International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Influence of Urea-Fortified Rice-Processing Wastes on Soil Properties and Maize (*Zea Mays* [L.]) Yield Components in Makurdi Local Government Area (Lga), Benue State, Nigeria

[1]Oroduen Joshua Ahile, [2*]Monday Akpegi Onah, [3]Lanre Tajudeen Ajibade, [4]Patricia I. Ali [5]Johnson Orfega Mage, [6]Terwase Shabu, [7]Elizabeth Nguwanger Jeiyol and [8]Marcellinus Akaangee Hula

[1, 2*, 4, 5, 6, 7 and 8]*Department of Geography, Benue State University, Makurdi, Nigeria.*

[3]*Department of Geography and Environmental Management, University of Ilorin, Ilorin, Nigeria.*

[2*] *Email - onah1982akpegi@gmail.com (+2348136827726)*

ABSTRACT

Maize is one of the most widely distributed of the world's food plants. Organo-mineral sources of plant nutrients are suitable, economical, effective, efficient and promising soil amendments for environmentally sustainable and economically profitable cropping in the tropics, Nigeria inclusive. A field experiment was undertaken during the 2024 cropping season at Agan Settlement in Makurdi LGA of Benue State to examine the influence of urea-fortified fresh rice-processing wastes (RPWs) on soil properties and maize yield components. Each experimental plot measured 4 m x 3 m (area = 12 m^2). The total physical size of the experimental site (piece of land) used was 21 m x 14 m (294 m^2) or 0.0294 Ha, with the plant spacing of 100 cm x 30 cm. The experiment was laid out in a randomized complete block design (RCBD). It consisted of 6 treatments (15 t/ha RPWs + 0 kg/ha Urea fertilizer [which served as the control]; 15 t/ha RPWs + 15 kg/ha Urea [N] fertilizer; 15 t/ha RPWs + 25 kg/ha Urea fertilizer; 15 t/ha RPWs + 35 kg/ha Urea fertilizer; 15 t/ha RPWs + 45 kg/ha Urea fertilizer; and 15 t/ha RPWs + 55 kg/ha Urea fertilizer) replicated thrice under the RCBD. Before their fortification with urea fertilizer and their subsequent incorporation into soils at the experimental site, the obtained fresh RPWs were analyzed in a standard laboratory for their chemical/mineralogic composition. The fresh RPWs were first weighed, after which urea fertilizer was added to them according to the pre-determined treatment levels. The urea-fortified RPWs were then incorporated about 30 cm into prepared seed beds and allowed to decompose substantially for about 4 weeks before sowing of the maize seeds. Pre-treatment/pre-cropping and post-harvest composite soil samples were collected from dug soil profile pits (0-30 cm depth) and analyzed in a standard soil laboratory to determine the soils' pre-amendment and post-harvest status of texture and chemical properties, respectively. A net plot of inner ridges for each treatment was used with 5 tagged maize plants for dry plant matter and number of seeds per cob. The grain yields of fully mature and dry cobs of 15% grain moisture for each net plot were extrapolated to yield in t/ha. The collected soil data were analyzed using descriptive statistics, while ANOVA for RCBD was performed on the data collected in respect of the maize yield parameters and yield per unit area using Genstat (2005). The obtained results revealed that the soils' amendment with the urea-fortified RPWs did not alter their textural class (sandy), but significantly improved the soils' chemical properties over their pre-amendment status. The 15 t/ha RPWs + 55 kg/ha Urea treatment gave the highest soil pH (6.68), TN (0.69%) and Ca^{2+} (3.99 cmol/kg) values; the 15 t/ha RPWs + 35 kg/ha Urea treatment gave the highest SOM value (2.60%); the 15 t/ha RPWs + 25 kg/ha Urea treatment gave the highest AP value (26.87 mg/kg), while the control gave the highest exchangeable Na^+, K^+ and Mg^{2+} values (0.22, 0.97 and 2.98, respectively). Similarly, the soils' amendment with the urea-fortified RPWs significantly increased maize yield components over the control. The 15 t/ha RPWs + 55 kg/ha Urea treatment gave the highest mean number of seeds per cob (423), while the 15 t/ha RPWs + 45 kg/ha Urea treatment produced the highest mean grain yield (3.17 t/ha) and dry plant matter (8.99 g/plant). Thus, it was concluded that judicious application of urea-fortified RPWs to soils had significant positive effects on soil chemical properties and, hence, on maize yield components. The 15 t/ha RPWs + 45 kg/ha Urea treatment was, therefore, recommended as being suitable, economical, effective and efficient in significantly improving soil chemical properties for the optimum yield of maize in the study area.

Key words: *Urea fertilizer, fortified rice-processing wastes, soil properties, maize yield components, organo-mineral sources of plant nutrients.*

INTRODUCTION

Attaining sustainable food security is a serious socio-economic challenge in the tropical region owing to the fragile nature and the low inherent fertility (low organic matter [OM] and poor nutrient-resource base) of the soils. Humid tropical soils are generally poor in OM and available essential nutrients; poorly buffered and low in cation exchange capacity (CEC); hence, the soils' fertility, productivity and sustainability decline over time when subjected to continuous cropping without adequate and timely soil nutrient-restoration measures. Recycling of agricultural wastes for soil fertility maintenance is, therefore, a great resource/means of enhancing sustainable crop growth and yields in Nigeria.

Albeit inorganic fertilizers are very important and effective/promising inputs that enhance higher crop productivity, over-reliance on, or indiscriminate/continuous use of, inorganic fertilizers leads to a decline in some soil properties and crop yield and similar serious ecological/environmental and socio-economic consequences or limitations over time (Hepperly, Lotter, Ulsh, Siedel & Reider, 2009). Inorganic fertilizers are environmentally unfriendly, very expensive and not readily available to peasant farmers. Interest in crop production through the application, to soils, of organic materials (e.g., organic manures, biological pest and weed control, organic supplements of plant nutrients in soils, etc.) is, therefore, generally increasing across the globe (USDA, 1980). Organic farming (OF) is simply a farming system that avoids the application of synthetic materials (Babalola, Adigun & Abiola, 2018a & b). OF is a philosophy of agriculture that does not allow the use of synthetic chemicals, but instead emphasizes the management of SOM and biological processes. The various systems of OF (e.g., organic manuring) focus centrally on soil quality and avoidance of the application of synthetic chemicals to soils for the purpose of agricultural production. At its core, OF strives to integrate ecologically-oriented good management practices. OF holds the promise of better farming tomorrow despite the low average yield today. It also offers soils some natural protection and preservation and encourages good and safe feeding. Summarily, OF is essential in improving soil fertility and productivity, increasing crop nutrition and maintaining biologically active soils. Thus, it is important to sustainable agriculture and environmental systems (Adinna, 2001; Havlin *et al*., 2014; Brady & Weil, 2015).

Maize (*Zea mays* [L.]) is one of the most widely distributed of the world's food plants (Kochhar, 1986). It is the third most important crop in the world after rice and wheat (FAO, 2000). It has high demand for major essential macro-nutrients, particularly nitrogen (N). Maize is one of the major staple crops produced and consumed in Nigeria that is well adapted to Nigerian savanna and rain forest ecologies. The crop is well adapted to the tropical rain forest zone of Nigeria, especially the Niger Delta (Zingore, Murwira, Delve & Giller, 2007; Monkwunye & Batiano, 2010; Kekong, Attoe & Adiaha, 2018). It is the most important/popular cereal grown and consumed worldwide, and is ranked third after wheat and rice on the basis of cultivated area in the world. In Nigeria, it is the third most important cereal crop after millet and sorghum. It is grown on more than 110 million hectares (ha) throughout the world, out of which over 52 million hectares are well distributed in developing countries. Average world yield of maize is about 4.04 tonnes per hectares (t/ha) (FAO, 1985, 2009; Agboola & Tijani, 1991; Ashraf, Salim, Sher, Sabir, Khan, Pan & Tang, 2016a). Byerlec and Kurtz (1997) asserted that about 26 million tonnes of maize were produced annually on 20 million hectares of land in Africa.

