INFLUENCE OF RICE HUSK - MULCH ON SOIL WATER BALANCE COMPONENTS UNDER SORGHUM AND MILLET CROPS IN MAIDUGURI, SEMI ARID NORTHEAST NIGERIA.

Eze, P. C.,[1] Odofin, A. J.,[1] Onyekwere, I. N.,[2] Musa, J. J.[3] and Tsado, P. A.[1]

[1]Department of Soil Science and Land Management, Federal University of Technology, Minna, Niger State.

[2]National Roots and Tuber Crops Research Institute, Umudike, Umuahia, Abia State.

[3]Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Niger State.

ABSTRACT

A 2 x 3 factorial experiment was conducted at two sites in Maiduguri, Borno State during the 2009 cropping season. The objective was to evaluate the influence of rice husk-mulch on soil water balance components under sorghum and millet crops. The treatments comprised of two test crops (sorghum and millet) and three rates of application (0, 10 and 15 t ha^{-1}) of rice husk mulch, fitted in a split plot design. The test crops were assigned to the main-plot, while the mulch application rates were assigned to the sub-plot. The treatments were replicated three times. The components of soil water balance determined were annual rainfall, moisture storage within sorghum and millet root zone, drainage below crop root zone and seasonal crop evapotranspiration. Profile moisture content was measured weekly with the aid of a neutron probe installed at a depth of 2.0 m using access tubes. Also, soil (0 – 30 cm depth) moisture content was determined gravimetrically on weekly basis. Rainfall was measured using a manual rain gauge installed at each of the two sites. Findings in this study indicated that, under the prevailing circumstances, annual rainfall was lower than the amount observed over a ten-year period in Maiduguri. Consequently, soil moisture storage, drainage and seasonal crop evapotranspiration generally declined. An average of over 90 % of this low annual rainfall was lost as seasonal crop evapotranspiration. Sorghum plots stored higher moisture within the root zone, had higher drainage and lower seasonal evapotranspiration than millet plots. Moisture storage and drainage increased with increasing mulch application rate, while, seasonal crop evapotranspiration decreased with it.

Key Words: Rice husk-mulch, soil water balance components, sorghum and millet.

INTRODUCTION

Maiduguri, located in the Semi-arid Northeast Nigeria belongs to the Sudano-Sahelian zone (SSZ) of West Africa as described by Sivakumar and Wallace (1991). The SSZ is characterized mainly by an average growing season that ranges between 60 and 150 days. Rainfall is scanty and highly variable, annual temperatures are high and evapotranspiration rates are excessively high (Eze, 2015). Under these prevailing conditions, declining national incomes and fall in per capita food production could result from recurrent drought and successive crop failure. Thus, agricultural management practices that would maximize the uptake and utilization of the limited moisture supply from rainfall are essential for sustainable soil productivity and enhanced crop growth and yield. In order to design appropriate management practices for enhanced water use efficiency, a complete understanding of soil water movement and its associated physical and hydraulic properties is required. Development of suitable soil and crop management technologies in a water-limited environment is a major challenge which could emanate from inadequate or even lack of complete data on soil physical and hydraulic properties, as well as on the spatial temporal variation of water balance components. Odofin *et al.* (2012), reported soil water balance components which include annual rainfall, water storage within crop root zone and drainage, amongst others, are quite difficult to determine. Their measurement is costly, tedious and time-consuming, therefore, have received little attention in Nigeria.

In Semi-arid zone of Nigeria, the use of crop residues such as rice husk and wood shavings as soil amendments have been found to be effective in improving soil physical and chemical properties, as well as enhancement of crop performance and water use efficiency (Chiroma *et al.,* 2003; Eze *et al.*, 2014a &b; Eze *et al.,* 2015a &b). Sorghum and millet are drought-resistant crops commonly grown as staple food in this zone (Ojeniyi *et al.,* 2009; Eze *et al.*, 2014a &b; Eze, 2015). A systematic study of soil water balance is essential for development of management options for sustainable agricultural production. Achievement of higher water use efficiency and management of water resources for their most profitable use in crop production would require an understanding of the magnitude of soil water balance components and their influence on crop growth and yield. Therefore, the objective of this study was to determine the influence of rice husk-mulch on soil water balance components under sorghum and millet crops.

