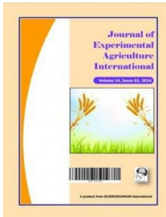

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Effect of Land Configuration and Crop Residue – Mulch on Millet Performance in Minna, Savanna of Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A 2 x 3 factorial experiment was conducted in cropping season at the old Teaching and Research Farm, Federal University of Technology, Minna, to determine the effect of land configuration and crop residue – mulch on the growth and yield of millet in Minna, Southern guinea savanna zone of Nigeria. It was a randomized complete block design with two types of land configuration (ridge and flat surface) and three mulch application rates (0, 10 and 15 t/ha), replicated three times. Composite soil samples were collected from the experimental site at 0 – 15 and 15 – 30 cm depths prior to the commencement of this study, for the determination of initial soil physicochemical properties. Crop growth parameters measured were plant height, number of leaves per plant, number of tillers per plant and leaf area index at 3, 6, 9 and 12 weeks after planting. Yield indices determined were panicle length and stover yield. Data collected were subjected to analysis of variance at 0.05 level of significance, while means separation was done using Duncan's multiple range test. Findings in this study showed that planting on ridge resulted in taller ($P \leq 0.05$) millet plants and a higher number of

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leaves per plant, a higher number of tillers per plant and higher leaf area index than planting on the flat. Plant height, the number of leaves per plant, the number of tillers per plant, leaf area index, panicle length and stover yield increased with increasing mulch application rates.

Keywords: Soil moisture content; millet; growth and yield parameters.

1. INTRODUCTION

Major constraints to high productivity of most soils of the savanna zone of Nigeria are low organic matter content, low nutrient status, poor structural stability, low water holding capacity and extremely high permeability [1]. Modifying soil surface condition of these soils in combination with the application of organic residues as ammendments have been found to improve their physical and chemical properties, with a consequent improvement in crop growth and higher crop yields [2,3,4] reported that alteration of soil surface condition plays a significant role in preventing loss of water through evaporation and in making available water beneficial for crop growth. Modification of soil surface could be in the form of ridge tillage with different configurations such as open-ridge, tied-ridge and a combination of the two. It could also be in the form of furrows, flat beds, raised beds, mounds, mulching and crop residue incorporation.

Ridges, due to their height, are exposed to more sunlight and exhibit higher temperature than furrows and flat soil surface. [5], reported that ridges had higher temperature than other forms of land configuration. Growth of crop is positively influenced by temperature, especially within certain limit. It has been documented that conservation tillage practices such as ridge tillage, lower soil bulk density and reduce penetration resistance [6,7]. This results promove root elongation and improving crop growth and yield. Organic residues could be chopped into smaller bits or as whole plant parts and then applied on the soil surface as mulch or incorporated into the soil. These technologies are gradually gaining popularity due to rapid degradation of agricultural lands in recent times, and the need to increase and sustain the productivity of arable lands. Researchers that made use of grain-cereal straw as crop residue-mulch noted that tillage practices that retain crop residues on the soil surface enhance the yield potential of crops by conserving moisture [8,9]. and improving soil fertility status [10,11]. Rice husk is available in huge quantities around rice mills where it is set on fire because it is not a desirable livestock feed. Therefore, it faces less competition unlike so many other crop residues such as maize, rice and wheat straws. Little or no attention has been given to this huge waste generated and its impact on the environment. A more serious issue is that there is no deliberate attempt to effectively utilize the rice husk, or at least, to safely dispose it.

Millet (*Pennisetum glaucum* (L.) R.Br.) is commonly grown on 5.2 million hectares for its grains, with an average yield of 9 t/ha [12,13], It is cultivated under a rain-fed condition in northern Nigeria mainly because of its drought-resistant characteristics [14]. It is a major staple food usually grown as sole crop or intercropped with legumes such as cowpea and groundnuts. However, the yield of millet has continued to decline to as low as between 5000 – 8000 kg/ha due mainly to low soil fertility status, declining annual rainfall, insect pests and diseases, striga, birds and low-yielding varieties [15]. The objective of this research was to determine the effect of land configuration and crop residue-mulch on the growth and yield of millet in Minna.

2. MATERIALS AND METHODS

2.1 Site Description

The research was conducted at the old Teaching and Research Farm, Federal University of Technology, Minna under rain-fed condition. The experimental site is located at longitude 9˚ 3'E and latitude 6˚ 27'N, and 240.50 m elevation above mean sea level. Minna is found within the Southern guinea savanna zone of Nigeria, which is characterized by alternate wet and dry seasons. Mean annual rainfall ranges between 1,000 and 1,200 mm. Rainfall commences between late April and early May and ends between late September and early October. Minimum temperature ranges from 18 – 22 ˚C, while mean maximum temperature is 40 ˚C between February and March, and 36 ˚C between November and December. Soils around Minna are derived from basement complex rocks. They range from sandy clay to loamy sands. The vegetation is characterized by vast grassland interspersed with few tree species and shrubs. Most of the arable crops (sorghum, millet, yams, rice, cowpea, maize and groundnuts) are usually grown under rain-fed conditions. Also, vegetables such as tomatoes, okra, pepper, spinach and cocchorus are grown under irrigation during the dry season.

