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Growth, Nutrient Composition and Straw Yield of Sorghum as Affected by Land Configuration and Wood-chips Mulch on a Sandy Loam Soil in Northeast Nigeria

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ABSTRACT

Six land configuration and wood-chips mulch treatments were evaluated from 1999 - 2002 on a sandy loam soil, northeast Nigeria for their effects on growth, leaf nutrient composition and straw yield of sorghum. Treatments evaluated include: flat bed (FB), open ridge (OR), tied ridge (TR), FB + mulch (FBM), OR + mulch (ORM) and TR + much (TRM). Early plant growth as measured by leaf number plant^{-1} and stem diameter were not significantly influenced by treatments in any given year but with advancement in growth, the mulched (FBM, ORM & TRM) treatments showed better growth than their bare (FB, OR & TR) counterparts. Sorghum leaf N, P, K, Ca and Mg contents were all higher in the mulched than in the bare treatments irrespective of tillage method. Averaged across the four experimental years (1999 - 2002) mean increases in straw yield relative to the FB treatment were 9.6% for OR, 16% for TR, 56% for FBM, 39% for ORM and 41% for TRM. The OR and TR treatments slightly increased straw yield in years with normal rainfall (1999, 2001 & 2002) but decreased straw yield in 2000, the year with poor rainfall distribution. It is concluded that under the edapho-climatic conditions of Maiduguri in northeast Nigeria, substantial improvement in the growth and straw yield of sorghum can be obtained when adequate amounts of wood-chips are applied to the surface of either a flat bed or ridge tilled soil with little/no risk of crop failure.

Key Words: Land configuration; Wood-chips; Mulch; Ridging; Sorghum

INTRODUCTION

Ridge tillage (RT) is a traditional method of seed bed preparation in semi-arid northeast Nigeria (Chiroma, 1996). Although planting on flat seed bed continues to be the dominant tillage practice among the small holder farmers in this region, the practice of RT is fast challenging its dominance in recent years. Whereas considerable research efforts has gone into characterizing the effects of this tillage practice on soil properties and subsequent crop yield in southern Nigeria (Ojeniyi & Adekayode, 1999; Ojeniyi *et al*., 1999; Ewulo, 2004) and neighbouring Niger Republic (Bielders *et al*., 2002; Bielders & Michels, 2002) little information exist in the literature regarding the effects of this tillage practice on soil and crop performance in the semi-arid northeast Nigeria.

Previous studies conducted on Alfisols in southwest Nigeria showed that ridging conserved soil fertility and increased yield of cowpea (Ojeniyi *et al*., 1999) and maize (Ojeniyi & Adekayode, 1999; Ewulo, 2004). Kronen (1994) reviewing the performances of tillage practices in the semi-arid areas of South Africa concluded that the advantage of the RT system in conserving water and increasing crop yields are only evident on soils with relatively high clay content and alluvium soils and not on lighter soils characterized by low water retention and poor soil fertility. He however, noted that on light textured soils, yield increases can be obtained when RT is combined with mineral fertilizers.

It is against this background that a 4 year field experiment was initiated in 1999 with a view to comparing the responses of sorghum grown on flat and ridge-tilled plots with and without wood-chips mulch on a light textured soil in the semi-arid northeast Nigeria. The effects of the tillage treatments on soil properties and crop performance has been reported in the previous papers (Chiroma *et al*., 2006a, b & c). These studies recorded improved soil chemical and physical conditions and a better growth of the crops in the flat bed and ridge tilled plots with mulch compared with their bare counterparts. Although the better growth with the mulched treatments was credited to the combined improvement in soil water storage and physico-chemical properties of the soil under the mulched treatment, plant nutrition could also be indirectly involved, an aspect comparatively little dealt with in the literature (Murillo *et al*., 1998). The present study deals with the effect of these tillage systems on nutrient composition and straw yield of sorghum crop.

MATERIALS AND METHODS

A 4 year field experiment was conducted on a sandy loam soil (*Typic Ustipsamment*) at the University of Maiduguri Research Farm (11^{o}54', 13^{o}5 E', altitude 352 m above mean sea level) in northeast Nigeria. The region has a semi-arid climate with a long-term average annual rainfall (1961 - 1990) of 553 mm and a very hot dry season that last for about eight month (Grema & Hess, 1994). The monthly rainfall during the study period for Maiduguri is given in Table I.

