

## **Original Research Article**

**Effect of Dried Algae and N Fertilizers on Soil Chemical Properties and the Yield of *Amaranthus* (*Amaranthus cruentus*) on Ultisols Southeastern Nigeria**

### **ABSTRACT**

Organic manure plays an important role in improving the fertility of Ultisols. A pot experiment to investigate the effect of dried algae and N fertilizer on the chemical properties and the yield of *Amaranthus* on Ultisol was conducted from March to June, 2017 in the Green House of Michael Okpara University of Agriculture, Umudike, Abia State of Nigeria, located about 122m above sea level. The experiment was arranged as Complete Randomized Design (CRD) with factorial pattern, consisted of two factors and provided with three replications. The first factor was the application of dried algae (0, 1, 2, 3 and 4 t/ha) and N fertilizers (0, 40, 80 and 120 kg/ha). The observed responds were chemical soils properties (pH, organic carbon,  $\gamma$  available phosphorus, total nitrogen, exchangeable bases, exchangeable acidity and effective cation exchange capacity) and the growth and the crop yield (plant height, numbers of leaves, stem girth and fresh yield). The experimental results revealed that the addition of dried algae as organic ameliorant and N-fertilizer improved most of the soil fertility properties as lone and combined treatments except in available P, total N were interaction effect were not significant. Application of 1-4 ton of algae without N fertilizers has increased the fresh yield about .....to ....%, while the application of N fertilizers without dried algae application increased only about the fresh crop yield. The highest fresh yield about 89.87 g to 97.13 g plant<sup>-1</sup> were obtained by application 4 ton ha<sup>-1</sup> died algae, while the highest fresh yield about 30.13 g plant<sup>-1</sup> without application of dried algae was obtained by the application of 120 kg Urea (please convert to N-urea). Consequently, the application of dried algae has a great prospect to improve the properties of Ultisols, to enhance the fertilizers efficiency and to increase the crop yield of *Amaranthus*

**Keywords:** Algae, N-fertilizer and soil chemical properties.

### **INTRODUCTION**

Soil fertility maintenance under intensive cropping has been a major challenge that is still elusive (Kekong *et al.*, 2008). Ultisols of Umudike are characterized with high acidity, low base saturation, low fertility status and therefore has little potentials to support good crop production without external fertilizer input (Osodeke, 1996). Emphasis has remained centralized on the use of inorganic fertilizers as the major source of soil nutrients with very low significant regard to organic manures. Although, inorganic fertilizers ensure quick release of nutrients to crops, but over dependency on them have made them scarce and expensive to many poor resource farmers. Apart from these, there are reports of environmental pollution associated with consistence use of inorganic fertilizers (Kushwaha and Ochi, 1991). Ojeniyi and Adeniyi (1999) reported that continuous use of mineral fertilizers aggravates soil acidity, nutrient imbalance and loss of organic matter. Consequently, recent studies have focused on the use of organic manures as soil improvers and source of soil nutrients (Awodun, 2007). Long term conservation of the soils health is the key benefit of organic fertilizers, which is vital to sustainable agriculture (Ghabbour and Aivis, 2001).

On this basis, farmers and scientists are now showing renewed interest in proper and effective use of organic manures to improve the nutrient status and to give a high residual effect on soil fertility.

Algae, which are one of the biological and organic component of the soil have been found to contain accumulated nutrients through photosynthesis, nitrogen fixation, mineralization of organic compounds as well as their involvement in mineral weathering (Joseph, 2007). The potentials of algae in soil fertility management was discovered early in the history of agriculture in Coastal Asia and Island of Europe (Dawnson, 1966). Eneje and Azu (2009) reported that the application of composted algae to soils led to improvement on chemical properties of soils studied. As in the case of other organic materials, the limitation in the use of algae as nutrient source is the difficulty in obtaining adequate quantities for large scale agriculture.

