

CUMULATIVE EFFECT OF RICE STRAW ASH ON SOIL PHYSICOCHEMICAL PROPERTIES AND YIELD OF CUCUMBER

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Abstract

Physicochemical properties of soil remain an essential factor in agricultural production all over the world. This study was conducted to assess the cumulative effect of Rice Straw Ash (RSA) on soil physicochemical properties and a corresponding yield of cucumber. The experiment was conducted at the orchard of the Faculty of Agriculture, Bayero University, Kano – Nigeria for the 2018/2019 and 2019/2020 dry seasons. It consisted of four (4) treatment plots with 0 kg, 1 kg, 2 kg, and 3 kg of RSA/m² and replicated three times resulting to twelve plots. For each experimental plot, soil properties (moisture content (MC), porosity, bulk density (BD), electrical conductivity (EC), organic matter (OM), pH, sodium concentration (Na), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg)) were measured and analyzed before and after each season. The results revealed that the application of RSA increases EC, OM, Na, porosity, and P but decreases pH, K, BD, Ca, and Mg at the end of the first and second seasons. However, MC and concentration of N decreased in the first season and increased in the second season. This could be a result of the change in antecedent moisture level between the two experiments and variation of atmospheric nitrogen fixation by Nitrosamines and Nitrobacter, respectively. The highest mean yield of cucumber was recorded in the control plot with 0 kg of RSA as 29.2 and 25.2 tons/ha during the first and second seasons, respectively. Moreover, the ranges of cucumber yield obtained in the plots treated with RSA were 13.3 – 23.7 tons/ha and 11.1 – 18.5 tons/ha during the first and second seasons. The study concluded that cumulative use of RSA results in declination of the yield of cucumber crops due to increasing EC levels. From this observation, farmers are advised to apply RSA as an improver for soil fertility enrichment for better yield of their crops.

Keywords: Rice, Straw, Ash, Cucumber, and Soil properties

1.0 INTRODUCTION

Soil is a fundamental resource for agricultural production. Excessive farming activities on the soil such as the prolonged period of cropping without the addition of proper materials to improve the quality of the soil can negatively affect the soil and make it unfavorable to meet the requirements of the plant. This is a constraint and for that reason, serious attention is needed to enhance and maintain the quality of the soil which improves its fertility status (Okonkwo *et al.*, 2011). Application of organic matter to the soil increases the carbon content, provides soil aggregation, retains moisture, and reduces compaction (Gupta *et al.*, 1977; Shanono *et al.*, 2015).

In Nigeria, the soil is strongly weathered and dominated by low-activity clay minerals with low nutrient status. Therefore, the soils cannot supply the quantities of nutrients required such that the level of crop yield decline rapidly once cropping commences due to soil degradation and nutrient depletion. This has become a serious threat to agricultural productivity in Nigeria (Olusegun, 2014). However, Sabo (2019) stated that to improve agricultural productivity and soil fertility it is necessary to add organic matter to the soil. Because of the limited resources of traditional organic materials such as animal manure, various wastes such as organic and inorganic waste can be used. Rice straw and millet are the vegetative part

of the harvested rice plant when or after the grain is harvested. It can be burned and left in the field before the next village, and it is mixed with tillage as a soil improver (Nasidi et al., 2018).

The chemical composition of the straw and the high amount of silicon are the major factors that affect the utilization efficiency and the nutritive quality. Rice straw ash is produced after a rice straw undergoes a combustion process which leads to the emission of carbon monoxide into the atmosphere, chemical composition of rice straw ash is composed of organic and inorganic matters (Govindarao, 1980; Nasidi et al 2020).

A preliminary study conducted by Alfred and Ibrahim (2017), revealed that farmers adopt the practice of burning rice straw on the field after harvesting and use the ash as an organic manure for soil treatment. However, Zakari *et al.*, 2019 reported that the application of rice straw ash to

agricultural soil shows increases in some of the physicochemical properties of the soil such as organic matter, soil moisture content, and electrical conductivity. The continuous application of rice straw ash may result in increasing soil fertility and crop production (Zakari *et al.*, 2019). It is on this note that this research aimed at the determination of the cumulative effect of rice straw ash on the physicochemical properties of the soil and the yield of cucumber to generate useful information that will help the farmers with the use of ash for soil treatment. The cucumber crop was selected because of its early maturity and being grouped under vegetable crops and all vegetable crops were reported to be affected by salinity rigorously. Salinity affects every facet of vegetable crop development including its morphology, physiological function, and yield (Shahbaz et al., 2012).