According to IITA (2012, 2016), the phenomenal increase in maize production in the past few decades has brought about by favourable government policies, which have facilitated its cultivation as well as the development and availability of farm inputs (such as inorganic chemical fertilizers), resulting ultimately in increased yield. The mineralogic/chemical composition of maize grain shows that it contains about 76-88% carbohydrates, 6-15% proteins, 4% ether extract, 2% crude fibre, 0.25% lysine, 0.18% methionine, 0.01% calcium (Ca) and 0.09% available phosphorus (AP) (Randjelovic, Prodanovic, Tomic & Simic, 2011). Several factors, such as declining soil fertility, imbalanced nutrition, disturbed soil properties (including physical structure and horizons), cultivars being grown, weed infestation, etc., limit maize yield worldwide. Different management practices are adopted to increase and optimize maize yield. Judicious application of organic manures alongside inorganic chemical fertilizers, for example, often significantly increases soil OM, moisture and nutrient status/contents and improves soil biological activity/properties, physical structure, texture and pH as well as base saturation (BS), cation exchange (CE), nutrient cycling, infiltration and water- and nutrient-retention capacities and, hence, ultimately improves crop growth and yield (Saha, Mina, Gopinath, Kundu & Gupta, 2008).

Kochhar (1986, pp. 96-97) has noted that maize is a rich-land crop and can be grown in a wide variety of climates and on very diverse kinds of soil as is evident from its wide geographical distribution, extending from Latitude 58ºN in Canada and the USSR to Latitude 40ºN in the Southern Hemisphere, with a maize crop maturing somewhere in the world every month of the year. The bulk of the crop is grown in the warmer parts of the temperate regions and in the humid subtropics. However, it is not a satisfactory crop in regions with semi-arid climates, nor in the wet tropical evergreen rain forests. Maize is grown from sea level to an elevation of 3300 m. For optimum production maize requires the following essentials: a fertile, well-drained loam soil; a generous well-distributed rainfall; a frost-free growing season of 110-130 days, and a moderately high temperature. It is grown on a wide variety of soils, ranging from fairly coarse sand to the heaviest of clays. It grows best on fertile, friable, well-drained warm loam and silty loam soils, well-supplied with OM and available nutrients. It can be grown under a wide variety of soil reactions, but the optimum pH range is from 5 to 7.

Organo-mineral sources of plant nutrients are effective, efficient and promising soil amendments for environmentally sustainable and economically profitable cropping in the tropics. Organic manures/organic-based fertilizers have been reported to significantly improve soil quality and, hence, increase crop growth and yield (Babalola & Olowokere, 2005; Babalola *et al.*, 2018a & b). Albeit organic manures are bulky to transport and release plant nutrients into soils very slowly, Hausenbuiller (1974), Adelekan, Laleye and Idowu (2003) and Okaro (2006) noted that they have the capacity to sustainably and valuably address the continuous demand/need for nutrients by crops. They also help greatly in conditioning soils' physical characteristics/properties (e.g., they reduce soil bulk density and surface runoff, moderate/regulate soil temperature, and improve soil texture, moisture content, physical structure, porosity, percolation, permeability, aeration, and water/nutrient retention and infiltration capacities) and improving soil biological properties, thereby appreciably improving crops' growth environment. The potentials, effectiveness and efficiency of agricultural wastes (e.g., rice mill wastes/husks and maize-cob ash) in improving soil nutrient base depend on their carbon-nitrogen (C/N) ratio. Chapman (2012), Havlin, Tisdale, Nelson and Beaton (2014) and Brady and Weil (2015) have noted that organic materials with high C/N ratios and high contents of phenols decelerate decomposition process and deplete native soil N to meet soil microbial needs. Rice-processing wastes (RPWs) or rice mill wastes/husks with low N contents occur in bulk/large quantities in rice-growing and processing areas of the world. The RPWs are used as organic amendments by farmers for soil enrichment. These RPWs are used either burnt or after long-term curing because of their high C/N ratio.

The fortification of RPWs with urea (N) would enhance their faster mineralization or release of their constituent nutrients into the soil solution for plants' absorption and use. It would also release appreciable OM into soils. The OM, in turn, is not only critical to crop production, but also has the capacity of improving all soil characteristics for increased crop growth and yield. Maize plant is a heavy feeder, requiring an intelligent fertilizer programme. It requires a lot of N, potash, P, Ca and Mg for a maximum yield. It responds very well to heavy N fertilization. Several studies have been undertaken to assess the effects of organic manures or inorganic fertilizers on soil properties and crop growth and yield in different parts of the world. Such works include Olayinka (1990), Olayinka, Adetunji and Adebayo (1998), Abdallahi and N'Dayegamiye (2000), Osundare (2004), Akanbi and Ojeniyi (2007) and Dania, Fagbola and Isitekhale (2012).

Previous research has shown that OF and conventional farming systems and soil management practices differ considerably with farmers, causing fewer hazards to wildlife, farm workers and rural residents (Lichtenbierg, 1992; Montalvo-Grijalva, 2008). However, very limited research has been carried out to empirically examine the effects of N-fortified rice mill wastes (RMWs) on soil properties and maize growth and yield in Nigeria (e.g., Kekong *et al*., 2018), even though Nigeria currently produces maize in very large quantities. Thus, it has become necessary to assess the effects of N-fortified RMWs on soil properties and maize growth and yield in Benue State, which is one of the major maize-producing states in Nigeria; hence, the need for this work. The present study, therefore, specifically investigated the influence of urea-fortified fresh RPWs on soil properties and maize yield at Agan Settlement in Makurdi LGA of Benue State, Nigeria.

MATERIALS AND METHODS

Location

The research was undertaken during the 2024 cropping season (i.e., between April and October) at Agan Settlement in Makurdi LGA of Benue State, Nigeria. Agan is part of Makurdi Town, which lies between approximately Latitudes 7°43'N and 45°N of the Equator and Longitudes 8°28'E and 32°E of the Prime Meridian. The town is sited almost entirely on the vast flood plains of the R. Benue in the R. Benue Trough. The land surface is generally low-lying and characterized by gently-undulating slopes in most parts. The area experiences the Koppen's Aw (i.e., tropical, seasonally wet and dry) climate, which is characterized by two distinct alternating seasons of wet (April-October) and dry (November-March), annual rainfall totals ranging from 1000 mm to 2000 mm, and a single maximum regime of rainfall (September) each year (Lyam, 2005a). Temperatures here fluctuate between 23℃ and 35℃ within a year, with the diurnal mean of about 23℃. Owing to its location in the valley of the R. Benue, Makurdi Town experiences warm temperatures for most parts of the year (Tyubee, 2003, 2005). This kind of climate (combined effects of rainfall/moisture and temperature) regime is able to support only the Guinea Savanna Biome, with its characteristic coarse grasses and scattered trees that become more stunted and less dense towards the northern parts of Benue State. Ancient (very hard) and young (not very hard) sandstones of sedimentary formation generally underlie the town and its environs. The dominant soils in the area are the ferruginous tropical soils, which broadly comprise lithosols, hydromorphic soils, and alluvial soils. The hydromorphic and alluvial soils characterize the flood plains of the R. Benue and its tributaries, whereas the lithosols develop outside the flood plains and overlie the original bedrocks on steep bare rock slopes, especially on the hillslopes. Soil surfaces in the area generally have a sandy texture. The most prominent drainage feature here is the R. Benue and its tributaries (Lyam, 2005a).

Experimental Materials and Agronomic Practices

The urea fertilizer used contained 46% nitrogen (N), and was bought from the Makurdi Modern Market. The variety of maize used was OBA Super 2 (an improved, fast-growing, early-yielding/maturing and high-yielding variety). This variety was obtained from the Crop Science Department of Joseph Sarwuan Tarka University, Makurdi (JOSTUM). The fresh rice-processing wastes (RPWs) used were sourced from the Wurukum Rice Mills, Makurdi. The fresh RPWs were first weighed, after which urea fertilizer was added to them according to the pre-determined treatment levels. The urea-fortified RPWs were then incorporated about 30 cm into prepared seed beds and allowed to decompose substantially for about four (4) weeks before sowing of the maize seeds. The major agronomic practices used were land clearing/preparation, tillage/ridging, weeding, organic manuring, inorganic fertilizer application, pest control, sowing, and harvesting.

