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Short communication

Mulching with branches of an indigenous shrub (*Guiera senegalensis*) and yield of millet in semi-arid Niger

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Abstract

Crop residues from millet production in southwest Niger are limited for their utilization as mulch because of many other uses. Thus, branches of an indigenous shrub (*Guiera senegalensis* J.F. Gmel.) were tested with a randomised block design for their effect on millet (*Pennisetum glaucum* L.) yield. Pearl millet was planted in 1995 and 1996 on a luvic Arenosol in southwest Niger. Three treatments were applied: control, 1000 kg ha^{-1} dry matter *Guiera*-mulch and 2000 kg ha^{-1} dry matter *Guiera*-mulch. Mulched plots had 68–94% higher millet yields compared to the control. Differences in soil properties before the treatments were applied, explained a high variability within the treatments. Significant differences of soil properties between blocks led to a distinction of infertile and fertile blocks. In infertile plots with 1000 kg ha^{-1} *Guiera*-mulch, millet yield was higher than in plots with 2000 kg ha^{-1} *Guiera*-mulch. Due to the many uses of *Guiera senegalensis* by the local farmers, an application of 1000 kg ha^{-1} *Guiera*-mulch, at least on infertile soils, seems a good possibility to increase millet production.

Keywords: Crop residues; Fallow; Soil fertility; Soil microvariability; West Africa

1. Introduction

The rapidly growing population in many parts of West Africa has led to a rising demand for food production in the last decades. The unfavourable agroecological conditions are difficult to handle and the results are often degradation of soils and decreasing crop yields. One possibility of overcoming this is the use of crop residues as a mulch. The positive effects of the use of crop residues are reduced soil erosion and enhanced water conservation (Unger et al., 1991). In Niger, higher millet yields with applied crop residues have been found by Bationo and Mokwunye (1991) but despite positive effects, the recommended application of 2000 kg ha^{-1} of crop residues is normally not realized because sufficient crop residue material is rarely available. Thus, other mulch is needed. One possibility is the use of branches from shrubs growing in the natural environment. *Guiera senegalensis* is the most abundant shrub in fallow sites and millet fields in SW-Niger. Therefore, the aim of this study was to evaluate the effects of *Guiera senegalensis* mulch on millet yield.

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2. Materials and methods

All crop data were collected from 1995 to 1996 at the ICRISAT Sahelian Center in southwest Niger, on a luvic Arenosol. The experiment was laid out using a randomised block design. Three treatments with four replications were applied: control, 1000 kg ha^{-1} dry matter *Guiera*-mulch and 2000 kg ha^{-1} dry matter *Guiera*-mulch. No fertilizer or crop residues were applied. The experimental plots (7 m $\times$ 7 m) were situated on a relatively infertile field, on which millet had been planted in previous years. Five soil samples from 0 cm to 10 cm and 10 cm to 20 cm depth for each plot were sampled with an auger (3 cm diameter) in October 1994, mixed and analysed for pH (1 : 2.5, soil : distilled water), concentrations of organic carbon (Walkley–Black procedure), total nitrogen (Kjeldahl method), available phosphorous (Bray-1 procedure), exchangeable acidity ($H^+ + Al^{3+}$) (titration after percolation of KCl solution) and exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, Na^+) (ammonium acetate method). The effective cation exchange capacity (ECEC) was calculated as the sum of exchangeable bases and exchangeable acidity.

Mulch (small branches) was broadcast on the soil surface and not incorporated. This was done in October 1994 because of the maximum leaf development of *Guiera senegalensis* during this period. Thus, the mulch was retained at the soil surface from October to June (dry season), before millet was planted. In June 1995 and 1996, millet was planted at density of 10 000 planting holes per ha spaced 1 m $\times$ 1 m. After 20 days, plants were thinned to four per planting hole. Weeding took place twice during the growing season. In each plot (without the border row) leaf/stover biomass and ears were harvested at the beginning of October. Millet samples of 24 rows, two of each plot, were oven-dried at 65°C for the determination of dry matter. The crop residues produced in 1995 on each plot were left unincorporated in the respective plots.

