PAT June, 2015; 11 (1): 12-21 **ISSN: 0794-5213**

Online copy available at

www.patnsukjournal.net/currentissue

Effects of Crop Residue - Mulch on Selected Soil Physical Properties and Root Zone Moisture Content Under Sorghum and Millet In Maiduguri, Nigeria.

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Abstract

A field trial was conducted under rain-fed conditions at two sites to determine the effects of different rates of rice bran-mulch on soil physical properties and root zone moisture content under sorghum and millet in Maiduguri, semi-arid north-east Nigeria. The study comprised six treatments replicated four times and laid out in a split-plot design. The soils of the experimental sites are sandy loam in texture. Following land preparation, rice bran was uniformly applied on the soil surface as mulch. Crop cultural practices were carried out. Profile moisture content (0 – 200 cm depth) was determined throughout the growing season using calibrated neutron probe, and gravimetrically (0 – 30 cm depth only). Soil physical were determined at 0 – 15 and 15 – 30 cm depths. Data collected were subjected to statistical analysis (ANOVA). At Site 1, 15 t/ha mulch treatment resulted in a lower bulk density (1.61 g/cm^3) with a consequent higher total porosity (39.11 %) compared with 0 (1.66 g/cm^3 and 37.50 %, respectively) and 10 (1.66 g/cm^3 and 37.31 %, respectively) t/ha mulch rates. At Site 2, 10 t/ha mulch treatment resulted in significantly ($P \leq 0.05$) higher (0.57 cm/hr) saturated hydraulic conductivity than 15 t/ha mulch treatment (0.50 cm/hr). The moisture content of the root zone of sorghum was found to be higher ($P \leq 0.05$) than that of millet throughout the growing season at the two sites. At planting, root zone moisture content increased with mulch rate at Site 2, whereas, at both vegetative growth and maturity stages, it decreased with mulch rate at Site 1.

Keywords: *Crop residue-mulch, sorghum, millet, soil physical properties and root zone moisture content.*

Introduction

Rainfall pattern in Maiduguri, semi-arid region of Nigeria, is characterized by limited and undependable rainfall. The rate of moisture loss into the atmosphere through the process of evapotranspiration is quite high (Grema and Hess, 1994). The soils are generally sandy in nature, poorly structured and inherently low in fertility, organic matter content and water holding capacity (Yandev and Sachan, 1985; Rayar, 1988; Chiroma, 2004).

The presence of crop residue on the soil surface as mulch has been reported to provide cover, decrease evaporation of soil water, retard surface runoff and enhance infiltration of water into the soil with a consequent improvement in the capacity of the soil to store water useful for growing crops (Odofin, 2005).Crop residue management practices have been shown to be quite effective in soil moisture conservation in semi-arid environments. It was observed that residue management practice irrespective of tillage system conserved more moisture during a dry period (Chiroma *et al.*, 2005). Also, Ojeniyi *et al.* (2009) and Agele *et al.* (2000) reported that soil moisture storage was significantly increased by mulch application irrespective of tillage treatment. Ogban *et al.* (2006) noted that residue-mulch applied on the soil surface of tilled or no-till soil could improve soil properties and increase crop growth and yields. The benefits that may accrue from soil management practices include improved water transmission characteristics, formation of stable soil aggregates, bulk density reduction, moderation of soil temperature, soil moisture conservation and increases in organic matter content (Ojeniyi and Ighomrore, 2004; Ogban, 2009). Crop residues returned to the soil have been found to be beneficial for the maintenance and/or improvement of the physical, chemical and biological properties of the soil that enhance easy tillage, crop growth and yield (Linden *et al.*, 2000; Ewulo, 2005). Khan (2002) reported a favourable (lower) bulk density under the influence of mulching practice, which may have resulted in better root growth and penetration to greater depth than bare plots. In a similar report, Jalo *et al.* (1998) noted that bulk density was significantly lower in mulched plots which also exhibited higher porosity compared to the zero mulch treatment plots. Results from these studies indicate that residue-mulch could provide favourable soil conditions necessary for enhanced crop growth and higher yields. Ojeniyi *et al.* (2009) observed a significant reduction in soil bulk density and temperature, and an increase in soil moisture content resulting from mulching practice irrespective of tillage treatment. This results so obtained indicates that surface application of plant residue-mulch ameliorated soil physical conditions to the benefit of sorghum crop. A similar observation was made for soil grown to tomato crop (Agele *et al.,* 2000). According to Ewulo (2005) and Akanbi and Ojeniyi (2007), mulch combined with manual tillage resulted in lower soil bulk density and temperature, whereas porosity and moisture content were increased at two sites under study when compared with tillage alone.

