



# Comparative effects of soil amendments on some post-harvest soil chemical properties in a three and four year old rubber plantations intercropped with snake tomato (*Trichosanthes cucumerina* L. Haines) in Iyanomo

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## ABSTRACT

The soil is very central to crop production and fertility management of rubber at the juvenile stage is critical to the productivity of rubber at maturity. The field study was conducted in 2018 and 2019 cropping season to determine the effects of rubber effluent and NPK 15:15:15 applications following cropping with rubber and snake on some post-harvest soil chemical properties in a three and four years old rubber plantation. The treatments involved a combination of sole and intercropped combination with NPK and rubber effluent application rates laid out in a randomized complete block design in three replications. Pre and Post-harvest soil analysis was carried out and data were collected on Particle size, Soil pH, Available Phosphorus, Exchangeable bases, total nitrogen and exchangeable acidity. The chemical analysis of the rubber effluent used for the study showed that it was moderately acidic with total dissolved solids, chemical oxygen demand and biochemical oxygen demand at safe levels (Table 2). It contained total N, available P, organic C, K, Mg, Na and Ca in appreciable amount. However, the composition of the effluent varies with sources. The results of the post-harvest fertility status of the soil, showed that the soil was improved, which implies that rubber effluent and NPK reduced soil acidity as the reaction changed from strongly acidic to moderately acidic. The soil analysis after the harvest of snake tomato showed that the soils benefited from the amendment with fertilizers (NPK and rubber effluent) and the soils improved with the application of NPK and rubber effluent.

## INTRODUCTION

The soil is the most important natural resource, because on it, the entire vegetation is dependent and by extension man. Man directly depends on vegetation for food, hence it's necessary to preserve the top soil and help to improve its organic matter content in order to increase its nutrient providing ability (Defoer, 2002). Fertilizers, according to the IFA (2008), are materials that contain 5% or more of the three essential plant nutrients. They are soil amendments that guarantee the minimum percentages of Nitrogen, Phosphate and Potassium (Adrian *et al.* 2014). Generally, Fertilizer among other advantages, improves soil nutrient, results in faster growth of crops, increases crop yield and improves the quality of fruits/crops, by making available the essential plant nutrients in readily available forms (EPA, 2013). The disadvantages of inorganic/synthetic fertilizer particularly in uncontrolled/continuous use, can result in problems of serious soil degradation, negative impact on the environment like contamination of water bodies close to the site of application, enhancing the growth of weeds, and also reducing the oxygen content in water making the water unsuitable for consumption, results in the death of aquatic animals (Wilfred, 2002), soil acidity and changes in soil microbial diversity (Carroll and Salt, 2004). The organic matter content of soils is one of the major key to soil productivity. The advantage of organic fertilizer over inorganic fertilizer in soil fertility management is its impact on soil fertility, moisture holding capacity and structural characteristic. It is helpful in binding the soil particles together to form aggregates. In most sandy soils, it improves the moisture – holding capacity, enhances soil permeability to water, increases the cation exchange capacity, buffers the soil against excessive or sudden pH change when soil amendments are added, enhances the formation of metal-organic matter complexes (Fe, Mn, Cu, Zn). It is a good source of both micro and macro nutrient (Udoh *et al.*, 2005; FAO, 2006). Globally, the use of organic fertilizer is being advocated for because of its soil conservation property and its eco-friendliness over the inorganic fertilizer.

## MATERIALS AND METHODS

### Experimental Site

The study was conducted in 2018 and 2019 cropping seasons at the Research farm of Rubber Research Institute of Nigeria (RRIN), Iyanomo near Benin City, Edo State, which lies within the Rain Forest zone of Nigeria. The study area falls between latitude 6°00' and 7°00'N and longitude 5°00' and 6°00'E. The rainfall pattern is bimodal with the peaks in the month of July and September but the highest in July and a short dry spell in August. The soils of this humid forest belt are mainly ultisols and the site is classified locally as kulfo

series with pH range between 4.0 and 5.5 (Vine, 1945; RRIN 1998).