Annual rainfall, distributed unimodally between mid-May and mid-October, was comparable in both the years (1995: 486 mm, 1996: 544 mm), but a drought of 26 days from mid-September to mid-October with only 3 mm rainfall occurred in 1996. No runoff or erosion was observed on the experimental plots during the growing seasons. Correlation analyses as well as analysis of variance (ANOVA) and the Scheffé Test for post-hoc comparison of ANOVA were performed on millet yields and soil parameters. Millet yield was regarded as a repeated measurement over time.

3. Results

Changes along a horizontal gradient of soil parameters can be seen in Table 1. From Plot 1–12 a significant increase was found for concentration of phosphorus (10–20 cm, $r^2 = 0.68$), organic carbon (0–10 cm, $r^2 = 0.64$; 10–20 cm, $r^2 = 0.57$), Ca^{2+} (0–10 cm, $r^2 = 0.50$) and Mg^{2+} (0–10 cm, $r^2 = 0.61$). Contrary to this, an increase of the concentration of Al^{3+} (0–10 cm, $r^2 = 0.59$) from Plot 12 to 1 was noted.

Average grain yields were higher for the mulched plots than for the unmulched plots. The gain for grain yield varied between 68% and 78% in 1995, and 69% and 94% in 1996, compared with that in the unmulched plots (Table 2). Moreover, significant yield differences between blocks occurred, whereby main effects were found between blocks 1 (plots 1–3) and 4 (plots 10–12) as well as blocks 2 (plots 4–6) and 4 (plots 10–12) (Scheffé Test). This allowed a comparison of average grain yield of blocks 1/2 to blocks 3/4. High differences were found between fertile and infertile blocks. The ANOVA gave significant differences between the fertile and infertile blocks for concentration of organic carbon (0–10 cm) ($p = 0.37$) and of phosphorus (10–20 cm) ($p < 0.001$), and probabilities for concentrations of organic carbon (10–20 cm) ($p = 0.063$) and of phosphorus (0–10 cm) ($p = 0.051$). If the concentration of phosphorus is used as a covariable for treatment effects, a significant difference was almost reached in 1995 with $p = 0.057$.

4. Discussion

The overall results suggested a trend towards higher grain yield for the mulched treatments, than for the unmulched treatments, but no significant differences could be achieved because of the variability of soil. This microvariability which is typical for soils in the Sahel is described by Geiger and Manu (1993). The

Table 1
Soil properties of the experimental plots before mulch application (ICRISAT Station, Niger)

Plot	C org ($g\ kg^{-1}$)	N total ($mg\ kg^{-1}$)	P Bray ($mg\ kg^{-1}$)	pH (H_2O)	H^+ ($cmol_c$)	Al^3 ($cmol_c$)	Ca^{2+} ($cmol_c$)	Mg^{2+} ($cmol_c$)	ECEC ($cmol_c$)	Base saturation (%)
	0–10									
1	1.07	120	15.8	5.2	0.12	0.40	0.21	0.07	0.87	41
2	1.03	78	9.0	5.2	0.11	0.39	0.21	0.07	0.83	41
3	1.28	109	13.9	5.2	0.09	0.37	0.25	0.09	0.87	47
4	1.22	110	12.4	5.1	0.08	0.42	0.30	0.09	0.95	48
5	1.21	115	11.9	5.1	0.14	0.44	0.23	0.07	0.96	39
6	1.13	93	9.0	5.1	0.14	0.42	0.22	0.08	0.95	42
7	1.10	98	13.2	4.9	0.14	0.40	0.20	0.06	0.90	40
8	1.26	106	11.3	5.1	0.15	0.35	0.25	0.09	0.91	46
9	1.32	114	17.9	5.1	0.14	0.28	0.28	0.11	0.90	53
10	1.38	115	16.5	5.2	0.08	0.29	0.30	0.11	0.89	58
11	1.33	105	16.4	5.1	0.11	0.21	0.31	0.12	0.88	64
12	1.47	131	17.0	5.2	0.06	0.28	0.33	0.12	0.88	62
	10–20									
1	1.05	96	2.9	4.9	0.13	0.58	0.12	0.04	0.95	24
2	1.00	90	4.9	5.0	0.13	0.45	0.18	0.06	0.89	35
3	1.14	103	4.1	4.8	0.16	0.56	0.16	0.05	0.99	28
4	1.22	105	5.0	4.9	0.13	0.57	0.19	0.05	1.01	31
5	1.23	101	4.7	5.3	0.16	0.53	0.20	0.05	1.00	31
6	1.10	104	2.3	5.0	0.16	0.53	0.23	0.06	1.07	36
7	1.11	90	7.2	4.9	0.14	0.52	0.18	0.05	0.99	33
8	1.13	103	8.0	5.2	0.12	0.37	0.28	0.11	0.96	48
9	1.37	115	10.9	5.1	0.14	0.47	0.22	0.08	1.02	40
10	1.29	122	9.2	5.1	0.17	0.51	0.19	0.07	1.03	34
11	1.22	107	8.7	4.9	0.15	0.43	0.22	0.08	0.98	41
12	1.45	117	9.1	4.9	0.09	0.55	0.21	0.07	1.04	38