Experimental Design and Treatments

Each experimental plot measured 4 m x 3 m (area: 12 m^2). The total areal extent of the experimental site/piece of land used was 21 m x 14 m (294 m^2) or 0.0294 Ha, with the plant spacing of 100 cm x 30 cm. The experiment was laid out in a randomized complete block design (RCBD). It consisted of 6 treatments (15 t/ha of RPWs + 0 kg/ha of urea fertilizer [which served as the control]; 15 t/ha of RPWs fortified with 15 kg/ha of urea [N] fertilizer; 15 t/ha of RPWs fortified with 25 kg/ha of urea fertilizer; 15 t/ha of RPWs fortified with 35 kg/ha of urea fertilizer; 15 t/ha of RPWs fortified with 45 kg/ha of urea fertilizer; and 15 t/ha of RPWs fortified with 55 kg/ha of urea fertilizer) replicated thrice under the RCBD. The plant spacing used was 100 cm x 30 cm

Data Collection

(a) Soil Sampling and Preparation/Processing of the Collected Soil Samples

Prior to the commencement of the actual field experiment, a reconnaissance survey of the study area was conducted during which soil profile pits were dug to the depth of 30 cm at random points within the experimental site. Pre-cropping soil samples were collected from each pit and bulked to obtain composite samples for laboratory analysis before the treatments and their replications were applied to the soils. The pits were carefully refilled before the actual field experiments began. The field-collected composite soil samples were properly processed or prepared (i.e., air-dried, ground, sieved through a 2-mm sieve, bagged, numbered, and labelled) and submitted at the soil science laboratory of JOSTUM for the pre-treatment/pre-cropping analysis of the soils' texture and chemical properties. After maize harvest, post-treatment soil sampling was undertaken by excavating random soil profile pits (0-30 cm depth) in each treatment and replication. Post-harvest/post-treatment soil samples were collected from the pits in each treatment and its three replications and bulked to obtain composite samples for laboratory analysis. The field-collected composite soil samples were properly prepared and sent to the soil science laboratory of JOSTUM for the post-amendment/post-harvest analysis of the soils' texture and chemical properties. The pits were carefully refilled after sample collection.

(b) Pre-fortification, Pre-amendment and Pre-application Analysis of the Chemical/Mineralogic Composition of the Rice-processing Wastes (RPWs)

Before their fortification with urea (N) fertilizer and their subsequent incorporation into soils at the experimental site, the obtained fresh RPWs were analyzed at the Benue State Ministry of Agriculture, Makurdi and/or in the laboratory of the Crop Science Department of JOSTUM to determine their chemical/mineralogic composition.

(c) Plant Sampling

A net plot of inner ridges for each treatment was used with five tagged maize plants for dry plant matter and number of seeds per cob. The grain yields of fully mature and dry cobs of 15% grain moisture for each net plot were extrapolated to yield in tonnes per hectare (t/ha). Destructive sampling was used in each of the tagged plants in the net plot of inner ridges to determine dry plant matter.

(d) Laboratory Analysis of the Collected Soil Samples

Pre-treatment and post-harvest analyses of the field-collected and prepared soil samples were carried out in the soil science laboratory of JOSTUM. The soil samples were analyzed for their texture (mineral particle-size distribution [PSD]) and chemical properties - pH, and organic carbon (OC), organic matter (OM), total nitrogen (TN), available phosphorus (AP), and exchangeable calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+) contents - following standard procedures of the International Institute of Tropical Agriculture (IITA) (1979) or as described by Carter (1993) and Udo, Ibia, Ogunwale, Ano and Esu (2009).

Soil PSD was determined by using hydrometer method (Gee & Or, 2002), pH with a digital electronic soil pH meter using a soil-water (H_2O) medium in the ratio of 1:2 (IITA, 1979; Carter, 1993; Lombin, 1999), and OC by the modified procedure of Walkley and Black using the dichromate wet oxidation method (Shamshuddin, Jamaila & Ogunwale, 1995; Nelson & Sommers, 1996). The percentage soil OC content was then calculated using the relationship: % Org. Carbon = N (V1-V2) 03 f. The percentage soil OM content was calculated from the relationship: % Org. Matter = % OC x 1.724 (i.e., by multiplying the obtained % OC content by the conversion factor of 1.724). It is common to use a conversion factor of 1.724 to convert a measured OC value to OM, implying that OM contains 58% C, though this is based on work conducted in the 19th Century. Values up to 2.0 for surface soils and 2.5 for subsoils have been published (Nelson & Sommers, 1996). Soil TN was determined using the regular modified macro-Kjeldahl digestion apparatus/method as described by Bremner and Mulvaney (1982) and Bremner (1996), and AP by the Bray-1 Extraction Method, followed by molybdenum blue colorimetry (Bray & Kurtz, 1945). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+) were extracted from each soil sample using 1N of normal ammonium acetate (NH_4OA_c) extraction method buffered at pH 7 (Thomas, 1982), after which the K and Na levels/contents in the NH_4OA_c extract were measured by a flame photometer (Helmke & Sparks, 1996), while the Ca and Mg contents/levels in the NH_4OA_c extract were determined by atomic absorption spectrophotometry (AAS) using the 0.01N of EDTA titration method (Chapman, 1965).

Statistical Analysis of the Generated/Collected Data

The collected soil data were analyzed using descriptive statistics (arithmetic mean, simple percentages), while analysis of variance (ANOVA) for RCBD was performed on the data collected in respect of the maize yield parameters (components) and yield per unit area using the computer software Genstat (Genstat, 2005). Fisher's Least Significant Difference (FLSD) ($P > 0.05$) was calculated to separate the means.

RESULTS AND DISCUSSION

Pre-fortification, Pre-amendment and Pre-application Chemical/Mineralogic Composition (Analysis) of the Rice-processing Wastes (RPWs) Used in this Study

The pre-fortification, pre-amendment and pre-application chemical/mineralogic composition of the RPWs used in this research is presented in Table 1. The RPWs had low total nitrogen (TN) (0.94%), total phosphorus (TP) (0.92 mg/kg), total potassium (TK) (0.38 cmol/kg), magnesium (Mg) (0.53 cmol/kg) and sodium (Na) (0.21 cmol/kg) but a high concentration of calcium (Ca) (2.21 cmol/kg), high percentage organic carbon (OC) content (38.1%) and a high C/N ratio (40.53). The low TN content of the RPWs indicates that they need to be properly fortified with inorganic sources of N, such as urea fertilizer, before being applied to heavy N-consuming crops, like maize. The high C/N ratio of the RPWs indicates that they have a low rate of organic decomposition if applied without any conscious efforts made to accelerate their decomposition. Their high C/N ratio also means that if they are applied to soils, they would deplete native soil N to meet soil microbial needs. Overall, the RPWs' high C/N ratio implies agronomically that they have a low potential, effectiveness and efficiency to improve soil nutrient (Chapman, 2012; Havlin *et al*., 2014; Brady & Weil, 2015).

Table 1: Pre-fortification, pre-amendment and pre-application chemical/mineralogic composition of the of the Rice-processing Wastes (RPWs) used in this study

SN	Property/Parameter/Component of the RPWs	Value/Content
1	Total Nitrogen (TN) (%)	0.94
2	Total Phosphorus (TP) (mg/kg)	0.92
3	Total Potassium (TK) (cmol/kg)	0.38
4	Calcium (Ca) (cmol/kg)	2.21
5	Magnesium (Mg) (cmol/kg)	0.53
6	Sodium (Na) (cmol/kg)	0.21
7	Percentage Organic Carbon (OC) (%)	38.1
8	C/N Ratio	40.53

Source: Results of Researchers' Field Survey and Laboratory Data Analysis (2024).

The lower TN content of the RPWs not yet fortified with urea (or inorganic N-source) could be due to the depletion of native soil N by soil microbes to initiate the biodegradation of the RPWs, which had a high C/N ratio (40.53). This trend/phenomenon was earlier reported by Abdallahi and N'Dayegamiye (2000) and Eghball (2000).

Pre-amendment, Pre-treatment or Pre-cropping Status of Soil Properties in the Study Area

The pre-treatment status of soil properties at the experimental site is presented in Table 2. Before the treatment of soils at the study site with urea-fortified RPWs, the soils had a sandy texture, medium/moderately acidic pH (5.7), and 1.06% OC, 1.83% OM, 0.16% TN, 6.69 mg/kg AP, and exchangeable Na^+ (0.12 cmol/kg), K^+ (0.14 cmol/kg), Mg^{2+} (0.33 cmol/kg) and Ca^{2+} (1.78 cmol/kg) contents. The soils' TN, AP and exchangeable K^+ contents were all low (Table 2) according to the limits defined by the Federal Fertilizer Department of Nigeria (Chude, Daudu, Olayiwola & Ekeoma, 2012). The soils were rated low in OM, TN, AP and exchangeable K^+, Mg^{2+} and Ca^{2+} as their contents were below the critical level of 3% OM, 0.20% N, 10.0 mg/kg AP, 0.16-0.20 cmol/kg exchangeable K^+, 0.40 cmol/kg exchangeable Mg^{2+}, and 2.0 cmol/kg exchangeable Ca^{2+} recommended for crop production in ecological zones of Nigeria (Akinrinde & Obigbesan, 2000; Adekiya *et al*., 2018). The soils, therefore, required organic and inorganic fertilizing and liming to enhance environmentally sustainable and economically profitable cropping.

