha^{-1}); S, maize straw (40 kg N ha^{-1}); S + U, maize straw (40 kg N ha^{-1}) + urea (40 kg N ha^{-1}). An alley of 2 m separated the blocks and the main plots were 19 m × 11 m and 5 m apart. The size of sub-plots was 5 m × 4 m separated by guard rows of 1 m. Triple super phosphate (TSP) was applied in all plots at a dose equivalent to 15 kg P ha^{-1} every year to avoid phosphorus limitation. Chemical properties of organic material applied during the 2 years are shown in Table 2.

Table 2
Chemical properties and application rate of organic materials applied in 2000 and 2001 at Gampela, Burkina Faso

Organic resources	Years			
	2000		2001	
	Maize straw	Sheep dung	Maize straw	Sheep dung
Total quantity (kg ha^{-1})	5195	2614	6780	2484
Carbon (C) (kg ha^{-1})	2343	659	3661	993
Nitrogen (N) (kg ha^{-1})	40	40	40	40
Phosphorus (P) (%)	0.18	0.33	0.08	0.19
Potassium (K) (%)	1.20	1.20	1.25	1.55
Lignin (L) (%)	0.16	0.16	0.14	0.28
C/N ratio	59	17	91	25
L/N ratio	0.21	0.1	0.24	0.17