Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

CROP RESIDUE MANAGEMENT EFFECTS ON RUNOFF AND MAIZE PERFORMANCE IN THE GUINEA SAVANNAH ZONE OF NIGERIA

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ABSTRACT

The effects of different residue management techniques on runoff, growth and yield of maize (*Zea mays*. L) were evaluated in a sandy loam soil (*Typic haplustalf*) at Ilorin, Nigeria, using maize stover as mulch material.Treatments consisted of surface placement and tillage incorporation of residue mulch at the application rates of 2, 4 and 6 t ha^{-1}, with three replications in a Randomised Complete Block Design (RCBD). Runoff was monitored using multi-divisor flumes in runoff plots. Optimum crop growth and highest grain yield were achieved from the tillage incorporated crop residue plots at an application rate of 2 t ha^{-1}. However, surface placement of residue mulch exhibited higher potential for runoff reduction than tillage incorporated residue. Overall, the results show the positive impact of residue mulching in runoff reduction and enhanced crop yield.

Keywords: Crop residue, tillage, runoff, crop growth, grain yield.

INTRODUCTION

In sub-Saharan Africa, 94% of agricultural production is rain-fed, and lack of predictability both in amount and timing of rainfall makes farming extremely tricky (McCartney and Smakhtin, 2010). Therefore, conserving even relatively small volumes of water in soil will minimize soil surface runoff and erosion and support crop growth and development during dry season, thus significantly increasing agricultural productivity. A simple and cost-effective means of achieving the above stated goal is through the application of crop residues and managing the intensity of soil disturbing activities. Soil cover plays a vital role in checking surface runoff and hence erosion (Aina, 1991; Ahaneku, 1998). In most conservation tillage systems, crop residues from previous harvest are left in place as a surface cover or incorporated into the soil. Both methods are known to reduce runoff soil loss. Several benefits to crop production emanating from the use of residue mulch have been enumerated (Lal 1983a & b) to include prevention of raindrop impact and soil crustation, enhancement of moisture regime; reduction of surface runoff and subsequent prevention of soil erosion.

Crop residue management has been in use in most developed countries that have earlier recognized that water availability in the soil is the most limiting factor in dry land agriculture (Pelegrin *et al.*, 1990). Limited work in crop residue management has been carried out in less developed countries including Nigeria. Most of the studies in Nigeria centered around the humid rainforest of Western and Eastern Nigeria, pioneered by researchers at the International Institute of Tropical Agriculture (IITA), Ibadan. More importantly, these research efforts laid more emphasis on soil properties (Ojeniyi and Ighomrore, 2004; Azzez *et al.*, 2007, and Mbah and Nneji, 2010) with little or no attention to run-off generation which is a precursor to soil degradation and erosion.

Despite the recognition given to the use of crop residues by these researchers, there is still an air of uncertainty as to what extent the rate and method of residue application limits water loss and hence crop performance. This paper presents results of a two year study (1994 and 1995) aimed at evaluating the effects of different residue application techniques and their rates in reducing runoff and its consequent impact on maize growth and yield in the guinea savannah zone of Nigeria.

MATERIALS AND METHODS

The study was conducted in the Guinea Savannah vegetation of Ilorin, Nigeria (8^0 26 N and 4^0 3 E) on a sandy loam soil with 3 – 5% slope for two cropping years (1994 and 1995). The treatments were laid out in 15 x 3 m runoff plots in a Randomized Complete Block Design (RCBD) with three replications. Two methods of mulching application were employed, namely surface placement and incorporation into the soil by tillage. All plots for surface placement of mulch were first ploughed and harrowed before the treatments were imposed. The rates of mulch application used were 2 t ha^{-1}, 4 t ha^{-1} and 6 t ha^{-1}. This range of rates was informed by the optimum range recommended for erosion control on slopes of up to 10% (Lal, 1983a & b). The mulch material used was maize stover.

Maize seeds were planted at spacing of 90 cm between rows and 30 cm within rows. Fertilizer was applied at the rate of 200 kg/ha^{-1} NPK. Performance indicators monitored were surface runoff (which signified the amount of rainfall lost by each treatment); growth (plant height) and grain yield. Surface runoff was measured with the aid of multi-divisor flumes connected to collection tanks placed in pits at the down slope end of each plot. The runoff was measured after each rainfall event. Crop growth rate was monitored by direct random measurement of plant height at 10 days intervals. The yield was measured by weighing the manually harvested grains on each plot and adjusted to 14% moisture content. The data generated were subjected to Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

Treatment effects on plant height.

Table 1 shows the results of treatments on plant growth. Plant height ranged between 2.13 – 2.78 m and 2.69 – 2.90 m in the tillage incorporated residue (TI) and surface placed residue (SP), respectively in the first growing season; while in the second growing season the values of plant height ranged between 1.96 – 2.36 m for TI and 2.12 – 2.20 m for SP, respectively. Unlike runoff control, higher rates of residue application did not result in enhanced plant growth in 1994 and 1995 seasons. There was a general significant ($P<0.05$) decrease in plant height both within and among treatments with time. In general, mulch incorporation through tillage consistently maintained a better and uniform growth in relation to surface application of residue mulch. Among the various application rates, mulch application at 2 t ha^{-1} proved to be more effective in growth enhancement.

The results obtained are in agreement with those reported by Mbah and Nneji (2010), in south-eastern Nigeria.