2.0 MATERIALS AND METHODS

2.1 The Study Area

The research was conducted at the Orchard of Faculty of Agriculture, Bayero University, Kano, Nigeria located at latitude $11^{\circ} 58' 38''$ North,

longitude $8^{\circ} 20' 80''$ East. The study location was situated at an altitude of 464m above sea level with a maximum temperature of 32°C and a minimum temperature of 20.9°C (Figure 1).

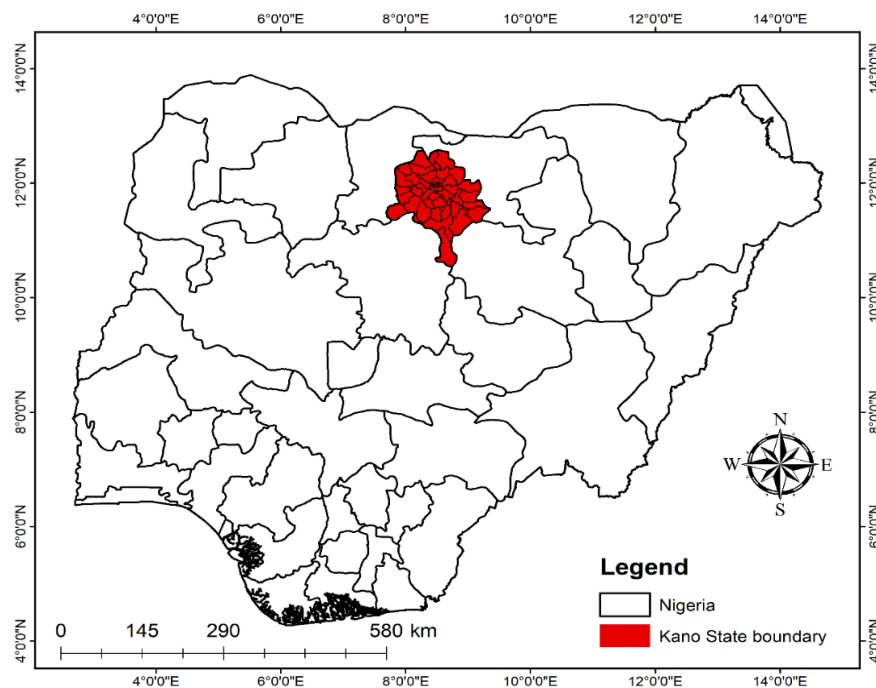


Figure (1): Map of the Study Location

2.2 Soil, Rice Straw Ash sample collection, and Laboratory Analyses.

The soil samples were collected from six separate locations in the experimental field using a soil auger and core sampler, at a depth of 0 cm to 40 cm below the surface of the soil. After open drying, the soil sample was crushed with a grinder and sieved through a 2mm diameter sieve. The samples were then analyzed in the laboratory to determine their physical and chemical properties.

Similarly, Rice straw ash was collected from a farm located at Kura LGA of Kano state and used for the study. The dry rice straw ash was collected and used on the experimental farm. It was reported by Ranasingh (1993) that there is about 15% ash from rice straw after burning and that for every 1000 kg of rice straw burnt, 150 kg of ash is formed, and about 82% silica content. Moreover, the chemical composition of rice straw ash is informed to have a similar constituent to that of many common organic fibers (Mohamed and Taher, 2006). However, the chemical composition of RSA includes Silica dioxide, SiO_2 (RSA=65.92%), Aluminum oxide, Al_2O_3 (RSA=1.78%), Ferric Oxide Fe_2O_3 (RSA=0.2%), Calcium Oxide, CaO (RSA=2.4%), Magnesium Oxide, MgO (RSA=3.11%), Sulfur trioxide, SO_3 (RSA=0.69%) and Loss on ignition (RSA=9.71%) as reported by Mohamed and Taher (2006).