Six treatments were laid out in a randomized complete block design with four replicates. The tillage treatments consisted of flat bed (FB); open ridge (OR); tried ridge (TR); FB + mulch (FBM); OR + Mulch (ORM) and TR + mulch (TRM). Ridges for the (OR, TR, ORM & TRM) treatments were made annually with a hoe (measuring about 0.30 m high) at 0.75 m apart and about 0.15 to 0.20 m high. Furrow in the TR and TRM treatments were tied at 2 m intervals. Mulch in the FBM treatment was applied uniformly on the surface of the flat bed, while that of the ORM and TRM treatments were applied in the furrow positions. Sorghum (variety Paul Biya) was sown each year on a 10 m x 5 m plot at a spacing of 0.75 m between rows and 0.45 m within rows. More details about the treatments and agronomic practices can be found in Chiroma *et al*. (2006c). The crop was harvested each year in November except for 2000 (October). The straw yields for each plot was assessed from an area of 24 m^2 at a 15% water content. Leaf number $plant^{-1}$ and stem diameter were determined each year on 15 randomly selected plants per plot at 45, 65 and 80 days after sowing (DAS), corresponding to the end of vegetative, booting and physiological maturity stages of growth, respectively. Number of fully developed leaves $plant^{-1}$ was counted manually, while stem diameter was measured using a Vernier Caliper.

Leaf samples were collected using a sharp steel knife during the 2001 and 2002 crop growing seasons from 10 randomly selected plants per plot at about 80 DAS. All leaf samples were collected at mid-day, oven dried at 65°C and then ground. N was determined by Kjeldahl approach. Mineral elements were determined following dry ashing and the ash dissolved in a mixture of HCl and $HN0_3$. P was determined using molybdenum blue colorimetry, K by flame emission and Ca and Mg by EDTA titration (Tel & Hagarty, 1984).

Data collected were subjected to analysis of variance and differences among means were evaluated by the LSD test. Grain and straw yields were related by regression.

RESULTS AND DISCUSSION

Plant development. Whereas the number of leaves $plant^{-1}$ in all treatments were comparable during each sampling of all the cropping seasons, significant ($P < 0.05$) treatment differences in stem diameter was observed in about 2/3 of the sampling dates (Table II). Differences in early plant growth among treatments were always similar irrespective of differences in the amounts of rainfall (Table I). Because wood-chips during each crop growing season was applied about two weeks after planting, early plant growth was always impaired by water shortage occasioned by high evaporative losses characteristics of the study area (Chiroma *et al.*, 2006c). However, with the advancement in crop growth, mulching promoted better growth causing maximum values of leaf number $plant^{-1}$ and stem diameter during all years studied. These positive growth responses by the mulched (FBM, ORM & TRM) treatments could be attributed to increased crop water availability. The soil profile water content during later part of the crop growing season in all years were often greater in the FBM, ORM and TRM treatments than in FB, OR or TR treatments (Chiroma *et al*., 2006c). The frequently moist rooting environment with the mulched treatments may have promoted better root growth, which in turn resulted in more efficient utilization of water and nutrients by the plants as indicated by the consistently higher straw yields in the mulched than in the bare treatments. These observations are consistent with earlier findings (Gajri *et al*., 1994; Chiroma *et al.*, 2005). The promotion of tree growth following the application of wood-chips mulch to a coarse textured mine soil has also been reported elsewhere (Schoenholtz *et al*., 1992). These workers observed that the better growth in the wood-chips amended mine soil was a consequence of lower soil temperature and evaporation resulting from the mulching effect of the applied wood-chips. The slow growth observed with the bare treatments particularly FB treatment persisted until maturity in all the four years. The least values of straw yield was always associated with the FB treatment except for 2000 when the FB treatment out yielded the OR and TR treatments by 16 and 11%, respectively.

Table I. Monthly distribution of rainfall (mm) at the experimental site during the experimental period

	April	May	June	July	August	Sept.	Oct.	Nov.	Total
1999	0.0	7.5	20.2	328.6	255.5	163.8	25.8	0.0	801.4
2000	0.0	13.0	98.6	201.4	243.1	61.9	32.4	0.0	650.4
2001	0.0	37.1	119.3	110.1	244.4	216.8	TR[1]	0.0	727.7
2002	2.8	5.8	5.3	184.8	169.3	189.7	29	0.0	586.7

[1] TR = trace.