Consequently, recent researches are advocating the combined use of organic and inorganic fertilizers in soil fertility management (Azu *et al.*, 2017)

Adediran *et al.*, (1999) observed that supplementation of organic and inorganic fertilizers were more superior to the application of either of the amendment alone. Similarly, FAO (1976) reported that combined use of organic and inorganic fertilizers proved a sound soil fertility management strategy in many countries.

Vegetable provide excellent means of supplementing mineral and vitamin deficiencies in the diets of Nigerian when properly cooked (Williams, 1993). *Amaranthus*, also called African spinach, produces the highest amount of protein and dry matter per unit area and time among vegetables (Mesiaen, 1992) and therefore could be a very valuable source of combating under nutrition and mal-nutrition in the tropics (Chadha, 2006), but the potential for sustained *amaranthus* production in southeastern Nigeria is very limited in the absence of amendments due to the inherent low soil fertility status of the area.

The effect of combined use of algae and urea on soil chemical and nutrient properties and the response of *Amaranthus cruentus* to these amendments have remained under researched in the humid tropics. It is this inadequate information on the potentials of combined use of algae and urea in fertilizing soils of southeastern Nigeria that informed the choice of this study.

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## 63 MATERIALS AND METHOD

The study to investigate the effect of dried algae and N fertilizer on the chemical properties and the yield of *Amaranthus* was carried out from March to June, 2017 in Green House condition in Michael Okpara University of Agriculture Umudike, Abia State Nigeria, latitude 5°29'N and longitude 7°35'E, elevation is about 122m above sea level with mean annual rainfall of about 2163mm, mean daily temperature range of 35°C to 20°C and a relative humidity of about 72% (Odurukwe *et al.*, 1995). The soil used for the study was an Ultisols from the teaching and research farm of the university and has been classified as Haplic Herisol (FAO/UNESCO, 1958).

Physical and chemical properties of the soil are presented in Table 1. The soil was acidic with mean values of 5.01 and 4.12 in water and CaCl<sub>2</sub> respectively which are below the pH range of 5.5-7.5 reported by Raemaeker (2001) as optimum for *amaranthus* production. The low value of pH (Udo *et al.*, 2009) indicated soil acidity and therefore suggested the need for liming in order to ensure the release of essential elements for plant growth (Onwuka *et al.*,

2009; Eneje and Azu, 2009). Organic carbon was low (13%) indicating a low soil fertility status (Woomer and Ingram, 1990). Total N was low with value of 0.103% which is less than the critical level of 0.15% reported by Adeoye and Agbola, (1984) for soils of humid tropical region. The low N level could be attributed to the high rate of mineralization and subsequent high rate of leaching that accompany the heavy rains associated with the forest zone of southeastern Nigeria (Osodeke, 1996). The soil also indicated a medium level of phosphorus with value 15.12mg/kg which is slightly higher than the critical level of 15mg/kg for most tropical crops (Osodeke and Uba, 2005). Generally, the soil was low in exchangeable cations, consequently, the ECEC was low (4.76) and B.S was 69.33%. The result of the physical and chemical properties of the soil used for the study generally showed that the soil was inherently low in fertility and therefore requires external fertilizer input for optimum and sustainable amaranthus production.

Table 1: Physicochemical Characteristics of the Soils Used for the Study

| Characteristics         | Value      |
|-------------------------|------------|
| Sand (%)                | 82.80      |
| Silt (%)                | 8.80       |
| Clay (%)                | 8.40       |
| Textural class          | Loamy sand |
| pH (H <sub>2</sub> O)   | 5.01       |
| pH (CaCl <sub>2</sub> ) | 4.12       |
| Organic carbon (%)      | 1.13       |
| Organic matter (%)      | 1.95       |
| Total nitrogen          | 0.103      |
| Av. P (mg/kg)           | 15.12      |
| Ca (Cmol/kg)            | 2.00       |
| Mg (Cmol/kg)            | 0.10       |
| K (Cmol/kg)             | 0.11       |
| Na (Cmol/kg)            | 0.09       |
| E.A (Cmol/kg)           | 2.46       |
| ECEC (Cmol/kg)          | 4.76       |
| B.S (%)                 | 48.32      |

Soil samples were collected with the soil **auger** from 0-20cm depth, air dried, sieved with 2mm sieve, after which sub-samples of 5kg each were weighed into 12L capacity plastic buckets perforated at the bottom to allow for air and water movement.