An improved soil physical environment and a consequent conservation of appreciable amount of water under mulched condition has been implicated in various studies in which enhanced crop growth and higher yields have been observed, especially in environments with scanty rainfall. Therefore, this work is aimed at assessing soil physical properties and root zone moisture content as influenced by crop residue-mulch application.

Materials and Methods

The experiment comprising two test crops (sorghum and millet) and three rates (0, 10 and 15 tons/ha) of rice bran residue was carried out at two sites (Sites 1 and 2) located in the University of Maiduguri. Site 1 is situated near Gate 2, in the Faculty of Agriculture Teaching and Research Farm (11^0 49′ N, 13^0 13′ E and 324 m above mean sea level), while Site 2 is situated in the Faculty of Agriculture orchard, opposite Centre for Arid Zone Studies complex (11^0 49′ N, 13^0 12′ E and 327 m above mean sea level). The two sites had been set aside exclusively, and found suitable for teaching and research purposes over a long period of time. The map of Borno State showing the location of the study area (Maiduguri) is shown in Fig. 1. The climate of the study area is the seasonal wet-dry, semi-arid type. The soils of the study area are sandy loam in texture.

The experiment was laid out in a split-plot design with test crops as the main-plot, and the residue rates as the sub-plot treatments. The treatments were replicated four times. The rates of residues (wheat straw and wood shavings) applied in the study area range between 4 and 10 tons/ha (Chiroma *et al.*, 2005; Chiroma, 2004). The edges of the plots measuring 8 m x 4 m were raised to minimize run-off and/or run-on to adjacent plots. The crop residue-mulch (rice bran) was uniformly applied just before planting. Sorghum seeds were sown at a spacing of 40 cm within rows and 75 cm between rows, while millet seeds were sown at a spacing of 50 cm within rows and 75 cm between rows (BOSADP, 1993). The seedlings were thinned to two plants per stand two weeks after planting to give a plant population of about 66,666 and 53,333 plants per hectare for sorghum and millet, respectively. Other cultural practices carried out were fertilizer application, weed control and harvesting.