Table 2: Pre-amendment, pre-treatment or pre-cropping status of soil properties in the study area

SN	Soil Property/Parameter (0-30 cm profile depth)	Status/Value/Content
1	Sand (g/kg)	840
2	Silt (g/kg)	96
3	Clay (g/kg)	64
4	Textural class	Sandy
5	pH (H_2O) and pH (KCl)	5.7 (medium/moderately acidic reaction) and 4.7 (very strongly acidic), respectively
6	Percentage OC content (%)	1.06
7	Percentage OM content (%)	1.83
8	TN content (%)	0.16
9	AP content (mg/kg)	6.69
10	Exchangeable Na^+ concentration (cmol/kg)	0.12
11	Exchangeable K^+ concentration (cmol/kg)	0.14
12	Exchangeable Mg^{2+} concentration (cmol/kg)	0.33
13	Exchangeable Ca^{2+} concentration (cmol/kg)	1.78

Source: Results of Researchers' Field Survey and Laboratory Data Analysis (2024).

The soils' pre-treatment low OM and nutrient contents and moderately acidic reaction are partly the characteristic feature of Nigerian rain forest and guinea savanna soils due to torrential rains of high durations and intensities with their accompanying rapid OM decomposition, deep chemical weathering and extensive/thorough leaching of exchangeable bases. This soil condition has been earlier documented/reported by Harpstead (1973), Chude (1998), Lombin (1999), Raji and Mohammed (2000), Faniran and Jeje (2002), Faniran, Jeje and Ebisemiju (2006), Ojo-Atere, Ogunwale and Oluwatosin

(2011), Thornbury (2011) and Kekong *et al*. (2018). The soils' low OM and nutrient contents could also be due to intensive/continuous cropping and intensive conventional tillage to which the study area had been previously subjected. The observed pre-treatment low OM and nutrient concentrations and moderately acidic reaction of soils in at the experimental site agree with Nyagba (1995b) and Lyam (2005a).

The Observed Effects of Urea-fortified Rice-processing Wastes (RPWs) on Soil Properties in the Study Area (i.e., Post-harvest, Post-amendment or Post-cropping Status of Soil Properties in the Study Area)

The obtained results of the post-harvest status of soil properties at the study/experimental site are presented in Tables 3a and 3b. After soils' amendment with the urea (N)-fortified RPWs and maize harvest, the soils' textural class (sandy) remained unaltered. This finding agrees with Hausenbuiller (1974), Lombin (1999), Aweto (2006a) and Brady and Weil (2015) who noted that texture is a property inherited by a soil from its parent rock; it is probably the most important of all soil characteristics, a basic property of a soil that influences the agricultural and engineering uses to which the soil can be put, and a relatively permanent feature of a soil in the field which will ordinarily not change during a man's lifetime. However, due to the substantial decomposition of the urea-fortified RPWs applied to soils at the experimental site, the chemical properties of the amended soils improved significantly ($P \leq 0.05$) over the pre-treatment status of the soils' chemical properties. The soils' chemical/nutrient status improved significantly. Thus, the observed post-harvest status of the soils' chemical properties was pH (H_2O) 6.27 (slightly acidic), 1.19% SOC, 2.05% SOM, 0.18% TN, 23.14 mg/kg AP, 0.22 cmol/kg exchangeable Na^+, 0.97 cmol/kg exchangeable K^+, 2.98 cmol/kg exchangeable Mg^{2+} and 3.69 cmol/kg exchangeable Ca^{2+} contents in the control; i.e., the 15 t/ha of RPWs + 0 kg/ha of Urea Fertilizer treatment (Tables 3a and 3b).

Table 3a: The observed effects of urea-fortified rice-processing wastes (RPWs) on soil properties in the study area (i.e., post-harvest or post-cropping status of soil textural class, pH, OC, OM and TN in the study area)

SN	Treatment	Textural Class	pH (H_2O)	SOC (%)	SOM (%)	TN (%)
1	15 t/ha RPWs + 0 kg Urea Fert./ha	Sandy	6.27	1.19	2.05	0.18
2	15 t/ha RPWs + 15 kg Urea Fert./ha	Sandy	6.15	1.32	2.26	0.21
3	15 t/ha RPWs + 25 kg Urea Fert./ha	Sandy	6.29	1.35	2.33	0.27
4	15 t/ha RPWs + 35 kg Urea Fert./ha	Sandy	6.42	1.51	2.60	0.44
5	15 t/ha RPWs + 45 kg Urea Fert./ha	Sandy	6.45	1.48	2.55	0.53
6	15 t/ha RPWs + 55 kg Urea Fert./ha	Sandy	6.68	1.44	2.48	0.69

Source: Results of Researchers' Field and Laboratory Surveys and Office Data Analysis (2024).

Table 3b: The observed effects of urea-fortified rice-processing wastes (RPWs) on soil properties in the study area (continuation) (i.e., post-harvest status of soil AP and exchangeable Na^+, K^+, Mg^{2+} and Ca^{2+} ions in the study area)

SN	Treatment	AP (mg/kg)	Na^+	K^+	Mg^{2+}	Ca^{2+}
			………………………… (cmol/kg) ..……………………….			
1	15 t/ha RPWs + 0 kg Urea Fert./ha	23.14	0.22	0.97	2.98	3.69
2	15 t/ha RPWs + 15 kg Urea Fert./ha	25.26	0.14	0.87	2.36	3.63
3	15 t/ha RPWs + 25 kg Urea Fert./ha	26.87	0.18	0.84	2.11	3.95
4	15 t/ha RPWs + 35 kg Urea Fert./ha	25.79	0.20	0.82	2.13	3.97
5	15 t/ha RPWs + 45 kg Urea Fert./ha	25.10	0.13	0.86	2.07	3.90
6	15 t/ha RPWs + 55 kg Urea Fert./ha	23.48	0.15	0.89	2.01	3.99

Key: SOC = Soil organic carbon; SOM = Soil organic matter; Fert. = Fertilizer; TN = Total nitrogen; AP = Available phosphorus

Source: Authors' Compilations and/or Computations (2025).

In the 15 t/ha of RPWs + 15 kg of Urea Fertilizer/ha treatment, the observed post-cropping status of soil chemical properties at the experimental site was pH (H_2O) 6.15 (slightly acidic), 1.32% SOC, 2.26% SOM, 0.21% TN, 25.26 mg/kg AP, 0.14 cmol/kg exchangeable Na^+, 0.87 cmol/kg exchangeable K^+, 2.36 cmol/kg exchangeable Mg^{2+} and 3.63 cmol/kg exchangeable Ca^{2+} contents. For the 15 t/ha of RPWs + 25 kg of Urea Fertilizer/ha treatment, the observed post-harvest status of soil chemical properties at the experimental site was pH (H_2O) 6.29 (slightly acidic), 1.35% SOC, 2.33% SOM, 0.27% TN, 26.87 mg/kg AP, 0.18 cmol/kg exchangeable Na^+, 0.84 cmol/kg exchangeable K^+, 2.11 cmol/kg exchangeable Mg^{2+} and 3.95 cmol/kg exchangeable Ca^{2+} contents. Similarly, in the 15 t/ha of RPWs + 35 kg of Urea Fertilizer/ha treatment, the observed status of the soils' chemical properties after maize harvest was pH (H_2O) 6.42 (slightly acidic), 1.51% SOC (highest), 2.60% SOM (highest), 0.44% TN, 25.79 mg/kg AP, 0.20 cmol/kg exchangeable Na^+, 0.82 cmol/kg exchangeable K^+, 2.13 cmol/kg exchangeable Mg^{2+} and 3.97 cmol/kg exchangeable Ca^{2+} contents (Tables 3a and 3b).