2.2 Treatments and Experimental Design

The experiment was a 2 x 3 factorial in laid out in a randomized complete block design with three replications. The treatment combinations were six in number, consisting of two land configuration (ridge and flat) and three mulch application rates (0, 10 and 15 t/ha).

2.3 Soil Sampling and Analysis

Prior to the commencement of the trial, soil samples were collected randomly at 5 m interval within the experimental site at two depth intervals (0 – 15 and 15 – 30 cm) using soil auger. The samples were bulked to obtain a composite soil sample, air-dried, gently crushed and passed through a 2 mm sieve for physicochemical analysis in accordance with standard procedures. The Bouyoucos hydrometer method [16] was used for the determination of particle size distribution. Textural class of the soil was determined using a textural triangle. Soil pH was determined using glass-electrode pH meter. The pH was determined on a 1:2.5 soil : solution ratio in both water and 0.01M $CaC1_2$ solution [17]. Total nitrogen was determined by employing the modified macro-Kjeldahl method [18]. The organic carbon content of the soil was determined by Walkley - Black [19] wet - oxidation method. Available phosphorus extraction was carried out by employing the Bray No.1 method [20]. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with 1N neutral ammonium acetate (NH_4OAc) solution [21]. Ca^{2+} and Mg^{2+} were determined by titration, while K^+ and Na^+ were measured by flame photometry [21]. Exchangeable H^+ and Al^{3+} were extracted with 1N KCl and the extract titrated with 0.05 N NaOH. The total exchangeable acidity was estimated by summing the amounts of H^+ and Al^{3+} determined [21]. Cation exchange capacity (CEC) was determined by the summation of the total exchangeable bases and total exchangeable acidity. Percent base saturation was computed as follows:

$$\%\ \text{Base saturation} = \frac{\text{Exchangeable bases, cmolkg}^{-1}}{\text{Cation exchange capacity, cmolkg}^{-1}} \text{x}100$$

2.4 Cultural Practices

The land was cleared, tractor-ploughed and leveled manually. The experimental plots were laid out. Fifteen cm high ridges were constructed manually, 0.75 m apart, using a hand-hoe. The crop residue-mulch (rice husk) was uniformly applied on the appropriate experimental plots shortly before planting. Five to six Apron-plus-treated seeds of millet (LCIC 9702 variety) were hand-sown per hole at a spacing of 75 x 50 cm. The gross and net plots dimensions were 6 x 3 m and 4.5 x 2 m, respectively. Seedlings were thinned to two plants per stand, two weeks after planting. NPK fertilizer (15:15:15) was applied in two split doses, at the recommended rate (60:30:32 kg/ha) at 3 and 7 weeks after planting. Weeding was carried out manually using a hand-hoe as at and when due. Harvesting of the stover was done at physiological maturity, 12 weeks after planting. The grains were destroyed by weaver birds.

2.5 Measurement of Crop Growth Indices

The crop growth indices determined at 3, 6, 9 and 12 weeks after planting were plant height, number of leaves, number of tillers and leaf area index. Ten plants were tagged within the net plot for these measurements. Plant height was measured from the base of the plant to the highest flag leaf using a metre-rule and a calibrated wooden pole. The number of leaves and tillers were counted on each of the tagged plants. Leaf area index was determined following the modified length and breadth product method by Dugje and Odo [22]:

$$\text{LAI} = \frac{\text{P} * \text{L} * \text{A}}{\text{GA}}$$

where, P is plant population per hectare, L is number of fully expanded green leaves per plant, A is single leaf area (cm^2) and GA represents ground area (hectare).

2.6 Determination of Crop Yield Indices

Crop yield indices determined at physiological maturity were stover yield and panicle length. The above-ground plant part (stover) was harvested 12 weeks after planting and left in the field for about two weeks to allow for thorough sun-drying, and weighed on a Saltre balance. The length of panicles was measured from the base to the tip of the panicles using a metre-rule.

2.7 Statistical Analysis

Data collected were subjected to analysis of variance at 0.05 level of probability using Statistix 8.0 (2005) statistical software. Where significant differences exist between means, Duncan's Multiple Range Test was employed for the purpose of means separation.