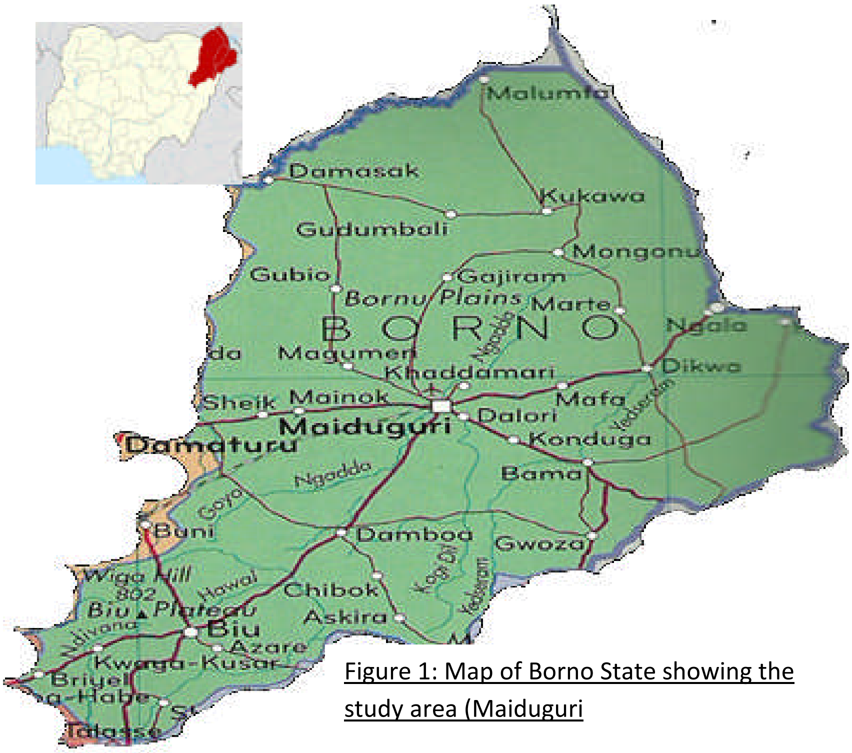

Figure 1: Map of Borno State showing the study area (Maiduguri

Three replicates of each treatment were instrumented with access tubes for the repetitive measurement soil moisture content at various soil depths. Soil moisture content (volumetric moisture content, θv) was measured weekly using a calibrated neutron probe (Eze *et al.*, 2007) at 0.1 m interval down to 2.0 m depth (i.e. below the rooting depth) throughout the study period. The rooting depth of sorghum and millet were observed during this study to be 100 and 90 cm, respectively. Also, gravimetric water content was determined on soil samples collected from the surface, 0 – 15 cm depth and subsurface, 15- 30 cm soil depth (Brady and Weil, 1999). Shortly after crop harvest, one soil sample was collected from four replicates of each treatment at 0-15 cm and 15-30 cm depths for the determination of soil physical properties. Bulk density was determined on core samples (Blake and Hartage, 1986) collected from crop row positions. The standard procedures of Ball-Coelho *et al.* (1998) were employed for the computation of total porosity, micro porosity and macro porosity. Saturated hydraulic conductivity was determined on undisturbed core samples using the falling head permeameter method (Singh, 1989). The data obtained were subjected to analysis of Variance using Statistix 8.0 software (2005). Where significant differences exist between treatments, the differences were separated using Duncan's Multiple Range Test (DMRT) at 5% significant level.

Results and Discussion

Soil Physical Properties

The soil physical properties of the surface (0 – 15 cm depth) and subsurface (15 – 30 cm depth) are presented in Table 1. At Site 1, mulch treatment had significant ($P \leq 0.05$) effect on the bulk density and total porosity of soils collected from 15 - 30 cm depth. The highest mulch rate (15 t/ha) had a lower bulk density with a consequently higher total porosity, compared with 0 and 10 t/ha mulch rates (Ewulo, 2005; Akanbi and Ojeniyi, 2007; Ojeniyi *et al.* 2009). The protection of the soil surface from compaction by raindrops could have been made possible by the better surface cover provided by the highest mulch application rate compared to the lower mulch rates. At Site 2 and in the combined data micro porosity was significantly ($P \leq 0.05$) affected by crop type only, at the 0 – 15 and 15 – 30 cm depths, respectively. At Site 2 and in the combined data, soils collected from sorghum plots had higher micro porosity than those from millet plots at 0 – 15 and 15 – 30 cm depths, respectively. Crop type and mulch rate had no significant effect on the macro pore space of soils collected from 0 – 15 and 15 – 30 cm depths at Sites 1 and 2, and the combined data. At Site 2, mulch treatment had significant ($P \leq 0.05$) effect on the saturated hydraulic conductivity of soil collected from 0 - 15 cm depth. Surprisingly, at Site 2, higher saturated hydraulic conductivity at 0 – 15 cm depth resulted from the application of 10 t/ha mulch compared with 15 t/ha mulch rate. The interaction of crop type and mulch treatment had no significant influence on the bulk density, total porosity, micro porosity, macro porosity and hydraulic conductivity of soils collected from 0 – 15 and 15 – 30 cm depths in the sorghum and millet plots at Sites 1 and 2, and the combined data.

Root Zone Moisture Content

The amount of moisture contained within the root zone of sorghum and millet at planting (0 week after planting (WAP)), at vegetative growth stage (6 WAP), at flowering (9 WAP) and at maturity (12 WAP) is presented in Table 2. The moisture content of the root zone of sorghum was found to be higher ($P \leq 0.05$) than that of millet at planting, vegetative growth, flowering and maturity stages, at Sites 1 and 2, and in the combined data. This could be attributed to the deeper penetration of the sorghum roots (100 cm depth each at Sites 1 and 2) than the rooting depth of millet (80 and 90 cm depths) throughout the growing season, at Sites 1 and 2, respectively, and in the combined data. The deeper penetration of the sorghum crop roots is related to its characteristic nature.