Parameters on soil physical properties were determined and these parameters include soil classification, soil texture, bulk density, and moisture content of the soil. The particle size analysis of the soil was conducted to determine the textural classification of the soil using the Bouyoucos Hydrometer method (Gee and Dr, 2002). The moisture content was determined using the gravimetric method (Michael and Ojha (2005), and the soil porosity was determined using the (describe method name) method (Michael and Ojha (2005). Moreover, the bulk density of soil was determined using the core sampler method (Gee and Dr, 2002), whereas the organic matter content was determined using the method of Michael and Ojha (2005) The soil porosity was determined using the method described by (Vomicile, 1965) moreover, the bulk density of

the soil was determined using core sampler method (Grossman and Reinch, 2002). The Walkley Black wet oxidation method (Udo *et al.*, 2009) was used to determine the percentage of organic matter content present in the soil.

Soil pH was determined using a pH meter (model, country of manufacturing. Eg: Hanna Instrument, Japan) in the laboratory, and soil salinity of the study area was also determined by obtaining electrical conductivity (EC) of the soil using the saturation extraction method described in Udo *et al.*, (2009). Similarly, the available nitrogen from the organic matter in the experimental soil was determined using the alkaline permanganate method described by (Thakur *et al.*, 2012). Next to nitrogen, phosphorous is an essential element in influencing plant growth and production. Moreover, a method was employed in determining the available phosphorous in the soil as described in Thakur *et al.*, 2012. The photometer flame method was used to determine the available potassium and sodium presence in the soil as described by Thakur *et al.*, 2012. El Mahi *et al.*, (1987) method was used in determining calcium and magnesium in the soil. The crop yield was computed for each of the experimental plots following the practice proposed by Igbadun *et al.*, (2012).

2.3 Land Preparation and Agronomic Practice

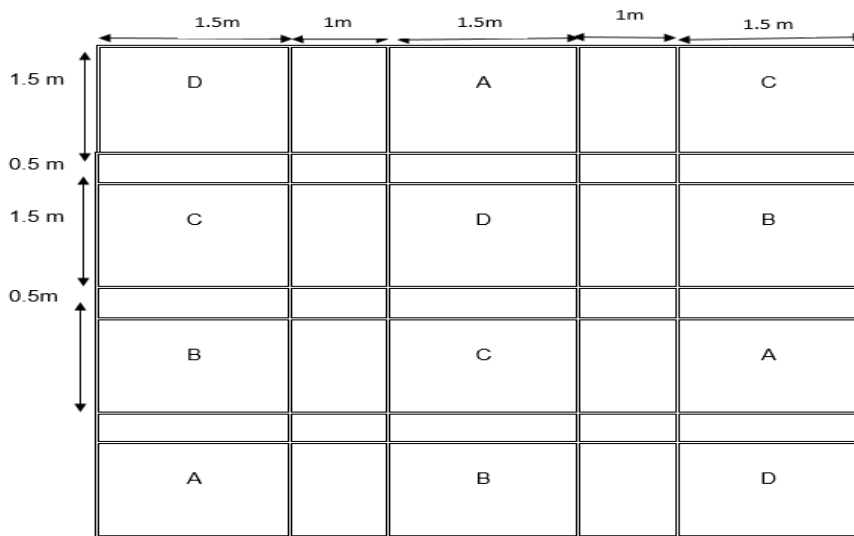
A land area of 7.5 m x 6.5 m was prepared into leveled basins of 1.5 m x 1.5 m. Soil tillage was conducted to allow sufficient aeration and the development of plant roots. Also, the basins were separated by 0.5 m as a buffer zone to minimize the lateral movement of water. Cucumber hybrid (*Nagano F1*) seed was sown at the rate of two seeds per hole in a row at a plant spacing of 50 cm between plant and between rows per basin, and the plant population per unit plot was approximately (9) cucumber and consequently (108) cucumber stand for the entire eighty-one (12) experimental plots. Azoxystrobin was applied after five weeks of planting. Various levels of rice straw ash of 0 kg/ m², 1kg/m², 2kg/ m² and 3kg/ m² were applied in A, B, C, and D basins respectively for the two seasons as shown in plates 1, 2 and Figure 2.



