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Original Article

Effect of rice straw ash on soil properties and yield of cucumber

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ABSTRACT

Many farmers in Nigeria are paying close attention to using Rice Straw Ash (RSA) as a soil fertility enhancement additive. The short and long-term effects of applying this ash to the soil quality were not adequately investigated, however. This research was conducted at the Departmental Farm of Agricultural and Environmental Engineering, Bayero University, Kano to access the impact of RSA on the soil's physiochemical properties and on cucumber yield. Twelve (12) experimental plots were treated with different amounts of RSA (0 Kg, 1 Kg, 2 Kg and 3 Kg) to assess the intensity effect of the treatment on both soil physiochemicals and crop yield. For each experimental plot, soil properties (moisture content, porosity, bulk density, electrical conductivity, organic matter, pH and sodium concentration, nitrogen, phosphorus, potassium, calcium and magnesium) were measured and analyzed before and after the experiment. The results showed that the application of ash increased moisture content, bulk density, porosity, electrical conductivity, organic matter and sodium concentration while reducing the pH, nitrogen, phosphorus, potassium, calcium and magnesium levels. The mean yield in 0 Kg RSA (21,84tons / ha) was found to be the highest. There was a drop in the yield (13.08-14.14tons / ha) of crop in the plots treated with RSA. The research concluded that continued use of RSA could lead to a reduction in crop yield as the EC level was found to be rising. It is on this basis that farmers are advised to avoid the use of RSA as an additive for soil fertility enhancement and other means should therefore be used.

1. Introduction

Soil is one of the important natural resources that sustain earthly life as many organisms rely on it for survival. Since soil is the traditional medium for the growth of agricultural products, its performance assessment is of paramount importance in order to improve productivity, farming and use the soil effectively. Soil quality is the ability of soil within the environment to function and maintain biological productivity for good, balanced plant and animal growth [1]. Good quality soils not only perform better in the production of food and fiber, but also help to establish natural environment water with improved air and quality [2]. The soil's fertility and nutrient balance are taken as some of the main soil quality indicators. In many parts of the globe, the availability, use and productivity of inorganic fertilizers has been limited, while land-use intensification and plant extension have occurred on marginal soils [3]. As a result, soil fertility has dropped and is considered prevalent, especially in sub-Saharan Africa [4-6]. The decrease in soil fertility is considered a major cause of low productivity in many soils [7, 8].

It has not received the same study attention as soil erosion; probably because the decline in soil fertility is less obvious, less dramatic and more difficult to measure [3]. Soil weathering and poor-activity clay mineral domination

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with low nutrient status are some of Nigeria's soil problems [9]. Therefore, preserving soil fertility is a major concern for maintaining agricultural productivity [10]. Cucumber (*Cucumis sativus* L) is an annual monoecious plant in the Cucurbitaceae family that is under human cultivation for more than 3,000 years [11]. Because of the economic value of cucumber, it was ranked fourth after tomato, cabbage and onion production in Asia [12] and next after tomato production in Western Europe [13], although it was not ranked in tropical Africa due to its limited usage. Rice straw ash (RSA) is a rice plant material obtained from rice straw burning. Rice strawburning has environmental consequences, including emissions of carbon dioxide resulting in serious air pollution and organic plant decomposition [14]. Preliminary survey revealed that farmers follow the custom of burning rice straw on the field after harvesting and use ash as organic manure for soil treatment during cultivation, while others use this approach as a way to get rid of the straw and the empirical/scientific influence of these activities in the area of study is yet to be determined. It is on this note that the aim of this research work was to investigate the impact of rice straw ash on the soil's physiochemical properties and cucumber yield.

2. Materials and Methods

2.1. Study area

The study was conducted at Agricultural and Environmental Engineering Departmental Demonstration Farm, Bayero University, Kano-Nigeria, which is located along Gwarzo road between the following coordinates: 11o58′37.2" , 8o25′1.92" and 11o58′37.56" , 8o25′15.96" northward and 11o58′10.92" , 8o25′13.08" and 11o58′0.48" , 8o24′41.76" southward [15]. The area has an altitude of 454m above sea level. The climatic condition of the area is; annual average minimum and maximum temperatures are 20.5^{o}C and 33.9 ^{o}C, maximum relative humidity of 82% and minimum relative humidity of 23% and an annual average rainfall of 890.40mm [16, 17].

2.2. Soil Analysis

The materials used are: auger, core samplers (5cm diameter), hammer, digger, hoe, shovel, steel ruler and rice straw ash.

The soil samples were taken from the experimental field before and after application of rice straw ash. The sample was taken randomly within the unit experimental plot. Six different points were randomly selected and the soil samples were taken at 0 to 40 cm. The samples were analyzed in the Laboratory. The analyses carried out were physiochemical properties of the soil. The sample of rice straw was collected from rice farm at Kura in Kura L.G Area of Kano state. The rice straw was burnt and obtained the rice straw ash to be used.