The algae used in the study were collected from the irrigation path around the university research and farm and other fresh water habitats around the study area and these were air dried for **one month**, ground and weighed out for application. The characteristics of the Algae used are presented in Table 2.

**Table 2: Characteristics of the Algae used for the Study**

| Properties              | Values |
|-------------------------|--------|
| pH (H <sub>2</sub> O)   | 8.86   |
| pH (CaCl <sub>2</sub> ) | 7.92   |
| Av.P (%)                | 19.04  |
| Nitrogen (%)            | 2.28   |
| Calcium (%)             | 6.66   |
| Magnesium (%)           | 2.81   |
| Potassium (%)           | 0.53   |
| Sodium (%)              | 0.04   |
| Organic carbon (%)      | 2.03   |

The algae contained high amount of N, P, Ca, Mg and OC, but moderately low in K and Na. **Eneje and Azu (2009)** reported a low Na content in algae which was responsible for increased aggregate stability of soils treated with algae. The high pH observed in the algae which is in agreement with the findings of Eneje and Azu (2009) and **Azu et al.(2017)** indicated the ability of algae in reducing acidity in soils. Thus, it is expected that, this high nutrient content in algae will have the potentials of establishing greater improvement on the chemical conditions of the soil under study as well as improve the nutrients and yield of Amaranthus..

#### **Pot Experiment**

The experiment was set up as randomized completely design with factorial pattern, consisted of two factor and provided with three replications. The first factor was application dried algae, **comprised** five rates (0, 1, 2, 3 and 4t/ha) algae, while N fertilizer was set up as the second factor, consisted of four rates ((0, 40, 80 and 120 kg/ha<sup>-1</sup>N). Five kg of air dried, sieved with 2 mm sieve were weighed into 12 L capacity plastic buckets perforated at the

bottom to allow for air and water movement. Subsequently, appropriate weights of algae and N fertilizers were taken and mixed thoroughly with the soils. The amended soils were incubated for four weeks with adequate watering at field capacity to keep the soils moist for microbial decomposition of the algae to release its nutrient content.). The amaranthus seeds were sown in drills using river sands after the incubation period and thinned to one seedling per bucket after three days of germination. The buckets were kept at about field moisture capacity throughout the green house study according to the method described by according to the method described by Whitehead and Hood (1965). The entire plants were harvested by uprooting after five weeks of planting as described by Shippers (2000) and the following agronomic and yield parameters measured: plant height, number of leaves per plant, fresh weight and stem girth. **Laboratory Analysis**

Pre-treatment and post harvest soil samples were subjected to the following chemical analysis: pH (Maclean, 1965) as modified by Eno *et al.*, (2009), organic carbon (Walkley and Black, 1934) total N (Jackson, 1962), available P (Bray and Kurtz, 1945) and ECEC (Kamprath, 1967) as modified by Eno *et al.*, (2009).

**Statistical Analysis**

Data collected from both yield parameters and soil analysis were subjected to analysis of variance (ANOVA) as outlined by Steel and Torrie (1980) and means were separated using (FLSD<sub>0.05</sub>).

## RESULTS AND DISCUSSION

Application of dried algae as organic fertilizers and N fertilizers gave a significant effect on soil pH (Table 3), available Phosphorus (Table 4), organic carbon (Table 5), total nitrogen (Table 6), total exchangeable bases (Table 7), total exchangeable acidity (table 8), and CEC (Table 9).