In the 15 t/ha of RPWs + 45 kg of Urea Fertilizer/ha treatment, the observed post-harvest status of the soils' chemical properties was pH (H_2O) 6.45 (slightly acidic), 1.48% SOC, 2.55% SOM, 0.53% TN, 25.10 mg/kg AP, 0.13 cmol/kg exchangeable Na^+, 0.86 cmol/kg exchangeable K^+, 2.07 cmol/kg exchangeable Mg^{2+} and 3.90 cmol/kg exchangeable Ca^{2+} contents. Finally, the observed post-cropping status of soil chemical properties at the experimental site was pH (H_2O) 6.68 (slightly acidic) (highest), 1.44% SOC, 2.48% SOM, 0.69% TN (highest), 23.48 mg/kg AP, 0.15 cmol/kg exchangeable Na^+, 0.89 cmol/kg exchangeable K^+, 2.01 cmol/kg exchangeable Mg^{2+} and 3.99 cmol/kg exchangeable Ca^{2+} (highest) contents in the 15 t/ha of RPWs + 55 kg of Urea Fertilizer/ha treatment (Tables 3a and 3b). The SOM values in the higher rates of RPWs + urea fortification (i.e., 15 t/ha of RPWs + 45 kg/ha Urea = 2.55% SOM; and 15 t/ha of RPWs + 55 kg/ha Urea = 2.48% SOM) were comparatively lower than the SOM value (2.60% SOM) in the 15 t/ha of RPWs + 35 kg/ha Urea. This could be attributed to influence of inorganic mineral nutrients that enhanced rapid mineralization of native SOM as reported earlier by Agboola (1990).

The observed improvement in the post-treatment/post-harvest soil solution pH (Table 3a) indicates the release of basic cations by the decomposition of the applied urea-fortified RPWs. The released cationic bases significantly reduced the acidifying effect/activity of exchangeable hydrogen (H^+) and aluminium (Al^{3+}) ions in these soils. The increase/improvement in soil solution pH due to the decomposition of organic amendments applied to soils in different locations has been reported earlier by Olayinka (1990), Natschner and Schwetmann (1991), Ojeniyi and Adetoro (1993), Olayinka, Adetunji and Adebayo (1998), Ojeniyi (2000, 2010), Ano and Agwu (2005), Akanbi and Ojeniyi (2007), Ojeniyi, Awodun and Odedina (2007), Adekiya *et al*. (2018), Babalola *et al*. (2018a & b), Kekong *et al*. (2018), Mohammad *et al*. (2018) and Olasupo *et al*. (2018). The observed increase in the soils' OM content (Table 3a) is attributable to the release of considerable OC amounts into the soils during the decomposition of the applied urea-fortified RPWs in these soils. The improvement in SOM level by the appropriate incorporation of organic amendments to soils has been documented/reported by earlier studies, including Olayinka (1990), Olayinka *et al*. (1998), Osundare (2004), Akanbi and Ojeniyi (2007), Odedina, Ojeniyi and Awodun (2007), Havlin *et al*. (2014), Brady and Weil (2015) and Kekong *et al*. (2018).

The higher TN content of the soils amended with urea-fortified RPWs (Table 3a), compared with the soils' low pre-amendment TN value (Table 2), could be due to the enhanced rapid mineralization of N (and, by extension, P and K) from the incorporated urea (N)-fortified RPWs, particularly from the higher rates of fortification (i.e., 15 t/ha of RPWs + 35 kg/ha Urea = 0.44% TN; 15 t/ha of RPWs + 45 kg/ha Urea = 0.53% TN; and 15 t/ha of RPWs + 55 kg/ha Urea = 0.69% TN as presented in Table 3a). Aweto (2006a), Edem (2008), Havlin *et al*. (2014) and Brady and Weil (2015) earlier noted this phenomenon, while Ayeni (2010) and Kekong *et al*. (2018) reported similar findings.

The significant ($P < 0.05$) increase in the soils' AP content (Table 3b) resulting from the decomposition of the applied urea-fortified RPWs could be attributed to the appreciable increase in the soils' solution pH, which, in turn, was capable of unlocking fixed P in these acidic soils. This finding is comparable to that of Kekong *et al*. (2018). The sole or integrated application of organic and inorganic amendments to improve/raise soil pH and consequently unlock fixed P in acidic soils has been variously studied and documented, and all the P values reported were above the critical minimum level (Adeoye & Agboola, 1985; Olayinka, 1990; Olayinka *et al*., 1998; Ojeniyi, 2000, 2010; Ano & Agwu, 2005; Akanbi & Ojeniyi, 2007; Ojeniyi *et al*., 2007; Kekong *et al*., 2018).

The greater concentrations/contents of exchangeable Na^+, K^+, Mg^{2+} and Ca^{2+} in the soils amended with urea-fortified RPWs (Table 3b), compared with the soils' low pre-amendment values of these basic cations (Table 2), indicate that these N-fortified organic amendments decomposed rapidly and substantially, thereby releasing high amounts of OM into the soils. In turn, the SOM was rapidly mineralized, thus exerting significant positive effects on the soils' concentrations of these cationic bases, so that even with the crop's (maize's) uptake and use of these bases and similar soil nutrients, there was no depletion in soils' contents of these cations during the period of the field experiment. Aweto (2006a) noted earlier that various essential nutrients, including N, P, sulphur (S), Mg, K, molybdenum (Mo), and boron (B), are sourced almost wholly from SOM upon its decomposition. The observed increase in soils' status of exchangeable cations due to sole application of organic amendments or in combination with inorganic commercial fertilizers has been variously examined and documented/reported by earlier studies (Olayinka, 1990; Ano & Agwu, 2005; Odedina *et al*., 2007; Ayeni, 2010; Kekong *et al*., 2018; Olasupo *et al*., 2018).

The Observed Effects of Urea-fortified Rice-processing Wastes (RPWs) on Maize Yield Components in the Study Area

The data-analysis results obtained on the influence of urea-fortified RPWs on maize yield parameters (components; attributes; characteristics) in the study area are presented in Table 4. The results revealed that substantial decomposition of the incorporated urea-fortified RPWs significantly ($P < 0.05$) improved the soils' chemical/fertility properties and this improvement manifested in, or translated to, a corresponding improvement in the field performance (vegetative growth and yield) of the test crop over the control. Thus, the number of seeds per cob, grain yield, and dry plant matter all increased significantly. This yield increase is comparable to the reported empirical findings of Ayoola and Makinde (2007), Dania, Fagbola and Isitekhale (2012), Babalola *et al*. (2018a) and Kekong *et al*. (2018) that highest maize yield was realized from the application of organo-mineral fertilizers to soils in their respective study areas. They also reported that the combined application of organic manures and inorganic commercial fertilizers to soils resulted in a significant increase in the growth and yield attributes of maize in their respective study areas.

Table 4: The observed effects of urea-fortified rice-processing wastes (RPWs) on maize yield components in the study area

SN	Treatment	Mean Number of Seeds per Cob	Mean Grain Yield (t/ha)	Mean Dry Plant Matter (g/plant)

1	15 t/ha RPWs + 0 kg Urea Fert./ha	329	1.27	7.13
2	15 t/ha RPWs + 15 kg Urea Fert./ha	340	1.64	7.92
3	15 t/ha RPWs + 25 kg Urea Fert./ha	402	2.88	8.14
4	15 t/ha RPWs + 35 kg Urea Fert./ha	421	3.01	8.93
5	15 t/ha RPWs + 45 kg Urea Fert./ha	418	3.17	8.99
6	15 t/ha RPWs + 55 kg Urea Fert./ha	423	3.15	8.97
7	FLSD (0.05)	9.42	0.09	0.63

Source: Results of Researchers' Field and Laboratory Surveys and Office Data Analysis (2024).

According to Table 4, the control (15 t/ha RPWs + 0 kg/ha Urea) produced the lowest average number of seeds per cob (329), grain yield (1.27 t/ha) and dry plant matter (7.13 g/plant). The observed lowest yield components of maize in the control could probably be due to the slow rate of decomposition of the non-urea fortified RPWs (or rice-mill husks) by the high C/N ratio (40.53) of the RPWs used in this field trial, as well as the decrease (slowing-down) in the rate of mineralization (of N, P, K, and similar nutrients) of the SOM resulting from these applied non-urea fortified organic amendments. Raycan and Jollen (1999) earlier made a similar observation.