At planting, water content within the root zone of sorghum and millet was observed to increase with mulch application rate arising from decrease in evapotranspiration due to better soil surface coverage at higher mulch rates, as observed from results obtained in this study at Site 2. Later on, during the growing season, differences in water content of crop root zone among mulch treatments was not significant, probably, due to lack of significant difference in canopy cover among mulch treatments at Site 2. The effect of mulch is usually masked during vegetative growth period and beyond, during the growing season, by cover provided by crop canopy. At Site 2, it was observed that the combination of sorghum and mulch application rates resulted in higher root zone moisture content than the combination of millet and mulch treatments, at planting (Table 3). Also, root zone water content was observed to increase with mulch application rate arising from greater water conservation arising from better soil surface coverage at higher mulch rates, as observed from results obtained in this study at Site 2. At vegetative growth stage, 15 t/ha mulch rate resulted in a lower root zone moisture content than both 0 and 10 t/ha mulch rate, while at maturity stage, root zone moisture content was higher under 0 t/ha than under 10 and 15 t/ha mulch rates, at Site 1.

This observation could be due to increase in depletion of moisture from the root zone following the application of 10 and 15 t/ha mulch, with a consequently higher plant height, grain and Stover yield under 10 and 15 t/ha mulch treatments as observed at Site 1. The depleted moisture may have been utilized by the crops for the production of higher plant height grain and Stover yield. Also at Site 1, a similar trend was found in which the combination of sorghum and mulch application rates resulted in higher root zone moisture content than the combination of millet and mulch treatments, at vegetative growth, flowering and maturity stages (Table 3). This could be adduced to the deeper penetration of the sorghum roots than the rooting depth of millet throughout the growing season, at Site 1.

Table 1: Effects of crop and mulch on selected soil physical properties at 0 – 15 and 15 – 30 cm depths under sorghum and millet after harvest at Maiduguri, 2009.

	Bulk density (g/cm^3)			Micro porosity (%)			Macro porosity (%)			Total porosity (%)			Hydraulic conductivity (cm/hr)		
Treatment	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined
0 – 15 cm depth															
A: Crop type															
Sorghum	1.53a	1.54a	1.53a	16.84a	18.07a	17.45a	25.55a	23.79a	24.67a	42.39a	41.86a	42.12a	0.65a	0.50a	0.57a
Millet	1.53a	1.56a	1.54a	17.65a	15.65b	16.65a	24.74a	25.67a	25.21a	42.39a	41.32a	41.86a	0.64a	0.57a	0.61a
SE ±	0.02	0.03	0.01	0.65	0.54	0.34	1.20	1.43	0.18	0.57	1.29	0.37	0.01	0.07	0.03
B: Mulch rate															
0 t/ha	1.55a	1.56a	1.55a	17.86a	16.44a	17.15a	23.75a	24.88a	24.31a	41.60a	41.32a	41.46a	0.66a	0.54ab	0.60a
10 t/ha	1.51a	1.57a	1.54a	16.86a	16.66a	16.76a	26.35a	24.00a	25.17a	43.21a	40.66a	41.93a	0.61a	0.57a	0.59a
15 t/ha	1.53a	1.52a	1.52a	17.01a	17.48a	17.24a	25.35a	25.31a	25.33a	42.36a	42.78a	42.57a	0.67a	0.50b	0.58a
SE ±	0.02	0.03	0.02	1.11	1.29	0.86	1.67	1.66	1.23	0.71	0.93	0.72	0.04	0.02	0.04
Interactionz															
A x B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
15 – 30 cm depth															
A: Crop type															
Sorghum	1.63a	1.72a	1.67a	18.34a	16.20a	17.27a	20.09a	19.02a	19.55a	38.43a	35.22a	36.82a	0.67a	0.49b	0.58a
Millet	1.66a	1.71a	1.68a	16.48a	15.95a	16.22b	21.03a	19.68a	20.36a	37.52a	35.63a	36.57a	0.60b	0.63a	0.61a
SE ±	0.02	0.03	0.01	0.72	0.33	0.30	0.88	1.42	0.36	0.84	1.15	0.46	0.01	0.04	0.02
B: Mulch rate															
0 t/ha	1.66a	1.72a	1.69a	16.96a	15.77a	16.37a	20.54a	19.42a	19.98a	37.50b	35.19a	36.34a	0.65a	0.54a	0.59a
10 t/ha	1.66a	1.72a	1.69a	17.88a	16.41a	17.15a	19.43a	18.73a	19.08a	37.31b	35.14a	36.23a	0.64a	0.55a	0.59a
15 t/ha	1.61b	1.70a	1.66a	17.40a	16.04a	16.72a	21.71a	19.90a	20.80a	39.11a	35.94a	37.52a	0.62a	0.60a	0.61a
SE ±	0.02	0.02	0.02	0.80	0.43	0.57	0.93	0.79	0.82	0.68	0.75	0.78	0.04	0.03	0.04
Interaction															
A x B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means with the same letter (s) in the columns are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5 % level of probability.
NS: Not Significant.