Treatment effects on maize grain yield

Table 1 shows effect of mulching rate and technique on maize yield. The data indicated that there are no statistical differences between the techniques and among the rates. However, the mean yield for the 2 t ha^{-1} mulch rates were consistently numerically higher than those of other rates in 1994, whereas, there was no consistency in 1995 among the application rates. Moreover, the data showed that there exists a threshold rate of residue mulch application (2 t ha^{-1}) beyond which the yield does not improve appreciably. This means that as far as grain yield is concerned, mulch materials can be conserved by applying a maximum rate of 2 t ha^{-1} for both surface technique and the method of tillage incorporation. Even though the ANOVA did not indicate significant differences at 5% level between techniques, it can be seen that incorporation by tillage out-yielded surface application. The relative increase in yield from the TI technique may be ascribed to faster improvement in soil organic matter content and water use by the crop. Similar results have been reported by Mohammad *et al*. (2010).

Treatment effects on runoff

The total rainfall received during the two successive years (1994 and 1995) were 1,241 and 1,409 mm, while the rainfall during the growing season were 724.4 and 1020.2 mm, respectively.

The effect of mulching technique and rates on runoff generation is presented in Tables 2a and 2b for 1994 and 1995, respectively. Results showed that higher mulch rates significantly reduced surface run-off. Tillage residue incorporation technique offers a better promise in terms of soil moisture conservation since the technique yielded lower amounts of runoff with time. The lower runoff resulting from higher mulch rate is not unexpected. Higher mulch rates imply larger surface toughness which dissipates raindrop energy, thus minimizing detachment, surface sealing and crusting (Lal, 1976) that usually lead to the clogging of soil pores thereby inhibiting infiltration (Ahaneku, 1985). Increased rates of mulch application therefore pave way for more infiltration opportunity time and hence less runoff and soil loss. Less runoff generated on the tillage residue incorporated plots implied that crops under this treatment have a better opportunity to utilize conserved soil moisture, which facilitates nutrient extraction by plant roots resulting in higher crop yields. Runoff volume was generally not significant among and within treatments in the first year, but became significant within treatments with time (Table 2a). Results showed a general positive effect of residue mulch on runoff, irrespective of the application technique. The second growing season witnessed a higher and more aggressive rainfall than that of the first year. Despite this significant change in rainfall amount, there was drastic reduction in runoff amount in the second growing year. Similar to the response in the first growing season, runoff volume was significantly different ($P<0.05$) within treatments with time and not among treatment techniques. The higher reduction in runoff volume during the second growing year could be ascribed to the residual effect of the previous year's mulch application coupled with the additional application in the second year. These actions should have combined to increase the soil structural stability and improved soil porosity leading to increased water infiltration, and soil water recharge and the consequent runoff reduction. These results are in agreement with the findings of Bazzoffi *et al.* (1998) and Shaver *et al.* (2003), who observed a general decrease in runoff volume during 3 years study with compost.

It is concluded that crop residue reduces runoff. Crop residues should be incorporated into the soil rather than leaving them on the soil surface. There exists a threshold rate of residue mulch application for a particular residue type and crop beyond which the yield does not improve appreciably. Crop residue rate equivalent to 2t ha^{-1} was found to be adequate in minimizing surface runoff.

Table 1: Treatment effects on crop height (m) and grain yield (t ha^{-1})

Treatment	Mulch Rate (t ha^{-1})	1994		1995	
		Height*	Yield	Height*	Yield
Tillage Incorporation (TI)	2	2.78	4.22	2.35	2.51
	4	2.13	4.16	2.36	2.93
	6	2.64	4.20	1.96	2.53
Surface placement (SP)	2	2.69	3.87	2.20	2.71
	4	2.90	3.56	2.16	2.89
	6	2.78	3.80	2.12	3.24
L.S.D.		0.08	NS	0.15	NS

* Maximum height attained after 50 days of planting
NS not significant

Table 2a: Effect of mulching technique and application rate on runoff volume (l) for 1994

Tillage Treatment	Rate (t ha^{-1})	Runoff Volume (l) 10+	11	17	26	32	33	41
Tillage Incorporated (TI)	2	0.14	0.41	161.2	124.2	66.05	67.3	0.0
	4	0.0	0.0	126.9	145.3	79.25	54.2	130.0
	6	1.61	0.0	142.7	136.2	128.2	133.5	0.0
Surface placement(SP)	2	0.38	0.0	111.0	130.8	127.0	74.0	63.4
	4	0.48	0.39	90.0	173.1	150.3	0.0	126.9
	6	0.29	0.42	81.9	79.3	73.8	119.7	0.0
L.S.D.		NS	NS	NS	NS	NS	NS	50.0

\+ - days after planting, NS – not significant.

Table 2b: Effect of mulching technique and application rate on runoff volume (l) for 1995.

Method	Rate (t ha^{-1})	Runoff Volume (l) 42+	46	56	62	64
Tillage Incorporation (TI)	2	0.81	0.24	1.23	0.0	0.0
	4	0.20	0.0	0.06	0.0	0.0
	6	0.0	0.0	4.78	1.50	0.85
Surface placement(SP)	2	1.50	0.68	3.04	0.34	0.92
	4	0.25	0.0	6.63	0.0	0.10
	6	0.0	0.0	2.91	0.69	0.65
L.S.D.		NS	0.39	3.27	1.06	0.42

\+ - days after planting, NS – not significant

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