MATERIALS AND METHODS

Field trials were conducted at two sites within University of Maiduguri, Borno State, Nigeria. Site 1 is located 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 (11^0 49′ N, 13^0 12′ E and 327 m above mean sea level). The study area is characterized by seasonal wet-dry, semi-arid climate. The annual rainfall ranges between 600 and 900 mm, while the temperature could be as low as between 18 and 20 °C during the harmattan period, and as high as between 38 and 42 ^{0}C during the peak period of the dry season, between January and April (Department of Meteorological Services, Maiduguri). Furthermore, potential evapotranspiration usually exceeds rainfall for about 8 to 9 months during a given year (Grema and Hess, 1994) except during the rainy periods. The texture of soils of the study area is sandy loam, developed from aeolian sand deposit (Eze *et al.*, 2014a &b; Eze, 2015). The study area is dominated by vast grassland interspersed with few drought tolerant tree species.

Treatments and Experimental Design

The experiment comprising two test crops (sorghum and millet) and three rates (0, 10 and 15 t/ha) of rice bran residue was carried out at the two sites. 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, giving a total of 6 treatment combinations. The treatment combinations were assigned randomly, and replicated three times. The 0 t/ha treatment (Control) represents the common cultural practice in the study area, while residue application rates (10 and 15 t/ha) represent the introduced technology.

Soil Characterization

For the purpose of characterization of the soils of the two experimental sites (Eze, 2015), one profile pit each was dug and described at the two sites following the guideline for profile pit description (Soil Survey Staff, 2006).

Agronomic Practices

Rice bran was uniformly applied on the soil surface at three rates just before planting. Five to six Apron star treated sorghum (var. ICSV III) seeds were hand-sown per hole on the flat, at a spacing of 75 cm by 40 cm, while millet seeds (var. LCIC MV-2 (LCIC 9702)) were sown at a spacing of 75 cm by 50 cm (BOSADP, 1993). The seedlings were thinned to two plants per stand two weeks after planting. Recommended fertilizer rate of NPK 64:32:30 kg/ha for sorghum and millet was applied (BOSADP, 1993). Weed control was carried out manually using hand-hoe. Harvesting was done at physiological maturity (12 weeks after planting) and the grains were threshed after thorough sun-drying.

Soil Moisture Content Determination

Access tubes were installed in three replicates of each treatment for the repetitive measurement of 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. Also, gravimetric water content was determined on soil samples collected from 0 – 15 and 15- 30 cm soil depths (Brady and Weil, 1999).

Soil Water Balance

Soil water balance was determined from the equation below:

$$\Delta S = P + C - ETcrop - D - R$$

where, ΔS is moisture storage change within the root zone, P is rainfall, C is capillary rise from the water table, ETcrop is crop evapotranspiration (water use), D is the drainage out of the root zone and R is runoff (-) or run-on (+) over a specified time period. Since the water table in this area is deeper than 10 m (Grema and Hess, 1994), and the soil is light-textured and possesses a high infiltration capacity, then, capillary rise would be quite negligible. Also, the sides of the plots were raised to prevent run-off/run-on. Therefore, evapotranspiration or water use was estimated from equation below, after determining the value of each of the factors on the right hand side of the equation (Gregory, 1991):

$$ETcrop = P - \Delta S - D$$

Drainage (D) occurring below the root zone was determined by the method of Zaongo *et al.* (1994). The drainage factor, D, that was used in the computation of water use (ETcrop¬) was that occurring between the bottom of the root zone and the measured profile (2.0 m). Drainage below the root zone was estimated as the sum of change in water content between 1.0 m and 2.0 m for sorghum, and 0.9 m and 2.0 m for millet. Some of the water stored above 2.0 m will be lost through drainage as the growing season progresses. A manual rain gauge was installed at each of the two sites prior to the commencement of the experiment to measure seasonal rainfall.

Statistical Analysis

Data collected were subjected to analysis of variance to determine differences between means at 5 % level of significance. Means separation was carried out using Duncan's Multiple Range Test (DMRT) with the use of Statistix 8.0 (2005) statistical package.