Laboratory Analysis

Soil samples taken from the experimental field before and after application of the rice straw ash were analyzed in the laboratory. The analyses carried out were the determination of physiochemical properties of the soil.

Determination of Soil Physical Characteristics

The physical characteristics of the soil were determined in the laboratory and these characteristics include: moisture content, bulk density and porosity of the soil.

a) Determination of soil moisture content

Gravimetric method is the technique adopted in the determination of the moisture content of the soil as described by [18] using Equation 1.

$$M_C = \frac{M_W - M_d}{M_d} \times 100 \qquad (1)$$

Where: M_c = moisture content (%), M_w = mass of wet soil (Kg), and M_d = mass of dry soil (Kg).

Determination of soil bulk density

Bulk density of the soil was determined using core sampler method [19] as described in Equation 2

$$\rho_b = \frac{M_S}{V_C} \qquad (2)$$

Where ρ_b = bulk density (g/cm^3), M_S = mass of oven dried soil (g), and V_C= volume of core sampler in (cm^3)

Determination of Soil Porosity

The soil porosity was determined as described by [20] and calculated using the Equation 3.

$$V_p = \frac{W_2 - W1}{P} \qquad (3)$$

Where V_p : Soil porosity (%), W_1 = weight of moist soil sample (g), W_2 = weight of dry soil sample (g) and P= soil density (g/cm^3)

Determination of Soil Chemical Characteristics

Parameters on soil chemical properties were determined and these parameters include, soil pH, electrical conductivity (E.C), soil organic matter and concentration of macro elements in the soil such as nitrogen, sodium, potassium, magnesium, calcium and phosphorous of the soil.

b) Determination of soil pH and Electrical Conductivity (EC)

The pH of the soil was determined using pH meter in the laboratory and electrical conductivity is also determined using saturation extraction method as described in [21].

c) Determination of Soil Organic Matter Content

Walkey Black wet oxidation method [21] was used to determine the percentage of organic matter content present in the experimental field soil as shown in Equations 4 and 5

$$\%Org.C = \frac{N(V_1 - V_2)}{W} \times 0.3f \qquad (4)$$

$$\%\text{Organic Matter} = Org.C \times 1.724 \qquad (5)$$

Where;
N: normality of ferrous sulphate solution, V_1: ferrous ammonium sulphate requires for the blank(ml), V_2 : required ferrous ammonium sulphate for the sample (ml)
W : mass of sample (g), and F : correction factor = 1.33

d) Determination of Macro Elements in the Soil

The available nitrogen from the organic matter in the experimental field soil was examined using alkaline permanganate method as described in [22]. Phosphorous is critical essential element influencing plant growth and production. Olsen's method was employed in determining the available phosphorous in the soil. Photometer flame method was used to determine the available potassium and sodium presence in the soil. [23] method was used in determining calcium and magnesium in the soil.

2.3 Experimental Treatments and Plant Analysis

A field experiment was performed to test the efficacy of the rice straw ash on soil physiochemical characteristic and yield of cucumber (*market more104*) at Agricultural and Environmental Engineering Departmental demonstration farm. The treatment consist of four levels of rice straw ash which labelled as A, B, C, and D. The four treatments were replicated three times making a total of 12 experimental runs. Strip plot design was used as an experimental design. Land preparation and agronomic operation aland area of 7.5 m x 6.5 m prepared into leveled basins of 1.5m x 1.5m. The basins were irrigated before plating as shown in plate 2.1. Cucumber (*market more104*) was planted in a row at plant spacing of 50 cm between plant and 50 cm between rows and the plant population per unit plot was approximately (9) cucumber and consequently (108) cucumber stand for the entire twelve (12) experimental plots. The mean weight of rice straw ash spread in plots A, B, C, and D were 0 Kg/m^2, 1 Kg/m^2, 2 Kg/m^2 and 3 Kg/m^2 respectively. Weeding was done and systemic insecticide was applied five week after planting. The buffer zones of 1m and 0.5m for main plots and sub-main plots respectively was provided in order to reduce the lateral movement of water. The plate 2.1 – 2.3 shows the experimental field setup and growth stages of cucumber.

Plate 2.1: Plot after Application of RSA

Plate 2.2: Growth of Cucumber at Second week after planting

Harvesting and Yield Determination of Cucumber

The cucumber yield was harvested depending on the matured fruits. The maturity of fruits was observed based on size and colour of the fruits. The crop yield was computed for each of the experimental plot in accordance with [24] using Equation 6.

$$Y = \frac{W}{A}\left(\text{Kg/m}^2\right) \qquad (6)$$

Where: Y is the crop yield kg/m^2.W is the weight of harvested cucumber (Kg) and A is the area of the plot harvested (m^2).