Table 3: Effect of dried Algae and N fertilizer on pH (H<sub>2</sub>O)

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |                    |                    |                    |                    |
|-----------------------------------------|-----------------------------------------|--------------------|--------------------|--------------------|--------------------|
|                                         | a <sub>0</sub> = 0                      | a <sub>1</sub> = 1 | a <sub>2</sub> = 2 | a <sub>3</sub> = 3 | a <sub>4</sub> = 4 |
| 0                                       | 4.95 a                                  | 5.24 b             | 5.59 c             | 5.90 d             | 6.03 e             |
| 40                                      | 5.07 f                                  | 5.32 bf            | 5.65 cf            | 5.94 df            | 6.06 ef            |
| 80                                      | 5.05 g                                  | 5.14 bg            | 5.66 cg            | 5.97 dg            | 5.98 eg            |
| 120                                     | 4.98 h                                  | 5.09 bh            | 5.25 ch            | 5.78 dh            | 5.84 eh            |
|                                         |                                         |                    |                    |                    |                    |

Means having the same letters within a row/ column are not significantly different at 5%.

The application of dried algae and N fertilizer had improvement on soil pH relative to control (Table 3). Significant differences (P<0.05) were observed when the materials were added to the soil both as lone and combined treatments.

157 The highest mean pH value of 6.06 was obtained when 4tons h<sup>-1</sup> dried algae was combined with 40kg h<sup>-1</sup> N  
 158 fertilizer, suggesting its suitability as a good replacement for commercial lime in acid soils. Eneje and Azu (2009) in  
 159 a similar experiment showed that there was a reduction in soil acidity when algae were incorporated into the soil as  
 160 compost.

161 **Table 4: Effect of dried Algae and N fertilizer on Soil available Phosphorus**

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |         |         |         |         |
|-----------------------------------------|-----------------------------------------|---------|---------|---------|---------|
|                                         | a0 = 0                                  | a1 = 1  | a2 = 2  | a3 = 3  | a4 = 4  |
| 0                                       | 21.80 a                                 | 39.93a  | 39.60a  | 42.20 b | 48.33 a |
| 40                                      | 28.80 c                                 | 27.93ac | 28.13 ? | 46.20ab | 65.00   |
| 80                                      | 32.47 ?                                 | 29.80 ? | 29.90 ? | 32.00ab | 56.60   |
| 120                                     | 43.60 d                                 | 52.73 ? | 53.33 ? | 54.74bc | 56.60ac |

**Comment [TS1]:** The value followed notation b is incorrect, while 48.33 has annotation a and yellow marked has no notation

**Comment [TS2]:** The value yellow marked has no notation

162 **Means having the same letters within a row/ column are not significantly different at 5%.**

163 The result showed that the treatments both as lone and their interaction led to increase on the available phosphorus.  
 164 Dried algae as single treatment showed consistence higher values compared to lone addition of N fertilizer. This  
 165 observation may be attributed on one hand to the high content of organic phosphorus in algae which mineralized to  
 166 release solution phosphorus and on the other hand to the high organic carbon and basic cations which helped in  
 167 reducing the soil pH and thus, P adsorption (Eneje and Azu, 2009; Azu et al., 2017). Similarly, Issa (2007) noted  
 168 that algae help in releasing adsorbed P during weathering. The highest value of 65.00mgkg<sup>-1</sup> was obtained when  
 169 4tons ha<sup>-1</sup> dried algae was combined with 40tons ha<sup>-1</sup> N fertilizer.