RESULTS AND DISCUSSION

Table 1 shows the soil water balance components (seasonal rainfall, moisture storage change within the root zone, drainage below the root zone, and seasonal crop evapotranspiration). The annual rainfall was quite low (< 500 mm) as expected at the two sites under study. At Site 1, irrespective of mulch treatments, root zone water storage under sorghum ranged between 31 and 36 mm, while under millet, it ranged between 12 and 16 mm. At Site 2, the amount of moisture stored within crop root zone ranged between 27 and 29 mm under sorghum, whereas under millet, the range was between 16 and 19 mm. An average of 8 and 3 % of annual rainfall was stored within the root zone of sorghum and millet, respectively, at Site 1. At Site 2, the amount of moisture stored was 6 and 4 % of annual rainfall under sorghum and millet, respectively. Drainage under sorghum at Site 1 ranged between 5 and 8 mm, which correspond to an average of 2 % of annual rainfall, while under millet the range was between 9 and 11 mm, corresponding to an average of 2 % of annual rainfall. At Site 2, drainage under sorghum ranged between 38 and 60 mm, which correspond to an average of 10 % of annual rainfall, while under millet the range was between 34 and 49 mm, corresponding to an average of 9 % of annual rainfall. Seasonal evapotranspiration under sorghum at Site 1 ranged between 398 and 404 mm, while under millet, the range was also narrow. Average seasonal crop evapotranspirational water losses were 91 and 94 % of annual rainfall, respectively under sorghum and millet crops at Site 1. At Site 2, seasonal evapotranspiration ranged between 390 and 414 mm under sorghum, which correspond to an average of 84 % of annual rainfall. In the millet plots, the range of seasonal evapotranspiration was between 414 and 427 mm, corresponding to an average of 87 % of annual rainfall.

The low annual rainfall observed in Maiduguri was expected, being a common feature of the semi-arid zone of Nigeria. The observed annual rainfall (< 500 mm) was actually lower than the annual (ranging between 600 and 900 mm) obtained between 2000 and 2009 (Department of Meteorological Services, Maiduguri). Therefore, it was not surprising that moisture storage, drainage and seasonal crop evapotranspiration were generally low, relative to amounts observed in earlier years. Most of the soil moisture received as rainfall was lost through evapotranspiration (above 90 and 80 %, respectively, at Sites 1 and 2) under sorghum and millet crops. Earlier workers (Grema and Hess, 1994; Chiroma, 2004) noted a steady decline in annual rainfall and excessively high seasonal crop evapotranspiration since the early 1960s. Hess *et al.* (1995) and Carter (1995), reported that evapotranspiration rates in the semi-arid region often exceed annual rainfall by a factor of 2 – 3 or more in most of the months due harsh climatic conditions of low relative humidity and high temperature, and low vegetative cover over the soil surface. Crops, especially less drought tolerant ones, are bound to suffer serious water stress in a situation where evapotranspiration is excessively high during the growing season. This necessitates the employment of appropriate agricultural management practices, as well as growth of drought tolerant crops, predominantly, in a water scarce environment such as the semi-arid North-east zone of Nigeria.

The results of the influence of crop type and mulch application rate on moisture storage within the root zone, drainage below the root zone, and seasonal crop evapotranspiration are presented in Table 2. The results showed that significantly higher ($P \leq 0.05$) amount of moisture was stored in the root zone of sorghum than in that of millet at the two sites and in the com-

Table 1: Soil water balance components under sorghum and millet at Maiduguri.

Site	Crop type	Treatment	Rainfall (mm)	ΔS (mm)	D (mm)	ETcrop (mm)
1	Sorghum	0 t/ha mulch	440.50	31.03	5.03	404.00
		10 t/ha mulch	440.50	36.63	6.70	397.17
		15 t/ha mulch	440.50	34.43	8.17	397.90
	Millet	0 t/ha mulch	440.50	12.30	10.90	417.30
		10 t/ha mulch	440.50	16.03	9.00	415.47
		15 t/ha mulch	440.50	15.87	10.10	414.53
2	Sorghum	0 t/ha mulch	479.20	27.07	38.43	413.70
		10 t/ha mulch	479.20	28.93	44.00	406.27
		15 t/ha mulch	479.20	29.57	59.77	389.87
	Millet	0 t/ha mulch	479.20	17.97	34.10	427.13
		10 t/ha mulch	479.20	19.10	44.30	415.80
		15 t/ha mulch	479.20	16.13	48.80	414.27

ΔS: Soil water storage change within the root zone
D: Drainage below the root zone
ETcrop: Seasonal crop evapotranspiration (seasonal crop water use)

Table 2: Effects of crop and mulch on soil water balance components at Maiduguri.