2.4 Statistical Analysis

The result obtained was evaluated using Analysis of Variance (ANOVA). Also t-test was conducted to analyze the efficacy of the rice straw ash on physical and chemical properties of experimental field soil before and after application of the RSA.

Plate 2.3: Growth of Cucumber at Fifth week after planting

3. Result and Discussion

3.1 Soil of the Experimental site before and after Application of Rice Straw Ash

Table 3.1 reveal the results of physiochemical properties of the soil before application of the rice straw ash. It was observed that, there were differences in some of the properties after application the rice straw ash. The table also presents the statistical analysis that shows the mean variation in the soil properties before and after application of RSA.

3.2 Physical properties

Table 3.1 present result of some physical properties conducted on the field and the soil was found to have values of moisture content, bulk density and porosity as 11%, 1.204667 g/cm^3 and 13.8% respectively before the application of RSA, after the application, the values changes to 14%, 1.302606 g/cm^3 and 20 % respectively. This indicated that, RSA improved the moisture content, bulk density and porosity by 21.4%, 8.13 % and 31%, respectively. The t-test conducted revealed that the application of RSA has no significant effect at 5 % level of significant on these physical properties analyzed in the experiment.

Table 3.1: Physiochemical properties of the soil before and after application of RSA

	Mean			
Soil parameters	**Before**	**After**	**t statistics**	**t critical**
Moisture Content	11.00316667	14.435	1.226513359	2.01504837
Bulk density	1.204667	1.302606	-1.11139	2.015048
Porosity	13.79917	20.02833	-1.11139	2.015048
pH	6.411667	6.266667	4.988152	2.015048
EC (ds/m)	0.177333	0.341662	-4.75288	2.01508
OM (%)	1.556616667	1.649	0.755204972	2.01504837
N (g/Kg)	2.39583333	2.285	0.5510027	2.01504837
P (cmol/Kg)	12.554	11.435	5.150524	2.015048
K (cmol/Kg)	1.091167	0.931667	1.011182	2.015048
Na (cmol/Kg)	0.495	1.783333	-0.9598854	2.01504837
Mg (cmol/Kg)	0.648167	0.611833	4.192308	2.015048
Ca (cmol/Kg)	2.736	2.643333	1.790332	2.015048

3.3 Chemical Properties of the Soil

The results of chemical properties of the soil before and after application of the RSA is also presented in Table 3.1. The soil was found to be acidic in nature with pH value of 6.4, after the application of RSA, the soil remain acidic with pH value of 6.3, this shows that the RSA application has high potential of adjusting the pH level of soil which agreed with [25] whose reported that continuous application of RSA in the field make the soil to become acidic in nature. Electric conductivity (EC) of the soil before and after application of RSA is as shown in Figure 3.2 in which the EC before application ranges from 0.115 – 0.272 dS/m with statistical mean of 0.177 dS/m. This indicated that the salinity level is low in the experimental field [21] thus injury to the plants is minimal while after application of RSA, the EC increases and ranges from 0.2512 – 0.4473 dS/m which implies that the RSA application have raised the soil salinity since the salinity increased by approximately 47%. The available organic matter presence in soil has a value of 1.0% before application of RSA and it slightly increased by 5% after application. Also, the concentration of macro elements have shown variations in the concentrate between before and after RSA application and such macro elements are nitrogen, phosphorous, potassium, sodium, calcium and magnesium with values of 2.40 g/Kg, 12.55 cmol/Kg, 1.09 cmol/Kg, 0.50 cmol/Kg, 2.74 cmol/Kg and 0.65 cmol/Kg respectively before RSA application meanwhile, after application of RSA the values change to 2.29g/Kg, 11.44cmol/Kg, 0.93 cmol/Kg, 1.78 cmol/Kg 2.64 cmol/Kg and 0.61 cmol/Kg respectively. However, despite the increase in EC level is not beyond the threshold, but it is believed that continuous application could raise the EC level of the soil which could adversely affect the growth of the crop and consequently, the yield of the crop. It was observed that the application of the RSA was responsible for the reduction in the concentration of some macro elements such as nitrogen, phosphorus, potassium, calcium and magnesium thereby increasing the concentration of sodium.

Moreover, Figure 3.1 graphically present the chemical properties of the experimental field soil before and after application of the RSA and table 3.1 also presents the results of t-test analysis that compared the mean value of soil properties before and after RSA application and it was observed that application of RSA has no significant effect in some of the chemical properties such as organic matter content, the concentration of N, Na, Ca, K and EC while RSA has significant effect on some of the properties such as pH and concentration of P and Mg as seen on table 3.1. But conversely, it can be observed from the Figure 3.1 that the EC level has risen up though not above the threshold level that can affect the crop but it is seen that continuous application of the RSA may consequently raise the EC beyond the threshold level which can adversely affect the growth of the crop and the yield.