170 **Table 5: Effect of dried Algae and N Fertilizer on Percent Organic Carbon (%)**

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (tons kg ha <sup>-1</sup> ) |         |         |          |         |
|-----------------------------------------|----------------------------------------------|---------|---------|----------|---------|
|                                         | a0 = 0                                       | a1 = 1  | a2 = 2  | a3 = 3   | a4 = 4  |
| 0                                       | 1.332a                                       | 1.400b  | 1.517c  | 1.710d   | 1.804e  |
| 40                                      | 1.366f                                       | 1.419bf | 1.521cf | 1.741df  | 1.806ef |
| 80                                      | 1.392g                                       | 1.414bg | 1.522cg | 1.766dg  | 1.824eg |
| 120                                     | 1.305h                                       | 1.400bh | 1.517ch | 1.1766dh | 1.827eh |

171 Means having the same letters within a row/ column are not significantly different at 5%.

172 Significant differences ( $P < 0.05$ ) were observed when the dried algae and N fertilizer were applied to the soils as  
173 lone and combined treatments. The organic carbon increased with the rate of dried algae application, but increased  
174 rate of N fertilizer application consistently decreased the amount of organic carbon. This can be attributed to the fact  
175 that algae when decomposed add large quantity of organic matter to the soil (Brady and Weil, 2008). Mike (2011)  
176 and Parshikova et al., (2006) reported that algae have pronounced effect in the generation of organic matter from  
177 inorganic substances. The superior values of P observed when both materials were interacted compared to their lone  
178 applications is in line with the findings of other researchers (Ano and Asumugha, 2000; Adediran et al., 1999) who  
179 reported better improvement on soil P when organic and inorganic fertilizers were combined compared to their  
180 single application.

181 Table 6: Effect of dried Algae and N fertilizer on Total Nitrogen (%)

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |         |         |         |         |
|-----------------------------------------|-----------------------------------------|---------|---------|---------|---------|
|                                         | a0 = 0                                  | a1 = 1  | a2 = 2  | a3 = 3  | a4 = 4  |
| 0                                       | 0.123a                                  | 0.141b  | 0.153c  | 0.165d  | 0.172e  |
| 40                                      | 0.138f                                  | 0.153bf | 0.158cf | 0.166df | 0.182ef |
| 80                                      | 0.148g                                  | 0.155bg | 0.162cg | 0.167dg | 0.192eg |
| 120                                     | 0.156h                                  | 0.161bh | 0.164ch | 0.169dh | 0.192eh |

182 Means having the same letters within a row/ column are not significantly different at 5%.

183 The effect of dried algae and N-Fertilizer on total nitrogen is presented in table 6. Results showed that relative to  
184 control, the application of dried algae and N-Fertilizer as single and combined treatment had significant ( $P < 0.05$ )  
185 improvement on the nitrogen content of the soil and the observed improvement increased with the rate of  
186 application. Both materials are known to be excellent sources of nitrogen (Brady and Weil, 2008). Apart from the  
187 nitrogen fixing ability of algae, they also create favourable environment for microbial mineralization of organic  
188 matter to release nitrogen (Parshikova et al., 2006). Thus, the performance of urea which is rated as superior to other  
189 forms chemical fertilizer in terms of nitrogen content can be enhanced by combining it with algae as this could  
190 increase the nitrogen content of the soil by more than 50% as observed in this study.

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194 **Table 7: Effect of dried Algae and N-Fertilizer on Total Exchangeable Bases**

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |        |         |         |         |
|-----------------------------------------|-----------------------------------------|--------|---------|---------|---------|
|                                         | a0 = 0                                  | a1 = 1 | a2 = 2  | a3 = 3  | a4 = 4  |
| 0                                       | 5.49a                                   | 6.65b  | 9.68c   | 11.49d  | 12.69e  |
| 40                                      | 5.49f                                   | 7.96bf | 9.73cf  | 11.64df | 12.74ef |
| 80                                      | 5.42g                                   | 9.38bg | 10.95cg | 12.16dg | 12.80eg |
| 120                                     | 5.05h                                   | 8.09bh | 10.31ch | 11.15dh | 12.52eh |

195 **Means having the same letters within a row/ column are not significantly different at 5%.**

196 The application of dried algae and N-fertilizer as lone and combined treatments exhibited varietal significant  
 197 (P<0.05) differences on the exchangeable bases content of the soil. Algae applied as lone treatment showed  
 198 consistent higher improvement on the basic cations compared to single application of N-fertilizer. The exchangeable  
 199 bases increased with the rate of algae, but decreased with increased rate of N-fertilizer. Young et al., (2000) had  
 200 observed that algae had the ability to remove H<sup>+</sup> and Al<sup>3+</sup> from soils, leaving behind the basic cations. Eneje and  
 201 Azu (2009) have also reported better improvement of soil cations when algae were applied.