	Moisture storage (mm)			Drainage (mm)			Seasonal crop evapotranspiration (mm)		
Treatment	Site 1	Site 2	Combined	Site 1	Site 2	Combined	Site 1	Site 2	Combined
A: Crop type									
Sorghum	34.03a	28.52a	31.28a	6.63a	47.40a	27.02a	399.83b	403.28b	401.56b
Millet	14.73b	17.73b	16.23b	10.00a	42.40b	26.20a	415.77	419.07a	417.42a
SE ±	2.84	1.12	1.48	1.01	0.26	0.40	1.91	1.32	1.10
B: Mulch rate									
0 t/ha	21.67b	22.52a	22.09a	7.97a	36.27c	22.12a	410.87a	420.42a	415.64a
10 t/ha	26.33a	24.02a	25.18a	7.85a	44.15b	26.00a	406.32a	411.03ab	408.68b
15 t/ha	25.15a	22.85a	24.00a	9.13a	54.28a	31.71a	406.22a	402.07b	404.14b
SE ±	1.06	2.86	1.83	2.19	3.31	9.15	2.63	4.14	2.70
Interaction									
A x B	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

bined data for the two sites. This was attributed to greater root zone depth and higher root perimeter (Eze *et al.*, 2014a). Eze *et al.* (2015a) noted that greater root zone depth of sorghum resulted in higher water storage than that of millet at vegetative, flowering and maturity growth stages in Maiduguri. Mulch application rate had significant ($P \leq 0.05$) influence on moisture storage at Site 1 only. Ten and 15 t/ha mulch application rates resulted in significantly higher ($P \leq 0.05$) moisture content than 0 t/ha rate. Earlier workers reported that mulching with or without tillage increased soil moisture storage (Odofin, 2005; Chiroma *et al.*, 2005; Akanbi and Ojeniyi, 2007; Ojeniyi *et al.*, 2009). Minimal evaporative losses can be achieved by application of surface residues which reduce exposure of the soil to solar radiation, vapour pressure gradient across the soil-atmosphere interface and air currents (Sow *et al.*, 1997; Tolk *et al.*, 1999). Interaction between crop type and mulch rate had no significant influence on soil water balance components in this study. Both crop type and mulch rate had no significant influence on drainage at Site 1 and in the combined data. However, at Site 2, drainage was significantly higher in the sorghum plots than in those of millet. Also, drainage increased with increase in mulch application rate. Seasonal evapotranspiration was found to be higher under sorghum than under millet crop in the two sites and in the combined data. This could be attributed to higher canopy cover provided by sorghum crop. Eze *et al.* (2014a) not that sorghum consistently maintained a higher leaf area index than millet at the vegetative, flowering and maturity growth stages. Also, crop evapotranspiration decreased with increasing mulch application rate at Site 2 and in the combined data. In a similar research finding, Odofin (2005) and Odofin *et al.* (2012) noted that mulching increased drainage and reduced evapotranspiration.

CONCLUSION

The results obtained in this study indicated that annual rainfall was lower than the average amount observed over a ten-year period in Maiduguri. Consequently, soil moisture storage, drainage and seasonal crop evapotranspiration generally declined. An average of over 90 % of this low annual rainfall was lost as seasonal crop evapotranspiration. Sorghum plots stored higher moisture within the root zone, had higher drainage and lower seasonal evapotranspiration than millet plots. Moisture storage and drainage increased with increase in mulch application rate, whereas, seasonal crop evapotranspiration had an inverse relationship with mulch application rate.

REFERENCES

Akanbi, O. S. and Ojeniyi, S. O. (2007). Effect of siam weed mulch on soil properties and performance of yam in Southwest Nigeria. *Nigerian Journal of Soil Science*, 17, 120-125.

BOSADP (1993). Package of crop recommendations for Borno State. Borno State Agricultural Development Programme, Maiduguri, Nigeria, Pp. 1-35.

Brady, N. C. and Weil, R. R. (1999). *The Nature and Properties of Soils*. 12th ed., New Jersey: Prentice – Hall, New Jersey, Pp. 178 – 189.

Carter, R. C. (1995). Resources and water management in Northern Nigeria. *Unpublished Ph.D Thesis*, School of Agriculture, Food and Environment, Silsoe Collage, Cranfield University, UK.

Chiroma, A. M. (2004). Effects of land configuration and wood-shavings mulch on soil properties, yield and water use of sorghum. *Unpublished Ph.D. Thesis,* University of Maiduguri.

Chiroma, A. M., Alhassan, A. B. and Bababe, B. (2005). Physical properties of a sandy loam soil in Northeastern Nigeria as affected by tillage and stubble management. *Nigerian Journal of Tropical Agriculture*, 6, 115-121.

Chiroma, A. M., Folorunso, O. A. and Kundiri, A. M. (2003). Effects of tillage and stubble management on root growth and water use of millet grown on a sandy loam soil. *Journal of Arid Agriculture*, 15, 83-89.

Eze, P. C. (2015). Effects of rice bran-mulch on soil properties and water use efficiency of sorghum and millet in Maiduguri, North-east Nigeria. *Unpublished Ph.D. Thesis*, University of Maiduguri.

