Effect of tillage and organic matter quality on sorghum fertilizer use and water use efficiency in semi-arid West Africa

Elisée Ouedraogo[A] and Abdoulaye Mando[B]

[A]Centre Ecologique A. Schweitzer, 04 B.P. 8645, Ouagadougou 04, Burkina Faso.
[B]International Center for Soil Fertility and Agricultural Development (IFDC), BP 4483, Lomé, Togo.

Abstract
A field experiment was conducted in Gampela (Burkina Faso) in 2000 and 2001 to assess the impact of organic and mineral sources of nutrients and combinations thereof in optimizing crop production under till and no-till and to assess the economic benefit of that option. At a dose equivalent to 40 kg N/ha, crop yield was better secured with organic-N than with urea-N. Combining organic and mineral sources of nutrients do not have only additive effects but real interaction, which significantly affect crop yield and water use efficiency. The use of soil and water management measures is a key to increase the economic benefit of mineral, organic or combined organic and mineral sources of nutrient application under semi-arid conditions.

Key Words
Burkina Faso, sorghum, fertilizer, organic resources, tillage, West Africa.

Introduction
Although it is widely accepted that organic matter additions are essential to maintain soil health, particularly, it is doubtful whether organic inputs alone will be able to compensate for the continuing removal of plant nutrients in harvested products (Vanlauwe *et al.* 2002). On the other hand, there are many examples from West Africa showing that continuous application of only mineral fertilizer ultimately results in yield declines. However, with a combination of mineral and organic sources of nutrients yield levels can be maintained (Bationo and Buerkert 2001). The sustainability of agricultural systems in West Africa seems therefore to rely on an integrated nutrient management geared to land use practices, which are economically viable and ecologically sound. This paper analyses the added effect (interaction) of combined organic resource and urea and economic benefit of combined vs. single application of organic resources of different qualities and urea during two consecutive cropping seasons under till and no-till systems.

Methodology
The study was conducted at Gampela, a village located at the central plateau of Burkina Faso between 12°-25'N, 1°21'W during two consecutive cropping seasons (2000 and 2001). Crop and soil management was the same during the two years. The site was under six year fallow prior to the set-up of the experiment. The climate is Soudano-Sahelian. The mean annual rainfall is about 770 mm. The soil is a Ferric Lixisol. The experiment was a three times replicated (blocks) of split plot design with tillage and no-till as main treatments. The plots were 19 x 11 m and 5 m apart. The size of sub-plots was 5 x 4 m separated by guard rows of 1 m. The blocks were separated by an alley of 2 m. The sub-treatments consisted of C = Control (0 N), U = Urea (40 kg N/ha), U 80 = Urea (80 kg N/ha), SD = Sheep dung (40 kg N/ha), SD+U =Sheep dung (40 kg N/ha) + urea (40 kg N/ha), S = Maize straw (40 kg N/ha), S+U = Maize straw (40 kg N/ha) + urea (40 kg N/ha). Triple super phosphate (TSP) was applied at a dose equivalent to 15 kg P/ha every year.

Crop and soil management
Improved sorghum (variety SARIASO14) was shown in all the plots at a rate of 31250 seedlings/ha during the two cropping seasons. Animal power was used for the tillage (12 cm). During the growing period the plots were manually weeded two times. Sorghum dry matter and grain yield data were obtained after sun drying. Rainfall amount was recorded using a rain gauge placed in the field. Water use efficiency (WUE) was calculated as: WUE = above ground biomass (kg/ha)/Total rainfall (mm). Total N uptake was calculated by correcting the N uptaken at flowering with the N post-anthesis uptake fraction for sorghum. Agronomic nitrogen use efficiency (ANUE) is calculated in 2000 and 2001 as: ANUE = (Yi-Yo)/Ni. Nitrogen utilisation efficiency in 2001 (NU_tE) is calculated as: NU_tE = (Yi-Yo)/(NRi-NRo); Nitrogen uptake efficiency (NUpE) is calculated as: NUpE = (NRi-NRo)/Ni where Yi = yield in fertilised plots, Yo = yield in the control, NRi = N recovered in the fertilised plots, NRo = N recovered in the control, Ni = N supplied in the fertilised plots.

Results

Sorghum nitrogen and water use efficiency

Figure 3 indicates that in till as well as in no-till plots ANUE was significantly higher in single organic resource or combined organic resource with urea than in single urea treatments in 2000. In 2001, the highest ANUE in tilled plots was noted in SD+U, S and SD and the lowest ANUE was observed in U80, U and S+U. In no-till plots ANUE was highest in S but did not differ significantly from S+U and SD+U and lowest in U, U80 and SD (Figure 1).

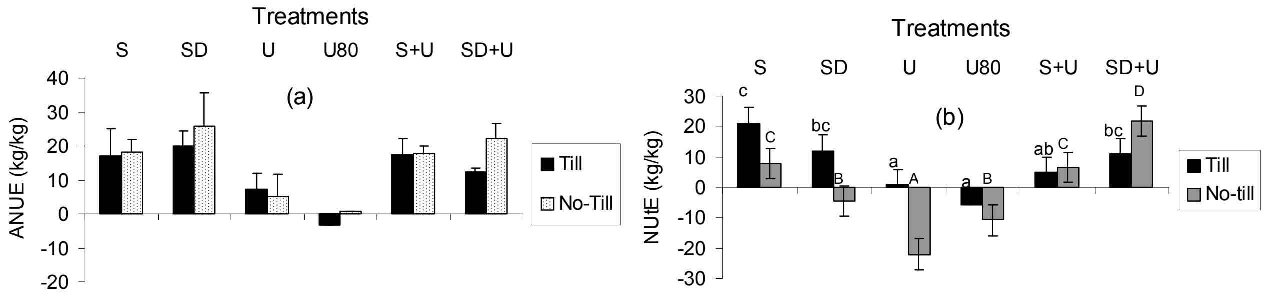

Figure 1. Agronomic nitrogen use efficiency (ANUE) in 2000 (a) and 2001 (b) at Gampela, Burkina Faso. Bars represent standard deviations.