202 **Table 8: Effect of dried Algae and N-Fertilizer on Total Exchangeable Acidity**

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |        |        |        |        |
|-----------------------------------------|-----------------------------------------|--------|--------|--------|--------|
|                                         | a0 = 0                                  | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0                                       | 1.32a                                   | 0.86b  | 0.44c  | 0.32d  | 0.31e  |
| 40                                      | 1.33f                                   | 0.59b  | 0.43c  | 0.40d  | 0.37ef |
| 80                                      | 1.34g                                   | 0.43b  | 0.54cg | 0/43d  | 0.51eg |
| 120                                     | 1.36h                                   | 0.53b  | 0.55c  | 0.53d  | 0.57eh |

203 **Means having the same letters within a row/ column are not significantly different at 5%.**

204 The result of the effect of dried algae and N-Fertilizer showed that the application of these materials as lone  
 205 treatments was significant (P<0.05) in influencing the exchangeable acidity. However, interaction was only  
 206 significant at the treatment combinations of 4tons ha<sup>-1</sup> dried algae and 40kgha<sup>-1</sup> N-fertilizer, 4tons ha<sup>-1</sup> algae and  
 207 80kgha<sup>-1</sup> N-fertilizer, 4tons ha<sup>-1</sup> dried algae and 120kgha<sup>-1</sup> N-fertilizer and 2tons ha<sup>-1</sup> dried algae and 80kgha<sup>-1</sup> N-

208 fertilizer. It was also observed that algae application lowered the exchangeable acidity consistently, while the  
 209 exchangeable acidity increased with rate of the N-Fertilizer. Mineral fertilizers have been linked to soil acidity,  
 210 while organic manures have been known to lower soil acidity (Awodun, 2007). The Effective Cation Exchange  
 211 Capacity (ECEC) of the soils was significantly improved with the application of dried algae and N-Fertilizer both as  
 212 lone and combined treatments. 4tons ha<sup>-1</sup> and 80kg ha<sup>-1</sup> N-Fertilizer gave the best result in terms of ECEC, table 9.  
 213 According to Wohler et al., (1999), algae in addition to improving the organic carbon content of the soil, also enrich  
 214 the soil with basic cations, thereby improving the cation exchange capacity of soils.

215 **Table 9: Effect of dried Algae and N-Fertilizer on CEC**

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |        |         |         |         |
|-----------------------------------------|-----------------------------------------|--------|---------|---------|---------|
|                                         | a0 = 0                                  | a1 = 1 | a2 = 2  | a3 = 3  | a4 = 4  |
| 0                                       | 6.81a                                   | 7.51b  | 10.12c  | 11.81d  | 12.99e  |
| 40                                      | 6.82f                                   | 8.54bf | 10.16cf | 12.04df | 13.12ef |
| 80                                      | 6.76g                                   | 9.51bg | 11.49cg | 12.58dg | 13.31eg |
| 120                                     | 6.41h                                   | 8.63bh | 10.85ch | 11.68dh | 13.09eh |

216 Means having the same letters within a row/ column are not significantly different at 5%.

217 ~~Effect of dried Algae and N-Fertilizer on Yield and~~ The Growth and yield of Amaranthus.