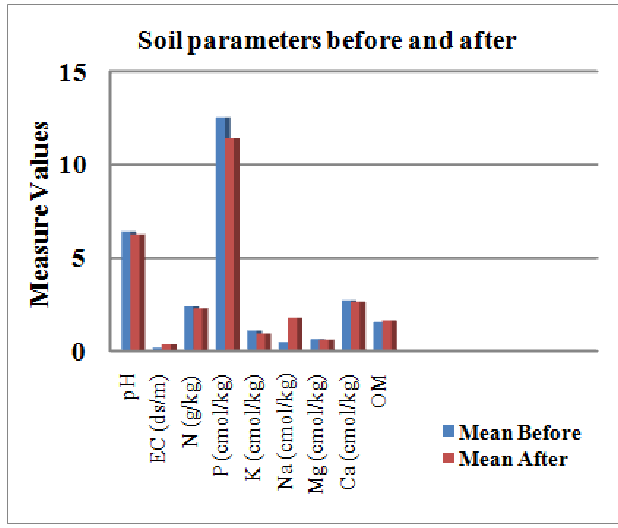

Figure 3.1: Comparison between Chemical Properties of Soil before and after application of RSA

3.4 Cucumber yield analysis

Table 3.2 show the total yield of cucumber and the mean yield harvested in the experimental field. The mean least yield (13.08 ton/ha) was obtained from the plots treated with 1Kg of RSA while the highest yield (21.84 ton/ha) was obtained in the plots treated with 0Kg of RSA. This may be attributed to the application of RSA whereby the concentration of some of the macro elements such as nitrogen, phosphorus and potassium have reduced after the RSA application as it can be seen on Table 3.1. The result of the mean yield of cucumber obtained in this research is not in agreement with that reported by [26] who gave the range of mean yield of cucumber as 40-70 tons/ha and this may be as result of different type of soil, climatic condition, variety and agronomical operations but the yield (21.84tons/ha) obtained in control plot agrees with the result reported by [27] as 21.3 tons/ha while the yield of other plots with RSA treatment were not closely in agreement as the yield obtained were within the range of 13.08-14.14 tons/ha (i.e. the yield with RSA treatment were below that stated by [27] but, these results were above the range of the yield reported by [28] who gave the mean yield of cucumber as 5-7 tons/ha. This low yield of cucumber reported by [28] may be as a result of difference in variety.

Table 3.2: Total and mean yield of cucumber

RSA (Kg)	Replicate 1 (Kg/2.25 m^2)	Replicate 2 (Kg/2.25 m^2)	Replicate 3 (Kg/2.25 m^2)	Mean (Kg/2.25 m^2)	Mean (tons/ha)
0	4.81	4.0515	5.885	4.9155	21.84
1	3.239	3.0175	2.576	2.9442	13.08
2	2.912	3.142	3.491	3.1817	14.14
3	2.351	3.784	2.871	3.0020	13.34

The result of statistical analysis (ANOVA) was presented in Table 3.3 and 3.4. The ANOVA showed that RSA is non-significant on the yield of cucumber, despite the variation of the quantity of RSA, the analysis shows that RSA does not affect the yield of cucumber. However, the reduction in the yield may result from RSA application in other plots and it was as well observed that the salinity level is increasing in those plots with RSA application, though the level of the salinity did not reach the threshold that may affect the yield but it is believed that continuous application may affect the yield of cucumber. Moreover, some of the macro-nutrients (N, K, P, Ca and Mg) have decreased (Figure 3.1) while the EC level has increased after application of the RSA when compared with the control and this could be the reason why the reduction in yield was observed in plots with RSA application.

Table 3.3: Analysis of Variance among the Treatment

Source of variation	degree of freedom	Sum of squares	Mean squares	Computed F	Tabular, F
Replicate	2				
RSA	3	7.98438483	2.66146161	5.58	0.036
Error	6	2.86160817	0.47693469		
Total	11	11.13225917			

Table 3.4: Statistical analysis of the effect of RSA on yield of cucumber

RSA (Kg)	Yield (Kg)
0	4.9155a
1	2.944a
2	3.1817a
3	3.002a
Significance	NS
LSD @ 5%	2.5418

4. Conclusion

Based on the findings obtained from this study, it could be deduced that the physiochemical properties of the soil changes due to application of the RSA. The RSA have impact on some soil chemical composition (pH, Na, Phosphorous and Magnesium) and many of the macro nutrients of soil decreased (N, K, Mg) which affect the yield of cucumber though is not significant. The application also raised the EC level though not beyond the threshold but continuous application can consequently raise the EC level beyond the threshold level which can adversely affect the growth of the crop and the yield.

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