As presented in Table 4, the significant increase in the average number of seeds per cob over the control (329 seeds) at the experimental site was in the order of 15 t/ha RPWs + 55 kg/ha Urea (423 seeds = highest) > 15 t/ha RPWs + 35 kg/ha Urea (421 seeds) > 15 t/ha RPWs + 45 kg/ha Urea (418 seeds) > 15 t/ha RPWs + 25 kg/ha Urea (402 seeds) > 15 t/ha RPWs + 15 kg/ha Urea treatments (340 seeds). These findings are comparable to those of Kekong *et al*. (2018).

Table 4 has shown that the 15 t/ha RPWs + 45 kg/ha Urea treatment gave the highest mean grain yield (3.17 t/ha), followed closely by the 15 t/ha RPWs + 55 kg/ha Urea (3.15 t/ha), 15 t/ha RPWs + 35 kg/ha Urea (3.01 t/ha), 15 t/ha RPWs + 25 kg/ha Urea (2.88 t/ha) and 15 t/ha RPWs + 15 kg/ha Urea treatments (1.64 t/ha), while the control gave the least average grain yield of 1.27 t/ha. Kekong *et al*. (2018) earlier reported findings comparable to those of the present work.

Similarly, the 15 t/ha RPWs + 45 kg/ha Urea treatment yielded the highest average dry plant matter (8.99 g/plant), followed closely by the 15 t/ha RPWs + 55 kg/ha Urea (8.97 g/plant), 15 t/ha RPWs + 35 kg/ha Urea (8.93 g/plant), 15 t/ha RPWs + 25 kg/ha Urea (8.14 g/plant) and 15 t/ha RPWs + 15 kg/ha Urea treatments (7.92 g/plant), whereas the control gave the lowest mean dry plant matter (7.13 g/plant) (Table 4). These findings are similar to those of Kekong *et al*. (2018).

CONCLUSION

Judicious application of urea-fortified RPWs to soils in the study area proved effective and efficient in significantly improving the soils' nutrient status and ultimately increasing maize yield components. Thus, it was concluded that appropriate incorporation of urea-fortified RPWs into soils had significant positive effects on soil chemical/fertility properties and, hence, on maize yield components in the study area. The 15 t/ha RPWs + 55 kg/ha Urea treatment gave the highest soil pH (6.68), TN (0.69%) and Ca^{2+} (3.99 cmol/kg) values and mean number of seeds per cob (423), while the 15 t/ha RPWs + 45 kg/ha Urea treatment produced the highest mean grain yield (3.17 t/ha) and dry plant matter (8.99 g/plant). The 15 t/ha RPWs + 45 kg/ha Urea treatment was, therefore, recommended as being suitable, economical, effective and efficient in significantly improving soil chemical/fertility properties for the optimum yield of maize and/or for environmentally sustainable and economically profitable maize production in the study area. There is need to empirically investigate the effects of application rates higher than 15 t/ha RPWs + 55 kg/ha Urea on soil chemical properties and growth and yield components of maize in this area.

REFERENCES

Abdallahi, M.M. and N'Dayegamiye, A. (2000). Effect of Green Manures on Soil Physical and Biological Properties and Wheat (*Triticum aestivum*) Yield and Nitrogen (N) Uptake. *Canadian Journal of Soil Science,* 80, 81-90.

Adekiya, A.O., Aboyeji, C.M., Dunsin, O. and Oyinlola, O.T. (2018). Effect of Urea Fertilizer and Maize Cob Ash on Performance of Okra (*Abelmoschus esculentus* [L.] Moench) and Soil Chemical Properties in a Derived Savanna Ecology. In: G.A. Oluwatosin, O.T. Ande, J.A. Adediran and M.A.N. Anikwe (Eds.), *Proceedings of the 42nd Annual Conference of the Soil Science Society of Nigeria (SSSN)* (pp. 286-295) held from 12th to 16th March, 2018 at the Institute of Agricultural Research and Training (IART), Obafemi Awolowo University (OAU), Moor Plantation, Ibadan, Nigeria. Published by the SSSN.

Adelekan, B.A., Laleye, A.O. and Idowu, O.J. (2003). *Spectrum Agricultural Science for Junior Secondary Schools 2* (Reprinted 1st Edition). Ibadan, Nigeria: Spectrum Books Ltd.

Adeoye, G.O. and Agboola, A.A. (1985). Critical Levels for Soil pH, Available Phosphorus (P), Potassium (K), Zinc (Zn) and Manganese (Mn) in Sedimentary Soils of South-eastern Nigeria. *Fertilizer Research,* 6, 65-71.

Adinna, E.N. (2001). The Adverse Impacts of Agriculture on the Environment. In: G.E.K. Ofomata and P.O. Phil-Eze (Eds.), *Geographical Perspectives on Environmental Problems and Management in Nigeria* (pp. 215-235). Enugu, Nigeria: JAMOE Enterprises (Nigeria).

Agbogidi, O.M., Eructor, P.G. and Akparobi, S.O. (2006). Effect of Soil Contaminated with Crude Oil on the Germination of Maize (*Zea mays* [L.]). *American Journal of Plant Physiology*, 1, 193-198.

Agboola, A.A. (1990). Organic Matter and Soil Fertility Management in the Humid Tropics of Africa. In: *Proceedings of the Third Regional Workshop of the Africa Land Programme* held at Antananarivo, Madagascar on 9th to 15th January, 1990.

Agboola, A.A. and Tijani, E. (1993).Suitability of Maize Production through Appropriate Farming Systems and Practices. In: M.A.B. Fakorede, C.O. Alofe and S.K. Kim (Eds.), Maize Improvement, Production and Utilization in Nigeria (pp. 149-156). *Proceedings of the Annual National Workshop of the Maize Association of Nigeria* held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Akanbi, O.S. and Ojeniyi, S.O. (2007). Effect of Siam Weed Mulch on Soil Properties and Performance of Yam in South-western Nigeria. *Nigerian Journal of Soil Science (NJSS)*, 17, 120-125.

Akinrinde, E.A. and Obigbesan, G.O. (2000). Evaluation of the Fertility Status of Selected Soils for Crop Production in Five Ecological Zones of Nigeria. In: O. Babalola (Ed.), *Proceedings of the 26th Annual Conference of the Soil Science Society of Nigeria (SSSN)* (pp. 279-288) held from 30th October to 3rd November, 2000 in Ibadan, Nigeria. Published by the SSSN.

Ano, A.O. and Agwu, J.A. (2005). Effects of Animal Manures on Selected Soil Properties. *Nigerian Journal of Soil Science (NJSS)*, 15, 14-19.

Ashraf, U., Salim, M.N., Sher, A., Sabir, S.R., Khan, A., Pan, G. and Tang, X. (2016a). Maize Growth, Yield Formation and Water-Nitrogen Usage in Response to Varied Irrigation and Nitrogen Supply under Semi-arid Climate. *Turk. Journal of Field Crops*, 21 (1), 87-95.

Aweto, A.O. (2006a). *GEO 416: Soil Study*. Ibadan, Nigeria: Distance Learning Centre, University of Ibadan, Ibadan, Oyo State, Nigeria.

Ayeni, L.S. (2010). Effect of Combined Cocoa Pod Ash and NPK Fertilizer on Soil Properties, Nutrient Uptake and Yield of Maize (*Zea mays* [L.]). *J. of American Science*, 6 (3), 79-84.

Ayoola, O.T. and Makinde, E.A. (2007). Complimentary Organic and Inorganic Fertilizer Application Influence on Growth and Yield of Cassava/Maize/Melon intercropped with Relayed Cowpea. *Australian Journal of Basic and Applied Sciences*, 1 (3), 187-192.

Babalola, O.A., Adigun, M.O. and Abiola, I.O. (2018a). Effect of Urea and Compost on Maize, Soil Microbial Activities and Chemical Properties. In: G.A. Oluwatosin, O.T. Ande, J.A. Adediran and M.A.N. Anikwe (Eds.), *Proceedings of the 42nd Annual Conference of the Soil Science Society of Nigeria (SSSN)* (pp. 214-222) held from 12th to 16th March, 2018 at the Institute of Agricultural Research and Training (IART), Obafemi Awolowo University (OAU), Moor Plantation, Ibadan, Nigeria. Published by the SSSN.