218 Application of dried algae as organic fertilizers and N fertilizers gave a significant effect on **plant height**  
 219 (Table 10), number of leaves (Table 11), stem girth (Table 12) and fresh yield (Table 13). In general,  
 220 application of dried algae as organic fertilizers has a significant effect on the increasing of growth parameters  
 221 (.....) and the crop yield. The highest results were obtained within the application N fertilizers (please  
 222 discuss? Why the application of organic fertilizers give the significant effect, pay attention on the Ultisols  
 223 properties)

224 Considering the yield and growth parameters of *amaranthus*, there were noticeable changes between treatments  
 225 (Tables 10, 11, 12 and 13). There were noticeable improvements on the yield and growth parameters as a result of  
 226 the amendments on the soils both as lone and combined applications over the control treatment. Significant  
 227 differences ( $P<0.05$ ) on the fresh weight and stem girth as a result of the addition of the two materials singly and  
 228 interactively were observed. However, only the main effect of algae was significant ( $P<0.05$ ) in influencing the plant  
 229 height. The interaction between the two had no significant effect on the number of leaves. Generally, it was  
 230 observed that combined treatments consistently showed higher improvement on both the growth and yield  
 231 parameters compared to their lone application. This observation justifies the higher improvement on soil fertility

**Comment [TS3]:** Please make adjustment to first paragraph

**Comment [TS4]:** In no need to mention in the text, it has already mentioned in Table

properties in soils that had dried algae and N-Fertilizer combined as observed earlier in this study. Other research work (Ano and Asumugha, 2000) also observed a greater yield by the integrated use of inorganic and organic fertilizers compared to either of them. It was also observed that relative to the other rates of application, soils amended with 120kg/ha urea either as lone or combined with algae, showed consistent reduction on the yield parameters. This could be due to the fact that at 120kg/ha, urea became toxic to plants and hence, adversely affected the yield. This observed reduction in the yield of amaranthus in the pot that had 120kg/ha urea could also be attributed to increased soil acidification due to increased urea use (Azu et al., 2017). Treatment combination of 4tonsha<sup>-1</sup> algae and 80kgha<sup>-1</sup> urea gave the highest increase for all yield parameters measured and it is therefore recommended for optimum and large scale production of *amaranthus* in southeastern Nigeria.

**Table 13:** Effect of Algae and Urea on Fresh yield Weight (g)

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |         |         |         |         |
|-----------------------------------------|-----------------------------------------|---------|---------|---------|---------|
|                                         | a0 = 0                                  | a1 = 1  | a2 = 2  | a3 = 3  | a4 = 4  |
| 0                                       | 17.43a                                  | 46.17b  | 62.67c  | 76.37d  | 89.87e  |
| 40                                      | 23.57f                                  | 52.43bf | 63.40cf | 79.53df | 92.37ef |
| 80                                      | 25.57g                                  | 52.17bg | 65.07cg | 81.33dg | 97.13eg |
| 120                                     | 30.13h                                  | 44.43bh | 48.07ch | 57.77dh | 62.50eh |

**Comment [TS5]:** Fresh yield or weight can be treated as main yield. Consequently presented after the growth parameters, to make possible the use of growth parameters to support in the discussion of result.

Means having the same letters within a row/ column are not significantly different at 5%.

The data in Table 13 revealed that application of either dried algae or N fertilizers gave a significant effect on the increasing crop fresh yield. Compared to the control, application 1-4 tons of dried algae has increased the crop yield about .... To.... %, while the N fertilizers increased the yield about ..... to ..... The highest fresh yield were obtained by the application of 4 tons of dried algae. Please discuss deeply and make use of the growth parameter and soil properties (as emenioned above) to support the results discussion. Finally compare to the available scientific literature

**Table 10:** Effect of dried Algae and N-Fertilizer on Plant Height (cm)

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |        |        |        |        |
|-----------------------------------------|-----------------------------------------|--------|--------|--------|--------|
|                                         | a0 = 0                                  | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0                                       | 19.27a                                  | 52.93b | 57.33c | 61.13d | 64.80e |
| 40                                      | 24.40a                                  | 50.13a | 56.47a | 61.63a | 63.80a |
| 80                                      | 25.37a                                  | 54.33a | 59.90a | 64.09a | 65.17a |
| 120                                     | 29.70a                                  | 47.43a | 47.60a | 51.87a | 51.73a |