### Experimental design and field layout

The treatments involved a combination of sole rubber and snake tomato and their intercropped combination with NPK (applied at 60kgNha<sup>-1</sup>) and rubber effluent application rates (0, 50, 60 and 70kgNha<sup>-1</sup>) laid out in a randomized complete block design in three replications. For rubber component in the intercrop, the treatments were:

RE1RS- Rubber Effluent at application rate of 50 Kg N ha<sup>-1</sup> cropped with rubber and snake tomato (Intercrop)  
 RE1SR- Rubber Effluent at application rate of 50 Kg N ha<sup>-1</sup> cropped with sole rubber  
 RE2RS- Rubber Effluent at application rate of 60 Kg N ha<sup>-1</sup> cropped with rubber and Snake tomato (Intercrop)  
 RE2SR- Rubber Effluent at application rate of 60 Kg N ha<sup>-1</sup> cropped with sole rubber  
 RE3RS- Rubber Effluent at application rate of 70 Kg N ha<sup>-1</sup> cropped with rubber and snake tomato (Intercrop)  
 RE3SR- Rubber Effluent at application rate of 70 Kg N ha<sup>-1</sup> cropped with sole rubber  
 RSC- Rubber and snake tomato intercrop control  
 RSNPK- 60 Kg NPK applied to rubber and snake tomato intercrop  
 SRC- Sole Rubber Control  
 SRNPK- 60 Kg NPK applied to sole rubber

### Cultural practices, data collection and Analysis

The snake tomato seeds were raised into seedlings in a polybag nursery filled with a mixture of top soil and poultry manure in ratio 3:1 for two weeks.

An experimental field measuring 26 by 60 m was cleared of the existing vegetation manually with the aid of cutlasses and hoes, the debris were packed out of the site, thereafter the field was marked out into plots measuring 3 by 7m with a metre pathway. The rubber effluent was applied immediately to the designated plots as per treatment two weeks prior to transplanting of rubber saplings, The pulled budded stump (young rubber) was placed in the hole in such a way that the budded patch is just above the ground level at a spacing of 3 by 7 m. The snake tomato seedlings were transplanted to designated plots at a spacing of 0.5 by 0.5 m, a week after the planting out of the rubber saplings. The NPK fertilizer was applied to the designated plots as per treatment two weeks after transplanting of snake tomato seedlings.

### Standardization of rubber effluent

Rubber Effluent sourced from three Rubber Factories in Edo State (Odia, Okomu, and Osse Rubber Estate) and analyzed to check for possible variation in nutrient composition from the different sources, which can also

give an idea of possible variation due to the type of clone. This was done using the standard laboratory standard (results of effluent analysis is shown in table 2). The Effluent was applied two weeks prior to transplanting of rubber sapling in order to decompose and equilibrate in the soil while NPK was applied two weeks after transplanting (WAT).

### Soil Analysis

Prior to cropping with rubber and snake tomato, soil samples were randomly collected from the experimental site at a depth of 0 - 30 cm depth using auger and bulked together to form a composite sample. The composite soil sample was air-dried and sieved through a 2 mm mesh and analyzed for its physical and chemical properties using standard laboratory procedures. After harvest, soil samples were randomly collected from each plot separately and analyzed for its post-harvest chemical properties.

Particle size analysis was determined by hygrometer method (IITA, 1979), The soil pH was determined in 1:2 soils to water ratio using glass electrode digital pH meter, Available Phosphorus was extracted using Bray-1 solution and the phosphate in the extract was assayed calorimetrically by the molybdenum blue colour method and was determined by a spectrometer as described by IITA (1979). Exchangeable bases were extracted using 1N neutral ammonium acetate solution. Calcium and magnesium

content of the solution were determined volumetrically by EDTA titration procedure by Houba *et al.* (1988). The level of calcium, potassium, and sodium was determined by flame photometer, the total nitrogen of the soil was determined by Micro kjeldahl procedure described by IITA (1979). The exchangeable acidity was determined by the KCL extraction and titration method of Houba *et al.* (1988).