Rainfall was better distributed in 2001 compared to 2000. In tilled-plots, the water use efficiency (WUE) in 2000 was significantly higher in SD+U and S+U compared to other treatments (Table 1). In S+U and SD+U, WUE increased significantly when compared to S and SD whereas no significant differences in WUE were observed between U, U80 and the control. In no-till plots, with the single application of organic resource and urea, the highest WUE was noted in SD and was significantly different from the control and U but did not differ from S. Significant WUE increase was observed in no-till plots in S+U and SD+U compared respectively to S and SD. No significant increase in WUE was observed when increasing urea dose in no-till plots. In 2001, with single urea and organic resource application, WUE was higher in S and significantly different from U and the control but did not from SD in tilled plots (Table 1).

Table 1. Water use efficiency (WUE) (kg/mm) in 2000 and 2001 at Gampela, Burkina Faso.

Treatments	Tillage	WUE	
		2000	2001
S	T	9.2 ^{a}	12.3 ^{cd}
	NT	8.3 ^{BC}	12.3 ^{D}
SD	T	11.6 ^{b}	11.3 ^{bc}
	NT	9.1 ^{C}	5.8 ^{A}
U	T	8.7 ^{a}	10.1 ^{ab}
	NT	6.9 ^{AB}	5.2 ^{A}
C	T	8.0 ^{a}	8.8 ^{a}
	NT	5.5 ^{A}	8.3 ^{B}
U80	T	8.5 ^{a}	9.4 ^{a}
	NT	7.5 ^{B}	7.6 ^{B}
S+U	T	16.7 ^{c}	14.4 ^{d}
	NT	11.5 ^{D}	10.3 ^{C}
SD+U	T	15.7 ^{c}	20.0 ^{e}
	NT	14.2 ^{E}	9.4 ^{BC}

S = maize straw (40 kg N/ha), SD = Sheep dung (40 kg N/ha), U = Urea (40 kg Nha^{-1}), C = Control (0N), U 80 = Urea (80 kg N/ha), T = Till, NT = No-till.

Discussion

In 2000, positive interaction in S+U in tilled plots suggest a synergistic effect, as sorghum did not significantly respond in S or U. Maize straw improved soil moisture conditions as indicated by the highest water content in 0-10 cm (Figure 5). The highest water potentials at 50 and 30 cm depth suggest that in this treatment water was more retained in the top soil compared to SD. However, the plants may have lacked nutrients to use available water (lowest soil total nitrogen was noted in S, Figure 2), as also indicated by the low water use efficiency in this treatment (Table 1). In U nutrients may have been easily released but water shortage may have limited nutrient use by plants as characterized by low WUE. The positive interaction observed may be due to increased nutrient and water use efficiencies (WUE was highest in S+U) and tillage may also reduce nutrient lost through run-off and volatilisation. In no-till plots, surface-applied urea may be lost with intensive rainfall as no significant difference in soil total nitrogen was observed between U and C and this reduced the ANUE. Surface-placed straw reduces run-off (Mando 1997) and therefore reduces surface-placed nutrient loss, and enhances soil moisture. This may explain the positive added effect of combined surface-placed maize straw and urea.

Addition of urea to sheep dung did not induce a significant difference in crop yield compared to single sheep dung application in tilled plots in 2000. The negative interaction observed may be attributed to low nutrient utilization efficiency, as characterized by low harvest index at high total biomass production. It is more obvious that the water stress at a maturing period may limit nutrient transfer from straw and leaves to grains and this reduces the nutrient utilization efficiency. Nutrient loss reduction when urea is combined with sheep dung and improved both ANUE and water use efficiency compared to single urea application (Fig 1). This had a positive impact on crop performance and explains the positive added effect when sheep dung and urea were combined.

Conclusions

The study showed that under rainfall deficiency, the use of single organic resource at an equivalent dose of 40 kg N/ha better secured crop yield than application of an equivalent amount as urea-N in semi-arid West African sandy soils. Combining organic resources and fertilizer was found better in increasing crop yield than applying the same N amount in the form of urea. In a year of rainfall deficiency, mixing organic resources and fertilizer in till or no-till systems will increase crop water use efficiency and allow the still get more yield as when all the N was supplied with urea. The results demonstrated that the use of N fertilizer alone may be risky under the prevailing rainfall conditions. Application of soil and water management measures can be of great contribution to increase the economic benefit of mineral, organic or combined organic and mineral-derived nutrient application under semi-arid conditions. Under such conditions, skillful combination of mineral and organic sources of nutrient may induce positive interaction.

References

Bationo A, Buerkert A (2001) Soil organic carbon management for sustainable land use in Soudano-Sahelian West Africa. *Nutrient cycling in Agroecosystems* **61**, 131-142.

Mando A (1997) The impact of termites and mulch on the water balance of crusted Sahelian soils. *Soil Technology* **11**, 121-138.

Vanlauwe B, Diels J, Sanginga N, Merckx R (2002) 'Integrated plant nutrient management in Sub-Saharan Africa: From concept to practice'. (CAB International: New York).