3. RESULTS AND DISCUSSION

3.1 Soil Physicochemical Properties before Cultivation

Results in Table 1 show the physicochemical properties of the soil of the experimental site. The results indicate that the soil is sandy loam in texture. According to the fertility ratings for soil data by FDALR [23] and FAO [24] the soil was neutral in reaction, low in organic carbon, total nitrogen, exchangeable magnesium, potassium and cation exchange capacity. Low available of phosphorus and exchangeable calcium, and moderate in organic matter, C:N ratio, sodium and percent base saturation. The sandy nature of this soil and its low fertility status necessitates the application of soil amendments such organic residues to improve soil physical condition, soil nutrient status and enhance its productivity [2,3].

3.2 Crop Growth Indices

3.2.1 Plant height, number of leaves per plant, number of tillers per plant and leaf area index

The crop growth indices studied were plant height, number of leaves per plant, number of tillers per plant and leaf area index at 3, 6, 9 and 12 weeks after planting (WAP). The results of the effect of land configuration and crop residue-mulch on plant height and number of leaves per plant are presented in Table 2. Planting on ridge had produced significantly taller ($P \leq 0.05$) plants than planting on the flat at 9 and 12 WAP. Also, plant height increased with increase in mulch application rate throughout the growing season. A similar trend was observed in which planting on ridge and increase in mulch rate resulted in significantly higher ($P \leq 0.05$) number of leaves per plant. Interaction between land configuration and mulch had a significant influence on plant height at 6 WAP. Table 3 indicated that combination of ridge treatment and 15 t/ha mulch produced the tallest millet plants. This attests to the superiority of planting on ridge and 15 t/ha mulch application rate compared to planting on the flat and lower mulch application rates.

Table 1. Soil physicochemical properties of the experimental site at Minna

Parameters		
Depth, cm	0 – 15	15 – 30
Sand, g kg^{-1}	745	655
Silt, g kg^{-1}	103	153
Clay, g kg^{-1}	152	192
Textural Class	Sandy loam	Sandy loam
pH (1:2.5) in Water	6.70	6.90
pH (1:2.5) in 0.01M $CaCl_2$	5.70	5.60
Organic Carbon, g kg^{-1}	7.70	7.40
Total Nitrogen, g kg^{-1}	7.40	7.00
C : N Ratio	1.04	1.06
Available Phosphorus, mg kg^{-1}	0.85	1.26
Exchangeable Calcium, cmol kg^{-1}	0.49	0.46
Exch. Magnesium, cmol kg^{-1}	0.51	0.49
Exch. Potassium, cmol kg^{-1}	0.28	0.25
Exch. Sodium, cmol kg^{-1}	0.52	0.50
Exch. Acidity ($H^+ + Al^{3+}$), cmol kg^{-1}	1.10	1.20
Cation Exch. Capacity, cmol kg^{-1}	2.90	2.90
Base Saturation, %	62.10	58.60

Table 2. Effects of land configuration and mulch on plant height and number of leaves per plant of millet at Minna

	Number of leaves/plant				Plant height (cm)			
Treatment	3 WAP	6 WAP	9 WAP	12 WAP	3 WAP	6 WAP	9 WAP	12 WAP
A: Land configuration								
Ridge	24.50a	110.60a	157.40a	171.50a	6.6a	6.8a	6.0a	4.9a
Flat	21.90a	93.60b	114.90b	136.20b	5.7b	5.9b	5.9a	4.2b
SE ±	1.9	5	6.2	5.9	0.2	0.2	0.3	0.1
B: Mulch rate								
0 t/ha	18.90b	72.20c	116.70b	122.20c	5.4b	5.6b	4.9b	4.2b
10 t/ha	23.90ab	102.10b	131.60b	151.90b	6.2a	6.5a	6.0ab	4.7ab
15 t/ha	26.80a	132.00a	160.20a	187.50a	6.8a	7.0a	6.9a	4.8a
SE ±	23	6.1	7.6	7.2	0.02	0.02	0.4	0.1
Interaction								
A x B	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; *: Significant at 5 % level of probability; WAP: Weeks After Planting*

Table 3. Interaction effects of land configuration x mulch on plant height (cm) of millet at 6 weeks after planting at Minna

	Land configuration	
Mulch rate	Ridge	Flat
0 t/ha	69.70b	74.80b
10 t/ha	103.20b	101.00b
15 t/ha	158.90a	105.10b
SE ±	8.8	

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

Results of the effect of land configuration and crop residue-mulch on a number of tillers per plant and leaf area index are presented in Table 4. Ridge treatment produced a higher number of tillers per plant than planting on the flat at 9 and 12 WAP. Fifteen t/ha mulch resulted in the highest number of tillers per plant at 3, 6, 9 and 12 WAP, followed by 10 t/ha rate. The lowest in number was produced when no mulch was applied. Similarly, planting on ridge resulted in higher leaf area index than planting on the flat at 12 WAP, while leaf area index increased with increase in mulch application rate. The interaction between land configuration and crop residue-mulch had no significant influence on number of tillers per plant and leaf area index.