### Data Analysis

Data collected were analyzed with GENSTAT programme, using analysis of variance and significant differences among treatments means were separated using the LSD procedure at 0.05 level of probability

### RESULTS

The soils were strongly acidic and low in organic C, total N, available P and exchangeable Ca (Table 1). The Ca/Mg ratios were moderate. The soils were texturally sandy loam. The chemical analysis of the rubber effluent used for the study showed that it was moderately acidic with total dissolved solids, chemical oxygen demand and biochemical oxygen demand (Table 2). It contained total N, available P, organic C, K, Mg, Na and Ca in appreciable amount. However, the composition of the effluent varies with sources

**Table 1: Pre-cropping characterization of some selected soils properties from the experimental site**

| Parameter                                     | Site Existing plantation | Critical level                                          | Fertility class |
|-----------------------------------------------|--------------------------|---------------------------------------------------------|-----------------|
| pH(H <sub>2</sub> O) 1:1                      | 5.40                     |                                                         | SA              |
| Organic carbon (g kg <sup>-1</sup> )          | 17.20                    | 30.00 g kg <sup>-1</sup> (Enwezoret <i>al.</i> , 1989)  | Low             |
| Total nitrogen (g kg <sup>-1</sup> )          | 0.81                     | 1.50 g kg <sup>-1</sup> (Solulo and Osiname, 1981)      | Low             |
| C:N                                           | 21.23                    |                                                         |                 |
| Available phosphorus (mg kg <sup>-1</sup> )   | 13.00                    | 16.00 mg kg <sup>-1</sup> (Adepetuet <i>al.</i> , 1979) | Low             |
| Exchangeable cation (cmol kg <sup>-1</sup> )  |                          |                                                         |                 |
| Calcium                                       | 0.82                     | 2.60 cmol kg <sup>-1</sup> (Agboola and Corey, 1973)    | Low             |
| Magnesium                                     | 0.25                     |                                                         |                 |
| Ca/Mg                                         | 3.40                     | 3.00 (FDALAR, 1975)                                     | Adequate        |
| Potassium                                     | 0.17                     | 0.16 - 0.20 (Hunter, 1975)                              |                 |
| Sodium                                        | 0.06                     |                                                         |                 |
| Exchangeable acidity (cmol kg <sup>-1</sup> ) |                          |                                                         |                 |
| Hydrogen                                      | 0.16                     |                                                         |                 |
| Aluminium                                     | 0.11                     |                                                         |                 |
| Particle size (gk g <sup>-1</sup> )           |                          |                                                         |                 |
| Sand                                          | 886.00                   |                                                         | NA              |
| Silt                                          | 64.00                    |                                                         | NA              |
| Clay                                          | 36.00                    |                                                         | NA              |
| Textural class                                | Sandy loam               |                                                         | NA              |

SA - Strongly acidic NA - Not applicable

**Table 2: Chemical composition of rubber effluent**

| Parameter                                       | Odia   | Okomu  | Michellin |
|-------------------------------------------------|--------|--------|-----------|
| pH (H <sub>2</sub> O)                           | 6.20   | 6.20   | 6.40      |
| Organic carbon (%)                              | 29.60  | 25.80  | 15.96     |
| Total nitrogen (%)                              | 1.10   | 0.40   | 0.80      |
| Phosphorus (%)                                  | 2.03   | 3.25   | 5.00      |
| Potassium (%)                                   | 0.22   | 0.24   | 0.43      |
| Magnesium (%)                                   | 0.38   | 0.38   | 0.40      |
| Calcium (%)                                     | 0.49   | 0.50   | 0.57      |
| Sodium (%)                                      | 0.04   | 0.05   | 0.06      |
| zinc (%)                                        | 0.05   | 0.05   | 0.07      |
| Copper (%)                                      | 0.02   | 0.02   | 0.03      |
| Manganse (%)                                    | 0.08   | 0.08   | 0.09      |
| Iron (%)                                        | 0.10   | 0.11   | 0.14      |
| Chemical oxygen demand (mg l <sup>-1</sup> )    | 410.00 | 230.00 | 550.00    |
| Biochemical oxygen demand (mg l <sup>-1</sup> ) | 250.00 | 270.00 | 870.00    |
| Total dissolved solids (mg l <sup>-1</sup> )    | 760.00 | 160.00 | 330.00    |