Plate 1: Experimental Plot before the 1st application of RSA



Plate 2: Experimental Plot after the 1st application of RSA



A is 0Kg of RSA/m²
B is 1Kg of RSA/m²
C is 2Kg of RSA/m²;
D is 3Kg of RSA/m²

Figure (2): Experimental field Layout

2.4 Experimental design and Statistical Analysis.

Strip plot design was used as an Experimental Design where the treatments were assigned to each experimental plot. The four treatments were

replicated three times which makes twelve (12) treatments. Analysis of variance (ANOVA) was used to evaluate the variability of soil treated with various quantities of rice straw ash.

3.0 RESULTS AND DISCUSSIONS

3.1 Physical Properties of the Soils.

Tables 1 and 2 present the mean values of physicochemical properties of the experimental field soil before and after the application of rice straw ash (RSA) for the two seasons. The soil was loamy sand in texture with an average bulk

density and moisture content of 1.52 g/cm³ and 9.72 % respectively after application for the first season. The application of RSA increases EC, OM, Na, porosity, and P, but decreases pH, K, BD, Ca, and Mg at the end of the first and second seasons. However, MC and concentration of N

decreased in the first season and increased in the second season. This could be a result of the change in antecedent moisture level between the

two experiments and variation of atmospheric nitrogen fixation by nitrosamines and Nitrobacter, respectively.

Table (1): Physicochemical properties of the soil before and after the first application of RSA

Soil parameters	Mean		t statistics	t critical
	Before	After		
Moisture Content (%)	12.60	9.72	4.73	2.02
Bulk density (g/cm ³)	1.58	1.52	1.64	2.02
Porosity (%)	40.51	42.77	-1.66	2.02
OM (%)	0.87	1.00	-0.37	2.02
EC (ds/m)	0.05	0.08	-2.90	2.02
N (meq L ⁻¹)	0.29	0.11	5.11	2.02
P (meq L ⁻¹)	15.40	21.77	-2.35	2.02
K (meq L ⁻¹)	0.60	0.39	3.30	2.02
Na (meq L ⁻¹)	0.12	0.16	-2.17	2.02
Mg (meq L ⁻¹)	2.92	1.80	2.01	2.02
Ca (meq L ⁻¹)	5.22	2.85	8.50	2.02
pH	6.94	5.85	4.97	2.02

Table (2): Physicochemical properties of the soil before and after the second application of RSA

Soil parameters	Mean		t statistics	t critical
	Before	After		
Moisture Content (%)	9.72	12.83	-6.17	2.02
Bulk density (g/cm ³)	1.52	1.37	4.33	2.02
Porosity (%)	42.77	48.32	-4.33	2.02
OM (%)	1.00	1.24	-0.97	2.02
EC (ds/m)	0.08	0.08	-0.14	2.02
N (meq L ⁻¹)	0.11	0.16	-2.66	2.02
P (meq L ⁻¹)	21.77	26.43	-2.85	2.02
K (meq L ⁻¹)	0.39	0.37	0.80	2.02
Na (meq L ⁻¹)	0.16	0.16	-0.21	2.02
Mg (meq L ⁻¹)	1.80	1.51	1.64	2.02
Ca (meq L ⁻¹)	2.85	1.59	11.74	2.02
pH	5.85	5.09	2.70	2.02

Rice straw ash of 0 kg/m², 1kg/m², 2 kg/m² and 3kg/m² were applied in A, B, C, and D basins respectively for the first season and an equal amount of application was done in the second season, as indicated by Plates 1 and 2 above. The soil samples were taken before application of the treatments and after harvesting of the crops for laboratory, physicochemical analysis in each season, and table 3 presents the results of the effect of the cumulative application of rice straw ash on the soil properties and statistical analysis

(t-test) that compared the mean values of the physicochemical properties of the soil. The moisture content, bulk density, and porosity were found to be 12.83 %, 1.37 g/cm³, and 48.32% respectively after the cumulative application of the rice straw ash. The soil remains acidic with a pH value of 5.088, the electrical conductivity (EC), organic matter content, and concentration of N, P, K, Mg, and Ca was also found to be 0.08ds/m, 1.24%, 0.16 meq L⁻¹, 26.43 meq L⁻¹, 0.37 meq L⁻¹, 1.51 meq L⁻¹ and 1.59 meq L⁻¹

respectively after the cumulative application. It was observed that cumulative application of the rice straw ash increased the porosity, organic matter, EC, and concentration of phosphorus by 19.3%, 42.4%, 56.6%, and 71.6%, respectively. The moisture content was slightly increased by 1.8%. These indicated that the soil physicochemical properties of the soil were responsive to the accumulation application of rice straw ash.