Eze, P. C., Alhassan, A. B., Kundiri, A. M. and Mamman, E. (2007). Neutron moisture meter: A tool for effective soil moisture monitoring. In: *Managing irrigation projects towards achieving Millennium Development Goals. Proceedings of the 13th National Irrigation and Drainage Seminar*. Gidan Matasa Cultural centre, Minna, Niger State, 11th – 13th June, 2007.

Eze, P. C., Alhassan, A. B., Tsado, P. A., Onyekwere, I. N., Kwari, J. D. and Dada, Y. M. (2014a). Effects of rice bran-mulch on the growth of sorghum and millet in Maiduguri, semi-arid North-east Nigeria. *Nigerian Journal of Soil Science,* 24(1), 59-71.

Eze, P. C., Alhassan, A. B., Kwari, J. D., Dada, Y. M., Tsado, P. A. and Lawan, A. N. (2014b). Effects of rice bran-mulch on the growth of sorghum and millet in Maiduguri, Semi-arid North-east Nigeria. *Nigerian Journal of Soil* Science, 24(1), 72-79.

Eze, P. C., Alhassan, A. B., Kundiri, A. M., Dada, Y. M., Odofin, A. J. and Tsado, P. A. (2015a). Effects of rice bran-mulch on soil physical properties and root zone moisture content under sorghum and millet in Maiduguri, Nigeria. *Production Agriculture and Technology Journal,* 11(1), 12-21.

Eze, P. C., Kwari, J. D., Kundiri, A. M., Tsado, P. A., Onyekwere, I. N. and Dada, Y. M. (2015b). Effects of rice husk-mulch on soil chemical properties under sorghum and millet in Maiduguri, Nigeria. *Production Agriculture and Technology Journal*, 11(1), 22-31.

Grema, A. K. and Hess, T. M. (1994). Water balance and water use of pearl millet – cowpea intercrops in Northeast Nigeria. *Journal of Agricultural Water Management*, 26, 169-185.

Gregory, P. J. (1991). Soil and plant factors affecting the estimation of water extracted by crops. pp.261-273. In: *Soil water balance in the Sudano-Sahelian zone. Proceedings of the Niamey* Workshop, February, 1991. IAHS Publ. No. 199.

Hess, T. M., Stephens, W. and Maryah, U. M (1995). Rainfall trends in Northeast arid zone of Nigeria., 1960-1990, *Agriculture and Forest Meteorology.*

Odofin, A. J. (2005). Effects of no-tillage with mulch on soil hydrology in Minna area of Nigeria's Southern guinea savanna. *Nigerian Journal of Soil Science*, 15(2), 9-15.

Odofin, A. J., Egharevba, N. A., Babakutigi, A. N. and Eze, P. C. (2012). Drainage beyond maize root zone in an alfisol subjected to three land management systems at Minna, Nigeria. *Journal of Soil Science and Environmental Management,* 3(9), 216-223.

Ojeniyi, S. O., Odedina, S. A., Odedina, J. N. and Akinola, M. O. (2009). Effect of tillage and mulch combination on soil physical properties and sorghum performance on alfisol of Southwest Nigeria. *Nigerian Journal of Soil Science,* 19(2), 16-20.

Sivakumar, M. V. K. and Wallace, J. S., (1991). Soil water balance in the Sudano-Sahelian zone: needs, relevance and objectives of the workshop. In: *Soil Water Balance in the Sudano-Sahelian Zone* (Proc. Niamey Workshop, February, 1991) (ed. By M. V. K Sivakumar, J. S., Wallace, C. Renard and C. Ginoux), 3-10. IAHS Publ. No. 199.

Soil Survey Staff (2006). *USDA Soil Survey manual. USDA Handbook* No. 18, Government printing office, Washington DC., Pp. 27.

Sow, A. A., Hossner, L. R., Unger, P. W. and Stewart, B. A. (1997). Tillage and residue effects on root growth and yields of grain sorghum following wheat. *Soil and Tillage Research*, 44, 121-129.

Statistix 8.0 (2005). *STATISTIX for windows (version 8). Analytical software*. Retrieved from support@statistix.com.

Tolk, J. A., Howell, T. A. and Evett, S. R. (1999). Effect of mulch, irrigation and soil type on water use and yield of maize. *Soil and Tillage Research,* 50, 137-147.

Zaongo, C. G. I., Hossner, L. R. and Wendt, C. W. (1994). Root distribution, water use and nutrient uptake of millet and grain sorghum on West African soils. *Soil Science*, 157, 379-388.