**Table 3a: Post-harvest soil chemical properties following cropping of snake tomato treated with NPK and rubber effluent in an existing rubber plantation**

| Treatment                     | pH (H <sub>2</sub> O) |          |          | Organic carbon (g kg <sup>-1</sup> ) |          |           | Total nitrogen (g kg <sup>-1</sup> ) |          |          | Available phosphorus (mg kg <sup>-1</sup> ) |          |          |
|-------------------------------|-----------------------|----------|----------|--------------------------------------|----------|-----------|--------------------------------------|----------|----------|---------------------------------------------|----------|----------|
|                               | 3 <sup>rd</sup>       | 4th year | Combined | 3rd                                  | 4th year | Combine d | 3 <sup>rd</sup>                      | 4th year | Combined | 3rd                                         | 4th year | Combined |
| RE1RS                         | 5.80                  | 5.87     | 5.83     | 10.60                                | 8.71     | 9.66      | 0.46                                 | 0.50     | 0.48     | 9.75                                        | 7.51     | 8.63     |
| RE1ST                         | 6.20                  | 5.97     | 6.08     | 10.00                                | 8.57     | 9.28      | 0.75                                 | 0.62     | 0.68     | 8.85                                        | 7.21     | 8.05     |
| RE2RS                         | 5.70                  | 6.10     | 5.90     | 8.95                                 | 9.00     | 8.97      | 0.69                                 | 0.74     | 0.71     | 9.54                                        | 9.04     | 9.29     |
| RE2ST                         | 5.70                  | 6.20     | 5.95     | 8.97                                 | 9.03     | 9.00      | 0.67                                 | 0.72     | 0.70     | 9.48                                        | 9.00     | 9.24     |
| RE3RS                         | 6.10                  | 6.53     | 6.32     | 8.38                                 | 9.44     | 8.91      | 0.71                                 | 0.87     | 0.79     | 9.12                                        | 8.99     | 9.06     |
| RE3ST                         | 6.03                  | 6.00     | 6.32     | 9.60                                 | 10.07    | 9.83      | 0.70                                 | 0.95     | 0.82     | 10.10                                       | 9.20     | 9.65     |
| RSC                           | 5.70                  | 5.23     | 5.47     | 12.90                                | 8.76     | 10.83     | 0.35                                 | 0.29     | 0.32     | 8.57                                        | 7.48     | 8.03     |
| RSNPK                         | 5.90                  | 6.60     | 6.25     | 12.40                                | 13.43    | 12.92     | 0.78                                 | 1.07     | 0.92     | 9.80                                        | 9.13     | 9.47     |
| STC                           | 5.80                  | 5.27     | 5.53     | 10.60                                | 8.74     | 9.67      | 0.73                                 | 0.49     | 0.61     | 9.44                                        | 7.49     | 8.47     |
| STNPK                         | 5.90                  | 6.60     | 6.25     | 10.60                                | 12.97    | 11.78     | 0.77                                 | 0.99     | 0.88     | 9.45                                        | 9.19     | 9.32     |
| Mean                          | 5.88                  | 6.10     | 5.99     | 10.30                                | 9.87     | 10.09     | 0.66                                 | 0.72     | 0.69     | 9.41                                        | 8.43     | 8.92     |
| LSD <sub>(0.05)TRT</sub>      | 0.201                 | 0.166    | 3.434    | 0.306                                | 0.325    | 0.211     | 0.148                                | 0.08     | 0.081    | 0.113                                       | 0.220    | 0.120    |
| LSD <sub>(0.05)</sub><br>year | 0.143                 |          |          | 0.094                                |          |           | 0.036                                |          |          | 0.054                                       |          |          |

RE1RS - Rubber effluent at application rate of 50 kg N ha<sup>-1</sup> cropped with rubber and snake tomato (Intercrop)

RE1ST - Rubber effluent at application rate of 50 kg N ha<sup>-1</sup> snake tomato (Sole)

RE2RS - Rubber effluent at application rate of 60 kg N ha<sup>-1</sup> cropped with rubber and snake tomato (Intercrop)

RE2ST - Rubber effluent at application rate of 60 kg N ha<sup>-1</sup> snake tomato (Sole)