average yield of the blocks indicated a distinction between infertile and fertile blocks. This distinction was supported by significant differences for certain soil properties between blocks. Scott-Wendt et al. (1988) found comparable results for a soil transect from a fertile to an infertile soil in semi-arid Niger. They found that an increase in concentration of exchangeable $Al^{3+} + H^+$ was related to decreased

Table 2
Effect of different rates of *Guiera*-mulch application on dry matter millet grain yield in 1995 and 1996 (ICRISAT station, Niger)

Treatment	Grain yield ($kg\ ha^{-1}$)		Average grain yield 1995/1996 ($kg\ ha^{-1}$)	
	1995	1996	Infertile blocks	Fertile blocks
Control	136	87	53	170
1000 $kg\ ha^{-1}$	228	147	114	261
2000 $kg\ ha^{-1}$	240	169	92	316
Analysis of variance[a]				
Treatment (T)	0.591	0.523	0.059	0.587
Block (B)	0.035	0.049		
Year (Y)	0.013		0.038	0.013
T×Y	0.832		0.021	0.336

[a] Probability of *F*-Test for significant different.

concentrations of Ca^{2+} and Mg^{2+} in the direction of the infertile soil.

Responses to mulch treatment effects were different in infertile blocks compared with those of fertile blocks. In the infertile blocks, the grain yield increases for the 1000 kg ha^{-1} treatment were slightly and nearly significantly higher than for 2000 kg ha^{-1} (Table 2). On the fertile plots grain yield increases were 53% and 85% for 1000 and 2000 kg ha^{-1}, respectively. This suggests that on infertile soils the application of more than 1000 kg ha^{-1} of mulch material will not result in additional increases in the yield of millet grain.

In a mulch trial with *Azadirachta indica* and *Albizia lebbeck* in semi-arid Burkina Faso, Tilander (1993) found increased yields of sorghum (*Sorghum bicolor* (L.) Moench). Mulch was applied at the beginning of the rainy season. For the increased yields, the direct availability of nutrients from the leaves as well as the higher water retention capacity of mulched soils was implicated. The present experiment did not provide evidence of increased water availability because mulching took place at the beginning of the dry season. The mulch was soon attacked by termites and almost entirely incorporated by the start of the following rainy season. The higher availability of nutrients in the mulched plots is suggested as the main factor for better yields, because sandy soils in this region have extremely low nutrient concentrations. Bationo and Mokwunye (1991) stated that phosphorus, and not water, is the limiting factor for plant production in the Southern Sahelian Zone. A further positive aspect of mulching is the protection of soils against wind and water erosion. At the beginning of the rainy season the entrapment of aeolian materials (fine sand) could be clearly seen along the branches. This entrapment generally has better fertility characteristics than does the subsoil (Geiger et al., 1992).

The resource of *Guiera senegalensis* branches for mulch is limited because this shrub is widely used by the rural people as firewood, for construction and for medicinal use. In some parts of southwest Niger this shrub species is already scarce because of continuous destruction in millet fields and fallows. Because of low fodder value, livestock do not browse it until the end of the dry season (March–May) when almost no other fodder is left.

5. Conclusions

Mulch of *Guiera senegalensis* increases millet yield. Soil microvariability is of great importance for the effects of mulch material applied on millet yields. On infertile soils the application of more than 100 kg ha^{-1} does not result in additional increases in yield of millet grain. As mulch of *Guiera senegalensis* is a limited resource, an application of 1000 kg ha^{-1} at least on infertile soils, in combination with crop residues where possible, seems to be a solution to increase the status of nutrients and organic matter in the soil and to protect the soil from wind and water erosion.

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