Leaf mineral composition. Land configuration and mulch treatments significantly ($P < 0.05$) influenced the contents of leaf N and P in both years (Table III). The contents of leaf N and P were significantly higher under the mulched (FBM, ORM & TRM) treatments than under the bare (FB, OR & TR) treatments in both years (Table III). Differences in the contents of leaf N and P among the three bare treatments were always small and insignificant. The contents of leaf N in the mulched treatments was 73 - 107% higher than the average for the bare treatments in 2001 and 65 - 94% higher in 2002. The corresponding increases in the contents of leaf P due to the mulch treatments relative to the bare treatments were 47 - 68% in 2001 and 52 - 71% in 2002. Although the land configuration and wood-chips mulch did not significantly influence the contents of leaf K, Ca and Mg in both years, the mulched treatments tended to accumulate greater concentrations of these elements relative to the bare treatments. As expected, the added wood-chips mulch significantly increased the amounts of oxidizable organic matter and nutrient contents in the surface layers of the mulched treated plots compared with the bare plots

Table II. Number of leaves plant^{-1} and stem diameter of sorghum as affected by land configuration and wood-chips mulch

Treatment	1999				2000				2001				2002			
	Veg[2].	Boot.	Mat.	Mean	Veg.	Boot.	Mat.	Mean	Veg.	Boot.	Mat.	Mean	Veg.	Boot.	Mat.	Mean
								Number of leaves plant^{-1}								
FB[1]	6.3	9.0	9.2	8.2	6.5	9.6	10.8	9.0	5.3	9.0	10.0	8.1	6.1	9.4	9.9	8.4
OR	6.3	10.3	10.6	9.1	6.8	10.9	11.0	9.6	6.0	9.3	10.0	8.4	6.3	9.8	10.0	8.7
TR	6.1	10.1	10.5	8.9	7.1	11.0	11.1	9.7	6.4	9.5	10.8	8.9	6.5	9.8	10.2	8.8
FBM	6.6	10.9	11.3	9.6	7.8	11.5	12.5	10.6	6.7	10.3	11.5	9.5	7.0	10.8	11.3	9.7
ORM	6.7	10.5	11.3	9.5	7.3	11.1	11.5	10.0	6.8	9.8	11.7	9.4	6.6	9.9	10.5	9.0
TRM	6.5	10.5	11.0	9.3	7.5	11.4	12.1	10.3	7.0	10.0	12.0	9.7	6.8	10.0	10.8	9.2
$LSD_{0.05}$	NS[3]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
								Stem diameter (cm)								
FB	1.60	2.30	2.40	2.10	1.60	2.60	2.60	2.26	1.60	2.10	2.40	2.03	1.40	2.40	2.80	2.14
OR	1.70	2.50	2.70	2.30	1.70	2.60	2.70	2.33	1.80	2.30	2.70	2.28	1.50	2.40	2.90	2.19
TR	1.50	2.30	2.70	2.20	1.60	2.60	2.80	2.33	1.80	2.60	2.70	2.37	1.50	2.50	3.00	2.22
FBM	1.70	2.90	3.20	2.60	1.80	3.00	3.30	2.70	1.80	3.00	3.30	2.70	1.80	2.90	3.20	2.62
ORM	1.70	2.80	3.20	2.60	1.70	2.90	3.10	2.57	1.90	2.70	3.10	2.58	1.50	2.50	2.90	2.33
TRM	1.60	2.70	3.10	2.50	1.70	3.00	3.20	2.63	1.90	2.90	3.20	2.67	1.50	2.50	3.00	2.39
$LSD_{0.05}$	NS	0.22	0.25	0.13	NS	0.25	0.19	0.13	NS	0.38	0.35	0.19	NS	NS	NS	0.15

[1]FB = flat bed, OR = open ridge, TR = tied ridge, FBM = flat bed + mulch, ORM = open ridge + mulch, TRM = tied ridge + mulch
[2]Veg. = Vegetative, Boot. = Booting, Mat. = Maturity
[3]NS= not significant

(Chiroma *et al*., 2005a). These results demonstrate the importance of wood-chips in improving the fertility status of these coarse textured soils as previous studies in the area have shown that soil organic matter is the dominant factor that contributes to the cation exchange capacity of these soils (Chiroma *et al*., 2002). An increase in soil fertility as a result of the use of wood-chips has earlier been reported by Schoenholtz *et al*. (1992) and by Ojeniyi and Ighomrore (2004). The study by Ojeniyi and Ighomrore (2004) showed that mulching with sawdust significantly improved the leaf nutrient status of cassava. Because carbonaceous materials such as wood-chips are known to decompose very slowly, their use as mulch material favours gradual but continuous supply of nutrients to the growing plants by safe guarding their losses against leaching and erosion.