RE3RS - Rubber effluent at application rate of 70 kg N ha<sup>-1</sup> cropped with rubber and snake tomato (Intercrop)

RE3ST - Rubber effluent at application rate of 70 kg N ha<sup>-1</sup> snake tomato (Sole)

RSC - Rubber-snake tomato intercrop without NPK/rubber effluent treatment (control)

STC - Sole snake tomato (control)

STNPK - Sole snake tomato treated with 60 kg N ha<sup>-1</sup> of NPK 15:15:15

RSNPK - Rubber-snake tomato treated with 60 kg N ha<sup>-1</sup> of NPK 15:15:15

**Table 3b: Post-harvest soil chemical properties following cropping of snake tomato treated with NPK and rubber effluent in an existing rubber plantation**

| Treatment                  | Exchangeable cation (cmol kg <sup>-1</sup> ) |          |          |           |          |          |           |          |          | Exchangeable acidity (cmol kg <sup>-1</sup> ) |          |          |          |          |          |          |          |          |
|----------------------------|----------------------------------------------|----------|----------|-----------|----------|----------|-----------|----------|----------|-----------------------------------------------|----------|----------|----------|----------|----------|----------|----------|----------|
|                            | Calcium                                      |          |          | Magnesium |          |          | Potassium |          |          | Sodium                                        |          |          | Hydrogen |          |          | Aluminum |          |          |
|                            | 3rd                                          | 4th year | Combined | 3rd       | 4th year | Combined | 3rd       | 4th year | Combined | 3rd                                           | 4th year | Combined | 3rd      | 4th year | Combined | 3rd      | 4th year | Combined |
| RE1RS                      | 0.90                                         | 0.69     | 0.79     | 0.22      | 0.19     | 0.21     | 0.20      | 0.35     | 0.28     | 0.10                                          | 0.09     | 0.10     | 0.14     | 0.13     | 0.14     | 0.08     | 0.06     | 0.07     |
| RE1ST                      | 0.98                                         | 0.67     | 0.83     | 0.24      | 0.22     | 0.23     | 0.27      | 0.18     | 0.23     | 0.12                                          | 0.11     | 0.11     | 0.09     | 0.09     | 0.09     | 0.05     | 0.05     | 0.05     |
| RE2RS                      | 0.91                                         | 0.70     | 0.80     | 0.21      | 0.24     | 0.23     | 0.24      | 0.19     | 0.22     | 0.13                                          | 0.16     | 0.14     | 0.12     | 0.13     | 0.12     | 0.04     | 0.05     | 0.05     |
| RE2ST                      | 0.86                                         | 0.70     | 0.78     | 0.20      | 0.25     | 0.22     | 0.22      | 0.19     | 0.20     | 0.15                                          | 0.17     | 0.16     | 0.10     | 0.12     | 0.11     | 0.06     | 0.06     | 0.06     |
| RE3RS                      | 1.22                                         | 0.99     | 1.10     | 0.25      | 0.30     | 0.28     | 0.24      | 0.22     | 0.23     | 0.15                                          | 0.18     | 0.17     | 0.11     | 0.14     | 0.13     | 0.05     | 0.06     | 0.05     |
| RE3ST                      | 1.36                                         | 1.10     | 1.23     | 0.25      | 0.30     | 0.28     | 0.26      | 0.24     | 0.25     | 0.15                                          | 0.18     | 0.16     | 0.11     | 0.13     | 0.12     | 0.06     | 0.06     | 0.06     |
| RSC                        | 0.80                                         | 0.62     | 0.71     | 0.22      | 0.19     | 0.20     | 0.24      | 0.18     | 0.21     | 0.11                                          | 0.08     | 0.10     | 0.15     | 0.12     | 0.13     | 0.06     | 0.06     | 0.05     |
| RSNPK                      | 0.92                                         | 0.70     | 0.81     | 0.24      | 0.22     | 0.23     | 0.25      | 0.34     | 0.30     | 0.11                                          | 0.08     | 0.10     | 0.10     | 0.15     | 0.13     | 0.05     | 0.06     | 0.05     |
| STC                        | 0.86                                         | 0.63     | 0.75     | 0.23      | 0.19     | 0.21     | 0.24      | 0.18     | 0.21     | 0.13                                          | 0.09     | 0.11     | 0.12     | 0.12     | 0.12     | 0.05     | 0.04     | 0.05     |
| STNPK                      | 0.94                                         | 0.70     | 0.82     | 0.23      | 0.21     | 0.22     | 0.25      | 0.34     | 0.30     | 0.11                                          | 0.08     | 0.10     | 0.08     | 0.15     | 0.12     | 0.04     | 0.05     | 0.05     |
| Mean                       | 0.98                                         | 0.75     | 0.86     | 0.23      | 0.23     | 0.23     | 0.24      | 0.24     | 0.24     | 0.13                                          | 0.12     | 0.12     | 0.11     | 0.13     | 0.12     | 0.05     | 0.05     | 0.05     |
| LSD <sub>(0.05)</sub>      | 0.075                                        | 0.04     | 0.041    | 0.030     | 0.030    | 0.020    | 0.026     | 0.178    | 0.087    | 0.019                                         | 0.012    | 0.011    | 0.018    | 0.021    | 0.013    | 0.021    | 0.014    | 0.012    |
| LSD <sub>(0.05)</sub> year | 0.019                                        |          |          | 0.009     |          |          | 0.039     |          |          | 0.005                                         |          |          | 0.006    |          |          | 0.005    |          |          |