In summary, ridge tillage resulted in taller millet plants, higher number of Leaves per plant, more tillers per plant and higher leaf area index than raising plants on the flat. The better performance of plants grown on ridges than those raised on the flat is well supported by the findings of other researchers. Materechera and Mioza-Banda [6] and Sow et al. [7], reported that improvement in crop growth resulted from decrease in soil bulk density and reduction in penetration resistance to root elongation. Ridge is a conservation tillage practice which raises the seed bed above the land surface, gathers the top fertile soil layer and conserve moisture on soils of Nigerian savanna characterized by low nutrient status [25,2,26] also noted that tallest plants, highest number of leaves per plant and higher garlic bulb diameter were produced on ridges than on furrows and flat planting methods.

The increase in growth parameters with increase in mulch application rate is adduced to better soil surface cover under the highest mulch treatment [27,28]. Another reason could be improved nutrient status following the application of 15 t/ha mulch. Eze et al. [29,30] reported that higher soil organic carbon and total nitrogen contents resulted from 15 t/ha mulch rate. This produced taller plants than 0 and 10 t/ha mulch treatments. A third reason for the production of the tallest plants as a result of application of 15 t/ha mulch could be reduction in evaporative moisture loss or lower crop evapotranspiration with increase in mulch application rate [29,14,30].

Table 4. Effects of Land configuration and mulch on number of tillers and leaf area index of millet at Minna

Number of leaves/plant					Plant height (cm)			
Treatment	**3 WAP**	**6 WAP**	**9 WAP**	**12 WAP**	**3 WAP**	**6 WAP**	**9 WAP**	**12 WAP**
A: Land configuration								
Ridge	2.2a	2.3a	2.7a	3.2a	0.14a	0.39a	0.52a	0.68a
Flat	2.0a	2.1a	2.2b	2.4b	0.11a	0.31a	0.48a	0.56b
SE ±	0.1	0.1	0.1	0.2	0.01	0.03	0.04	0.02
B: Mulch rate								
0 t/ha	2.0b	2.1b	2.2c	2.5b	0.07b	0.17c	0.31b	0.41c
10 t/ha	2.0b	2.1b	2.5b	2.6ab	0.13a	0.37b	0.52a	0.61b
15 t/ha	2.2a	2.4a	2.8a	3.3a	0.17a	0.52a	0.67a	0.84a
SE ±	0.1	0.1	0.1	0.2	0.02	0.03	0.05	0.03
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.
NS: Not Significant; WAP: Weeks after Planting

Table 5. Effects of land configuration and mulch on panicle length and stover yield of millet at Minna

Treatment (kg/ha)	**Panicle length (cm)**	**Stover yield**
A: Land configuration		
Ridge	20.40a	3,432.10a
Flat	19.00a	3,333.30a
SE ±	0.80	275.10
B: Mulch rate		
0 t/ha	17.6b	2,222.20b
10 t/ha	19.80ab	3,277.80b
15 t/ha	21.60a	4,648.10a
SE ±	0.90	337.40
Interaction		
A x B	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

3.3 Crop Yield Indices

3.3.1 Panicle length and stover yield

Table 5 displays the results of the effect of land configuration and crop residue-mulch on panicle length and stover yield. Although, land configuration did not influence the two parameters significantly, they increased with increase in mulch rate. Fifteen t/ha mulch rate produced longer panicles and higher stover yield than both 0 and 10 t/ha rates. This observation could be attributed to lower crop evapotranspiration and better microclimate resulting from higher soil surface cover and higher leaf canopy cover under 15 t/ha mulch treatment [31]. Other reasons could be higher soil nutrient content. In a similar study, higher soil organic carbon and total nitrogen contents that resulted from the highest mulch application rate (15 t/ha) were found to be responsible for longest panicles and highest sorghum stover and grain yields [30].

4. CONCLUSION

Findings in this study showed that planting on ridge resulted in taller ($P \leq 0.05$) millet plants and a higher number of leaves per plant, a higher number of tillers per plant and higher leaf area index than planting on the flat. Plant height, the number of leaves per plant, number of tillers per plant, leaf area index, panicle length and stover yield increased with increasing mulch application rate. Furthermore, studies are recommended to determine the extent to which these observations can be reproduced under field conditions considering the production systems from the farmers.

DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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