The bulk density of the soil decreases in both seasons after the application of RSA and this agrees with Mahmoud *et al.*, (2017) who added biochar to the soil for amendment and found that the soil bulk density reduced, and this is apparent as it is known that soil has higher density compared to bio-residues of equal volume. However, the increases in these parameters (porosity, organic matter, and phosphorus) are favorable to cucumber production (particularly the phosphorus being one of the micronutrients needed for crop production) except the sodium and EC which is detrimental to most crop production when it exceeds the permissible limit though, it has been reported in Torsten (2016) that cucumber is not very salt-tolerant and the decreased in these parameters (K, Ca, Mg) are unfavorable for cucumber production. As reported by Torsten (2016) that higher relative values of K, Ca, and Mg are required for the

production of cucumber and although the growth rate is not affected by a relatively high uptake of cations, especially of K. Contrary to the findings of this research, Mahmoud *et al.*, (2009) reported that the application of rice straw compost and water treatment residuals (WTR) decreased soil salinity and increased Ca^{+2} , K^{+} . This is obvious because rice straw ash was applied as a treatment instead of rice straw. Moreover, the result of statistical analysis (t-test) from Table 3 and Figure 3 shows that cumulative application of rice straw ash has a significant difference in all the physicochemical properties analyzed at a 5% level of significance except in the organic matter and soil moisture content were not significant. The insignificance difference observed in the moisture content and organic matter content disagrees with Zakari *et al.*, (2018) who reported that the application of rice straw ash is proportional to the increase in the soil moisture and organic matter content of agricultural soil. However, the significant difference obtained in some of the properties such as nitrogen, phosphorous, magnesium, and potassium conforms with Sabo, (2019) who revealed that the application of organic material to the soil can improve the concentration of nitrogen, phosphorous, magnesium and potassium even though Sabo *et al.*, (2019) used millet chaff and poultry manure as organic material.

Table (3): Statistical analysis of the cumulative application of RSA on soil physicochemical properties

Soil parameters	Mean		t statistics	t critical
	Before	After		
pH	6.94	5.09	5.89	2.02
EC (ds/m)	0.05	0.08	-4.03	2.02
N (g/kg)	0.29	0.16	3.74	2.02
P (meq L ⁻¹)	15.40	26.43	-4.93	2.02
K (meq L ⁻¹)	0.60	0.37	4.51	2.02
Na (meq L ⁻¹)	0.12	0.16	-2.49	2.02
Mg (meq L ⁻¹)	2.92	1.51	3.07	2.02
Ca (meq L ⁻¹)	5.22	1.59	15.10	2.02
OM (%)	0.87	1.24	-0.79	2.02
Bulk density (g/cm ³)	1.58	1.37	9.28	2.02
Porosity (%)	40.51	48.32	-9.34	2.02
Moisture Content (%)	12.60	12.83	-0.40	2.02

It is important to note that the application of the RSA increases EC, OM (due to plant materials), Na, porosity, and P but decreases pH, K, BD, Ca, and Mg at the end of the first and second seasons. However, MC and concentration of N decreased

in the first season and increased in the second season. This could be a result of the change in antecedent moisture level between the two experiments and variation of atmospheric nitrogen fixation by nitrosamines and Nitrobacter, respectively.