Foot note

RE1RS - Rubber effluent at application rate of 50 kg N ha<sup>-1</sup> cropped with rubber and snake tomato (Intercrop)RE1ST - Rubber effluent at application rate of 50 kg N ha<sup>-1</sup> snake tomato (Sole)RE2RS - Rubber effluent at application rate of 60 kg N ha<sup>-1</sup> cropped with rubber and snake tomato (Intercrop)RE2ST - Rubber effluent at application rate of 60 kg N ha<sup>-1</sup> snake tomato (Sole)RE3RS - Rubber effluent at application rate of 70 kg N ha<sup>-1</sup> cropped with rubber and snake tomato (Intercrop)RE3ST - Rubber effluent at application rate of 70 kg N ha<sup>-1</sup> snake tomato (Sole)

RSC - Rubber-snake tomato intercrop without NPK/rubber effluent treatment (control)

STC - Sole snake tomato (control)

STNPK - Sole snake tomato treated with 60 kg N ha<sup>-1</sup> of NPK 15:15:15RSNPK - Rubber-snake tomato treated with 60 kg N ha<sup>-1</sup> of NPK 15:15:15



## Post-harvest soil chemical properties

The results of the postharvest soil chemical properties as influenced by NPK and rubber effluent and intercrop in a rubber-snake tomato intercrop in an existing rubber plantation are presented in Tables 3a and 3b. The pH values were lowest in RE2ST, RSC and RE2ST which were identical with RE1RS, RSNPK, STC and STNPK while RE1ST had the highest pH value in the 3<sup>rd</sup> year experiment but identical with RE3RS and RE3ST. In the 4<sup>th</sup> year experiment, the highest pH values were recorded in STNPK and RE3RS which were identical with RE3RS. The lowest pH was recorded in RSC and STC. There were no significant differences among treatments in respond to pH in the combined analysis.

The highest and lowest organic C content values were recorded in RSC and RE3RS, respectively in the 3<sup>rd</sup> year experiment. Plot with RSNPK had the highest organic C content while RE1ST had the lowest organic C which was similar with RE1RS, RSC and STC plots in the 4<sup>th</sup> year experiment. In the combined analysis, RSNPK had the highest organic C while RE3RS which was similar with RE3ST and RE2RS had the lowest organic C content. Organic C was higher in the 3<sup>rd</sup> year experiment than in the 4<sup>th</sup> year experiment.

In the 3<sup>rd</sup> year experiment, a significant difference existed among treatments for total N and ranged from 0.35 g kg<sup>-1</sup> for RSC and 0.78 g kg<sup>-1</sup> for plot with RSNPK. RSNPK was identical with all other treatments except RE1RS and RSC. In the 4<sup>th</sup> year experiment and in the combined analysis, the lowest total N content was recorded in RSC plot while the highest content was recorded in RSNPK which was identical with STNPK. Total N was higher in the residual 4<sup>th</sup> year experimental plots than in the residual 3<sup>rd</sup> year experimental plots.