254 Means having the same letters within a row/ column are not significantly different at 5%.

255 **Table 11:** Effect of dried Algae and N-Fertilizer on Number of Leaves

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |        |        |        |        |
|-----------------------------------------|-----------------------------------------|--------|--------|--------|--------|
|                                         | a0 = 0                                  | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0                                       | 16.00a                                  | 51.67b | 61.67c | 66.33d | 68.67e |
| 40                                      | 23.67f                                  | 50.67i | 62.00i | 66.33i | 68.67i |
| 80                                      | 24.33g                                  | 53.00i | 63.33i | 67.67i | 70.33i |
| 120                                     | 26.67h                                  | 47.67i | 47.00i | 53.00i | 57.67i |

256 Means having the same letters within a row/ column are not significantly different at 5%.

257 **Table 12:** Effect of dried Algae and N-Fertilizer on Stem Girth (cm)

| N-Fertilizers<br>(kg ha <sup>-1</sup> ) | Dried Algae Rate (kg ha <sup>-1</sup> ) |        |        |        |        |
|-----------------------------------------|-----------------------------------------|--------|--------|--------|--------|
|                                         | a0 = 0                                  | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0                                       | 2.47a                                   | 4.20b  | 4.90c  | 5.47d  | 6.57e  |
| 40                                      | 3.03f                                   | 4.27bf | 4.73cf | 5.63df | 6.53ef |
| 80                                      | 2.90g                                   | 4.56bg | 5.10cg | 6.43dg | 6.93eg |
| 120                                     | 3.43h                                   | 3.67bh | 4.33ch | 4.33dh | 5.20eh |

258 Means having the same letters within a row/ column are not significantly different at 5%.

## 259 CONCLUSION

260 Generally, application of dried algae as organic ameliorant within N fertilizers has increased and improved the soil  
261 properties of Ultisols (please mentioned). The highest of ....., and, .....were obtained by the  
262 application of .... to ton of dried algae (pay attention particularly on the soil pH, organic carbon, CEC). The  
263 highest fresh yield about 89.87 g to 97.13 g plant<sup>-1</sup> were obtained by application 4 ton ha<sup>-1</sup> died algae, while the  
264 highest fresh yield about 30.13 g plant<sup>-1</sup> without application of dried algae was obtained by the application of 120  
265 kg Urea (please convert to N-urea). Consequently, the application of dried algae has a great prospect to improved  
266 the properties of Ultisols, to enhance the fertilizers efficiency and to increase the crop yield of Amaranthus,. (please  
267 make furtherer adjustment

268

269 Potentials for sustained *amaranthus* production in southeastern Nigeria are very limited in the absence of  
270 amendments due to the inherent low soil fertility status of the zone. This study has led to the conclusion that soils  
271 amended with algae and urea as lone treatments and interactively gave appreciable higher improvements on soil  
272 fertility properties and yield of *amaranthus*. The observations therefore emphasize the importance of algae  
273 especially when combined with urea or other mineral fertilizers as soil amendment for maintaining the fertility status  
274 of tropical soils. Comparable soil chemical properties and yields obtained indicates that detrimental effects on soil  
275 and crops associated with consistent and prolonged use of large amount of mineral fertilizers could be reduced by  
276 supplementation with algae as an organic manure. It is therefore recommended that to reduce or avoid the residual  
277 adverse effects resulting from the over-use of mineral N-fertilizers, soil fertility management strategy of combining  
278 4tons ha<sup>-1</sup> algae with 80 kg ha<sup>-1</sup> N- fertilizers should be adopted. This will help farmers develop interest on the  
279 potentials of algae as a farm resource which when effectively and properly used, has direct positive effect on soil  
280 nutrient properties and yield of crops.

**Comment [TS6]:** Need to be refined. The sentence must be clear, sharp and efficiently

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