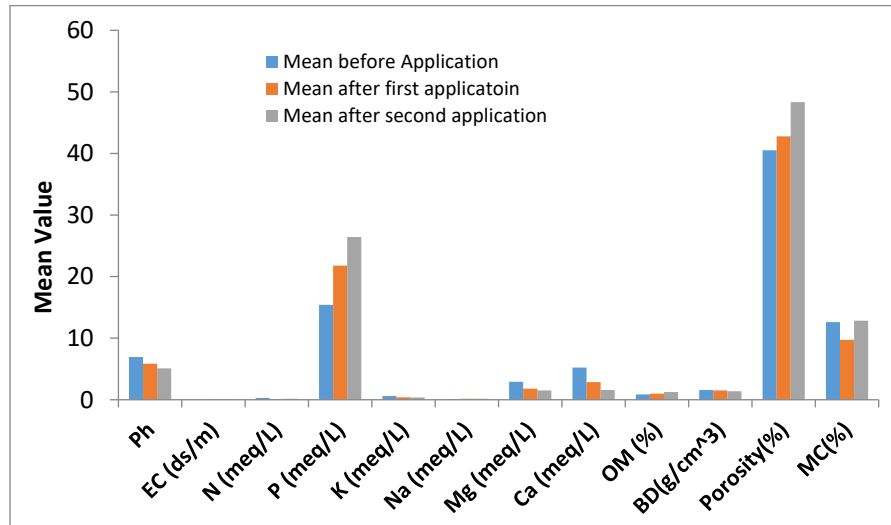


Figure (3): Physicochemical properties of the soil before and after 1st and 2nd RSA application

Tables 4 and 5 showed the total and mean value of cucumber yield harvested from the treatment in the first and second seasons of the experiment. The mean least yields were obtained to be 13.33 tons/ha and 11.11 tons/ha all from plots treated with 3 kg RSA for the two seasons respectively, while the highest yield was found to be 29.18 tons/ha and 25.18 tons/ha both from the plots treated with 0 kg RSA which implies that the application of RSA has a negative effect on the yield of cucumber and this result is contrary to the findings of Mahmoud *et al.*, (2017) whose rate of application of biochar to soil increases

proportionately the yield. It was expected that the highest will be from the plots treated with the highest quantity of the material since rice straw ash is a product of organic material. The least yield obtained in this study disagrees with Zakari *et al.*, 2019 who reported that the application of 1 kg of RSA results in a cucumber yield of 13.08 ton/ha. However, the mean yield obtained from all treatments is in-line with Remission, 2005 who revealed that the range yield of cucumber is 5-7 tons/ha. Even though the Remison experiment is in a different location from this experiment.

Table (4): First season's total and mean yield of cucumber

RSA (kg)	Replicate 1	Replicate 2	Replicate 3	Mean tons/ha
0	7.00	5.50	7.20	29.18
1	4.50	5.00	6.50	23.70
2	4.50	2.00	3.00	14.07
3	3.50	4.00	1.50	13.33

Table (5): Second season's total and mean yield of cucumber

RSA (kg)	Replicate 1	Replicate 2	Replicate 3	Mean tons/ha
0	5.50	6.00	5.50	25.18
1	2.50	4.50	4.00	16.29
2	5.00	3.50	4.00	18.51
3	2.00	3.00	2.50	11.12

The cumulative application of RSA has shown differences in the yield of cucumber concerning the level of RSA application. It can be observed that the RSA application is inversely proportional to the yield, and this could result from the increase in EC level from the application of the RSA. However, statistical analyses using ANOVA were presented in Table 6 from the analyses of the

result, the cumulative application of RSA has no significant difference in the yield of cucumber. This indicated that the continuous application of rice straw ash on the soil resulted in declination in the yield of cucumber. Therefore, farmers are advised to discontinue from the application of RSA as a means of improving the fertility of the soil.

Table (6): Statistical analysis of the effect of RSA on the second season's yield of cucumber

RSA (kg)	Yield (kg)
0	5.67 ^a
1	3.67 ^a
2	4.17 ^a
3	2.50 ^a
Significance	NS
LSD @ 5%	2.90

4.0 CONCLUSION

The study evaluates the cumulative effect of rice straw ash on soil physicochemical properties and the yield of cucumber. Based on the result obtained, the physicochemical properties of soil were responsible for the cumulative application of rice straw ash. The RSA application has increased soil properties and parameters such as porosity, organic matter, and phosphorus which are favorable to cucumber production. Except the sodium and EC which is detrimental to most crop production when it exceeds the permissible limit.

Also, there is a decrease in some parameters (K, Ca, Mg) as a result of the application, which is unfavorable for cucumber production although, the growth rate is not affected by a relatively high uptake of cations, especially of K. It was discovered that cumulative application of RSA has no significant difference in the yield of cucumber. This indicated that continuous application of rice straw ash on the soil could result in declination in the yield potentials of cucumber.

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