The available P was highest in plot with RE3ST both experiments and in the combined analysis. However, available P recorded in the plot with RE3ST was comparable with STNPK, RE3RS, RE2ST and RE2RS plots in the 4<sup>th</sup> year experiment and RE1RS, RE2RS, RE2ST, RE3RS, RSNPK, STC and STNPK plots in the combined analysis. The lowest available P content in the 3<sup>rd</sup> year experiment and in the combined analysis was recorded in RSC plot but was comparable with RE1ST in the combined analysis. The lowest available P was recorded RE1ST in the 4<sup>th</sup> year experiment.

Exchangeable Ca was highest in RE3ST in both experiments and in the combined analysis. The lowest exchangeable Ca was recorded in RE2ST, RSC and STC in the 3<sup>rd</sup> year experiment. In the 4<sup>th</sup> year experiment and combined analysis, the lowest exchangeable Ca was recorded in RSC and STC. Exchangeable Ca was higher in the 3<sup>rd</sup> year experiment than in the 4<sup>th</sup> year.

The highest exchangeable Mg was recorded in RE3RS and RE3ST in both experiments and in the combined analysis. However, in the 3<sup>rd</sup> year

experiment, the exchangeable Mg recorded in RE3RS and RE3ST was comparable with RE1RS, RE1ST, RSC, STC and STNPK had the lowest concentration. The lowest exchangeable Mg concentration in the 4<sup>th</sup> year experiment and in the combined analysis was recorded in RSC. However, RSC was identical with STNPK, STC, RSNPK, RE1ST and RE1RS in the 4<sup>th</sup> year experiment and in the combined analysis, RSC and STC were comparable with RE1RS and STNPK. The plots with RE2RS and RE2ST recorded the lowest exchangeable concentration in the 3<sup>rd</sup> in the 3<sup>rd</sup> year experiment.

In the 3<sup>rd</sup> year experiment, the highest exchangeable K content was recorded in RE1ST which was not significantly different from RE3ST, RSNPK and STNPK. The plot with RE1RS had the highest exchangeable K which was identical with RSNPK and STNPK in the 4<sup>th</sup> year experiment. In the combined analysis, the lowest exchangeable K was recorded in RE2ST which was not significantly different from STC and RSC.

The lowest exchangeable Na content was observed in RE1RS which was comparable with RSC, RSNPK and STNPK while the highest exchangeable Na content was observed in RE2ST, RE3RS and RE3ST in the 3<sup>rd</sup> year experiment. In the 4<sup>th</sup> year experiment, the lowest exchangeable Na was recorded in RE1RS, RSC, RSNPK, STC and STNPK. The highest exchangeable Na content was recorded in RE3ST and RE3RS in the 4<sup>th</sup> year experiment. In the combined analysis, the plot RE3RS had the highest exchangeable Na which was comparable with RE2ST and RE3ST plots. The lowest exchangeable Na content increased with increasing rate of rubber effluent application.

Exchangeable H<sup>+</sup> ranged from 0.08 and 0.15 cmol kg<sup>-1</sup> for STNPK and RSC, respectively in the 3<sup>rd</sup> year experiment. However, RSC was comparable with RE1RS while, STNPK was identical with RE1ST. In the 4<sup>th</sup> year experiment, the highest exchangeable H<sup>+</sup> was recorded in STNPK and RSNPK and was comparable with RE1RS, RE3RS and RE3ST while the lowest concentration was recorded in RE1ST. RE1ST plot also had the lowest exchangeable H<sup>+</sup> concentration in the combined analysis while the highest exchangeable H<sup>+</sup> concentration was recorded in RE1RS which was identical with RE3RS, RSC and RSNPK. Exchangeable H<sup>+</sup> concentration was higher in the 4<sup>th</sup> year experiment than in the 3<sup>rd</sup> year experiment. In the 3<sup>rd</sup> year experiment the highest exchangeable Al<sup>3+</sup> was recorded in RE1RS plot which was comparable with the plots with RE2ST, RE3ST and RSC. Exchangeable Al<sup>3+</sup> was lowest in the plots with RE2RS and STNPK and was comparable with RE1ST, RE3ST, RSNPK and STC plots. Exchangeable Al<sup>3+</sup> was identical in values in all the experimental plots except the plot with STC in the 4<sup>th</sup> year experiment. All treatments had identical exchangeable Al<sup>3+</sup> values in the combined analysis experiment.