Babalola, O.A., Adigun, M.O. and Abiola, I.O. (2018b). Variation in Soil Chemical and Microbiological Properties as a Result of Yearly Amendment with Organic Fertilizer. In: G.A. Oluwatosin, O.T. Ande, J.A. Adediran and M.A.N. Anikwe (Eds.), *Proceedings of the 42nd Annual Conference of the Soil Science Society of Nigeria (SSSN)* (pp. 234-241) held from 12th to 16th March, 2018 at the IART, Obafemi Awolowo University (OAU), Moor Plantation, Ibadan, Nigeria. Published by the SSSN.

Babalola, O.A. and Olowokere, F.A. (2005). Contributions of Legume Green Manure to Soil Fertility and Maize Growth. In: *Proceedings of the First National Conference on Organic Agriculture* (pp. 1793-1798) held in University of Agriculture, Abeokuta, Nigeria on 25th to 28th October, 2005.

Brady, N.C. and Weil, R.R. (2015). *The Nature and Properties of Soils* (14th Edition). Noida, India: Pearson India Education Services Pvt. Ltd.

Bray, R.H. and Kurtz, L.T. (1945). Determination of Total Phosphorus, Organic Phosphorus, and Available Phosphorus in Soils. *Soil Science*, 59, 39-45.

Bremner, M.J. (1996). Total Nitrogen. In: C.A. Black (Ed.), *Methods of Soil Analysis, Part 2* (pp. 1149-1178). Madison, Wisconsin, USA: Published by the Amer. Soc. of Agronomy (ASA).

Bremner, M.J. and Mulvaney, C.S. (1982). Total Nitrogen. In: A.L. Page, R.S. Miller and D.R. Keeney (Eds.), *Methods of Soil Analysis, Part II: Chemical and Microbiological Properties* (pp. 643-698). Madison, Wisconsin, USA: Published by the ASA.

Byerlec, D. and Kurtz, L.K. (1997). *African Emergency Maize Reductions*. Boulder Colorado, USA: Lynne Rienner Publishers.

Carter, M.R. (1993). *Soil Sampling and Methods of Analysis*. Canadian Society of Soil Science. Boca Raton, FL, Canada: Lewis Publishers.

Chapman, H.D. (1965). Cation Exchange Capacity. In: C.A. Black (Ed.), *Methods of Soil Analysis, Agronomy 9 Monograph* (pp. 891-901). Madison, Wisconsin, USA: Published by the ASA.

Chapman, P.J. (2012). "Soils, Biogeography and Ecology". In: J. Holden (Ed.), *An Introduction to Physical Geography and the Environment* (pp. 143-174) (3rd Edition). Essex, England: Pearson Educ. Ltd.

Chude, V.O. (1998). *Understanding Nigerian Soils and their Fertility Management for Sustainable Agriculture*. Inaugural Lecture delivered at Ahmadu Bello University (ABU), Zaria, Kaduna State on 26th November, 1998. 1998 Inaugural Lecture Series 13.

Chude, V.O., Daudu, C., Olayiwola, S.O. and Ekeoma, A. (2012). Fertilizer Use and Management Practices for Crops in Nigeria. In: *Federal Fertilizer Department (FFD), Federal Ministry of Agriculture and Rural Development (FMARD), Abuja* (4th Edition) (pp. 40-41). Published by the FMARD.

Dania, S.O., Fagbola, O. and Isitekhale, H.H.E. (2012). Effects of Sawdust and Inorganic Mineral Fertilizer and their Residual Effects on the Yield of Maize on Degraded Soil. *Pakistan Journal of Agricultural Science*, 49 (1), 61-66.

Edem, S.O. (2008). *Soils and their Potentials for Crop Production*. Uyo, Nigeria: Abaam Publishing Company.

Eghball, B. (2000). Nitrogen Mineralization from Field-applied Beef Cattle Feedlot Manure or Compost. *Soil Science Society of America (SSSA) Journal*, 64, 2024-2030.

Faniran, A. and Jeje, L.K. (2002). *Humid Tropical Geomorphology*. Ibadan, Nigeria: Heinemann Educational Books (Nigeria) Plc.

Faniran, A., Jeje, L.K. and Ebisemiju, F.S. (2006). *Essentials of Geomorphology: Earth in the Service of Humans*. Ibadan, Oyo State, Nigeria: Penthouse Publications (Nigeria).

Food and Agriculture Organization (FAO) (1985). *Production Year Book*. FAO of the United Nations (UN), Rome, Italy. 174 pp.

Food and Agriculture Organization (FAO) (2000). FAOSTAT Website: www.fao.org. FAO of the UN, Rome, Italy. Accessed by 01:57 a.m. on November 3, 2024.

Food and Agriculture Organization (FAO) (2009). *Maize, Rice and Wheat: Area Harvested, Production Quantity, and Yield*. FAO of the UN, Rome, Italy.

Gee, G.W. and Or, D. (2002). Particle-size Analysis. In: In: J.H. Dane and G.C. Topp (Eds.), *Methods of Soil Analysis, Part 4: Physical Methods* (pp. 255-293). Madison, Wisconsin, USA: Published by the ASA.

Genstat (2005). Genstat Release 4.24DE (PC/Windows XP) Copyright 2005, Laves Agricultural Trust (Rothamstal) Experimental Station) Discuring edt. 2.

Harpstead, M.T. (1973). Classification of Some Nigerian Soils. *Soil Science*, 116, 437-442.

Hausenbuiller, R.L. (1974). *Soil Science Principles and Practices* (3rd Printing of the 1st Edition). Dubuque, Iowa, USA: WM. C. Brown Company Publishers.

Havlin, J.L., Tisdale, S.L., Nelson, W.L. and Beaton, J.D. (2014). *Soil Fertility and Fertilizers: An Introduction to Nutrient Management* (8th Edn.). Delhi, India: PHI Learning Private Ltd.

Helmke, P.A. and Sparks, D.L. (1996). Exchangeable Potassium. In: D.L. Sparks, A.L. Page, P.A. Helmke and R.H. Leoppert (Eds.), *Methods of Soil Analysis, Part 3: Chemical Methods* (pp. 869-920). No. 5 in Soil Science Society of America (SSSA) Book Series. Madison, Wisconsin, USA: Soil Science Society of America (SSSA).

Hepperly, Y.P., Lotter, D., Ulsh, C.Z., Siedel, R. and Reider, C. (2009). Compost Manure and Synthetic Fertilizer Influence Crop Yields, Soil Properties, Nitrate Leaching and Crop Nutrient Content. *Compost Sci. Util*., 17, 117-126.

International Institute of Tropical Agriculture (IITA) (1979). *Selected Methods for Soil and Plant Analysis. Manual Series No. 1*. Ibadan, Nigeria: IITA.

International Institute of Tropical Agriculture (IITA) (2012). Growing Maize in Nigeria. *Commercial Crop Production Guide Series*. Information and Communication Support for Agricultural Growth in Nigeria. United States Agency for Int'l Development (USAID).

International Institute of Tropical Agriculture (IITA) (2016). *Maize*. IITA Research to Nourish Africa. Ibadan, Nigeria: IITA.

Kekong, M.A., Attoe, E.E. and Adiaha, M.S. (2018). Effect of Nitrogen-fortified Rice Mill Waste on Soil Chemical Properties and Yield of Maize in Nigerian Rain Forest. In: G.A. Oluwatosin, O.T. Ande, J.A. Adediran and M.A.N. Anikwe (Eds.), *Proceedings of the 42nd Annual Conference of the Soil Science Society of Nigeria (SSSN)* (pp. 331-337) held from 12th to 16th March, 2018 at the IART, Obafemi Awolowo University (OAU), Moor Plantation, Ibadan, Nigeria. Published by the SSSN.

Kochhar, S.L. (1986). *Tropical Crops: A Textbook of Economic Botany*. London, United Kingdom: Macmillan Publishers Limited.

Lichtenbierg, E. (1992). Alternative Approach to Pesticide Regulation. *North-East Journal of Agricultural Research and Economics*, 21, 83-92.

Lombin, G. (1999). Soil Science. In: Youdeowei, A., Ezedinma, F.O.C. and Onazi, O.C. (1999), *Introduction to Tropical Agriculture* (pp. 34-87) (5th Impression of the 1st Edition). Harlow, England: Pearson Education Limited.

Lyam, A. (2005a). "The Benue Environment in the Twentieth Century". In: A. Lyam, Y.A. Ochefu, J.A. Sambe and A.M. Adejo (Eds.), *Benue State in Perspective* (pp. 93-122) (A Re-issuance of the First Edition). Makurdi, Nigeria: Aboki Publishers (A Division of Aboki Associates).