Table 2: Effects of crop and mulch on root zone moisture content (cm) at planting, vegetative growth, flowering and maturity stages under sorghum and millet at Maiduguri, 2009.

	At planting			At vegetative growth stage			At flowering stage			At maturity stage		
Treatment	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined
A: Crop type												
Sorghum	12.75a	13.28a	13.02a	11.16a	12.93a	12.04a	9.74a	10.45a	10.10a	10.26a	11.51a	10.88a
Millet	9.71b	11.56b	10.64b	8.81b	11.04b	9.92b	7.47b	9.02b	8.25b	8.24b	9.79b	9.01b
SE ±	0.33	0.16	0.11	0.08	0.22	0.08	0.14	0.03	0.05	0.22	0.21	0.01
B: Mulch rate												
0 t/ha	11.13a	12.24c	11.69a	10.07a	11.91a	10.99a	8.74a	9.73a	9.23a	9.48a	10.49a	9.98a
10 t/ha	11.36a	12.45b	11.91a	10.03a	11.97a	11.00a	8.64a	9.70a	9.17a	9.20b	10.55a	9.88a
15 t/ha	11.20a	12.58a	11.89a	9.85b	12.08a	10.96a	8.43a	9.79a	9.11a	9.07b	10.90a	9.99a
SE ±	0.10	0.05	0.34	0.07	0.17	0.50	0.09	0.14	0.31	0.07	0.28	0.38
Interaction												
A x B	NS	*	NS	*	NS	NS	*	NS	NS	*	NS	NS

Means with the same letter (s) in the columns are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5 % level of probability.
*: Significant at 5 % probability level. NS: Not Significant.

Table 3: Interaction effects of crop x mulch on root zone moisture content (cm) under sorghum and millet at planting at Site 2, and at vegetative growth, flowering and maturity stages at site 1 at Maiduguri, 2009.

	At planting (Site 2)		At vegetative growth stage (Site 1)		At flowering stage (Site 1)		At maturity stage (Site 1)	
	Treatment							
Mulch rate	Sorghum	Millet	Sorghum	Millet	Sorghum	Millet	Sorghum	Millet
0 t/ha	13.04c	11.45e	11.14ab	8.99c	9.96a	7.52c	10.54a	8.41c
10 t/ha	13.28b	11.62d	11.32a	8.74d	9.85a	7.43c	10.30a	8.10d
15 t/ha	13.53a	11.62d	11.01b	8.69d	9.41b	7.45c	9.94b	8.21cd
SE ±	0.17		0.11		0.18		0.24	

Means with the same letter (s) in the columns are not significantly different according to Duncan's Multiple Range Test (DMRT) at 5 % level of probability.

The influence of mulch treatments may have been overshadowed by the deeper root penetration of sorghum crop. These findings, so far made, attest to the superiority of mulching over no-mulch practice in respect of soil moisture conservation and storage (Ewulo, 2005; Odofin, 2005; Akanbi and Ojeniyi, 2007; Ojeniyi *et al.*, 2009).

Change in root zone moisture content (moisture storage) under sorghum and millet was found to be positive between planting and flowering stage, whereas, at maturity stage, it was observed to be negative, indicating soil moisture extraction from the root zone (Table 3). Rainfall partially recharged root zone soil moisture at planting, vegetative growth and flowering stages. Therefore, soil moisture extraction from sorghum and millet root zone was masked by the partial replenishment of soil moisture by rainfall during this period. However, at maturity stage, crop water use gave rise to soil moisture extraction, as observed from the negative root zone moisture storage values at crop maturity. These observations are consistent with those of Baumhardt *et al.* (1993).

Conclusion

From the findings in the present study, the following conclusions are made:

i. Fifteen t/ha mulch application resulted in lower bulk density and higher total porosity at Site 1, while 10 t/ha mulch resulted in higher saturated hydraulic conductivity at Site 2.
ii. Root zone moisture content increased with mulch rate at planting at Site 2, while at both vegetative growth and maturity stages at Site 1, it decreased with mulch rate.

Acknowledgement

I wish to appreciate the management of University of Maiduguri, Borno State and Federal University of Technology, Minna, Niger State, Nigeria for their moral and financial support towards the successful completion of this study.

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