## DISCUSSION

Contrary to expectation that sole crop will exhaust the soil less than the rubber/snake tomato intercrop but this was not to be. The study indicated that intercropping rubber and snake tomato had similar effect on soil fertility as solely cropped snake tomato. This was evidenced as plots where rubber was intercropped with snake tomato and plots where snake tomato was grown alone had similar soil nutrient contents.

The soils of the experimental site were strongly acidic with values lower than critical level for some essential nutrients (table 1). This implied that the soil has low fertility status. Law-Ogbomo and Osaigbovo (2008) reported that most Nigerian soils are of low in native fertility owing to the highly weathered soils coupled with leaching and continuous cropping. Soil fertility is a very important factor in soil productivity in relation to nutrient and yield (Erhabor, 2005). Plants need supply of appropriate proportionate essential nutrients from the soil for optimum growth, development and yield. Low soil fertility status without adequate soil nutrient amendment will result in growth and yield depression due to nutrient deficiencies (Law-Ogbomo *et al.*, 2020).

The analysis of the rubber effluent showed variability depending on location. They were moderately acidic and contain N, P, K and Ca in appreciable quantity. The effluent has high concentration of organic carbon, COD and BOD at safe level. This finding is in agreement with Orhue *et al.* (2007) who reported highly significant amount of total suspended and dissolved solids, phosphate and total N in rubber effluent. Orhue and Osaigbovo, (2013) reported that rubber effluent had great potential as organic fertilizer and could be beneficial to arable crops without additional cost as effluent are waste product of rubber processing factories and its disposal has been a major concern to factory owners. This is an indication that rubber effluent which ought to be waste and pollutant to the environment can be made to be an avenue for wealth creation through its conversion to organic fertilizer.

The post-harvest fertility status of the soil was improved. Law-Ogbomo *et al.* (2014) reported an increase in fertility status after fertilizer application which is a reflection of the availability of essential plant nutrients in NPK and rubber effluent. The increase in soil pH, N, Ca, Mg, K, and Na and decrease in exchangeable acidity in plots fertilized with NPK and rubber effluent is attributed to the amending effects of the fertilizer. This finding implies that rubber effluent and NPK reduced soil acidity as the reaction changed from strongly acidic to moderately acidic.

The decrease in exchangeable acidity might have led to higher soil pH. The increase in soil pH could have led to higher availability of exchangeable cations. The decrease in organic carbon in both the fertilized and unfertilized plots is not in conformity with the

observation of Odedina *et al.* (2003), who reported that organic fertilizer increased soil organic matter.

The increase in N content in soil of rubber intercropped with snake tomato treated with NPK (RSNPK) compared to the sole snake tomato soils treated with NPK (STNPK) is a demonstration of N cycling as reported by Mbow *et al.* (2014). The decrease in available P compared to the initial concentrations could have resulted from decrease in soil organic carbon. The mineralization of available P due to microbial actions resulted in the production of organic acid, which make soil P available (Law-Ogbomo *et al.*, 2016). The higher exchangeable Ca observed in RE3RS and RE2ST plots implies higher rate of mineralization of Mg as the fertilized plots contained more nutrient reserve than the unfertilized plots. The increase in exchangeable cation implies increase in the soil effective cation exchange capacity (ECEC) brought about through fertilizer application.

## CONCLUSION

- The soils of the experimental sites were of low fertility status.
- Rubber effluent was variable in chemical composition but contained appreciable amount of plant essential nutrients.
- The soil analysis after the harvest of snake tomato showed that the soils benefited from the amendment with fertilizers (NPK and rubber effluent).
- The soil analysis after harvest showed that soil was improved with the application of NPK and rubber effluent

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