Mohammed, A., Mohammed, T., Zakari, S.I. and Ahmed, I. (2018). Evaluation of Mineralized Soil Nitrogen Contents as Influenced by Fertilizer N and Cowpea Residue Amendments in an Entisol of Sokoto Sudan Savanna Zone of Nigeria. In: G.A. Oluwatosin, O.T. Ande, J.A. Adediran and M.A.N. Anikwe (Eds.), *Proceedings of the 42nd Annual Conference of the Soil Science Society of Nigeria (SSSN)* (pp. 344-353) held from 12th to 16th March, 2018 at the IART, Obafemi Awolowo University (OAU), Moor Plantation, Ibadan, Nigeria. Published by the SSSN.

Monkwunye, U. and Batiano, A. (2010). *Meeting the Phosphorus (P) Needs of the Soils and Crops of West Africa: The Role of Indigenous Phosphate Rocks in Integrated Plant Nutrients Management in Sub-Saharan Africa (SSA) from Concept to Practice*. Ed. CAB International M 209-224.

Montalvo-Grijalva, D.F.M. (2008). *Nitrogen and Phosphorus Availability and Liming Effect of Poultry Layer Manures in North Carolina Coastal Plain and Piedmont Soils*. North Carolina State University (NCSU) Thesis Library, 2008. Available at http://repository.lib.ncsu.edu/ir/bitstream/1840.16/2201/1/etd.pdf. Accessed by 11:32 a.m. on November 3, 2024.

Natschner, I. and Schwetmann, U. (1991). Proton Buffering in Organic Horizons of Acid Forest Soils. *Geoderma*, 48, 93-106.

Nelson, D.W. and Sommers, L.E. (1996). Total Carbon, Organic Carbon and Organic Matter. In: D.L. Sparks (Ed.), *Methods of Soil Analysis, Part 3* (pp. 961-1010). No. 5 in the 2nd Edition of Soil Science Society of America (SSSA) Book Series. Madison, Wisconsin, USA: Published by the ASA and SSSA.

Nyagba, J.L. (1995b). "Soils and Agriculture in Benue State". In: D.I. Denga (Ed.), *Benue State, the Land of Great Potentials: A Compendium* (pp. 98-110). Calabar, Cross River State, Nigeria: Rapid Educational Publishers Limited.

Odedina, O.G., Ojeniyi, S.O. and Awodun, M.A. (2007). Effects of Agroindmatrial Vaster on Nutrient Status and Performances of Tomato. *Global Journal of Environmental Research*, 1 (1), 18-20.

Ojeniyi, S.O. (2000). Effects of Goat Manure on Soil Nutrients and Okra Yield in a Rain Forest Area of Nigeria. *Applied Tropical Agriculture*, 5, 20-23.

Ojeniyi, S.O. (2010). *Advances in Integrated Nutrient Management for Crop Production in Nigeria Monograph*. Ibadan, Nigeria: Dominion Publishers. pp. 1-7

Ojeniyi, S.O. and Adetoro, A.O. (1993). Use of Chromolaena Mulch to Improve Yield of Late Season Okra. *Nigerian Journal of Technical Education*, 10, 144-149.

Ojeniyi, S.O., Awodun, M.A. and Odedina, S.A. (2007). Effect of Animal Manure-amended Spent Grain and Cocoa Husks on Soil Nutrient Status, Growth and Yield of Tomato in the Middle East. *Journal of Sciences Research*, 2 (1), 33-36.

Ojo-Atere, J.O., Ogunwale, J.A. and Oluwatosin, G.A. (2011). *Fundamentals of Tropical Soil Science*. Ibadan, Nigeria: Evans Brothers (Nigeria Publishers) Limited.

Okaro, E.U. (2006). *Intensive Agricultural Science for Junior Secondary Schools: Years 1, 2 and 3* (4th Reprint of the 1st Edition). Onitsha, Nigeria: Elites' Publishers.

Olasupo, I.O., Muhammad, Z.Y., Muhammad, L., Maigatari, A.A., Muhammad, A. and Danladi, I. (2018). Effect of Decapitation and Soil Amendment on Growth, Cumulative Yield and Dry Biomass of Okra in Sudan Savannah of Nigeria. In: G.A. Oluwatosin, O.T. Ande, J.A. Adediran and M.A.N. Anikwe (Eds.), *Proceedings of the 42nd Annual Conference of the Soil Science Society of Nigeria (SSSN)* (pp. 308-313) held from 12th to 16th March, 2018 at the Institute of Agricultural Research and Training (IART), Obafemi Awolowo University (OAU), Moor Plantation, Ibadan, Nigeria. Published by the SSSN.

Olayinka, A. (1990). Effect of Poultry Manure, Corn Straw and Saw Dust on Plant Growth and Soil Chemical Properties. *Journal of Agriculture*, 12 (1), 36-44.

Olayinka, A., Adetunji, A. and Adebayo, A. (1998). Effect of Organic Amendments on Nodulation and Nitrogen Fixation by Cowpea. *Journal of Plant Nutrition*, 21 (11), 2455-2464.

Osundare, B. (2004). Effect of Different Companion Crops and Fertilizer Types on Soil Nutrient Dynamics and Performance of Cassava. *Nigerian Journal of Soil Science*, 14, 13-17.

Raji, B.A. and Mohammed, K. (2000). The Nature of Acidity in Nigerian Savanna Soils. *Samaru Journal of Agricultural Research (SJAR)*, 16, 15-24.

Randjelovic, V., Prodanovic, S., Tomic, Z. and Simic, A. (2011). Genotype X Year Effect on Grain Yield and Nutritive Values of Maize (*Zea mays* [L.]). *Journal of Anim. Vet. Sc. Adv.*, 10 (7), 835-840.

Raycan, I. and Jollen, M. (1999). Source: Sink Ratio and Leaf Effects of Poultry Manure on Corn Straw and Sawdust Senescence in Maize and in Organic Matter Accumulation and Partitioning during Grain Filling. *Field Crops Research: An Armsterdam*, 60 (2), 245-253.

Saha, S., Mina, B.L., Gopinath, K.A., Kundu, S. and Gupta, H.S. (2008). Organic Amendments Affect Biochemical Properties of a Sub-temperate Soil of the Indian Himalayas. *Nutr. Cycl. Agroecosys.*, 80, 233-242.

Shamshuddin, J., Jamaila, I. and Ogunwale, J.A. (1995). Organic Carbon Determination in Acid Sulfate Soils. *Pertanika Journal of Tropical Agricultural Sc*ience, 17 (3), 197-200.

Thomas, G.W. (1982). Exchangeable Cations. In: A.L. Page, R.S. Miller and D.R. Keeney (Eds.), *Methods of Soil Analysis* (Eds.), *Methods of Soil Analysis, Part 2, 3rd Edition of Agronomy Monograph 9*. Madison, Wisconsin, USA: Published by the ASA and SSSA.

Thornbury, W.D. (2011). *Principles of Geomorphology* (2nd Edition). New Delhi, India: New Age International (P) Limited, Publishers.

Tyubee, B.T. (2003). Thermal Problem and Physiological Indoor Comfort in Makurdi, Nigeria. *Journal of Science and Technological Research*, 1 (1 & 2), 152-140.

Tyubee, B.T. (2005). *Influence of Extreme Climate on Communal Disputes in Tivland of Benue State*. Paper presented during the Conference on Conflicts in the Benue Valley held in Benue State University, Makurdi, Nigeria on 16th and 17th March, 2005.

Udo, E.J., Ibia, T.O., Ogunwale, J.A., Ano, A.O. and Esu, I.E. (2009). *Manual of Soil, Plant and Water Analyses*. Lagos, Nigeria: Sibon Books Limited.

United States Department of Agriculture (USDA) (1980). *Report and Recommendation on Organic Farming*. D.Z. Washington DC Systems, University of Florida, IFAS, Indian River Research and Education Centre, 2199 S. Pack Road, Ft. Piece.

Zingore, S., Murwira, H.K., Delve, R.J. and Giller, K.E. (2007). Soil Type, Historical Management and Current Resource Allocation: Three Dimensions Regulating Variability of Maize Yields and Nutrients Use Efficiency on African Small-holder Farms. *Field Crops Research*, 101, 296-305.