Straw yield. Sorghum straw yields varied significantly ($P < 0.05$) both among years and among treatments within a year (Tables IV & V). Sorghum straw yield was significantly influenced by year and mulch and by year, land configuration and mulch interactions (Table IV). Application of wood-chips on the soil surface increased the straw yield of sorghum both in years with average rainfall and above average rainfall. However, the least rainfall received during 2002 was reflected in lower straw yields than those observed in 1999, 2000 and 2001 cropping seasons. During the 4 years study, straw yield was higher with the FBM treatment than with either ORM or TRM treatments, although differences among these treatments were not significant in any given year. Pooled across the years, mean straw yield with FBM, TRM, ORM, TR and OR treatments were 56, 41, 39, 16 and 10% higher, respectively than the average yield for the FB treatment. The mulched (FBM, ORM & TRM) treatments also produced the highest grain yield in all the four experimental years (Chiroma *et al*., 2006c). The regression of grain yield (y) on straw yield (x) for the four cropping seasons (1999 - 2002) indicated highly significant ($P < 0.05$) positive and linear correlation represented by the equations:

$$Y = -18.69 + 0.24x, \quad r^2 = 0.97 \ (1999)$$
$$Y = -711.33 + 0.45x, \quad r^2 = 0.93 \ (2000)$$
$$Y = -96.95 + 0.32x, \quad r^2 = 0.85 \ (2001)$$
$$Y = 45.12 + 0.28x, \quad r^2 = 0.88 \ (2002).$$

Based on the slope of the regression line, the increase in grain yield associated with straw production was greatest in 2000, where each unit increase in straw production increased grain yield by 0.45 kg ha^{-1}.

It is evident from the results of this study that combining the practice of flat seed bed cultivation or ridge

Table III. Effects of land configuration and wood-chip mulch on sorghum leaf mineral composition (%)

Treatment	N	P	K	Ca	Mg
			2001		
FB[1]	1.7	0.021	0.063	0.091	0.082
OR	1.3	0.017	0.055	0.088	0.077
TR	1.5	0.019	0.057	0.086	0.079
FBM	3.1	0.032	0.071	0.098	0.089
ORM	2.8	0.028	0.069	0.097	0.088
TRM	2.6	0.029	0.067	0.097	0.086
$LSD_{0.05}$	0.471	0.0047	NS[2]	NS	NS
			2002		
FB	1.9	0.023	0.064	0.093	0.083
OR	1.5	0.019	0.058	0.092	0.079
TR	1.8	0.022	0.062	0.089	0.082
FBM	3.3	0.036	0.073	0.103	0.094
ORM	3.1	0.032	0.070	0.100	0.091
TRM	2.8	0.034	0.070	0.102	0.089
$LSD_{0.05}$	0.466	0.0048	NS	NS	NS

[1]FB = flat bed, OR= open ridge, TR = tied ridge, FBM = flat bed + mulch, ORM = open ridge + mulch, TRM = tied ridge + mulch
[2]NS = not significant

Table IV. Analysis of variance table for straw yield

Source of variation	DF	MS
Block	3	367551
Year (YR)	3	1917129*
Land configuration (LC)	2	185198NS
Mulch (M)	1	32560000**
YR x LC	6	423206NS
YR x M	3	241820NS
LC x M	2	2264901NS
YR x LC x M	6	770849*
Error	69	500064

* = Significant at 5% probability level, ** = Significant at 1% probability level
NS = not significant

Table V. Effects of land configuration and wood-chips mulch on straw yield of Sorghum, 1999-2002

	Straw yield ($kgha^{-1}$)				
Treatments	**1999**	**2000**	**2001**	**2002**	**Mean**
FB[1]	2515	4100	3265	2760	3160
OR	3184	3488	3565	3620	3465
TR	4121	3683	3788	3107	3675
FBM	4716	4925	5200	4896	4934
ORM	4467	4575	4726	3803	4393
TRM	4245	4713	4986	3925	4467
Mean[2]	3875	4247	4255	3686	
$LSD_{0.05}$	1355	758	936	1222	499

[1]FB = flat bed, OR open ridge, TR = tied ridge, FBM = flat bed + mulch, ORM = open ridge + mulch, TRM = tied ridge + mulch
[2] LSD for treatments means over years = 308

tillage with mulching using wood-chips can promote better growth and yield (grain & straw) of sorghum. The superior growth and yield response by the plants grown in the mulch treated plots was a consequence of cumulative effect of improvement in soil physical environment as evidenced by low bulk density and penetration resistance (Chiroma *et al*., 2006b) and greater storage of rain water in the soil profile (Chiroma *et al.,* 2006c) thus creating a favourable environment for crop growth. Further more, improvement in the fertility of the surface 0 - 0.075 m layers of the mulch treated plots (Chiroma *et al*., 2005a) may have also influenced the growth and straw yield of sorghum, in line with the findings of a study conducted on a similar soil and under similar climatic conditions (Selvaraju *et al*., 1999). However, differences in straw yield between FB, OR and TR treatments were always small and insignificant except for 1999 when TR treatment significantly out yielded the FB treatment by about 64%.

CONCLUSION

It is concluded that under the soil and climatic conditions of Maiduguri, northeast Nigeria, the practice of retaining wood-chips on the surface of flat seed bed or ridge-tilled field can improve the growth and straw yield of sorghum compared to planting on flat seed bed or ridged tilled-field in the absence of wood-chips mulch. This study also demonstrated the effectiveness of wood-chip as a valuable nutrient source for improving the growth and straw yield of sorghum.

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REFERENCES

Bielders, C.L. and K. Michels, 2002. On-farm evaluation of ridging and residue management options in a Sahelian millet-cowpea intercrop 2. Crop development. *Soil Use Management*, 18: 309–15

Bielders, C.L., K. Michels and A. Bationo, 2002. On-farm evaluation of ridging and residue management options in a Sahelian millet-cowpea intercrop. 1 Soil quality changes. *Soil Use Management*, 18: 216–22

Chiroma, A.M., 1996. *The Farming System of Futchimiram in Yobe State, Nigeria,* P: 72. Working Paper No 4. Cambridge and Bayero Universitie's Department of Geography

Chiroma, A.M., J.D. Kwari and A.B. Alhassan, 2002. Effect of different management practices on selected soil fertility parameters in a sandy soil in northeast Nigeria. *J. Sust. Agric. Environ*., 4: 264–74

Chiroma, A.M., O.A. Folorunso and A.M. Kundiri, 2005. Effects of tillage and stubble management on root growth and water use of millet grown on a sandy loam soil. *J. Arid Agric.*,15: 83-89

Chiroma, A.M., O.A. Folorunso and A.B. Alhassan, 2006a. The effects of land configuration and wood-shavings mulch on the properties of a sandy loam soil in northeast Nigeria. 1. Changes in chemical properties. *Tropicultura*, 24(3): (In press)

Chiroma, A.M., O.A. Folorunso and A.B. Alhassan, 2006b. The effects of land configuration and wood-shavings mulch on the properties of a sandy loam soil in northeast Nigeria. 2. Changes in physical properties. *Tropicultura*, 24: 33-38

Chiroma, A.M., O.A. Folorunso and A.B. Alhassan, 2006c. Soil water conservation, growth, yield and water use efficiency of sorghum as affected by land configuration and wood-shavings mulch in a semi-arid soil of northeast Nigeria. *Expt. Agric*., 42: 199–216

Ewulo, B.S., 2004. Effect of reduced manual tillage on soil and maize yield in the rainforest zone of southwest Nigeria. *Nigeria J. Soil Sci.*, 14: 25–9

Gajri, P.R., V.K. Arora and M.R. Chaudhary, 1994. Maize growth responses to deep tillage, straw mulching and farmyard manure in a coarse textured Soils of N.W. India. *Soil Use Management,* 10: 15–20

Grema, A.K. and T.M. Hess, 1994. Water balance and water use of millet-cowpea intercrops in northeast Nigeria. *Agricultural Water Management*, 26: 169–285

Kronen, M., 1994. Water harvesting and conservation techniques for smallholder crop production systems. *Soil Tillage Res.*, 32: 71–86

Murillo, J.M., F. Moreno, F. Pelegrín and J.E. Fernández, 1998. Responses of sunflower to traditional and conservation tillage under rainfed conditions in southern Spain. *Soil Tillage Res*., 49: 233–41

Ojeniyi, S.O. and F.O. Adekayode, 1999. Soil conditions and cowpea and maize yield produced by tillage methods in the rainforest zone of Nigeria. *Soil Tillage Res*., 51: 161–4

Ojeniyi, S.O. and H. Ighomrore, 2004. Comparative effect of mulches on soil and leaf nutrient content and cassava yield. *Nigerian J. Soil Sci*., 93–7

Ojeniyi, S.O., A.O. Adetoro and S.A. Odedina, 1999. Effect of manorial tillage methods on soil density, moisture content and cowpea grain yield. *J. Agric. Tech*., 7: 16–9

Schoenholtz, S.H., J.A. Burger and R.E. Kreh, 1992. Fertilizer and organic amendmend effects on mine soil properties and revegetation success. *Soil Sci. Soc. American J*., 56: 1177–84

Selvaraju, R., P. Subbian, A. Balasubramanian and R. Lal, 1999. Land configuration and soil management options for sustainable crop production on Alfisols and Vertisols of southern Peninsular India. *Soil Tillage Res.,* 52: 203–16

Tel, D.A. and M. Hagarty, 1984. *Soil and Plant Analysis*, P: 277. IITA/University of Ghelph

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